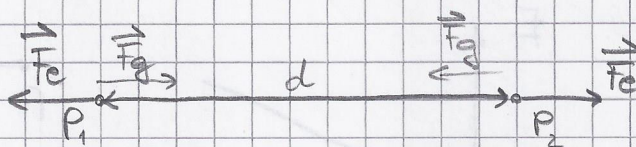
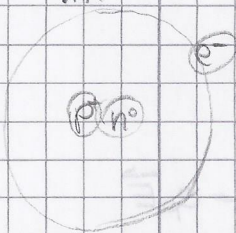


V neki molekuli sta protona na razdalji $d = 3,8 \cdot 10^{-10} \text{ m}$.
Kakšna je sila med delcema?

ATOM



$$d = 3,8 \cdot 10^{-10} \text{ m}$$

$$e_p = e_e = 1,6 \cdot 10^{-19} \text{ As}$$

$$m_p = 1,67 \cdot 10^{-27} \text{ kg}$$

$$F_e = ?$$

$$F_g = ?$$

$$F_e = \frac{e_p e_e}{4\pi\epsilon_0 d^2} = \frac{(1,6 \cdot 10^{-19} \text{ As})^2}{4\pi \cdot 8,85 \cdot 10^{-12} \frac{\text{As}}{\text{Vm}} \cdot (3,8 \cdot 10^{-10} \text{ m})^2} =$$

$$= \frac{2,56 \cdot 10^{-38}}{1,6 \cdot 10^{-29}} = 1,6 \cdot 10^{-9} \text{ N}$$

$$F_g = G \frac{m_p m_p}{d^2} = G \cdot \frac{m_p^2}{d^2} = 6,67 \cdot 10^{-11} \frac{\text{kg m}^3}{\text{s}^2} \cdot \frac{(1,67 \cdot 10^{-27} \text{ kg})^2}{(3,8 \cdot 10^{-10} \text{ m})^2} =$$

$$= 1,3 \cdot 10^{-45} \text{ N}$$

$$\frac{F_e}{F_g} \sim 10^{36}$$

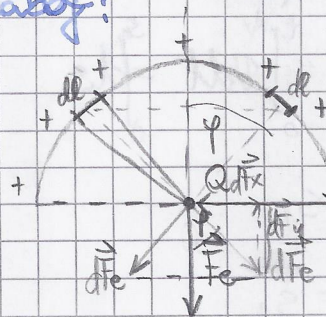
Tanka kovinska žica je zvita v polkrog, $R = 0,1 \text{ m}$. Žica je enakomerno nabitena, naboj / dolžina $q = 10^{-4} \frac{\text{As}}{\text{m}}$. Na sredi je točkasti naboj. Kakšna je sila na točkasti naboj?

$$R = 0,1 \text{ m}$$

$$q = 10^{-4} \frac{\text{As}}{\text{m}}$$

$$Q = 10^{-8} \text{ As}$$

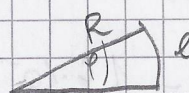
$$F_e = ?$$



$$dF_y = dF_e \cos \varphi$$

$$dF_x = dF_e \sin \varphi$$

$$F_e = \int dF_y = \int dF_e \cos \varphi$$



$$\varphi (\text{rad}) = \frac{l}{R}$$

$$l = R \varphi$$

$$dl = R d\varphi$$

$$\left\{ \begin{array}{l} dF_x = 0 \\ \cos \varphi = 0 \end{array} \right.$$

$$dF_e = \frac{Q \cdot q \cdot dl}{4\pi\epsilon_0 R^2} = \frac{Q \cdot q \cdot R d\varphi}{4\pi\epsilon_0 R^2} =$$

$$= \frac{Q \cdot q \cdot d\varphi}{4\pi\epsilon_0 R}$$

$$F_e = \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \frac{Q \cdot q \cdot d\varphi}{4\pi\epsilon_0 R} \cos \varphi = \frac{Q \cdot q}{4\pi\epsilon_0 R} \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \cos \varphi d\varphi = \frac{Q \cdot q}{4\pi\epsilon_0 R} \sin \varphi \Big|_{-\frac{\pi}{2}}^{\frac{\pi}{2}} =$$

$$\frac{Q \cdot q}{4\pi\epsilon_0 R} \cdot (1 - (-1)) = \frac{2Qq}{2 \cdot 4\pi\epsilon_0 R} = \frac{Q \cdot q}{2\pi\epsilon_0 R}$$

$$F_e = \frac{Q \cdot q}{2\pi \epsilon_0 R} = \frac{10^{-9} \text{ AS} \cdot 10^{-9} \text{ AS/m}}{2\pi \cdot 8,85 \cdot 10^{-12} \frac{\text{AS}}{\text{V} \cdot \text{m}} \cdot 0,1 \text{ m}} = \underline{\underline{18 \text{ mN}}}$$

Prostor gibljivi proton:

$$E(t) = k \cdot t$$

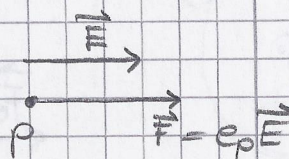
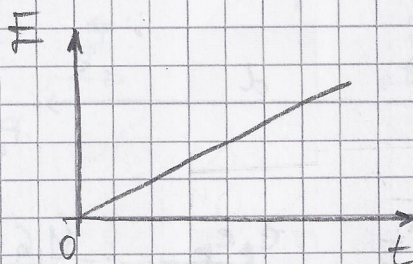
$$k = 2 \frac{\text{V}}{\text{ms}}$$

$$v_0 = v(t=0) = 0$$

$$t_1 = 1 \text{ ms}$$

$$v(t_1) = v_1 = ?$$

$$\Delta(t_1) = \Delta_1 = ?$$



$$F = m \cdot a$$

$$e_p E(t) = m_p a(t)$$

$$e_p k t = m_p \frac{dv}{dt} \quad \bigg| \cdot \frac{dt}{m_p}$$

$$\frac{e_p k t}{m_p} \cdot dt = dv$$

$$\int_0^{v_1} dv = \frac{e_p k}{m_p} \int_0^{t_1} t dt$$

$$v_1 = \frac{e_p k}{m_p} \cdot \frac{t^2}{2} \bigg|_0^{t_1} = \frac{e_p k}{m_p} \cdot \frac{t_1^2}{2}$$

$$v_1 = \frac{e_p k t_1^2}{2 m_p} = \frac{1,6 \cdot 10^{-19} \text{ AS} \cdot 2 \frac{\text{V}}{\text{ms}} \cdot 1 \cdot 10^{-6} \text{ s}^2}{2 \cdot 1,67 \cdot 10^{-27} \text{ kg}} \approx 95,8 \frac{\text{m}}{\text{s}}$$

$$N \cdot m = V \cdot A \cdot s$$

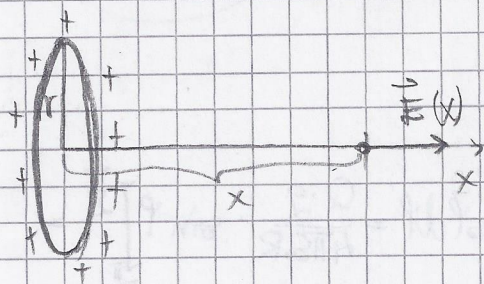
$$v = \frac{ds}{dt} \quad \bigg| \int \quad = \int_0^{t_1} v dt = \int_0^{s_1} ds$$

$$\int_0^{t_1} \frac{e_p k t^2}{2 m_p} dt = s_1$$

$$\frac{e_p k}{2 m_p} \cdot \frac{t^3}{3} \bigg|_0^{t_1} = s_1$$

$$s_1 = \frac{e_p k t_1^3}{6 m_p} = \frac{1,6 \cdot 10^{-19} \text{ AS} \cdot 2 \frac{\text{V}}{\text{ms}} \cdot 10^{-9} \text{ s}^3}{3 \cdot 1,67 \cdot 10^{-27} \text{ kg}} = \underline{\underline{33,3 \text{ mm}}}$$

naelektron, obrat

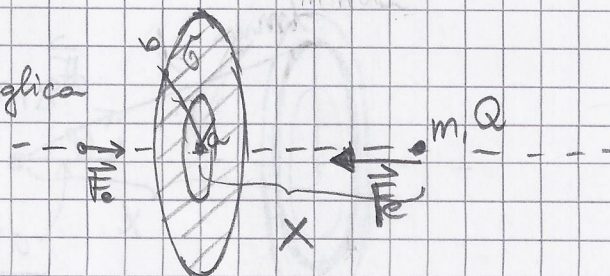


$$E(x) = \frac{e \cdot x}{4\pi \epsilon_0 (r^2 + x^2)^{3/2}}$$

$$E(x=0) = 0$$

nal. 11 / str. 13

$$\begin{aligned} m &= 0,1 \text{ g} = 10^{-4} \text{ kg} \\ Q &= -10^{-5} \text{ As} \\ b &= 10 \text{ cm} \\ a &= 5 \text{ cm} \\ \sigma &= 10^{-5} \frac{\text{As}}{\text{m}^2} \end{aligned} \quad \left. \begin{array}{l} \\ \\ \\ \\ \end{array} \right\} \text{ kroglica}$$



a) t_0 ($x \ll a$) = ?
majhni odmiki

$$\ddot{X} = -\omega^2 X$$

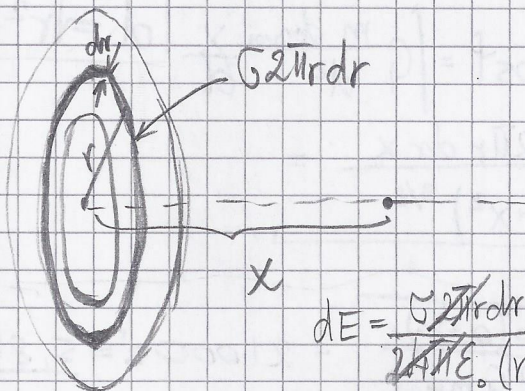
sinusno nihanje

$$t_0 = \frac{2\pi}{\omega}$$

Newton-ov zakon:

$$F_e = m \cdot a$$

$$QE = m \ddot{X}$$



$$dE = \frac{\sigma 2\pi r dr \cdot x}{2\pi \epsilon_0 (r^2 + x^2)^{3/2}}$$

$$E(x) = \int dE = \frac{\sigma x}{2\epsilon_0} \int_a^b \frac{r dr}{(r^2 + x^2)^{3/2}}$$

$$\int \frac{r dr}{(r^2 + x^2)^{3/2}} = \int \frac{du}{2 u^{3/2}} \quad \begin{aligned} u &= r^2 + x^2 \\ du &= 2r dr \end{aligned} = \frac{1}{2} \cdot \frac{u^{-1/2}}{-1/2} = -u^{-1/2} = -\frac{1}{\sqrt{u}} + C = -\frac{1}{\sqrt{r^2 + x^2}} + C$$

$$-\frac{\sigma x}{2\epsilon_0} \left[\frac{1}{\sqrt{r^2 + x^2}} \right]_a^b = \frac{\sigma x}{2\epsilon_0} \left[\frac{1}{\sqrt{r^2 + x^2}} \right]_b^a = \frac{\sigma x}{2\epsilon_0} \left(\frac{1}{\sqrt{a^2 + x^2}} - \frac{1}{\sqrt{b^2 + x^2}} \right)$$

$$Q \frac{\sigma x}{2\epsilon_0} \left(\frac{1}{a} - \frac{1}{b} \right) = m \ddot{X} \quad \begin{aligned} \frac{1}{a} \\ \frac{1}{b} \end{aligned}$$

$$|Q| \frac{\sigma x}{2m\epsilon_0} \left(\frac{1}{a} - \frac{1}{b} \right) = \ddot{X}$$

$x \ll a$
 $x \ll b$

konstantno za
majhne odmike

$$t_0 = \frac{2\pi}{\omega} = 2\pi \sqrt{\frac{2m\epsilon_0}{|Q|\sigma \left(\frac{1}{a} - \frac{1}{b} \right)}}$$

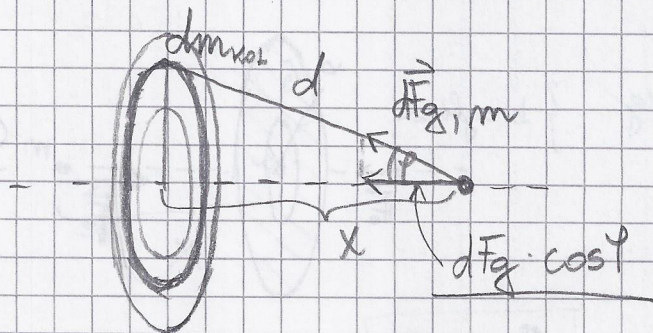
$$= 2\pi \sqrt{\frac{2 \cdot 10^{-4} \text{ kg} \cdot 8,85 \cdot 10^{-12} \frac{\text{As}}{\text{Vm}}}{10^{-5} \text{ As} \cdot 10^{-5} \frac{\text{As}}{\text{m}^2} (10 \text{ m}^{-1})}} =$$

$$= 8,35 \cdot 10^{-3} \text{ s}$$

$$\nu = \frac{1}{t_0} \approx 100 \text{ Hz}$$

b) $Q=0$

$m_{\text{kon}} = 0,5 \text{ kg}$
 $d(x < a) = ?$



$$dF_g = G \frac{dm_{\text{kon}} \cdot m}{d^2}$$

$$\cos \phi = \frac{x}{d}$$

$$d = \sqrt{r^2 + x^2}$$

$$F_g = \int dF_g \cdot \cos \phi = \int G \frac{m \cdot dm_{\text{kon}}}{d^2} \cdot \frac{x}{d}$$

$$= \int G \frac{m \cdot \rho_{\text{kon}} \cdot 2\pi r \cdot dr \cdot x}{(r^2 + x^2)^{3/2}} =$$

$$\rho_{\text{kon}} = \frac{m_{\text{kon}}}{\pi(b^2 - a^2)}$$

$$dm_{\text{kon}} = \rho_{\text{kon}} \cdot dS =$$

$$t_0 = ? = 2\pi \sqrt{\frac{ab(a+b)}{2Gm_{\text{kon}}}} \approx 21000 \text{ s} \approx 5,8 \text{ h}$$

$$F = m \cdot \ddot{x}$$

→ vedno kaže proti ravnovesni legi

$$-|F| = m\ddot{x}$$

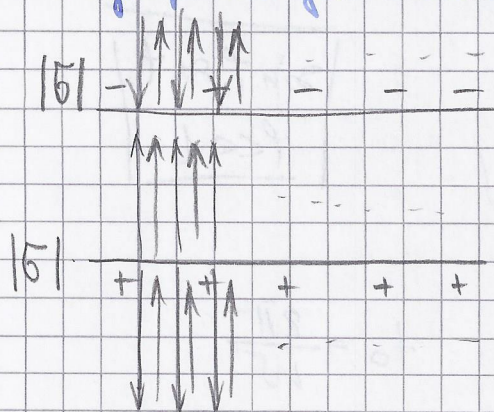
$$\ddot{x} = - \frac{|F|}{m} \cdot \frac{x}{x} \Rightarrow \omega^2$$

$$t_{\text{oe}} = 2\pi \sqrt{\frac{mx}{|F|}}$$

$$\frac{t_{\text{og}}}{t_{\text{oe}}} = \frac{2\pi \sqrt{\frac{mx}{|F|}}}{2\pi \sqrt{\frac{mx}{|F_g|}}} = \frac{\sqrt{|F|}}{\sqrt{|F_g|}} =$$

$$= \sqrt{\frac{\int \frac{Q \cdot G \cdot dS}{4\pi \epsilon_0 d^2} \cdot \frac{x}{d}}{\int G \frac{m \cdot \rho_{\text{kon}} \cdot dS}{d^2} \cdot \frac{x}{d}}}$$

$$= \sqrt{\frac{Q \cdot G \int \frac{dS}{d^3}}{4\pi \epsilon_0 G m \rho_{\text{kon}} \int \frac{dS}{d^3}}}$$



$$E = \frac{\sigma}{\epsilon_0}$$

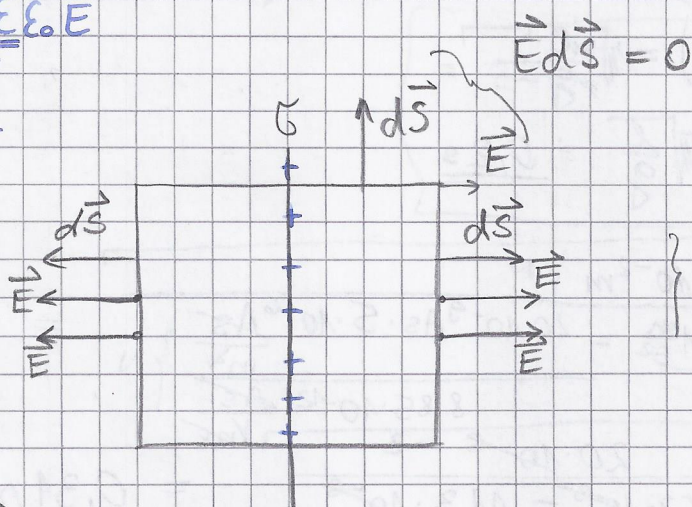
GAUSSOV ZAKON

$$\oint_S \vec{D} \cdot d\vec{S} = e$$

$$\vec{D} = \epsilon \epsilon_0 \vec{E}$$

tenzor

- zakon o električnem pretoku



$$\vec{E} \cdot d\vec{S} = E \cdot dS$$

$$\epsilon_0 \oint_S \vec{E} \cdot d\vec{S} = e$$

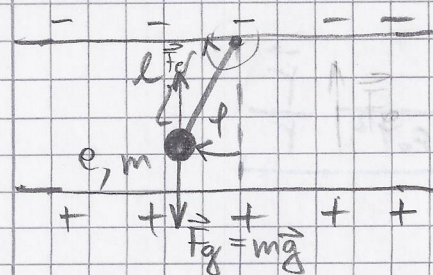
$$\epsilon_0 E \int dS = \epsilon_0 E \cdot 2S = e$$

K integralu prispevata le vzporedni ploskvi.

$$E = \frac{e}{2\epsilon_0 S}$$

$$\sigma = \frac{e}{S}$$

$$E = \frac{\sigma}{2\epsilon_0}$$



Na zelo lahki nitki dolžine $l=1m$ je obešena naelektrna kroglica z nabojem $e=20 \cdot 10^{-9} As$. Masa ji 2g. Kroglica se nahaja med ploščama, $\sigma = \pm 5 \mu As/m^2$.

S kolikšnim nihajnim časom zavije kroglica, če jo za malenkost izmaknemo iz ravnovesne lege?

$$l = 1 \text{ cm}$$

$$e = 20 \cdot 10^{-9} \text{ As}$$

$$m = 2g = 2 \cdot 10^{-3} \text{ kg}$$

$$\sigma = \pm 5 \frac{\text{MA s}}{\text{m}^2}$$

$$T_0 (p \ll 1) = ?$$

$$\vec{M} = \vec{r} \times \vec{F}$$

$$M = r \cdot F \cdot \sin \varphi$$

$$M = r \cdot F \cdot \varphi$$

$$M = I \alpha$$

$$\left| \sin \varphi \approx \varphi \right|$$

$$\left| \varphi \ll 1 \right|$$

$$-X(F_g - F_e) \varphi = m l \ddot{\varphi}$$

$$\ddot{\varphi} = - \frac{(F_g - F_e)}{m l} \varphi \rightarrow \omega^2$$

$$T_0 = \frac{2\pi}{\omega}$$

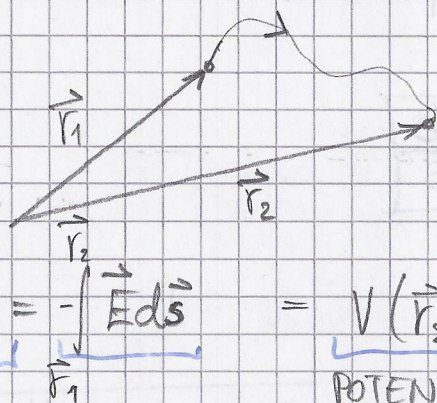
$$T_0 = 2\pi \sqrt{\frac{m l}{F_g - F_e}} = 2\pi \sqrt{\frac{m l}{m \cdot g - \frac{e \sigma}{\epsilon_0}}}$$

$$T_0 (e=0 \text{ ali } \sigma=0) = 2\pi \sqrt{\frac{m l}{m g}} =$$

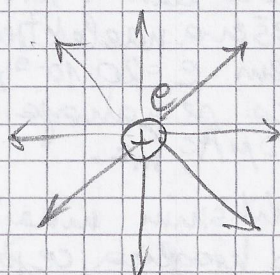
$$= 2\pi \sqrt{\frac{l}{g}} = \underline{0,2 \text{ s}}$$

$$= 2\pi \sqrt{\frac{2 \cdot 10^{-3} \text{ kg} \cdot 1 \cdot 10^{-2} \text{ m}}{2 \cdot 10^{-3} \text{ kg} \cdot 9,81 \frac{\text{m}}{\text{s}^2} - \frac{20 \cdot 10^{-9} \text{ As} \cdot 5 \cdot 10^{-6} \frac{\text{As}}{\text{m}^2}}{8,85 \cdot 10^{-12} \frac{\text{As}}{\text{Vm}}}}} =$$

$$= 2\pi \sqrt{\frac{20 \cdot 10^{-5} - 3}{19,62 \cdot 10^{-3} - 11,3 \cdot 10^{-3}}} = \underline{0,31 \text{ s}}$$



napetost ni odvisna od poti,
le od začet. in kon. točke



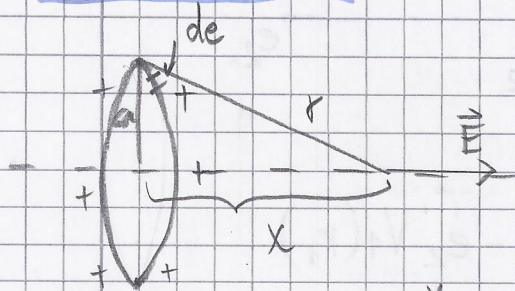
$$\vec{E} = \frac{e}{4\pi\epsilon_0 r^2} \frac{\vec{r}}{r}$$

POTENCIJALNA ENERGIJA

$$W_p = e \cdot V$$

$$\Delta W_p = e \cdot U$$

the black project - in the disc



$$E = \frac{e \cdot x}{4\pi\epsilon_0 (a^2 + x^2)^{3/2}}$$

r^3

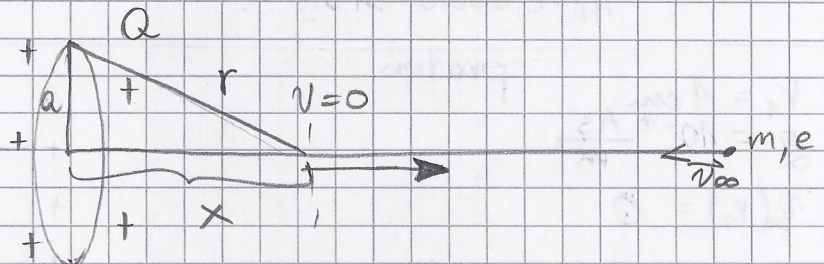
$$U(x_2, x_1) = - \int_{x_1}^{x_2} E dx$$

$$V(x) = \int dV = \int \frac{de}{4\pi\epsilon_0 r} = \frac{e}{4\pi\epsilon_0 r}$$

16. nal. / str. 17

$$\begin{aligned} m &= 3g \\ e &= 8 \mu As \\ a &= 3cm \\ Q &= 0,1 \mu As \\ v_{\infty} &= 30 km/s \end{aligned} \quad \left. \begin{array}{l} \text{kroglica} \\ \text{obroč} \end{array} \right\}$$

$$x = ?$$



$$\Delta W_k + \Delta W_p = 0$$

$$0 = \underbrace{\frac{1}{2} m v_{\infty}^2}_{\Delta W_k} + eV(x) - eV(\infty) = 0$$

$$\begin{aligned} \frac{e \cdot Q}{2\pi\epsilon_0 r} - 0 &= \frac{1}{2} m v_{\infty}^2 \\ r &= \frac{eQ}{2\pi\epsilon_0 m \cdot v_{\infty}^2} = \frac{8 \cdot 10^{-6} As \cdot 0,1 \cdot 10^{-6} As}{2\pi \cdot 8,85 \cdot 10^{-12} \frac{As}{Vm} \cdot 3 \cdot 10^{-3} kg \cdot (8,33 \frac{m}{s})^2} \\ r &= 6,9 cm \end{aligned}$$

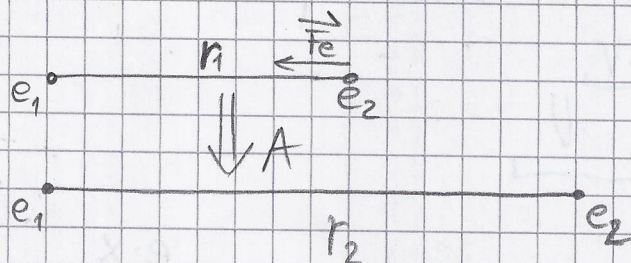
$$x^2 = r^2 - a^2$$

$$x = \sqrt{(6,9 cm)^2 - 3 cm^2} = 6,2 cm$$

12. nal. / str. 14

$$\begin{aligned} e_1 &= +10^{-7} \text{ As} \\ e_2 &= -10^{-8} \text{ As} \\ r_1 &= 10 \text{ cm} \\ r_2 &= 20 \text{ cm} \end{aligned}$$

$$A = ?$$



$$A = \int \vec{F} \cdot d\vec{s}$$

$$A = \Delta W_p = e_2 V_1(r_2) - e_2 V_1(r_1)$$

$$V_1(r) = \frac{e_1}{4\pi\epsilon_0 r}$$

$$A = \frac{e_1 e_2}{4\pi\epsilon_0 r_2} - \frac{e_1 e_2}{4\pi\epsilon_0 r_1} = \frac{e_1 e_2}{4\pi\epsilon_0} \left(\frac{1}{r_2} - \frac{1}{r_1} \right)$$

$$A = \frac{-10^{-13} \text{ (As)} \cdot V_m}{4\pi \cdot 8,85 \cdot 10^{-12} \text{ As}} \left(\frac{5}{\text{m}} - \frac{10}{\text{m}} \right) = \frac{10^{-3} \cdot 5}{4\pi \cdot 8,85} \approx \underline{45 \mu\text{J}}$$

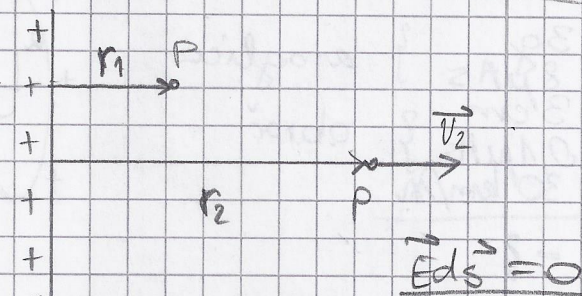
$$\begin{aligned} r_1 &= 1 \text{ cm} \\ Q &= 10^{-7} \frac{\text{As}}{\text{m}} \end{aligned}$$

$$V(r_1) = 0$$

$$e_{pr} = e_0 = 1,6 \cdot 10^{-19} \text{ As}$$

$$V(r_2) = V_2 = ?$$

proton:



$$\Delta W_k + \Delta W_p = 0$$

$$\frac{1}{2} m_{pr} V_2^2 - 0 + e_{pr} V(r_2) - e_{pr} V(r_1) = 0$$

$$\epsilon_0 \oint \vec{E} \cdot d\vec{s} = e$$

$$\epsilon_0 \int E ds = e$$

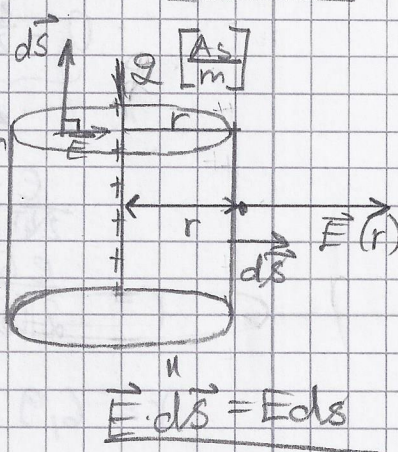
po plasek

$$\epsilon_0 E \cdot 2\pi r h = e$$

$$E = \frac{e/h}{2\pi\epsilon_0 r} = \underline{\underline{\frac{Q}{2\pi\epsilon_0 r}}}$$

$$U(r_2, r_1) = - \int_{r_1}^{r_2} E dr = - \frac{Q}{2\pi\epsilon_0} \int_{r_1}^{r_2} \frac{dr}{r} = \frac{Q}{2\pi\epsilon_0} \ln r \Big|_{r_1}^r =$$

$$\underline{\underline{V(r) = - \frac{Q}{2\pi\epsilon_0} \ln r}}$$



$$\frac{1}{2} m_{pr} v_2^2 + e_{pr} \left(\frac{-q}{4\pi\epsilon_0} \ln \frac{r_2}{r_1} \right) = 0$$

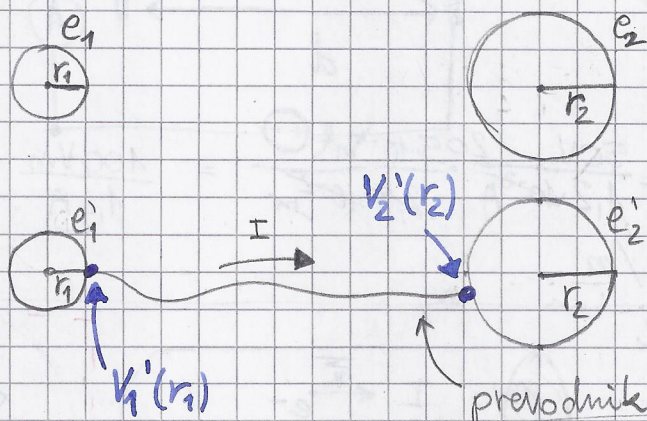
$$v_2 = \sqrt{\frac{e_{pr} \left(\frac{2}{4\pi\epsilon_0} \ln \frac{r_2}{r_1} \right)}{m_{pr}}} = \sqrt{\frac{1,6 \cdot 10^{-19} \text{ As} \cdot 10^{-7} \frac{\text{As}}{\text{m}} \cdot \ln 5}{1,7 \cdot 10^{-27} \text{ kg} \cdot 8,85 \cdot 10^{-12} \frac{\text{As}}{\text{Vm}}}} = 7,4 \cdot 10^5 \text{ m/s}$$

20. nal. / str. 18

$$\begin{aligned} r_1 &= 2 \text{ cm} \\ e_1 &= 2 \cdot 10^{-6} \text{ As} \end{aligned} \quad \left. \begin{array}{l} \\ \end{array} \right\} 1. \text{ KR.}$$

$$\begin{aligned} r_2 &= 5 \text{ cm} \\ e_2 &= 10^{-6} \text{ As} \end{aligned} \quad \left. \begin{array}{l} \\ \end{array} \right\} 2. \text{ KR.}$$

$$\begin{aligned} G_1' &= \frac{e_1'}{4\pi r_1^2} \\ G_2' &= \frac{e_2'}{4\pi r_2^2} \end{aligned} \quad \left. \begin{array}{l} \\ \end{array} \right\} ?$$



OHRANITEV NABOJA:

$$e_1 + e_2 = e_1' + e_2'$$

RAVNOVEŠJE:

$$v_1'(r_1) = v_2'(r_2)$$

$$\vec{E} = \begin{cases} r > r_0: \frac{e}{4\pi\epsilon_0 r^2} \\ r < r_0: 0 \end{cases}$$

$$V(r > r_0) = \frac{e}{4\pi\epsilon_0 r}$$

$$\frac{e_1'}{4\pi\epsilon_0 r_1} = \frac{e_2'}{4\pi\epsilon_0 r_2}$$

$$e_2' = e_1' \frac{r_2}{r_1}$$

$$e_1 + e_2 = e_1' + e_1' \frac{r_2}{r_1} = e_1' \left(1 + \frac{r_2}{r_1} \right)$$

$$e_1' = \frac{e_1 + e_2}{1 + \frac{r_2}{r_1}} = \frac{3 \cdot 10^{-6} \text{ As}}{1 + \frac{5}{2}} = \frac{6 \cdot 10^{-6} \text{ As}}{7}$$

$$e_1' = \frac{6}{7} \cdot 10^{-6} \text{ As}$$

$$e_2' = \frac{6}{7} \cdot 10^{-6} \cdot \frac{5}{2} = \frac{15}{7} \cdot 10^{-6} \text{ As}$$

$$G_1' = \frac{e_1'}{4\pi r_1^2} = 1,7 \cdot 10^{-4} \frac{\text{As}}{\text{m}^2}$$

$$G_2' = \frac{e_2'}{4\pi r_2^2} = 0,68 \cdot 10^{-4} \frac{\text{As}}{\text{m}^2}$$

$$e = \int_0^\infty I dt = |e_1' - e_1| = |e_2' - e_2|$$

sumek toka:

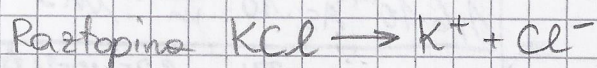
$$e = \int_0^\infty I \cdot dt \equiv \text{naboj, ki se pretaka po prevodniku}$$

$$\int Idt = 1,14 \text{ As}$$

Tok teče iz kroglice r_1 proti krogli r_2 ker je na prvi krogli na začetku več naboja.

16.3.2011

40. nal. / str. 33



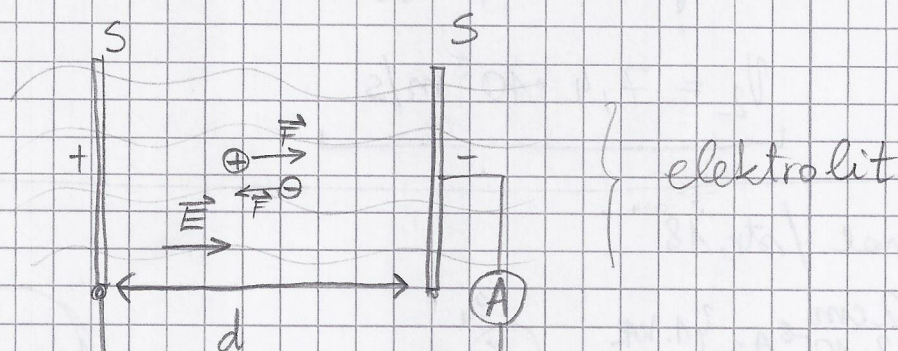
$$\begin{aligned} S &= 5 \text{ cm}^2 \\ d &= 2,5 \text{ cm} \\ U &= 50 \text{ V} \\ I &= 1,2 \text{ mA} \end{aligned}$$

$$G = \frac{1}{S} \left[\text{specifična prevodnost elektrolita} \right]$$

$$R = S \frac{d}{S} = \frac{U}{I}$$

$$S = \frac{U \cdot S}{I \cdot d} = \frac{50 \text{ V} \cdot 205 \cdot 10^{-4} \text{ m}^2}{1,2 \cdot 10^{-2} \text{ A} \cdot 2,5 \cdot 10^{-2} \text{ m}} = \frac{100 \text{ Vm}}{1,2 \text{ A}} = 833 \frac{\text{Vm}}{\text{A}}$$

$$G = 1,2 \text{ mS/m}$$



37. nal. / str. 32

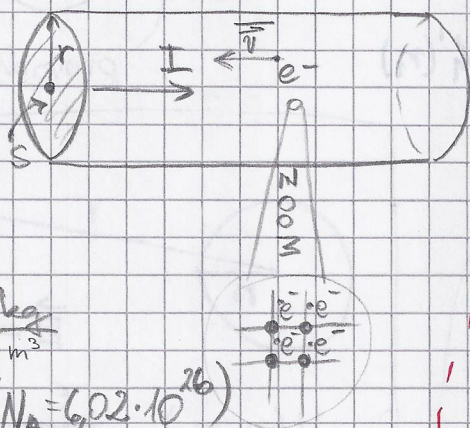
$$\bar{N}_{\text{ATOMOV}} = \bar{N}_e =$$

$$\begin{aligned} 2r &= 1 \text{ mm} ; r = 0,5 \text{ mm} \\ I &= 1 \text{ A} \end{aligned}$$

$$\bar{v} = ?$$

$$\rho = 9 \text{ g/cm}^3 = 9000 \frac{\text{kg}}{\text{m}^3}$$

$$M = 64 \text{ kg/kmol} \quad (N_A = 6,02 \cdot 10^{26})$$



$$j = \frac{I}{S} = n_e \cdot e \cdot \bar{v}$$

$$n_e = \frac{N_e}{V}$$

$$I = \frac{e \cdot N_e}{t}$$

$$j = \frac{e \cdot N_e \cdot x}{t \cdot S \cdot x} =$$

$$\Rightarrow j = \frac{e \cdot N_e \bar{v}}{V}$$

$$\frac{I}{S} = \left(\frac{N_e}{V} \right) \cdot (-e) \cdot \bar{v}$$

$$\rho = \frac{m}{V} = \frac{\bar{m}_1 \bar{N}_{\text{AT}}}{V} = \frac{M}{N_A} \cdot \frac{\bar{N}_{\text{AT}}}{V}$$

$$\bar{m}_1 = \frac{M}{N_A} = \frac{64 \text{ kg/kmol}}{6,02 \cdot 10^{26} \frac{1}{\text{kmol}}} = 1,1 \cdot 10^{-25} \text{ kg}$$

$$\frac{\bar{N}_{\text{AT}}}{V} = \frac{N_A \cdot \rho}{M}$$

$$\frac{I}{\pi r^2} = \frac{N_A \cdot \rho}{M} \cdot (-e) \cdot \bar{v}$$

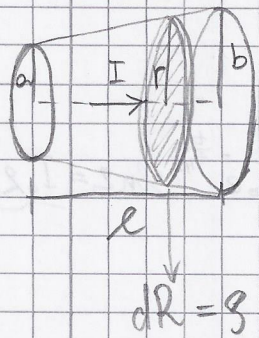
$$\bar{v} = \frac{I \cdot M}{\pi r^2 \cdot N_A \cdot \rho \cdot (-e)}$$

$$\bar{v} = \frac{1 \text{ A} \cdot 64 \text{ kg/kmol}}{\pi \cdot (0,5 \cdot 10^{-3} \text{ m})^2 \cdot 6,02 \cdot 10^{26} \frac{1}{\text{kmol}} \cdot 9000 \frac{\text{kg}}{\text{m}^3} \cdot 1,6 \cdot 10^{-19} \text{ C}}$$

$$\bar{v} = -94 \cdot 10^{-6} \frac{\text{m}}{\text{s}} \approx -94 \frac{\mu\text{m}}{\text{s}}$$

ker so elektroni nosilci naboja, se gibajo v nasprotno smer od toka.

Kakšno je upornost upora oblike prišekovega stožca



$$\frac{a, b, l}{S}$$

$$R = ?$$

$$dR = \rho \frac{dl}{\pi r^2}$$

$r(l)$

$$R = \int dR = \dots = \frac{\rho \cdot l}{\pi a b}$$

Tok v žici se spreminja po enačbi $I(t) = a + bt^2$

$$a = 4 \text{ A}$$

$$b = 2 \frac{\text{A}}{\text{s}^2}$$

$$I = \frac{dQ}{dt}$$

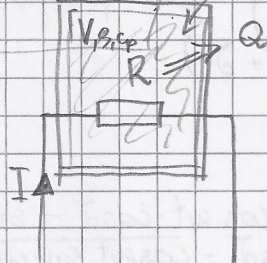
$$\int dQ = \int I dt$$

$$Q = \int_{t_1}^{t_2} (a + bt^2) dt = \left(at + \frac{bt^3}{3} \right) \Big|_{t_1}^{t_2} =$$

$$\left(at_2 + \frac{bt_2^3}{3} \right) - \left(at_1 + \frac{bt_1^3}{3} \right) = 706 \text{ As} - 103,3 \text{ As} = \underline{603 \text{ As}}$$

MOC

$$\left\{ P = U \cdot I = \frac{dA}{dt} = \frac{U^2}{R} = RI^2 \right\}$$



$$R = 10 \Omega$$

$$V = 1 \text{ dm}^3 = 1 \text{ l} = 1 \text{ kg}$$

$$e_0 = 10^4 \text{ As}$$

$$t_0 = 1,5 \text{ h}$$

$$I = \frac{e_0}{t_0}$$

$$t_1 = 10 \text{ min}$$

izgube zanemarimo

$$\Delta T = ?$$

$$Q = m \cdot c_p \cdot \Delta T$$

$$P = RI^2 = 34,23 \text{ W}$$

$$A = Q = P \cdot t = 20535 \text{ J}$$

$$\Delta T = \frac{Q}{m c_p} = \frac{20535 \text{ J}}{1 \text{ kg} \cdot 4200 \text{ J/kg K}} = 4,9 \text{ K} \approx \underline{5 \text{ K}}$$

$$I_0 = 5400 \text{ A}$$

$$I = \frac{e_0}{t_0} = \underline{1,85 \text{ A}}$$

$$\rho = 1000 \frac{\text{kg}}{\text{m}^3} = 1 \text{ kg/l} \Rightarrow m = \rho \cdot V = 1 \text{ kg}$$

$$c_p = 4200 \text{ J/kg K}$$

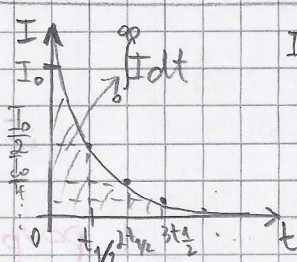
$$\int e^{ax} dx = \frac{1}{a} e^{ax}$$

$$R = 8 \Omega$$

$$Q_0 = 30 \text{ As}$$

$$t_{1/2} = 24 \text{ s}$$

$$Q = ?$$



$$I(t) = I_0 e^{-\frac{t}{\tau}}$$

$$Q = \int_0^{\infty} P dt = RI_0^2 \int_0^{\infty} e^{-\frac{2t}{\tau}} dt =$$

$$Q = RI_0^2 \left(-\frac{\tau}{2} \right) e^{-\frac{2t}{\tau}} \Big|_0^{\infty} =$$

$$Q = -RI_0^2 \left(\frac{\tau}{2} \right) \left[e^{-\frac{2t}{\tau}} - e^{-\frac{2 \cdot 0}{\tau}} \right] =$$

$$Q = RI_0^2 \left(\frac{\tau}{2} \right) *$$

$$e_0 = \int_0^{\infty} I dt = I_0 \int_0^{\infty} e^{-\frac{t}{\tau}} dt = -\tau I_0 e^{-\frac{t}{\tau}} \Big|_0^{\infty} = -\tau I_0 [e^{-\infty} - e^{-0}] =$$

$$e_0 = \tau I_0 \Rightarrow I_0 = \frac{e_0}{\tau}$$

$$I(t_{1/2}) = \frac{I_0}{2}$$

$$I(t) = I_0 e^{-\frac{t}{\tau}} = I_0 e^{-\frac{t}{\tau_{1/2} \ln 2}} = I_0 2^{-t/\tau_{1/2}}$$

$$I_0 = e^{-\frac{t_{1/2}}{\tau}} = \frac{I_0}{2}$$

$$2 = e^{\frac{t_{1/2}}{\tau}} / \ln$$

$$\ln 2 = \frac{t_{1/2}}{\tau} \Rightarrow \tau = \frac{t_{1/2}}{\ln 2}$$

$$Q = \frac{1}{2} R \frac{e_0^2}{\tau} = \frac{R e_0^2 \ln 2}{2 t_{1/2}} = \frac{8 \cdot (30 \text{ A})^2 \cdot \ln 2}{2 \cdot 24 \text{ s}} \approx 1047$$

PRETOČNI BÖTLER

$$\phi_V = 9 \frac{\text{L}}{\text{min}}$$

$$T_1 = 15^\circ \text{C}$$

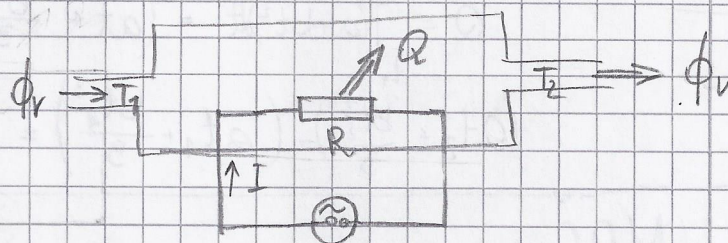
$$T_2 = 70^\circ \text{C}$$

$$M = 85\% = 0,85$$

$$U_{\text{eff}} = 220 \text{ V}$$

$$I_0 = ?$$

↑
amplituda
toka



$$u(t) = U_0 \cos(\omega t) \rightarrow \text{fazni zomik}$$

$$i(t) = I_0 \cos(\omega t + \delta)$$

$$P = u(t) \cdot i(t)$$

$$P = U_0 \cos(\omega t) \cdot I_0 (\cos \omega t \cdot \cos \delta - \sin \omega t \cdot \sin \delta)$$

$$* \frac{P}{P} = \frac{U_0 \cdot I_0}{U_0 \cdot I_0} (\cos^2 \omega t \cdot \cos \delta - \cos \omega t \sin \omega t \cdot \sin \delta)$$

$$\overline{\cos^2 \varphi} = \frac{\int_0^{2\pi} \cos^2 \varphi d\varphi}{2\pi} = \frac{1}{2\pi} \int_0^{2\pi} \cos^2 \varphi d\varphi \quad \text{konstante} \rightarrow \overline{\sin^2 \varphi} = \frac{1}{2}$$

$$\overline{\cos^2 \varphi} = \overline{\sin^2 \varphi} = 0$$

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

$$\sin^2 \varphi = \frac{1}{2} (1 - \cos 2\varphi)$$

$$\int_0^{2\pi} \cos^2 \varphi d\varphi = \int_0^{2\pi} \frac{1}{2} d\varphi + \int_0^{2\pi} \frac{1}{2} \cos 2\varphi d\varphi = \frac{2\pi}{2} + 0 = \pi$$

$$\int_0^{2\pi} \sin^2 \varphi d\varphi = \pi$$

$$* \overline{P} = U_0 I_0 (\overline{\cos^2 \omega t} \cdot \cos \delta - \overline{\cos \omega t \sin \omega t} \cdot \sin \delta)$$

$$\overline{P} = \frac{1}{2} U_0 I_0 \cos \delta = \frac{U_0}{\sqrt{2}} \cdot \frac{I_0}{\sqrt{2}} \cos \delta = U_{\text{eff}} I_{\text{eff}} \cos \delta$$

própréčna móč,
ki se porablja na
bremenú

upor:

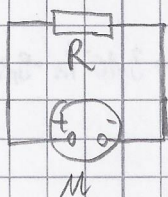
$$M = R \cdot I \quad \left\{ \begin{array}{l} \overline{P} = U_{ef} \cdot I_{ef} \\ J=0 \end{array} \right.$$

$$\eta \cdot \overline{P} = \frac{Q}{t} = \frac{m c_p \Delta T}{t} = \frac{S \cdot \rho \cdot m c_p \Delta T}{t} = S \phi_r c_p (T_2 - T_1)$$

$$\eta U_{ef} \cdot \frac{I_0}{\sqrt{2}} = S \phi_r c_p (T_2 - T_1)$$

$$I_0 = \frac{S \phi_r c_p (T_2 - T_1) \sqrt{2}}{\eta U_{ef}} = \frac{\sqrt{2} \cdot 1 \text{ kg/m}^3 \cdot 9 \frac{\text{J}}{\text{kg} \cdot \text{s}} \cdot 4200 \frac{\text{J}}{\text{kg} \cdot \text{K}} \cdot 55 \text{ K}}{0,85 \cdot 220 \text{ V}} = 262 \text{ A}$$

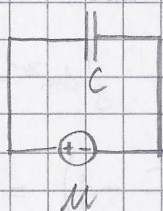
23.3.2011



$$U + U_R = 0$$

$$U_R = -U$$

$$U_R = R \cdot I$$



$$U = C \cdot U$$

$$U + U_C = 0$$

$$U_C = -U$$

$$U_C = -\frac{Q}{C}$$

KONDENZATOR

$$S = 150 \text{ cm}^2$$

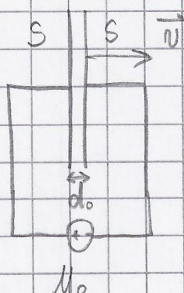
$$d_0 = 1 \text{ mm}$$

$$U_0 = 12 \text{ V}$$

$$t_1 = 1 \text{ ms}$$

$$v = 1 \text{ m/s}$$

$$I(t_1) = ?$$



Kolik šem I odteka s kondenzatorja 1ms
potem ko začnemo oddaljevati plošči s
hitrostjo $\vec{v}$.

$$C = \epsilon_0 \frac{S}{d(t)}$$

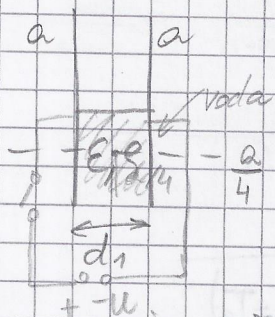
$$I = \frac{dQ}{dt} = \frac{d(CU_0)}{dt} = \frac{dC}{dt} \cdot U_0 = \frac{-\epsilon_0 S \cdot v}{(d_0 + vt)^2} \cdot U_0 = \frac{-8,85 \cdot 10^{-12} \frac{\text{As}}{\text{Vm}} \cdot 150 \cdot 10^{-4} \text{ m}^2}{(1 \cdot 10^{-3} \text{ m} + 1 \cdot 10^{-3} \text{ m})^2}$$

$$C = \epsilon_0 \frac{S}{d_0 + vt}$$

$$= -33,2 \text{ nA} \cdot 12 = -400 \text{ nA}$$

$$\frac{dC}{dt} = \frac{0 - \epsilon_0 S \cdot (0 + v)}{(d_0 + vt)^2} = \frac{-\epsilon_0 S \cdot v}{(d_0 + vt)^2}$$

$$U_0 = 12 \text{ V}$$



$$a = 10 \text{ cm} \Rightarrow S = a^2 = 100 \text{ cm}^2$$

$$d_1 = 3 \text{ mm}$$

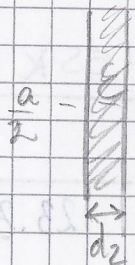
$$S = 1 \frac{\text{kg}}{\text{dm}^3} \rightarrow \text{voda}$$

$$d_2 = \frac{d_1}{2}$$

$$\epsilon_r = 80$$

$$U = 800 \text{ V}$$

plošči zblížamus ; koliko dela opravimo? ; kond. izoliramo



$$A = \Delta W_p + \Delta W_c = m g \Delta h + \left(\frac{1}{2} C_2 U_2^2 - \frac{1}{2} C_1 U_1^2 \right) =$$

$$= \rho \cdot \frac{S}{2} \cdot d_1 \cdot g \cdot \frac{a}{4} + \frac{1}{2} \epsilon_0 \frac{C_2^2}{C_2^2} U_2^2 - \frac{1}{2} C_1 U_1^2 =$$

$$A = \frac{\rho^3}{8} S d_1 g + \frac{1}{2} C_1 U_1^2 (C_1 - 1) = \frac{1}{8} \text{ dm}^3 \cdot \frac{1 \text{ kg}}{\text{dm}^3} \rightarrow 3 \cdot 10^{-3} \text{ m} \cdot 9.81 \frac{\text{m}}{\text{s}^2} +$$

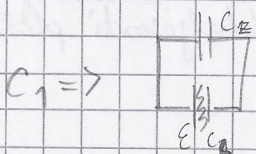
$$\epsilon_1 = \epsilon_2$$

$$C_1 U_1 = C_2 U_2$$

$$U_2 = \frac{C_1}{C_2} U_1$$

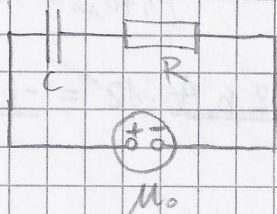
$$V_1 = V_2$$

$$C_2 = \epsilon_0 \epsilon_r \frac{S}{d_2} = 9.44 \text{ nF}$$



$$C_1 = C_2 + C_s = \epsilon_0 \frac{a^2}{d_1} + \epsilon_0 \epsilon_r \frac{a^2}{d_1}$$

$$C_1 = \epsilon_0 \frac{a^2}{2d_1} (1 + \epsilon_r)$$



$$C = 100 \mu\text{F}$$

$$R = 1000 \Omega$$

$$W_e(t_1) = \frac{1}{4} W_0$$

$$t_1 = ?$$

$$W_0 = \frac{1}{2} C U_0^2$$

$$W_c(t_1) = \frac{1}{4} W_0$$

$$\frac{1}{2} C U_c^2(t_1) = \frac{1}{4} C U_0^2$$

$$U_c = \frac{1}{2} U_0$$

POPLNJENJE KONDENZATORJA:

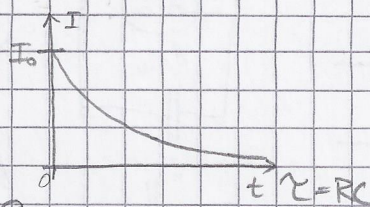
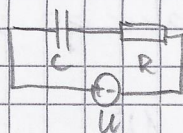
$$U_0 + U_C + U_R = 0$$

$$U_0 - \frac{q}{C} - RI = 0 \quad \bigg/ \frac{d}{dt}$$

$$0 - \frac{1}{C} \frac{dq}{dt} - R \frac{dI}{dt} = 0$$

$$I_0 = \frac{U_0}{R}$$

; kond. je prazen - tok je največji

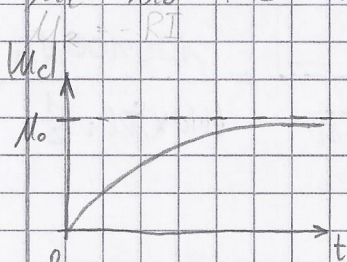


$$\int_{I_0}^{I_1} \frac{dI}{I} = - \int_0^{t_1} \frac{dt}{RC} \Rightarrow \ln \frac{I_1}{I_0} = - \frac{1}{RC} \cdot t_1 / e$$

$$\frac{I_1}{I_0} = e^{-\frac{t_1}{RC}} \Rightarrow I_1 = I_0 e^{-\frac{t_1}{RC}}$$

$$U_C = -U_0 - U_R$$

$$U_C = -U_0 + RI = -U_0 + RI_0 e^{-\frac{t_1}{RC}} = -U_0 + U_0 e^{-\frac{t_1}{RC}} = -U_0 (1 - e^{-\frac{t_1}{RC}})$$



napetost na kond. pri polnjenju.

$$|U_C| = \frac{1}{2} U_0$$

$$U_0 (1 - e^{-\frac{t_1}{RC}}) = \frac{1}{2} U_0$$

$$1 - \frac{1}{2} = e^{-\frac{t_1}{RC}} \quad \bigg/ (-)$$

$$e^{\frac{t_1}{RC}} = 2 \quad \bigg/ \ln$$

$$\frac{t_1}{RC} = \ln 2 \Rightarrow t_1 = RC \cdot \ln 2$$

$$t_1 = 1000 \cdot 100 \cdot 10^{-6} \cdot \ln 2 \approx 69.3 \text{ ms}$$

PRAZNIJENJE KONDENZATORJA

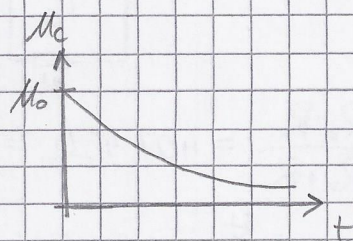
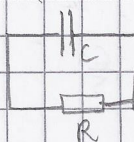
$$U_C + U_R = 0$$

$$-\frac{q}{C} - RI = 0 \quad \bigg/ \frac{d}{dt}$$

$$-\frac{I}{C} - R \frac{dI}{dt} = 0 \Rightarrow I = I_0 e^{-\frac{t}{RC}} \quad ; \quad \tau = RC$$

$$U_C = -U_R = -(-RI)$$

$$U_C = R \cdot \frac{I_0}{U_0} e^{-\frac{t}{RC}} = U_0 e^{-\frac{t}{RC}}$$



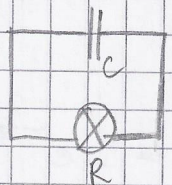
$$P = 100 \text{ W}$$

$$U = 110 \text{ V}$$

$$t_1 = 10 \text{ s}$$

$$C = ?$$

$$U_{\min} = 20 \text{ V}$$



želim, da žarnice po prekinutvi
svetijo še 10s, najmanjša napetost
je 20V. Kolšen kondenzator in
kako ga vezemo?

$$P = \frac{U_0^2}{R}$$

$$R = \frac{U_0^2}{P}$$

$$U_C(t_1) = U_{\min}$$

$$U_0 e^{-\frac{t_1}{\tau}} = U_{\min}$$

$$\frac{U_0}{U_{\min}} = e^{+\frac{t_1}{\tau}}$$

$$\ln \frac{U_0}{U_{\min}} = \frac{t_1}{RC}$$

$$C = \frac{t_1}{R \cdot \ln \frac{U_0}{U_{\min}}} = \frac{10 \text{ s} \cdot P}{U_0^2 \ln \frac{U_0}{U_{\min}}} = \frac{10 \text{ s} \cdot 100 \text{ W}}{(110 \text{ V})^2 \ln \frac{11}{2}} =$$

$$C = 48,5 \text{ mF}$$

$$C = 25 \mu\text{F}$$

$$U_0 = 60 \text{ V}$$

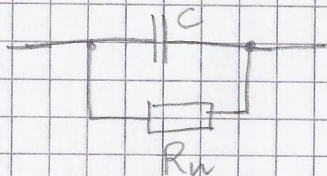
$$U_0(t_1) = 50 \text{ V}$$

$$t_1 = 10 \text{ ms}$$

$$R = 500 \Omega$$

$$U_C^{(R)}(t_1) = ?$$

slaba izolacija, do katere napetosti se bo
izpraznil po priključu upora v črnu.



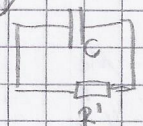
id. kond.
 $R_n \rightarrow \infty$

$$U_C(t_1) = U_0 e^{-\frac{t_1}{R_n C}}$$

$$e^{-\frac{t_1}{R_n C}} = \frac{U_0}{U_C(t_1)} \quad / \ln$$

$$\frac{t_1}{R_n C} = \ln \frac{U_0}{U_C(t_1)}$$

$$R_n = \frac{t_1}{C \ln \frac{U_0}{U_C(t_1)}} = \frac{10^{-2} \text{ s}}{25 \cdot 10^{-6} \frac{\text{As}}{\text{V}} \ln \frac{6}{5}} = 2194 \Omega \approx \underline{\underline{2,2 \text{ k}\Omega}}$$

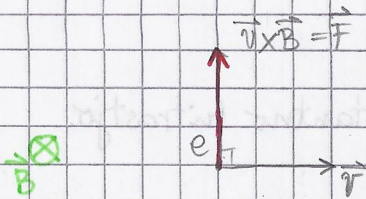


$$R' = \frac{R_n R}{R_n + R} = 407,4 \Omega \approx 407 \Omega$$

$$U_C^{(R)}(t_1) = U_0 e^{-\frac{t_1}{\tau}} \approx \underline{\underline{22,5 \text{ V}}}$$

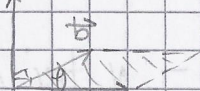
$$\tau = R' C = 10 \cdot 10^{-3} \text{ s}$$

$$\vec{F} = e\vec{E} + e\vec{v} \times \vec{B}$$



$$\begin{aligned} \vec{D} &= \epsilon \epsilon_0 \vec{E} \\ \vec{B} &= \mu_0 \mu \vec{H} \\ \mu_0 &= 4\pi \cdot 10^{-7} \frac{Vs}{Am} \end{aligned}$$

$$\vec{v} \times \vec{B}$$



$$|\vec{v} \times \vec{B}| = v \cdot B \cdot \sin \varphi$$

elektron:

$$\begin{cases} e = -e_0 \\ m_e = 9,1 \cdot 10^{-31} \text{ kg} \end{cases}$$

$$(m_e \cdot c^2) = 0,51 \text{ MeV}$$

mirorna masa delca

$$1 \text{ eV} = 1,6 \cdot 10^{-19} \text{ As} \cdot \text{V} = 1,6 \cdot 10^{-19} \text{ J}$$

Elektron z energijo 10 eV kroži v ravnini, ki je pravokotna smer mag. polja $B = 10^{-4} \text{ T}$. Kolikšen je radij kroga in v kakšnem času naredi 1 obhod.

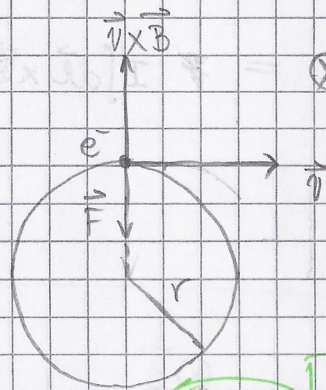
$$W_k = 10 \text{ eV}$$

$$B = 10^{-4} \text{ T}$$

$$\vec{v} \perp \vec{B} \Rightarrow \sin 90^\circ = 1$$

$$r = ?$$

$$t_0 = ?$$



$$\vec{F} = e\vec{v} \times \vec{B}$$

$$F = evB = -e v \cdot B = m \cdot a_r$$

$$a_r = \frac{v^2}{r}$$

$$e v B = m \cdot \frac{v^2}{r} \Rightarrow r = \frac{m v}{e \cdot B}$$

$$W_k = \frac{mv^2}{2} \Rightarrow v = \sqrt{\frac{2W_k}{m}} = \sqrt{\frac{20 \cdot 1,6 \cdot 10^{-19} \text{ J}}{9,1 \cdot 10^{-31} \text{ kg}}} \approx 1,9 \cdot 10^6 \frac{\text{m}}{\text{s}}$$

$$v = \sqrt{\frac{2W_k}{m}} = \frac{2 \cdot 10 \text{ eV}}{0,51 \frac{\text{eV}}{c^2}} \approx 2 \cdot 10 \cdot 10^{-3} c \approx 0,006 c$$

$$r = \frac{9,1 \cdot 10^{-31} \text{ kg} \cdot 1,9 \cdot 10^6 \frac{\text{m}}{\text{s}}}{1,6 \cdot 10^{-19} \text{ As} \cdot 10^{-4} \text{ T}} \approx 0,11 \text{ m} \approx 11 \text{ cm}$$

$$t_0 = \frac{2\pi r}{v} = \frac{2\pi \cdot 0,11 \text{ m}}{1,9 \cdot 10^6 \frac{\text{m}}{\text{s}}} \approx 364 \text{ ns}$$

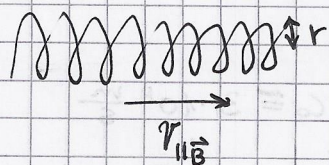
$$\nu = \frac{1}{t_0} \approx 2,7 \text{ MHz}$$

$$\varphi \neq 90^\circ$$

$$\underbrace{e v B}_{\text{projekcija}} = m \frac{v^2}{r} \quad \text{projekcija}$$

$$r = \frac{m v \cdot \sin \varphi}{e B}$$

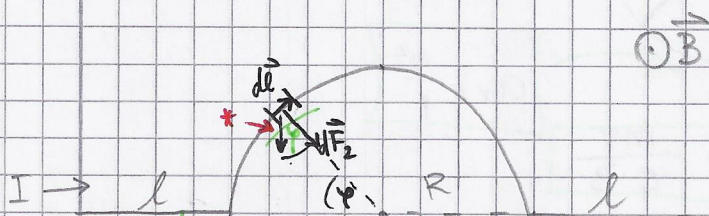
$v_{\parallel B} = v \cdot \cos \varphi$ - v tej smeri se giblje s konstantno hitrostjo.



$$\vec{F} = e \cdot \vec{E} + e \vec{v} \times \vec{B} \quad \Rightarrow \quad I = \frac{de}{dt}$$

$$d\vec{F} = \underbrace{de}_{I dt} \cdot \vec{v} \times \vec{B} = I \cdot \underbrace{\vec{v} dt}_{d\vec{l}} \times \vec{B} = I \int d\vec{l} \times \vec{B}$$

$$\boxed{\vec{F} = I \int d\vec{l} \times \vec{B}}$$



Kakšna nile deluje na žico, če teče tok I , $\vec{B}$ pa je $\perp$ na ravnino žice?

I, B, l, R

$$\vec{F} = I \int d\vec{l} \times \vec{B}$$

$$F_1 = F_3 = BIl$$

$$\vec{F} = ?$$

$$|d\vec{l} \times \vec{B}| = dl \cdot B$$

$$* dF_2 \cdot \sin \varphi$$

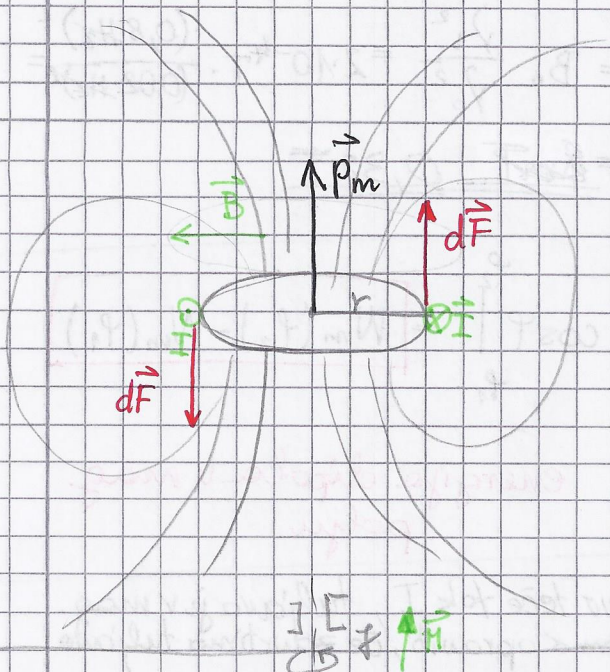
$$dl = R \cdot d\varphi$$

$$dF_2 = I \cdot dl \cdot B$$

$$F_2 = \int dF_2 \cdot \sin \varphi = \int I dl B \sin \varphi = I \cdot B \cdot R \cdot \int_0^\pi \sin \varphi d\varphi = \underline{+ I B R \cdot (1 - (-1)) = 2 I B R}$$

$$F_{\text{sk}} = F_1 + F_2 + F_3 = 2 I l B + 2 I R B = \underline{2 I B (l + R)}$$

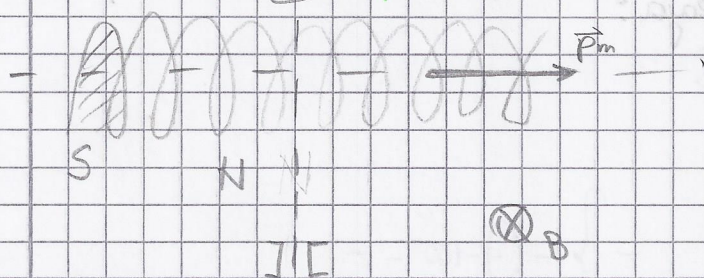
Isto je kot, če bi bila žica ravna $\rightarrow$ lahko jo tudi projiciramo na ravnino.



$$\vec{p}_m = I \cdot \vec{S} \rightarrow \text{mag. dipolni moment}$$

$$\vec{M} = \vec{p}_m \times \vec{B}$$

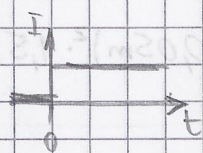
$$M = p_m \cdot B \cdot \sin \varphi$$



Tuljava s 40 navoj in presekom S se nahaja v mag. polju B . Vrtilna os tuljave je pravokotna na njeno geometrijsko os, obe pa sta pravokotni na polje. S kakšnim kotnim pospeškom se vrti tuljava?

$$\begin{aligned} N &= 40 \\ S &= 10 \text{ cm}^2 \\ B &= 0.8 \text{ T} \\ I &= 1.5 \cdot 10^{-3} \text{ kg m}^2 \\ I &= 0.2 \text{ A} \end{aligned}$$

$$\angle(t=0) = ?$$



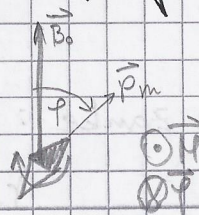
$$\vec{M} = \vec{p}_m \times \vec{B} = N \cdot I \cdot S \cdot B = 6.4 \cdot 10^{-3} \text{ Nm}$$

$$M = J \cdot \alpha \Rightarrow \alpha = \frac{M}{J} = \frac{6.4 \cdot 10^{-3} \frac{\text{kg m}^2}{\text{s}^2}}{1.5 \cdot 10^{-3} \text{ kg m}^2} = 4.3 \frac{1}{\text{s}^2}$$

V zemeljskem mag. polju B miha magnetnica okoli navpične osi s frekvenco ν_0 . Izmerimo novo frekvenco; kakšno je novo polje B_1 ?

$$\begin{aligned} B_0 &= 2 \cdot 10^{-4} \text{ T} \\ \nu_0 &= 0.02 \text{ Hz} \\ \nu_1 &= 0.8 \text{ Hz} \\ B_1 &= ? \end{aligned}$$

$$\varphi \ll 1 \quad M = J \cdot \alpha$$



$$\ddot{\varphi} = -\omega^2 \varphi$$

$$\begin{aligned} p_m \cdot B \cdot \sin \varphi &= J \cdot \ddot{\varphi} \\ p_m \cdot B \cdot \varphi &= J \cdot \ddot{\varphi} \end{aligned}$$

$$\omega = \frac{2\pi \nu}{1} = \frac{1}{2\pi} \sqrt{\frac{p_m \cdot B}{J}} \Rightarrow B = \frac{(2\pi \nu)^2 J}{p_m}$$

$$\frac{B_1}{B_0} = \frac{\frac{(2\pi I_1)^2}{\mu_0}}{\frac{(2\pi I_2)^2}{\mu_0}} = \frac{I_1^2}{I_2^2} \Rightarrow B_1 = B_0 \cdot \frac{I_1^2}{I_2^2} = 2 \cdot 10^{-4} \text{ T} \cdot \frac{(0,8 \text{ Hz})^2}{(0,02 \text{ Hz})^2} = \underline{\underline{0,32 \text{ T}}}$$

$$A = \int_{\varphi_1}^{\varphi_2} M \cdot d\varphi = p_m \cdot B \cdot \int_{\varphi_1}^{\varphi_2} \sin \varphi d\varphi = -p_m \cdot B \cdot \cos \varphi \Big|_{\varphi_1}^{\varphi_2} = \boxed{W_m(\varphi_2) - W_m(\varphi_1)}$$

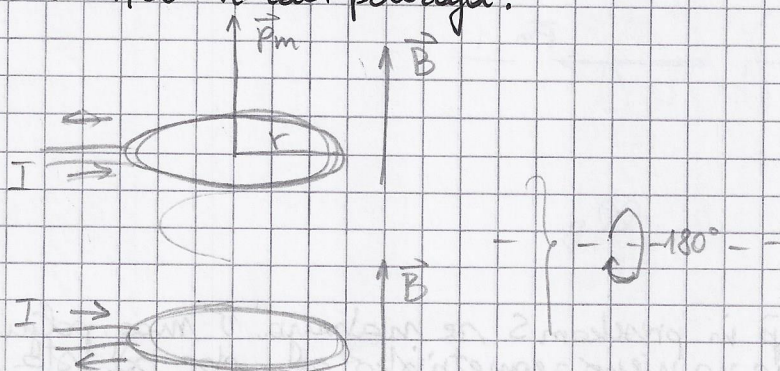
$$\boxed{W_m = -p_m \cdot B \cdot \cos \varphi = -\vec{p}_m \cdot \vec{B}}$$

energija dipola v mag. polju

Okrogla ploščata tuljava: Skozi tuljavo teče tok I , tuljavo je v mag. polju B . Kolikšno delo moramo opraviti, če zavrtimo tuljavo za 180° iz zač. položaja?

$$\begin{aligned} N &= 100 \\ r &= 0,05 \text{ m} \\ I &= 0,1 \text{ A} \\ B &= 1,5 \text{ T} \end{aligned}$$

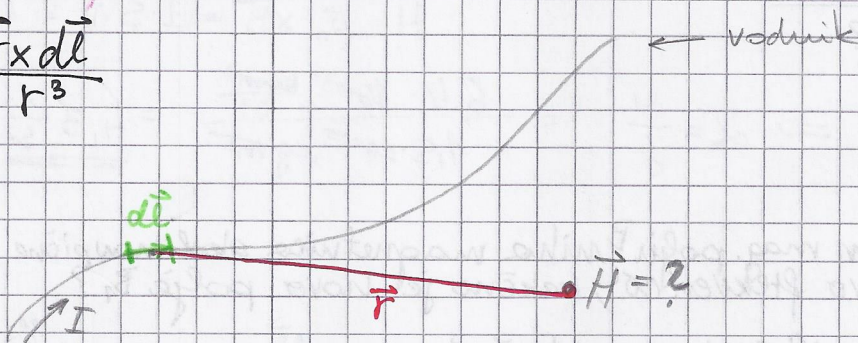
$$A = ?$$



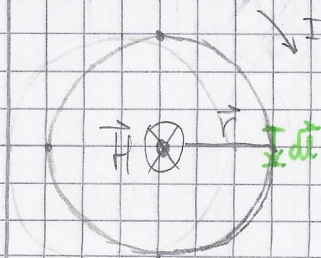
$$\begin{aligned} A = \Delta W_m &= -p_m \cdot B \cdot \cos 180^\circ - (-p_m \cdot B \cdot \cos 0^\circ) = 2p_m B = 2 \cdot N \cdot I \cdot S \cdot B = \\ &= 2 \cdot N \cdot I \cdot \pi r^2 \cdot B = 2 \cdot 100 \cdot 0,1 \text{ A} \cdot \pi \cdot (0,05 \text{ m})^2 \cdot 1,5 \text{ T} \approx \underline{\underline{0,24 \text{ J}}} \end{aligned}$$

BIOT-SAVARTOV zakon

$$\vec{H} = \frac{I}{4\pi} \int \frac{\vec{r} \times d\vec{l}}{r^3}$$



H v središču krožne zanke:



$$H = \frac{I}{4\pi} \int \frac{r_{\perp} dl}{r^3} = \frac{I}{4\pi r^2} \cdot \int dl = \frac{I}{2\pi r^2} \cdot 2\pi r =$$

$$\boxed{H = \frac{I}{2r}}$$

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kvadratični okvir

$$\rho = 0,03 \frac{\Omega \cdot \text{mm}^2}{\text{m}}$$

$$S_0 = 1 \text{ mm}^2 \rightarrow \text{preseki žice}$$

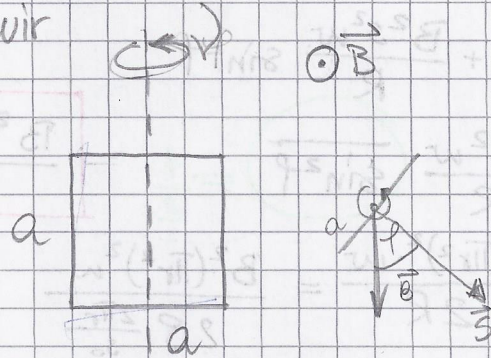
$$S = 121 \text{ cm}^2 \rightarrow \text{površina kvadrata}$$

$$Q = 11 \text{ cm}$$

$$\gamma = 20 \text{ Hz}$$

$$B = 1 \text{ T}$$

$$\varphi = 90^\circ$$



Kolikšna je amplituda toka, ki teče po okvirju?

$$I_0 = ?$$

$$\phi_m = \int \vec{B} \cdot d\vec{S} \Rightarrow \vec{B} \cdot \vec{S} = B \cdot S \cdot \cos \varphi =$$

$$\varphi = \omega t + \varphi_0$$

postavimo, da
sta vzporedna

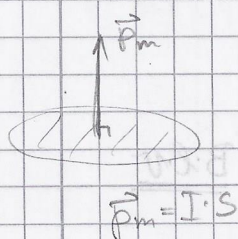
$$= B \cdot S \cdot \cos \omega t$$

$$U_i = \frac{d\phi_m}{dt} = -BS\omega \sin \omega t \quad \leftarrow \text{ind. nap. na okvirju}$$

$$I = \frac{U}{R} = - \frac{BS\omega \sin \omega t}{R} = - \frac{B \cdot \frac{Q \cdot 4a}{S_0} \cdot \omega \sin \omega t \cdot S_0}{2 \cdot 0,03 \frac{\Omega \cdot \text{mm}^2}{\text{m}}}$$

→ amplituda I_0

$$I_0 = \frac{B \cdot \frac{Q \cdot 4a}{S_0} \cdot \omega \cdot S_0}{2 \cdot 0,03 \frac{\Omega \cdot \text{mm}^2}{\text{m}}} = \frac{B \cdot Q \cdot 4a \cdot \omega}{2 \cdot 0,03 \frac{\Omega \cdot \text{mm}^2}{\text{m}}} = \frac{1 \cdot 11 \cdot 4 \cdot 20}{2 \cdot 0,03} = 115,13 \text{ A}$$



$$\vec{M} = \vec{p}_m \times \vec{B}$$

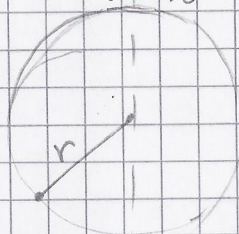
$$M = p_m \cdot B \cdot \sin \varphi$$

87. nal. / str. 52

$$\rho, r, S_0, B, \omega$$

$$M_1 = ?$$

okrogel obroč



$$M = I \cdot S \cdot B \cdot \sin \varphi$$

$$I = \frac{U_i}{R} = \frac{-B \cdot S \cdot \omega \cdot \sin \varphi}{R}$$

$$M = \frac{-B^2 S^2 \omega \sin^2 \varphi}{R}$$

$$M_1 = -M = + \frac{B^2 S^2 \omega}{R} \sin^2 \varphi$$

$$\overline{M}_1 = \frac{B^2 S^2 \omega}{R} \overline{\sin^2 \varphi} = \frac{1}{2} = \frac{B^2 S^2 \omega}{2R}$$

prosečno navor
obroča.

$$\overline{M}_1 = \frac{B^2 (\pi r^2)^2 \omega}{2R} = \frac{B^2 (\pi r^2)^2 \omega}{2 \cdot 9 \frac{2\pi r}{s_0}}$$



88. mal. / str. 52

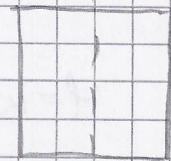
kv. okvir

$$S = 0,1 \frac{\text{mm}^2}{\text{m}}$$

$$S_0 = 1 \text{ mm}^2$$

$$a = 10 \text{ cm}$$

$$B = 0,1 \text{ T}$$



$\odot B$

Koliko dela opravimo za en
obrat okvirja s frekvenco

$$\nu = 60 \text{ Hz}$$

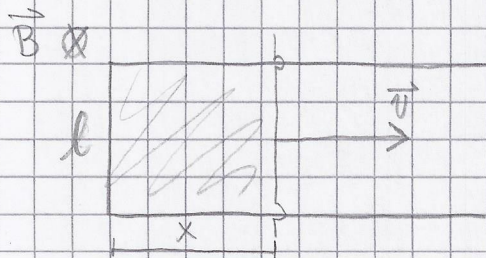
$$A = \int_0^{2\pi} M_1 d\varphi = \dots$$

$$A = ?$$

$$A = \overline{M}_1 \cdot 2\pi = \frac{B^2 S^2 \omega}{2R} = \frac{(0,1 \text{ T})^2 \cdot (0,1 \text{ m})^2 \cdot 2\pi \cdot 2\pi \nu}{2 \cdot 9 \frac{\text{kg}}{\text{s}^2 \text{m}}}$$

$$A = \frac{(0,1 \text{ T})^2 \cdot (0,1 \text{ m})^2 \cdot 2\pi \cdot 60 \text{ Hz} \cdot 10^{-3} \text{ m}^2}{2 \cdot 0,1 \frac{\text{kg}}{\text{m}} \cdot 4 \cdot 10^{-5} \text{ m}^2 \cdot 0,1 \text{ m}} \approx 0,003 \text{ J} \approx \underline{\underline{3 \text{ mJ}}}$$

$$A = \int_0^{t_0} P dt = \int_0^{t_0} U \cdot I dt$$



$$\mathcal{M}_i = \frac{d\Phi_m}{dt} = \frac{B \cdot l \cdot \frac{dx}{dt}}{dt} = B \cdot l \cdot v$$

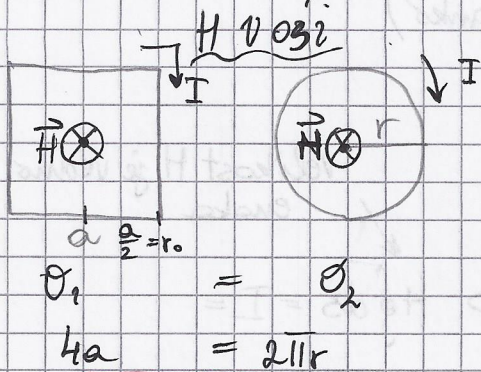
$$\mathcal{M}_i = \int \vec{v} \cdot (\vec{B} \times d\vec{\ell})$$

INDUKCIJSKI ZAKON

$$\mathcal{M}_i = - \int \vec{E} \cdot d\vec{s}$$

$$\oint \vec{E} \cdot d\vec{s} = - \int \frac{\partial \vec{B}}{\partial t} d\vec{s}$$

2 ploščati tuljavi navijemo na enako št. navojev. 1. je navitna na kvadrat, 2. pa na obroč.
Kakšno je razmerje, če po obeh tuljavah teče isti tok.



$$\Phi_1 = \Phi_2$$

$$4a = 2\pi r$$

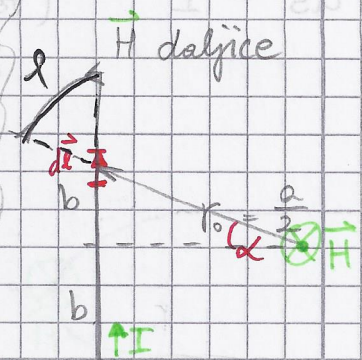
$$a = \frac{\pi r}{2}$$

$$l_1 = l_2$$

$$N_1 = N_2 = N$$

$$I = I_1 = I_2$$

$$\frac{H_1}{H_2} = ?$$



prevedemo na integral v odvisnosti od α

vsi prispevki $\vec{H}$ kažejo v istosmer

$$H = \frac{I}{4\pi} \int \frac{r \cdot dl \cdot \sin \alpha}{r^3} =$$

$$H = \frac{I}{2\pi r_0} \frac{b}{\sqrt{b^2 + r_0^2}}$$

$$H_1 = 4 \cdot H_a$$

$$H_1 = \frac{2l \cdot I \cdot N}{2\pi \cdot \frac{a}{2}} \cdot \frac{\frac{\pi}{2}}{\sqrt{\frac{a^2}{4} + \frac{a^2}{4}}} =$$

$$H_1 = \frac{2\sqrt{2} \cdot I \cdot N}{\pi a}$$

$$\alpha = \frac{\pi r}{2}$$

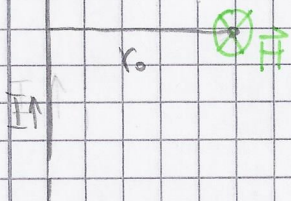
$$H_1 = \frac{2\sqrt{2} \cdot I \cdot N}{\pi \cdot \frac{\pi r}{2}} = \frac{4\sqrt{2} \cdot I \cdot N}{\pi^2 \cdot r}$$

V osi kvadratne tuljave bo jakost mag. polja za pribl. 15% večja kot v osi krožne tuljave.

$$\frac{H_1}{H_2} = \frac{\frac{4\sqrt{2} \cdot I \cdot N}{\pi^2 \cdot r}}{\frac{NI}{2r}} = \frac{8\sqrt{2}}{\pi^2} (= 1,15)$$

$\vec{H}$ premice:

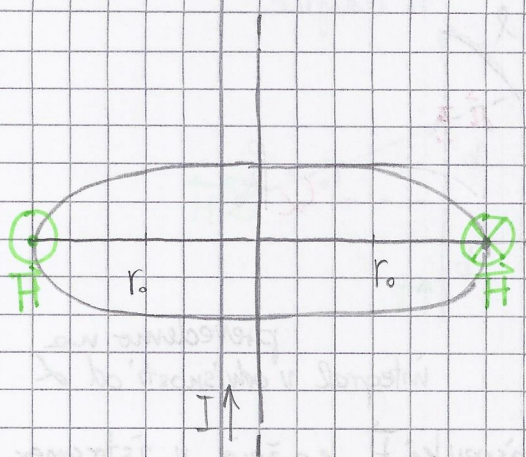
$$\underline{H_{\infty}} = \lim_{b \rightarrow \infty} \left(\frac{I}{2\pi r_0} \cdot \frac{b}{\sqrt{b^2 + r_0^2}} \right) = \underline{\frac{I}{2\pi r_0}}$$



AMPERE-OV ZAKON → zakon o magnetni napetosti

$$\oint \vec{H} \cdot d\vec{s} = I \quad (\text{tok, ki teče skozi zanko})$$

$$\left\{ \vec{B} = \text{konst.} \right\}$$



$$\vec{H} \parallel d\vec{s}$$

velikost H je vedno enaka

$$\oint H ds = I \Rightarrow H \oint ds = I =$$

$$H = \frac{I}{2\pi r_0}$$

Po valjasti žici z radijem R teče po vsem preseku enakomerno tok I. Kolikšna je jakost H na razdalji r?

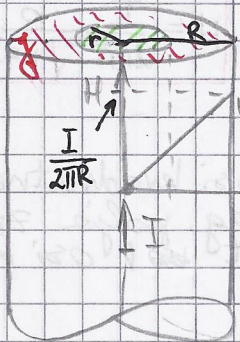
$$R = 1 \text{ cm}$$

$$I = 1000 \text{ A}$$

$$j = \frac{I}{S} = \frac{I}{\pi R^2}$$

$$r = 0,5 \text{ cm}$$

$$H(r) = ?$$



$$\oint \vec{H} \cdot d\vec{s} = j \cdot \pi r^2$$

$$H \cdot 2\pi r = \frac{I}{\pi R^2} \cdot \pi r^2$$

$$H = \frac{I r}{2R^2\pi} = \frac{10^3 \text{ A} \cdot 0,5 \cdot 10^{-2} \text{ m}}{2 \cdot 1 \cdot 10^{-4} \cdot \pi} \approx \underline{\underline{8000 \frac{\text{A}}{\text{m}}}}$$

6.5.2011

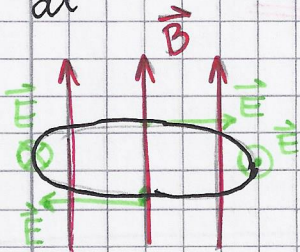
INDUKCIJA

$$\Phi_m = \int \vec{B} \cdot d\vec{s}$$

$$\mathcal{U}_i = \frac{d\Phi_m}{dt}$$

LENZovo PRAVILO

"Ind. nap. vedno nasprotuje vzroku svojega nastanka."



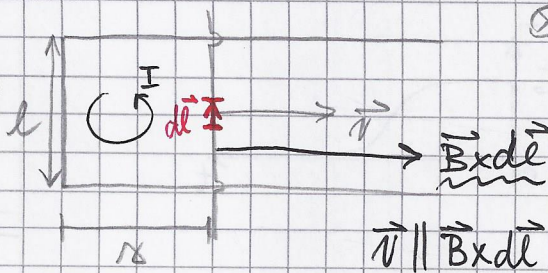
$$\frac{dB}{dt} > 0$$

2 dolga vzp. vodnika v razmiku 5 cm sta na prvih krajiščih povezane s prečko, druge prečke pa drži po njima. V na ravni vodnikov je $B = 1 \text{ T}$. Premična prečka se iz začetne lege začne gibati enakomerno pospešeno. Kolikšna je razdalja od prečke do krajišč ko je tok maksimalen?

$l = 5 \text{ cm}$
 $B = 1 \text{ T}$ ← (odvečen padatek)
 $s(t=0) = 0$
 $v(t=0) = 0$
 $a = \text{konst}$

$$\begin{cases} v = at \\ s = \frac{at^2}{2} \end{cases}$$

$s(I_{\text{max}}) = ?$



$$\mathcal{U}_i = \int \vec{v} \cdot (\vec{B} \times d\vec{l}) = \int v B dl = v B l = at B l$$

$$I = \frac{\mathcal{U}}{R} = \frac{at B l}{\frac{2l + 2s}{s}} \rightarrow \frac{at^2}{2} = \frac{2at B l s}{2l + 2s} = \frac{a B l s}{s} \cdot \frac{t}{(2l + at^2)}$$

$$\frac{dI}{dt} = \frac{a B l s}{s} \cdot \frac{1 \cdot (2l + at^2) - t(2at)}{(2l + at^2)^2} = 0 \quad \leftarrow \text{pogoj za ekstrem}$$

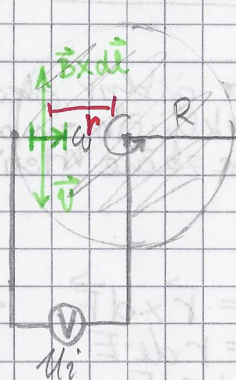
$$2l + at^2 - 2at^2 = 0$$

$$2l = at^2$$

$$l = \frac{at^2}{2} = s$$

v tem primeru bo tok največji - zanka ^{mora biti} kvadrat.

Kovinska plošča



$$\mathcal{U}_i = - \int \vec{v} \cdot \vec{B} \cdot d\vec{l} = - \int \omega r \cdot B \cdot dr$$

$$\mathcal{U}_i = -\omega B \int_0^R r \cdot dr = -\omega B \cdot \frac{R^2}{2} =$$

$$= -200 \text{ s}^{-1} \cdot 0,1 \frac{\text{Vs}}{\text{m}^2} \cdot \frac{0,04 \text{ m}^2}{2} = -0,4 \text{ V}$$

93. nal. / str. 54

$R = 20 \text{ cm}$

$\omega = 200 \text{ rad/s}$

$B = 0,1 \text{ T}$

$\mathcal{U}_i = ?$

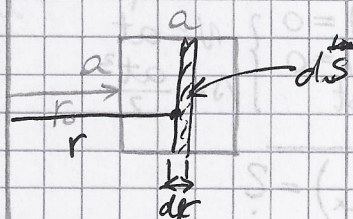
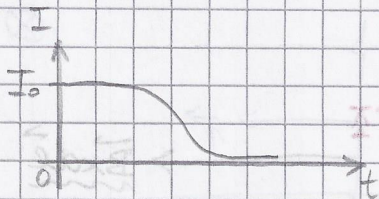
$$\mathcal{U}_i = \frac{d\phi_m}{dt} \Rightarrow \int_{t_1}^{t_2} \mathcal{U}_i dt = \int_{\phi_m(t_1)}^{\phi_m(t_2)} d\phi_m = \phi_m(t_2) - \phi_m(t_1)$$

$\int \mathcal{U}_i dt = \Delta \phi_m$ razenik inducirane napetosti

V ravnini ravnega vodnika po katerem teče tok I_0 je žičnat ovaj v obliki kvadrata s stranico a . 2 stranici sta vzp. z vodnikom, bližnja je oddaljena od vodnika za r_0 . Kolikšen tokovni suneke nastane v žanki, če izključimo tok v vodniku.

$$\begin{aligned} I_0 &= 300 \text{ A} \\ a &= 5 \text{ cm} \\ r_0 &= 3 \text{ cm} \\ \epsilon &= 0,02 \frac{\Omega \text{ mm}^2}{\text{m}} \\ S_0 &= 1 \text{ mm}^2 \end{aligned}$$

$$e = \int I dt = ?$$



$$\int R \cdot I dt = \Delta \phi_m$$

$$R \int I dt = \Delta \phi_m = 0 - \phi_{m, r_0+a}$$

$$\phi_m = \int_{r_0}^{r_0+a} \frac{\mu_0 I}{2\pi r} \cdot a dr = \frac{\mu_0 I a}{2\pi} \int_{r_0}^{r_0+a} \frac{dr}{r} =$$

$$\phi_m = \int B \cdot dS$$

$$B = \frac{\mu_0 I}{2\pi r}$$

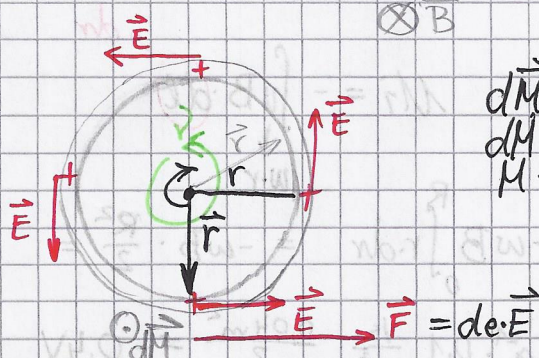
$$\phi_m = \frac{\mu_0 I a}{2\pi} \ln \frac{r_0+a}{r_0}$$

$$\int I dt = -\frac{\phi_m}{R} = -\frac{\mu_0 I_0 a \cdot S_0}{2\pi \epsilon a} \cdot \ln \frac{r_0+a}{r_0} = -\frac{\mu_0 I_0 S_0}{8\pi \epsilon} \ln \frac{r_0+a}{r_0} =$$

$$= -\frac{4\pi \cdot 10^{-7} \frac{\text{Vs}}{\text{Am}} \cdot 300 \text{ A} \cdot 1 \cdot 10^{-6} \frac{\text{m}^2}{\text{m}}}{28\pi \cdot 0,02 \frac{\Omega \text{ mm}^2}{\text{m}}} \cdot \ln \frac{8}{5} = \underline{\underline{0,75 \text{ mAs}}} \quad 0,35 \text{ mAs}$$

Tanek obroč z radijem r in maso m je prosti gibljiv okoli geo. osi in ima po vsem volumnu enako porazdeljen ~~naboj~~ ~~naboj~~ ~~naboj~~. Vključimo mag. polje B , no silci naboja niso gibljivi. S kakšno frekvenco se začne vrteti obroč?

$$\begin{aligned} r &= 10 \text{ cm} \\ m &= 10^{-2} \text{ kg} \\ e &= 10^{-2} \text{ AS} \\ B &= 1 \text{ T} \\ \gamma &= ? \end{aligned}$$



$$\begin{aligned} d\vec{M} &= \vec{r} \times d\vec{F} \\ dM &= r \cdot dQ \cdot E \\ M &= r \cdot e \cdot E \end{aligned}$$

manj površ
kažejo $\odot$, lahko
jih seštejemo

$$\int M dt = \Delta \Gamma$$

$$r e \int E dt = \gamma \cdot \omega - 0$$

$$r e \int E dt = m r^2 \cdot 2\pi \gamma$$

$$r \cdot e \int \frac{U_i}{2\pi r} dt = m r^2 \cdot 2\pi \gamma$$

$$U_i = \int E \cdot dS = E \cdot 2\pi r \Rightarrow E = \frac{U_i}{2\pi r}$$

$$\frac{e}{2\pi} \int \underbrace{M_i \cdot dt}_{\Phi_m = B \cdot S = B \cdot \pi r^2} = m r^2 \cdot 2\pi \gamma$$

$$\frac{VA_s}{m} = N = \frac{kg \cdot m}{s^2}$$

$$\frac{e}{2\pi} B \pi r^2 = m r^2 2\pi \gamma \Rightarrow \gamma = \frac{e \cdot B}{4\pi m} = \frac{10^{-2} As \cdot 1 \frac{kg \cdot m}{s^2 \cdot A \cdot m}}{4\pi \cdot 10^{-2} kg}$$

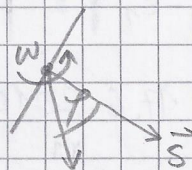
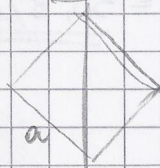
$$= 0,0796 \text{ Hz} \approx \underline{\underline{80 \text{ mHz}}}$$

13.4.2011

1 KOL. 2009

4. $a = 2 \text{ cm}$
 $\omega = 11 \text{ Hz}$
 $B = 0,2 \text{ T}$

kv. zanka $\odot \vec{B}$



a) $M_i^2, t = 1,5 \text{ ms}$

$$\varphi = \omega t + \varphi_0$$

kažeta y
magnitni
momenti

$$M_i = -BS\omega \sin(\omega t + \varphi_0) = -B \cdot a^2 \cdot 2\pi \gamma \sin(2\pi \gamma t + \pi)$$

$$M_i = \underline{\underline{572 \mu V}}$$

b) $R = 0,07 \Omega$

$$\overline{M} = ?$$

$$\overline{M} = \frac{B^2 S^2 \omega}{2R} = \underline{\underline{3,16 \mu Nm}}$$

$$\vec{M} = \vec{p}_m \times \vec{B}$$

$$M = p_m B \cdot \sin \varphi$$

$$\vec{p}_m = I \vec{S}$$

$$p_m = \frac{M_i}{R} \cdot S = \frac{BS^2 \omega \sin \varphi}{R}$$

1. $v = 80 \text{ km/s}$
 $B = 10^{-2} \text{ T}$
 $\varphi = 70^\circ$

$$W_k = W_e$$

$$\frac{1}{2} m v^2 = e_0 \hbar$$

$$\Rightarrow M = \frac{m v^2}{2 e_0} = \underline{\underline{33,4 \text{ V}}} \quad \textcircled{c}$$

$$\omega = \frac{e_0 B}{m}$$

$$\frac{v_1}{v} = \sin \varphi$$

$$\omega = \frac{e_0 B}{m}$$

$$r = \frac{v_1}{\omega} = \frac{v \sin \varphi m}{e_0 B} = \underline{\underline{78,5 \text{ mm}}} \quad \textcircled{B}$$

5. $d = 20 \text{ m}$
 $e_1 = -4 \cdot 10^{-5} \text{ As}$
 $r_1 = 0,05 \text{ m}$
 $r_2 = 0,1 \text{ m}$
 $e_2 = 27,5 \mu\text{As}$

$$E = \frac{|e_1| + |e_2|}{4\pi\epsilon_0 \left(\frac{d}{2}\right)^2} = \frac{|-4 \cdot 10^{-5} \text{ As}| + |27,5 \cdot 10^{-6} \text{ As}|}{4\pi\epsilon_0 \cdot 100 \text{ m}^2}$$

$E = 6072 \frac{\text{V}}{\text{m}}$ (d)

$$e_1 + e_2 = e_1' + e_2'$$

$$\frac{e_2'}{4\pi\epsilon_0 r_2} = \frac{e_1'}{4\pi\epsilon_0 r_1}$$

$$e_1' = e_2' \frac{r_1}{r_2}$$

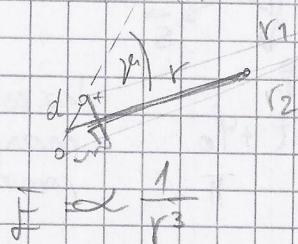
$$e_1 + e_2 = e_2' \left(\frac{r_1}{r_2} + 1 \right)$$

$$-8,3 \mu\text{As}$$

$$\int Idt = |e_1 - e_1'| = |e_2 - e_2'| = \underline{\underline{35,8 \mu\text{As}}} \quad (c)$$

12PIT 17.6.2010

(5)



$$\frac{1}{r^3}$$

$$E \propto \frac{1}{r^3}$$

$$r_1 r_2 \approx r^2$$

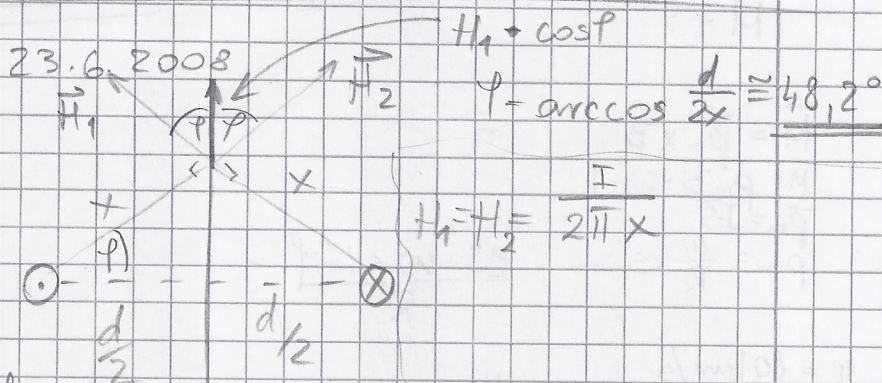
$$r_2 - r_1 = d \cos \varphi$$

$$V = \frac{e_1}{4\pi\epsilon_0 r_1} + \frac{e_2}{4\pi\epsilon_0 r_2} = \frac{e}{4\pi\epsilon_0} \left(\frac{1}{r_1} - \frac{1}{r_2} \right)$$

FIZ 2 UNI

4. $d = 4 \text{ m}$
 $I = 0,7 \text{ A}$
 $x = 3 \text{ m}$

$$H = ?$$



$$H = |\vec{H}_1 + \vec{H}_2| = 2H_1 \cos \varphi =$$

$$= 2 \cdot \frac{I}{2\pi x} \cdot \frac{d}{2} = \frac{Id}{2\pi x} \approx \underline{\underline{0,05 \frac{\text{A}}{\text{m}}}} \quad (d)$$

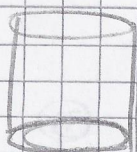
12PIT

1.10.10

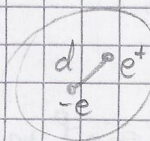
6. $\phi_m = 10 \text{ Vs}$

$$\oint \vec{B} \cdot d\vec{s} = 0$$

ϕ_m (as. plotaar) = -10 Vs



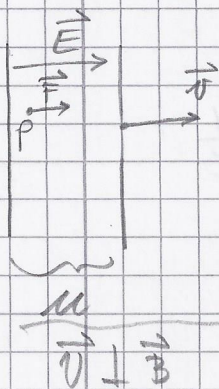
7.



$$\oint \vec{B} \cdot d\vec{s} = Q$$

$$\underline{\underline{\phi_e = 0}}$$

6.



$$r_p = 45 \text{ mm}$$

$$e_x = 2e_p$$

$$m_x = 4m_p$$

 r_x

$$W_k = W_e$$

$$\frac{1}{2}mv^2 = eU$$

$$v = \sqrt{\frac{2eU}{m}}$$

$$r_x = \sqrt{\frac{2m_x U}{e_x B^2}}$$

$$r_p = \sqrt{\frac{2m_p U}{e_p B^2}}$$

$$\vec{F} = e \vec{v} \times \vec{B}$$

$$F = e v B$$

$$m a = e v B$$

$$m \frac{v^2}{r} = e v B$$

$$r = \frac{mv}{eB}$$

$$r = \frac{m \sqrt{\frac{2eU}{m}}}{eB} = \sqrt{\frac{2eUm}{e^2 B^2}} =$$

$$r = \sqrt{\frac{2Um}{eB^2}}$$

$$\frac{r_x}{r_p} = \frac{\sqrt{\frac{2m_x U}{e_x B^2}}}{\sqrt{\frac{2m_p U}{e_p B^2}}} = \sqrt{\frac{m_x}{e_x} \cdot \frac{e_p}{m_p}} = \sqrt{\frac{4}{2}} = \frac{2}{\sqrt{2}}$$

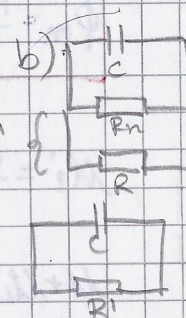
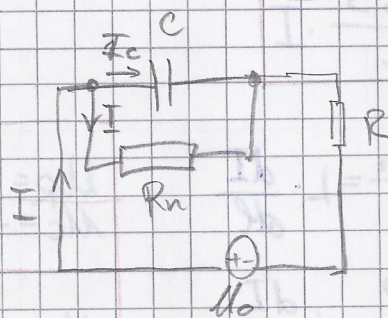
$$r_x = \sqrt{2} r_p = \sqrt{2} \cdot 45 \text{ mm} = 63,6 \text{ mm} \quad \textcircled{A}$$

$$2. \quad C = 3 \mu\text{F}$$

$$R_n = 8000 \Omega$$

$$R = 1000 \Omega$$

$$U_0 = 12 \text{ V}$$



$$+ (e_c = \frac{2}{3} e_p) = ?$$

$$e_c = \frac{2}{3} e_p$$

$$R = \frac{R R_n}{R + R_n} = 890 \Omega$$

$$e = C U_0$$

$$C U_c = \frac{2}{3} C U_0$$

$$a) \quad I(t \rightarrow \infty) = ?$$

$$I_c = I_0 e^{-\frac{t}{\tau}}$$

$$I_c(t \rightarrow \infty) = 0$$

$$U_c = -U_0 (1 - e^{-\frac{t}{\tau}}) \xrightarrow{t \rightarrow \infty} -U_0$$

$$I = \frac{U_0}{R_n + R} = \frac{12 \text{ V}}{9000 \Omega} = 1,3 \text{ mA} \quad \textcircled{D}$$

TRANSIENTE

$$U = U_0 e^{-\frac{t}{\tau}}$$

$$U_0 e^{-\frac{t}{\tau}} = \frac{2}{3} U_0$$

$$\frac{2}{3} = e^{-\frac{t}{\tau}} \quad \ln$$

$$t = \tau \ln \frac{3}{2} = R' C \ln \frac{3}{2} =$$

$$= 890 \frac{\text{V}}{\text{A}} \cdot 3 \cdot 10^{-6} \frac{\text{As}}{\text{V}} \cdot \ln \frac{3}{2} =$$

$$= 1,08 \text{ ms} \quad \textcircled{B}$$

2. način

$$I = I_0 e^{-\frac{t}{\tau}} \quad I = \frac{dq}{dt}$$

$$I_0 e^{-\frac{t}{\tau}} = \frac{dq}{dt}$$

$$\int_0^{t'} I_0 e^{-\frac{t}{\tau}} dt = \int_0^{\frac{2}{3}e_0} dq$$

$$\int e^{kt} dt = \frac{e^{kt}}{k} \quad ; \quad k = -\frac{1}{\tau}$$

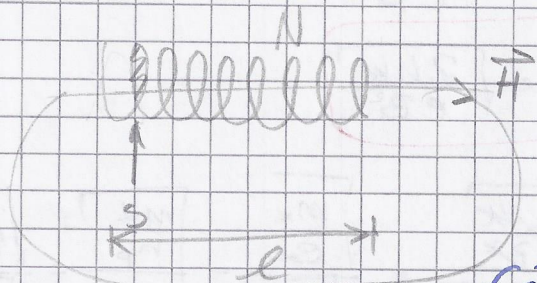
$$I_0 (-\tau) e^{-\frac{t}{\tau}} \Big|_0^{t'} = \frac{2}{3}e_0 - e_0$$

$$I_0 \tau \left(e^{-\frac{t'}{\tau}} - 1 \right) = -\frac{1}{3}e_0$$

$$e^{-\frac{t'}{\tau}} = \frac{\frac{1}{3}e_0 + 1}{I_0 \tau} \quad / \ln$$

$$-\frac{t'}{\tau} = \ln \left(\frac{\frac{1}{3}e_0 + 1}{I_0 \tau} \right)$$

20.4.2011



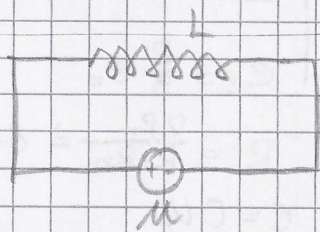
$$\Phi_m = NBS = N\mu_0 H \cdot S = N\mu_0 \frac{NI}{l} \cdot S = \left(\frac{N^2 \mu_0 S}{l} \right) \cdot I$$

$$\oint \vec{H} \cdot d\vec{l} = NI$$

$$Hl = NI$$

$$H = \frac{NI}{l}$$

$$\Phi_m = \frac{N^2 \mu_0 S}{l} \cdot I$$



$$\mathcal{U}_i = \frac{d\Phi_m}{dt} = L \cdot \frac{dI}{dt}$$

$$\mathcal{U} + \mathcal{U}_L = 0$$

$$\mathcal{U}_L = -\mathcal{U} = -L \frac{dI}{dt}$$

$$\mathcal{U}_R = -R \cdot I$$

$$\mathcal{U}_C = -\frac{q}{C}$$

$$\mathcal{U}_L = -L \frac{dI}{dt}$$

Nikajnikrog sestavlja kond. s C in tuljavo z L. Kond. nabijemo nato po sklenem nih. krog (priključimo tuljavo). Po kolikšnem času odda kond. polovico svoje energije tuljavi?

$$C = 1 \mu F$$

$$L = 10^{-3} \frac{Vs}{A}$$

$$W_C = \frac{1}{2} C U_0^2$$

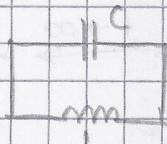
$$W_L = \frac{1}{2} L I^2$$

$$\mathcal{U}_C(t=0) = \mathcal{U}_0$$

$$t(W_C = \frac{1}{2} W_0) = ?$$

$$W_C = \frac{1}{2} W_0$$

$$W_C = W_L$$



$$\mathcal{U}_C = -\mathcal{U}_L = +L \frac{dI}{dt}$$

$$\mathcal{U}_C = L \omega \cos(\omega t + \delta)$$

$$\mathcal{U}_C = \mathcal{U}_0 \cos(\omega t + \delta)$$

$$U_C + U_L = 0$$

$$-\frac{e}{C} - L \frac{dI}{dt} = 0 \quad \bigg| \frac{d}{dt}$$

$$I + \left(\frac{1}{LC} \right) \cdot I = 0$$

$$\left(\frac{de}{dt} \right) \leftarrow I$$

$$-\frac{1}{C} - L \frac{d^2 I}{dt^2} = 0 \quad \bigg| \left(-\frac{1}{C} \right)$$

$$I = I_0 \sin(\omega t + \delta)$$

$$\omega = \frac{1}{\sqrt{LC}}$$

$$W_C = \frac{1}{2} W_0$$

$$\frac{1}{2} C U_0^2 \cos^2(\omega t + \delta) = \frac{1}{2} \cdot \frac{1}{2} C U_0^2$$

$$\cos^2(\omega t) = \frac{1}{2} \quad \bigg| \sqrt{}$$

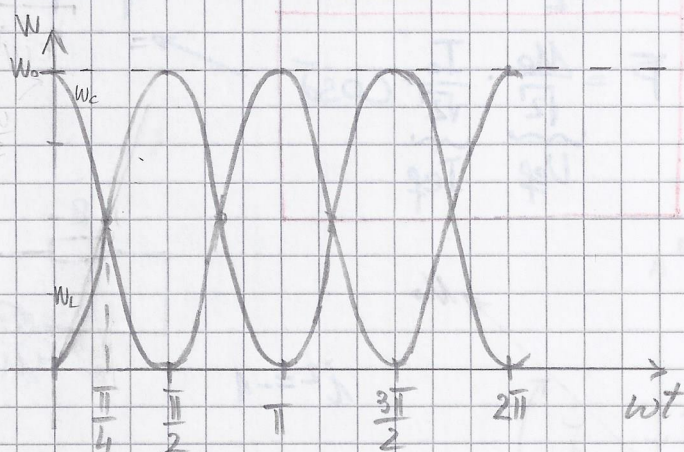
$$\cos(\omega t) = \frac{\sqrt{2}}{2}$$

$$\omega \cdot t = \frac{\pi}{4}$$

$$t = \frac{\pi}{4 \omega} = \frac{\pi}{4} \cdot \sqrt{LC}$$

$$t = \frac{\pi}{4} \sqrt{10^{-3} \frac{Vs}{A} \cdot 1 \cdot 10^{-6} \frac{Vs}{A}} =$$

$$= \frac{\pi}{4} \sqrt{10^{-9} s} \approx \underline{\underline{24,8 \mu s}}$$



$$U_C(t=0) = U_0$$

$$U_0 \cos(0 + \delta) = U_0$$

$$\cos \delta = 1$$

$$\delta = 0$$

$$W_C = W_0 \cdot \cos^2(\omega t)$$

$$W_L = \frac{1}{2} I_0^2 L \sin^2(\omega t)$$

$$W_0$$

$$\underline{\underline{W_L + W_C = W_0 (\sin^2 \omega t + \cos^2 \omega t) = W_0}}$$

Nihajni krog sestavlja kond. LC, upor z_R in tuljava z_L . Izračunaj nih. čas ter koeficient dušenja β tega nih. kroga.

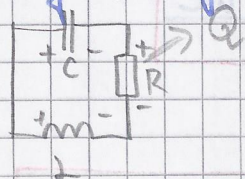
$$C = 0,5 \mu F$$

$$L = 10^{-3} \frac{Vs}{A}$$

$$R = 1,5 \Omega$$

$$t' = ?$$

$$\beta = ?$$



$$U_C + U_R + U_L = 0$$

$$-\frac{e}{C} + R \cdot I - L \frac{dI}{dt} = 0 \quad \bigg| \frac{d}{dt} \quad \left(-\frac{1}{C} \right)$$

$$\ddot{I} + \left(\frac{1}{LC} \right) I + \left(\frac{R}{L} \right) \dot{I} = 0$$

$$\omega^2 \quad 2\beta$$

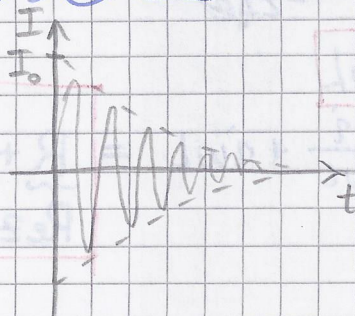
$$\ddot{I} + \omega^2 I + 2\beta \dot{I} = 0$$

$$I = I_0 e^{-\beta t} \sin(\omega' t + \delta)$$

$$\beta = \frac{R}{2L}$$

$$\omega' = \sqrt{\omega^2 - \beta^2}$$

$$I = I_0 e^{i \omega t}$$



$$\beta = \frac{1}{\gamma} = \frac{R}{2L} = \frac{1,5 \frac{\Omega}{\text{m}}}{2 \cdot 10^{-3} \frac{\text{Vs}}{\text{A}}} = 750 \text{ s}^{-1}$$

$$\omega^2 = \frac{1}{LC} = 2 \cdot 10^3 \text{ s}^{-2}$$

$$\omega' = \sqrt{\omega^2 - \beta^2} = \sqrt{(2 \cdot 10^3 \text{ s}^{-2}) - (750 \text{ s}^{-1})^2} = 44,7 \text{ k} \frac{1}{\text{s}}$$

$$t_0' = \frac{2\pi}{\omega'} = 140,4 \mu\text{s}$$

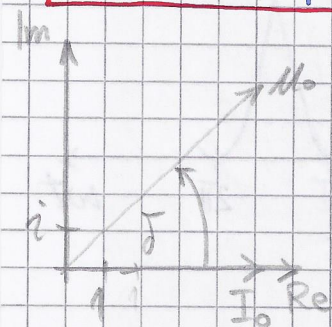
$$u_g = u_0 \cos(\omega t + \delta) = u_0 = u_0 e^{i\omega t}$$

$$I = I_0 \cos(\omega t) \Rightarrow I = I_0 e^{i\omega t}$$

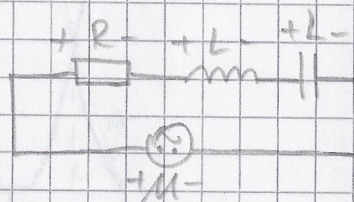
$$P = u \cdot I$$

$$\bar{P} = \frac{1}{2} u_0 I_0 \cos \delta \rightarrow \text{průměrná moc}$$

$$\bar{P} = \underbrace{\frac{u_0}{\sqrt{2}}}_{U_{\text{eff}}} \cdot \underbrace{\frac{I_0}{\sqrt{2}}}_{I_{\text{eff}}} \cos \delta$$



$$i^2 = -1$$



RLC - vezje

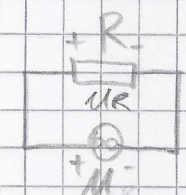
$$u_g = Z \cdot I$$

↑
impedancia

$$u_0 e^{i\omega t} = Z \cdot I_0 e^{i\omega t}$$

$$u_0 = Z \cdot I_0 \Rightarrow |u_0| = \sqrt{R^2 + (\omega L - \frac{1}{\omega C})^2} \cdot I_0$$

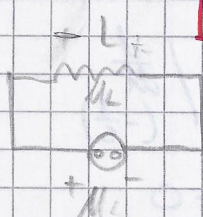
$$\tan \delta = \frac{\text{Im} Z}{\text{Re} Z} = \frac{\omega L - \frac{1}{\omega C}}{R}$$



$$u_R = R \cdot I$$

$$u_R = Z_R \cdot I$$

$$Z_R = R$$



$$-u_L = u_g - Z \cdot I$$

$$L \cdot \frac{dI}{dt} = Z \cdot I$$

$$L i \omega I_0 e^{i\omega t} = Z I_0 e^{i\omega t}$$

$$Z_L = i \omega L$$

$$Z_R = R$$

$$Z_L = i \omega L$$

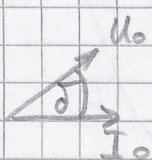
$$Z_C = \frac{1}{i \omega C} = -\frac{i}{\omega C}$$

$$Z = Z_R + Z_C + Z_L = R + \frac{-i}{\omega C} + i \omega L = \underbrace{R}_{\text{Re} Z} + i \underbrace{(\omega L - \frac{1}{\omega C})}_{\text{Im} Z}$$

nal. 56 / str. 42

V zap. veznem RLC vezju teče I_{ef} . Troši se pov. moč $\bar{P}$. Tok zaostaja za napetostjo za δ . Kolikšna je impedanca celotnega vezja?

$$\begin{aligned} I_{ef} &= 300 \text{ mA} \\ \bar{P} &= 3 \text{ mW} \\ \delta &= 30^\circ \\ Z &= ? \end{aligned}$$



- 1. način:

$$\bar{P} = U_{ef} \cdot I_{ef} \cos \delta = Z I_{ef}^2 \cdot \cos \delta$$

$\Downarrow$

$$U_{ef} = Z \cdot I_{ef}$$

$$Z = \frac{\bar{P}}{I_{ef}^2 \cdot \cos \delta} = \frac{3 \cdot 10^{-3} \text{ W}}{0,09 \text{ A}^2 \cdot \cos 30^\circ} \approx \underline{\underline{38,5 \text{ m}\Omega}}$$

Energija se izgublja samo na uporah, tam se tudi troši moč.

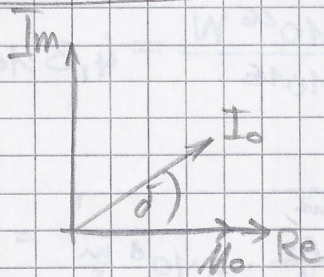
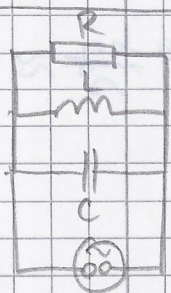
- 2. način:

$$\bar{P} = \bar{P}_R = U_{ef} \cdot I_{ef} = R \cdot I_{ef}^2$$

$$R = \frac{\bar{P}}{I_{ef}^2} = \frac{3 \cdot 10^{-3} \text{ W}}{90 \cdot 10^{-5} \text{ A}^2} = 33,3 \text{ m}\Omega \quad \tan \delta = \frac{WL - \frac{1}{WC}}{R}$$

$$WL = \frac{1}{WC} = R \tan \delta$$

$$\begin{aligned} Z &= \sqrt{R^2 + \left(WL - \frac{1}{WC}\right)^2} = \\ &= \sqrt{R^2 + R^2 \tan^2 \delta} = \underline{\underline{38,5 \text{ m}\Omega}} \end{aligned}$$



$$I_0 = Z \cdot I$$

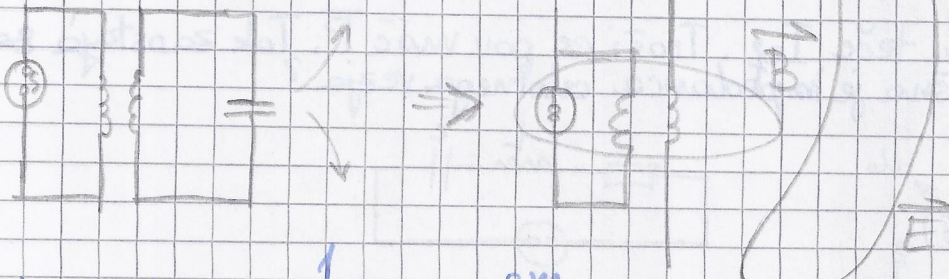
$$I_0 = \frac{1}{Z} \cdot I_0$$

$$I_0 = \left(\frac{1}{Z_R} + \frac{1}{Z_C} + \frac{1}{Z_L} \right) \cdot I_0 = \left(\frac{1}{R} + i\omega C - \frac{1}{\omega L} \right) \cdot I_0 = \underbrace{\left(\frac{1}{R} + i\left(\omega C - \frac{1}{\omega L}\right) \right)}_{\frac{1}{Z}} \cdot I_0$$

$$|I_0| = \frac{1}{|Z|} \cdot I_0 = \sqrt{\frac{1}{R^2} + \left(\omega C - \frac{1}{\omega L}\right)^2} \cdot I_0$$

$$\tan \delta = \frac{I_m \frac{1}{Z}}{I_0 \frac{1}{Z}} = R \left(\omega C - \frac{1}{\omega L} \right)$$

EMV



Maxwell $\Rightarrow \epsilon_0 = \frac{1}{\mu_0 c^2} = 3 \cdot 10^{-8} \frac{\text{m}}{\text{s}}$

$\vec{B} \perp \vec{c}$

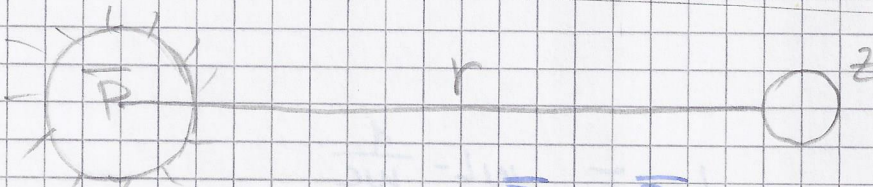
$\vec{E} = \vec{B} \times \vec{c}$

$E = B \cdot c_0$

DIPOLNA ANTENA

Povprečna gostota en. toka:

$\vec{j} = \frac{\vec{P}}{S} = \frac{\frac{dW}{dt}}{S} = \frac{1}{2} \epsilon_0 c_0 E_0^2$



$r \approx 150 \cdot 10^9 \text{ m}$
 $j \approx 1360 \text{ W/m}^2$

$j = \frac{P}{S} = \frac{P}{4\pi r^2} \Rightarrow P = j 4\pi r^2 =$
 $= 1360 \text{ W/m}^2 \cdot 4\pi (150 \cdot 10^9 \text{ m})^2 = 2,84 \cdot 10^{26} \text{ W}$

$P = ? ; E_0 = ?$

$\boxed{W = m \cdot c^2} \Rightarrow P = \frac{dW}{dt} = \frac{dm}{dt} c^2$

$\frac{dm}{dt} = \frac{P}{c^2} = \frac{3,85 \cdot 10^{26} \text{ W}}{9 \cdot 10^{16}} = 4,3 \cdot 10^9 \frac{\text{kg}}{\text{s}} \approx$

$\approx 4 \frac{\text{GT}}{\text{s}}$

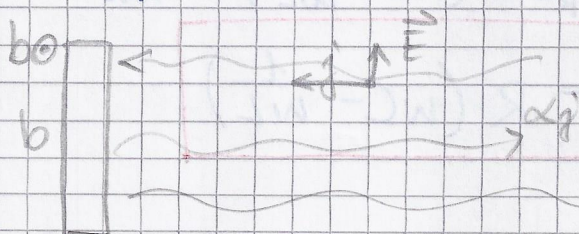
$j = \frac{1}{2} \epsilon_0 c_0 E_0^2 \Rightarrow E_0 = \sqrt{\frac{2j}{\epsilon_0 c_0}} = \sqrt{\frac{2 \cdot 1360 \text{ W/m}^2}{8,85 \cdot 10^{-12} \frac{\text{As}}{\text{Vm}} \cdot 3 \cdot 10^8 \frac{\text{m}}{\text{s}}}} =$

$\Rightarrow E_0 = 1012 \text{ V/m}$

mal. 52 / str. 27

Na eno stran tanke homogene plošče, ki se nahaja v vesolju pada proti pravokotni ruteni z amplitudo E_0 . Odkojnost plošče ni odvisna od val. dol. in je enaka α . Kolikšen j oddaja plošča v stacionarnem stanju?

$b = 1 \text{ m}$
 $E_0 = 100 \text{ V/m}$
 $\alpha = 0,6$ (albedo)
 $p^* = ?$



stacionarno stanje:

$$j_{\text{ABS}} = j - \alpha j = (1 - \alpha) j$$

$$P^* = P_{\text{ABS}} = j_{\text{ABS}} \cdot S = (1 - \alpha) j \cdot b^2 = \frac{1}{2} (1 - \alpha) \epsilon_0 \epsilon_0 E^2 b^2 = 0,4 \cdot \frac{1}{2} \cdot 8,85 \cdot 10^{-12} \cdot 310^8 \cdot 10^4$$

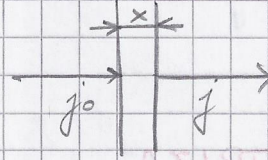
$$P^* = \underline{5,31 \text{ W}}$$

4.5.2011

ABSORBCIJA

$$j = \frac{P}{S_{\perp}}$$

$$j = j_0 \cdot e^{-\mu x} \leftarrow \text{debelina snovi}$$



$\mu \leftrightarrow$ razpolovna debelina

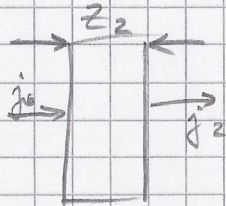
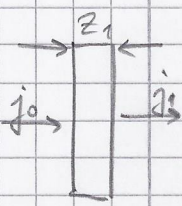
$$j(x_2) = \frac{j_0}{2}$$

$$P(x_2) = \frac{P_0}{2}$$

gostota toka.

tok.

1. Ploščici iz enakega sivega stekla prepuščata po 20 in 75% vpadnega svet. toka pri pravokotnem vpadanju. Kolikšno je razmerje med debelinami ploščic?



$$\frac{j_1}{j_0} = 0,2$$

$$\frac{z_1}{z_2} = ?$$

$$\frac{j_2}{j_0} = 0,75$$

$$j_1 = 0,2 j_0$$

$$j_2 = 0,75 j_0$$

$$j_1 = j_0 e^{-\mu z_1} \Rightarrow 0,2 j_0 = j_0 e^{-\mu z_1} \quad / \ln$$

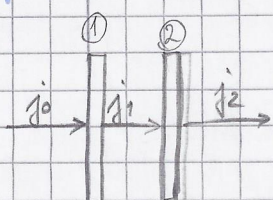
$$j_2 = j_0 e^{-\mu z_2} \Rightarrow 0,75 j_0 = j_0 e^{-\mu z_2} \quad / \ln$$

$$\ln 0,2 = -\mu z_1$$

$$\ln 0,75 = -\mu z_2$$

$$\frac{z_1}{z_2} = \frac{\ln 0,2}{\ln 0,75} = \frac{-1,61}{-0,29} = \underline{5,6}$$

2. Sipa je sestavljena iz dveh plasti. 1. plast je debela x_1 , razp. debelina = 5 cm. Debelina 2. plasti x_2 , razp. debelina = 3 cm. Kolikšen del vpadne svetlobe ne absorbira / sipa?



$$x_1 = 2 \text{ mm}$$

$$x_{1/2} = 5 \text{ cm}$$

$$x_2 = 1,5 \text{ mm}$$

$$x_{2/2} = 3 \text{ cm}$$

$$A = ? \quad [\%]$$

$$j_1 = j_0 e^{-\mu x_1}$$

$$j_2 = j_1 e^{-\mu x_2}$$

$$j_2 = j_0 e^{-\mu x_1} e^{-\mu x_2}$$

$$\frac{j_2}{j_0} = e^{-(\mu_1 x_1 + \mu_2 x_2)} \quad / \ln$$

$$\frac{j_2}{j_0} = e^{-\frac{\ln 2}{x_{1/2}} x_1 - \frac{\ln 2}{x_{2/2}} x_2}$$

$$\ln \frac{I_2}{I_0} = -\mu (x_1 + x_2)$$

RAZMERJE MED RAZPOLOVNIH DEBELINAH

$$\mu \leftrightarrow x_{1/2}$$

$$j(x_{1/2}) = \frac{j_0}{2} = j_0 \cdot e^{-\mu x_{1/2}} / \ln$$

$$\ln\left(\frac{1}{2}\right) = -\mu x_{1/2}$$

$$\ln(1) - \ln(2) = -\mu x_{1/2}$$

$$\mu = \frac{\ln 2}{x_{1/2}}$$

$$j_2 = \left(\frac{\ln 2}{5} \cdot 0,2 - \frac{\ln 2}{3} \cdot 0,15 \right) = 0,94$$

$$A = \frac{j_{AB}}{j_0} = \frac{j_0 - j_2}{j_0} = 1 - \frac{j_2}{j_0} =$$

$$A = 6\%$$

FOTOMETRIJA

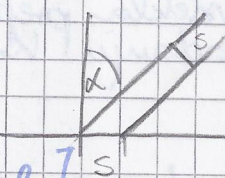
$$j = \frac{P}{S_L} \quad \text{gostota svetlobnega toka} \quad \left[\frac{W}{m^2} \right]$$

• OSVETLJENOST:

$$j' = \frac{P}{S} = j \cos \alpha$$

$$\left[\frac{W}{m^2}; \frac{lm}{m^2} = \text{lukss-lx} \right]$$

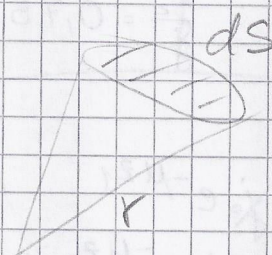
fiziološke enote



• SVETILNOST:

$$I = \frac{dP}{d\Omega}$$

prostorski kot / steradian.



$$d\Omega = \frac{dS}{r^2}$$

$$I = \frac{P}{4\pi r^2 \sin \alpha}$$

za točkasto telo

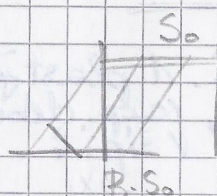
$$j = \frac{P}{4\pi r^2} = \frac{I}{r^2}$$

• SVETLOST B:

$$B = \frac{I}{S_0}$$

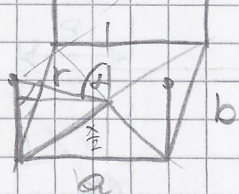
$$I = B \cdot S_0 \cos \beta$$

I_0



3. Nad oglišči pravokotne mize so na višini h obešene enake majhne žarnice z močjo P . Kolikšna je osvetljenost središča mize? Žarnice so točkaste izvori in ne dajejo izstopa.

$$\begin{aligned} a &= 2\text{ m} \\ b &= 3\text{ m} \\ h &= 1\text{ m} \\ P &= 60\text{ W} \\ j &=? \end{aligned}$$



$$X = \sqrt{a^2 + b^2} = \sqrt{13}\text{ m}$$

$$\frac{X}{2} = \frac{\sqrt{13}}{2}\text{ m}$$

$$r = \sqrt{h^2 + \left(\frac{X}{2}\right)^2} = \sqrt{1\text{ m}^2 + \frac{13}{4}\text{ m}^2} = \sqrt{\frac{17}{4}} = \frac{\sqrt{17}}{2}\text{ m}$$

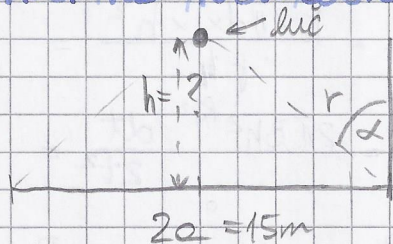
$$\cos \alpha = \frac{h}{r}$$

$$\alpha = \arccos \frac{h}{r} = 60,1^\circ$$

$$j' = \frac{P}{S} = j \cos \alpha$$

$$j'^* = 4j' = \frac{4P}{4\pi r^2} \cos \alpha = \frac{60\text{ W}}{\pi \cdot \frac{17}{4}\text{ m}^2} \cos 60,1^\circ = \underline{\underline{2,18 \frac{\text{W}}{\text{m}^2}}}$$

4. Svetilka je obešena nad prečno 15m široko ceste. Za vse smeri ima enak osvetljenost. Kakšna višina od tal mora biti svetilka, da bo osvetljenost na robu ceste največja?



$$j' = \frac{P}{S} = \frac{P}{4\pi r^2}$$

$$j' = \frac{P}{S} = j \cos \alpha$$

$$\cos \alpha = \frac{h}{r}$$

$$j = \frac{1}{r^2} \cdot \frac{h}{r} = \frac{1 \cdot h}{r^3} = \frac{1 \cdot h}{(h^2 + a^2)^{3/2}}$$

$$\frac{dj}{dh} = \frac{I(h^2 + a^2)^{3/2} - I h \cdot \frac{3}{2}(h^2 + a^2)^{1/2} \cdot 2h}{(h^2 + a^2)^3} = \frac{I(h^2 + a^2)^{3/2}}{(h^2 + a^2)^3} - \frac{3Ih^2(h^2 + a^2)^{1/2}}{(h^2 + a^2)^3} =$$

$$= \frac{I}{(h^2 + a^2)^{3/2}} - \frac{3Ih^2}{(h^2 + a^2)^{5/2}} \Rightarrow (h^2 + a^2)^{-3/2} - 3Ih^2(h^2 + a^2)^{-5/2} = 0$$

$$(h^2 + a^2)^{-3/2} = 3h^2(h^2 + a^2)^{-5/2} = 0$$

$$(h^2 + a^2)^1 = 3h^2$$

$$2h^2 = a^2$$

$$h^2 = \frac{a^2}{2}$$

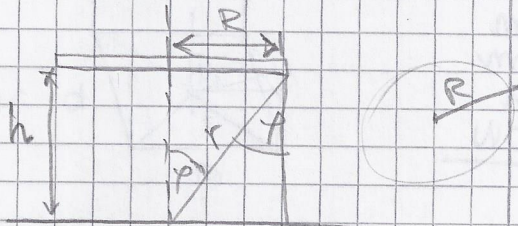
$$h = \frac{\sqrt{2}}{2} \cdot a = \frac{\sqrt{2}}{2} \cdot \frac{15}{2} = \frac{15\sqrt{2}}{4} = \underline{\underline{5,3\text{ m}}}$$

5) Nad uničo je na strop pritrjena svetilka v obliki tanke okrogle plošče s površino S . Svetlost svetilke je neodvisna od smeri in je enaka B . Kolikšna je osvetljenost prečne miže, če je višina razlika med stropom in mižo $2h$?

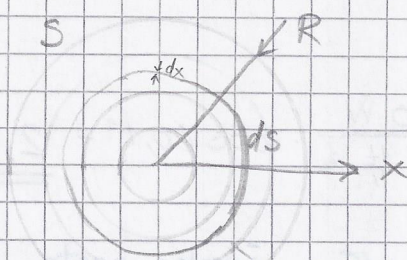
$R = 0,4 \text{ m}$
 $h = 2 \text{ m}$
 $B = 100 \frac{\text{W}}{\text{m}^2}$
 $2h = 2 \text{ m}$

$B(P) = B_0$
 LAMBERTOV ZAKON
 $j = ?$

$I = B \cdot S \cdot \cos \beta$
 $j = j \cdot \cos \alpha = \frac{I}{r^2} \cos \alpha$
 $j = \frac{B_0 \cdot S \cdot \cos \beta}{r^2} \cos \alpha$



$r = \sqrt{h^2 + R^2} =$
 $r = \sqrt{h^2 + x^2}$

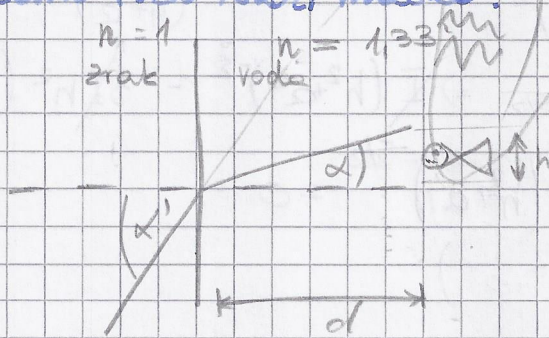


$j' = j \cdot \cos \alpha$
 $\frac{I}{r^2} = \frac{B \cdot S \cdot \cos \beta}{r^2}$

$dj' = B \cdot dS \cdot \cos^2 \beta =$
 $dj' = \frac{B \cdot 2\pi dx \cdot x}{r^2} \cos^2 \beta = \frac{B \cdot 2\pi dx \cdot x}{r^2} \left(\frac{h}{r}\right)^2 = \frac{B \cdot 2\pi dx \cdot x \cdot h^2}{r^4} =$
 $= \frac{2\pi B h^2 x dx}{(h^2 + x^2)^{3/2}} = \frac{2\pi B h^2}{h^2} \int_0^R \frac{x dx}{(h^2 + x^2)^{3/2}} = 2\pi B h^2 \int_0^R \frac{dt}{2t^2} =$
 $h^2 + x^2 = t$
 $2x dx = dt$
 $x dx = \frac{dt}{2}$
 $= \frac{2}{2} \pi B h^2 \left(-\frac{1}{t} \right) \Big|_0^R = \pi B h^2 \left(-\frac{1}{h^2 + x^2} \right) \Big|_0^R =$
 $= \pi B h^2 \left(+\frac{1}{h^2} - \frac{1}{h^2 + R^2} \right) = 12,08 \text{ W}$

6) Potapljač iz razdalje d opazuje ribo velikost h . Ocenite kolikokrat povečamo ribo skozi masko?

$d = 50 \text{ cm}$
 $h = 10 \text{ cm}$



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

$\tan \alpha = \frac{h}{d}$
 $\alpha = \arctan \frac{h}{d} = 11,3^\circ$

$\frac{\sin \alpha}{\sin \alpha'} = \frac{1}{n} \Rightarrow \alpha' = \arcsin (n \cdot \sin \alpha) =$

$\alpha' = \arcsin (1,33 \cdot \sin 11,3^\circ)$

$\alpha' = 15,12^\circ$

$M = \frac{h'}{h} = \frac{h'}{d} = \frac{\tan \alpha'}{\tan \alpha} = \frac{\tan 15,12^\circ}{\tan 11,3^\circ} = 1,35$

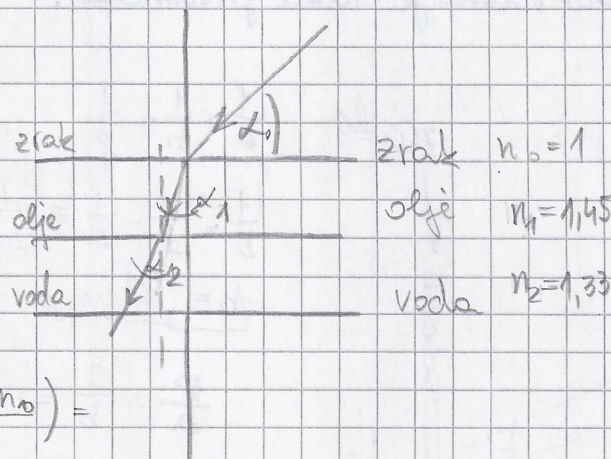
7. V katerem smjer imajo sončni žarki med vodo in kateri plavajo olje. Sonce je pod kotom α_0 , lomni količnik vode je n_2 , olja pa n_1 .

$$\alpha_0 = 45^\circ$$

$$n_2 = 1,33$$

$$n_1 = 1,45$$

$$n_0 = 1$$



$$\frac{\sin \alpha_0}{\sin \alpha_1} = \frac{n_1}{n_0} = \Delta \alpha_1$$

$$\alpha_1 = \arcsin\left(\frac{\sin 45^\circ \cdot n_0}{n_1}\right) =$$

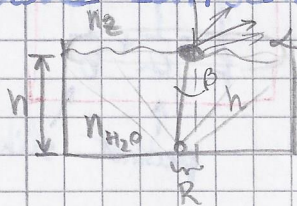
$$\alpha_1 = 29,19^\circ$$

$$\frac{\sin \alpha_1}{\sin \alpha_2} = \frac{n_2}{n_1}$$

$$\alpha_2 = \arcsin\left(\frac{\sin \alpha_1 \cdot n_1}{n_2}\right) = \arcsin\left(\frac{\sin 29,19^\circ \cdot 1,45}{1,33}\right) =$$

$$\alpha_2 = 32,12^\circ$$

8. Majna lučka na dnu bazena z globino h , pošlje svetlobo enakomerno na vse strani. Kolikšen je polmer kroga, ki ga lučka zariše na površini bazena?



Pri katerem kotu β bo nastal totalni lom?

$$\alpha = 90^\circ$$

$$h = 1,5 \text{ m}$$

$$n_2 \sin \beta = n_1 \sin \alpha$$

$$\beta = 48,75^\circ$$

$$\tan \beta = \frac{R}{h}$$

$$R = \tan \beta \cdot h = 1,71 \text{ m}$$

11.5.2011

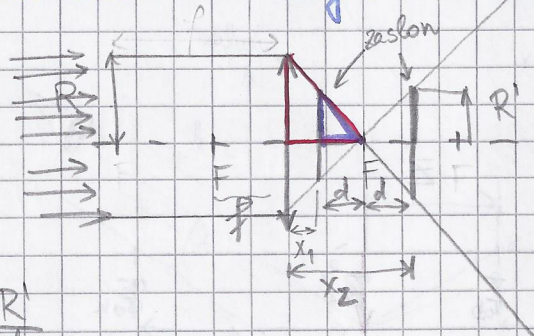
9. Sončna svetloba pade pravokotno na tanko zbiralno lečo z gor. razdaljo f in radijem R . Vaporedno zbiran lečo postavimo zaslon tako, da ima slika kroga na zaslonu radij R' . Na kakšni razdalji od leče je zaslon?

$$f = 5 \text{ cm}$$

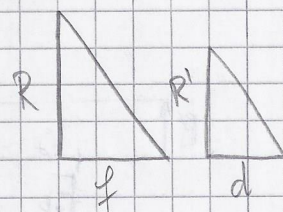
$$R = 10 \text{ cm}$$

$$R' = 6 \text{ cm}$$

$$x_1, x_2 = ?$$



dobimo 2 rešitvi..



$$\frac{R}{f} = \frac{R'}{d}$$

$$d = \frac{R' \cdot f}{R} = \frac{6 \cdot 5 \text{ cm}}{10 \text{ cm}} = 3 \text{ cm}$$

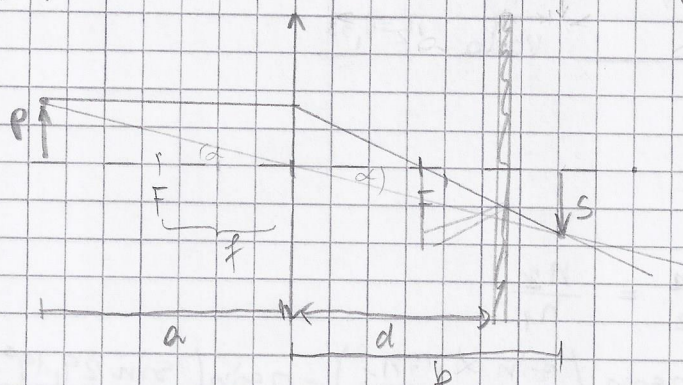
Čisto geometrijska naloga

$$f = x_1 + d \Rightarrow x_1 = f - d = 2 \text{ cm}$$

$$f = x_2 - d \Rightarrow x_2 = 8 \text{ cm}$$

- 2.) Predmet višine p postavimo na oddaljenost a pred zb. lečo z gor. razdaljo f . Na drugo stran postavimo pokončno zrcalo na oddaljenost d od leče. Kako velika je slika predmeta?

$$\begin{aligned} p &= 1,5 \text{ cm} \\ a &= 30 \text{ cm} \\ d &= 38 \text{ cm} \\ f &= 20 \text{ cm} \\ s &= ? \end{aligned}$$



$$\frac{1}{a} + \frac{1}{b} = \frac{1}{f}$$

$$\frac{1}{b} = \frac{1}{f} - \frac{1}{a} = \frac{1}{20} - \frac{1}{30} = \frac{30-20}{600} = \frac{10}{600} = \frac{1}{60 \text{ cm}}$$

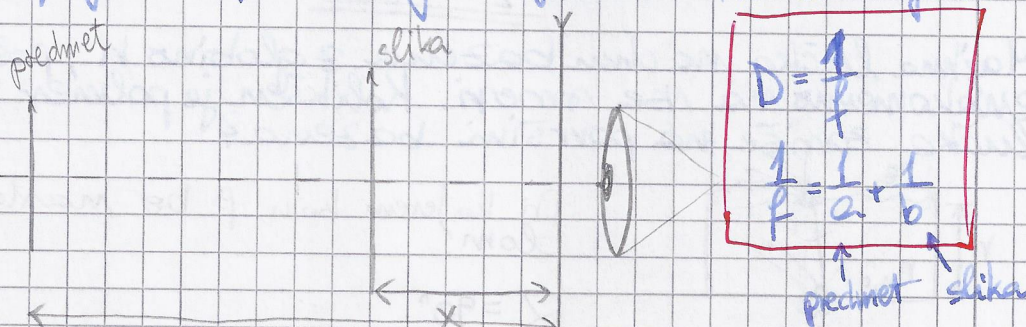
$$b = 60 \text{ cm}$$

$$\frac{p}{a} = \frac{s}{b} \Rightarrow s = \frac{p \cdot b}{a} = \frac{1,5 \text{ cm} \cdot 60 \text{ cm}}{30 \text{ cm}} =$$

$$s = 3 \text{ cm}$$

- 3.) Kratkovidna oko ne vidi jasno predmetov, ki so oddaljeni več kot 1m. Kolikšna je dioptrija očal, da vidi jasno predmete na oddaljenosti 5m.

$$\begin{aligned} x &= 1 \text{ m} \\ y &= 5 \text{ m} \end{aligned}$$

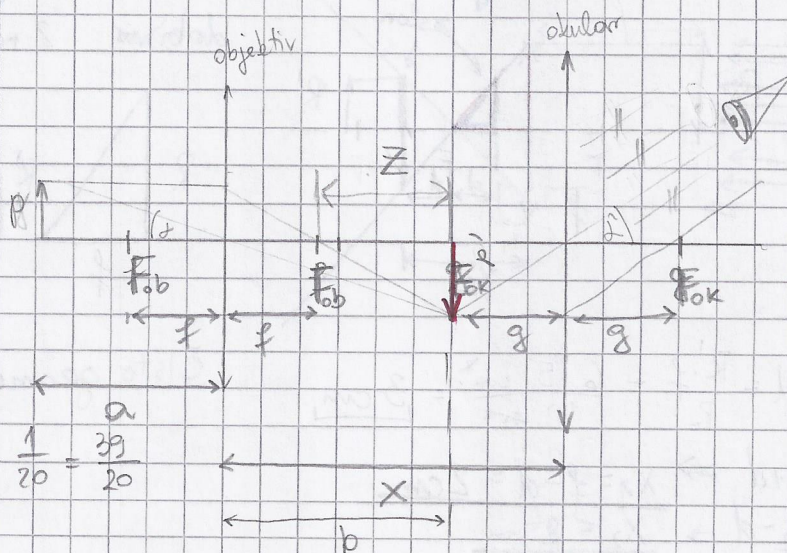


$$\frac{1}{f} = \frac{1}{y} - \frac{1}{x} \Rightarrow \frac{1}{f} = -\frac{5}{4} \text{ m}$$

$$D = -\frac{4}{5} = -0,8 \text{ m}^{-1}$$

- 4.) Pri mikroskopu je gor. razdalja objektiv f , gor. razd. okularja je g . Med obojema lečama je razdalja x . Kolikšna mora biti razdalja predmeta od objektivne, da je slika predmeta za gledalca navidezno neskončno velika? Kolikšna je povečava mikroskopa, če je razdalja nastanjenja na y ?

$$\begin{aligned} f &= 0,5 \text{ cm} \\ g &= 2 \text{ cm} \\ x &= 22 \text{ cm} \\ y &= 25 \text{ cm} \\ a &= ? \end{aligned}$$



$$\frac{1}{f} = \frac{1}{a} + \frac{1}{b}$$

$$b = x - g = 20 \text{ cm}$$

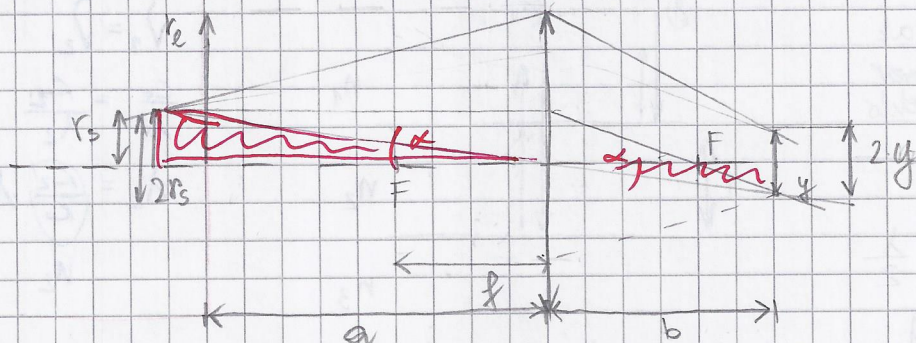
$$\frac{1}{a} = \frac{1}{f} - \frac{1}{b} = \frac{1}{0,5} - \frac{1}{20} = 2 - \frac{1}{20} = \frac{39}{20}$$

$$a = \frac{20}{39} = 0,51 \text{ cm}$$

$$M = \frac{\tan \alpha'}{\tan \alpha} = \frac{y \cdot z}{f \cdot g} = \frac{25(x - p - g)}{0,5 \cdot 22} = \frac{25 \cdot 19,5}{1} = 487,5$$

5.) Na opt. os tanke zb. leće zgoriščno razdalja f ; postavimo svetilko polmerom r_s na razdalji a . Za lečo postavimo zaslon tako, da na njem vidimo ostro sliko. Kolikšna je svet. tok na sliki, če zvažamo P_0 .

$$\begin{aligned} f &= 0,3 \text{ m} \\ a &= 1,5 \text{ m} \\ r_s &= 0,03 \text{ m} \\ P_0 &= 10 \text{ W} \\ r_l &= 0,01 \text{ m} \\ f &= ? \end{aligned}$$

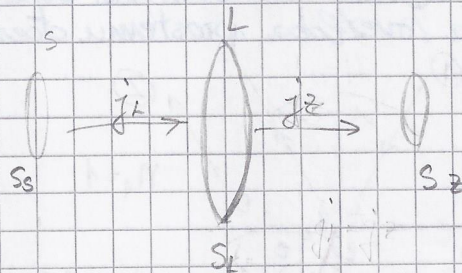


$$\frac{1}{f} = \frac{1}{a} + \frac{1}{b}$$

$$\frac{1}{b} = \frac{1}{a} + \frac{1}{f} = -\frac{1}{1,5} + \frac{1}{0,3} = -\frac{2}{3} + \frac{10}{3} = \frac{8}{3}$$

$$\frac{r_s}{a} = \frac{r_l}{b} \Rightarrow y = \frac{0,03 \cdot 3}{8 \cdot 1,5} = \frac{3}{40} = 0,075 \text{ m}$$

$$\frac{1}{f} = \frac{1}{a^2} = \frac{P}{4\pi a^2}$$



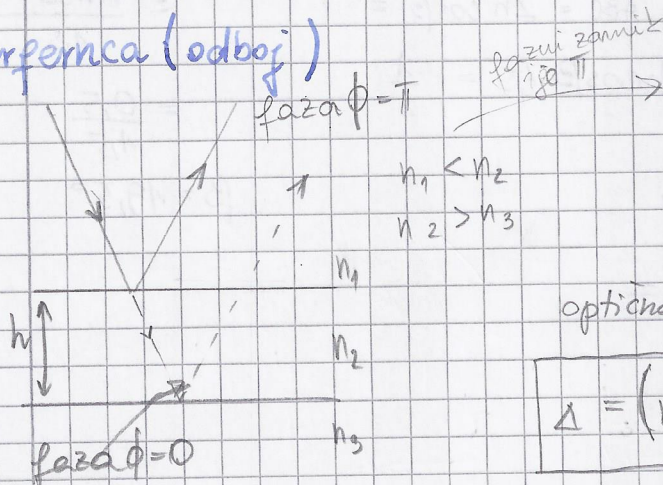
$$P_1 = P_2$$

$$j_1 \parallel r_1^2 = j_2 \parallel y^2$$

$$j_2 = \frac{j_1 r_1^2}{y^2} = \frac{P r_l^2}{4\pi a^2 y^2} = \frac{10 \cdot 0,01^2}{4\pi \cdot 1,5^2 \cdot 0,075^2} = 6,3 \cdot 10^{-3} \frac{\text{W}}{\text{m}^2}$$

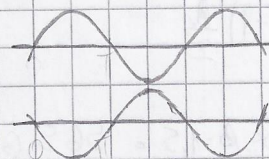
VALOVNA OPTIKA

- interferenca (odboj)



fazni zamik π

$$\begin{aligned} n_1 &< n_2 \\ n_2 &> n_3 \end{aligned}$$



optična pot: $2h \cdot n_2$

$$\Delta = (r_1 n_1 - r_2 n_2)$$

$$\Delta \phi = 2\pi N; N = 0, 1, 2, \dots$$

$$\Delta \phi = (2N + 1)\pi \dots$$

$$\Delta \phi = \frac{2\pi \Delta}{\lambda}$$

← ojačitev

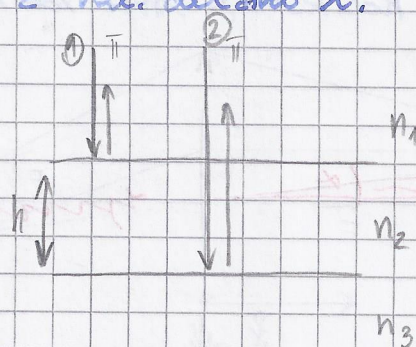
← oslabilitev

otlaker: $\Delta = N\lambda$
 otlaker: $\Delta = (2N+1) \frac{\lambda}{2}$

← žanka sta v fazi $\nearrow \phi = 0$
 ← žanka sta nepravilna $\nearrow \phi = \pi$

1.) Z najmanjši kolino debelo plastjo moramo količnikom n_2 moramo preplesti steklo z lomnim kol. n_3 , da se na njem odbije največ svetlobe z val. dolžino λ .

$n_1 = 1 \rightarrow$ zrak
 $n_2 = 1,2 \rightarrow$ smor
 $n_3 = 1,5 \rightarrow$ steklo
 $\lambda = 500 \text{ nm}$



$$\lambda_1 = \lambda_2$$

$$\frac{c_0}{\lambda_0} = \frac{c_2}{\lambda_2}$$

$$\lambda_2 = \frac{c_2}{c_0} \cdot \lambda_0$$

$$n_2$$

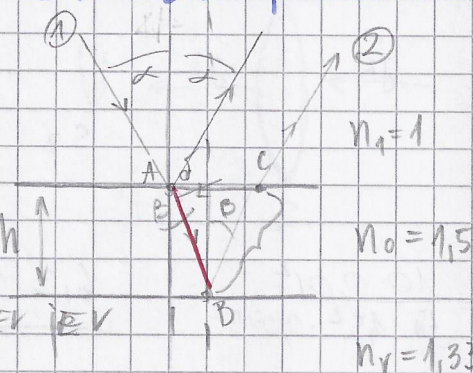
$\Delta = (2N+1) \frac{\lambda}{2}$

$2n_2 h = n_1 \frac{\lambda}{2}$

$h = \frac{\lambda}{4n_2} = \frac{500 \cdot 10^{-9} \text{ m}}{4 \cdot 1,2} = 104,17 \cdot 10^{-9} \text{ m} = 0,104 \mu\text{m}$

2.) Na $0,1 \mu\text{m}$ debelo plast dja na vodi posvetimo z-vrednoim curkom bele svetlobe pod kotem 30° . Lom. kol. dja in vode, n_v in n_o . Kakšne barve se zdi odbita svetloba prostemu očesu?

$h = 0,1 \mu\text{m}$
 $\alpha = 30^\circ$
 $n_o = 1,5$
 $n_v = 1,33$
 λ



① $\Delta \phi = \pi$
 ② $\Delta \phi = 0$

POGOT ZA OTLAKER EV TEM PRIMERU:

$\Delta = (2N+1) \frac{\lambda}{2}$

$\Delta r n_o = (2N+1) \frac{\lambda}{2}$

$\Delta r = ABC = 2h \cos \beta =$

$2h \cos \beta \cdot 1,5 = \frac{\lambda}{2}$

$\lambda = 4h \cos \beta \cdot 1,5 = 565,6 \text{ nm}$

rumeno

$\frac{\sin \alpha}{\sin \beta} = \frac{n_o}{n_v} \Rightarrow$

$\sin \beta = \frac{\sin \alpha n_o}{n_v} =$
 $= \frac{\sin 30^\circ \cdot 1}{1,5}$

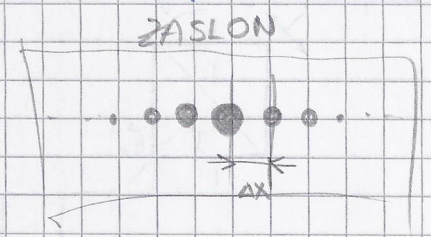
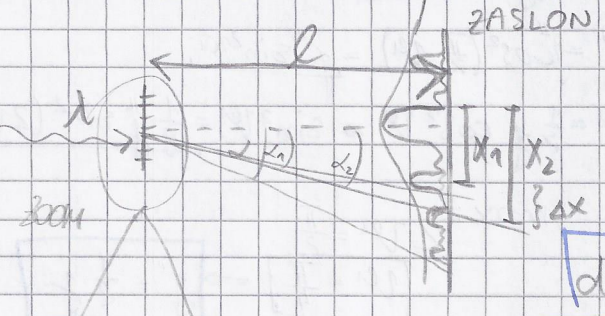
$= \frac{0,5}{1,5}$

$\beta = 19,5^\circ$

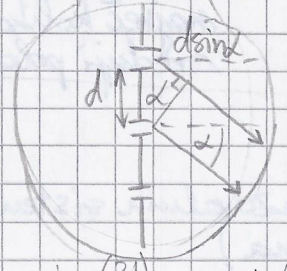
$\lambda = 500 \text{ nm}$
 $l = 1 \text{ m}$
 $d = 2 \mu\text{m}$

$\alpha_1, \alpha_2 = ?$
 $\Delta x = x_2 - x_1 = ?$

Svetloba z val razdaljo λ pada pravokotno na uklonsko mrežico z razdaljo med režami d . Izračunaj 2 najmanjše kota opeštre. Kolikšna je razdalja med maksimumi na zaslonu?



$d \sin \alpha = N \lambda$ $N = 0, 1, 2, 3$

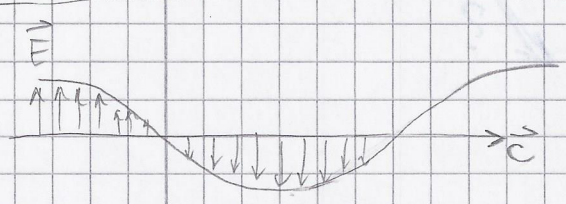


$N=0: d \sin \alpha_0 = 0 \Rightarrow \alpha_0 = 0 \leftarrow \text{centralni maksimum}$

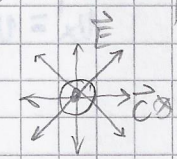
$N=1: d \sin \alpha_1 = \lambda \Rightarrow \alpha_1 = \arcsin \frac{\lambda}{d} = \arcsin \left(\frac{500 \text{ nm}}{2 \mu\text{m}} \right) = \arcsin(0,25) = 14,47^\circ$

$N=2: \alpha_2 = \arcsin \left(\frac{2\lambda}{d} \right) = \arcsin \left(\frac{1}{2} \right) = 30^\circ$

$x_1 = l \cdot \tan \alpha_1$
 $x_2 = l \cdot \tan \alpha_2$
 $\Delta x = x_2 - x_1 = l (\tan \alpha_2 - \tan \alpha_1) \approx 32 \text{ cm}$

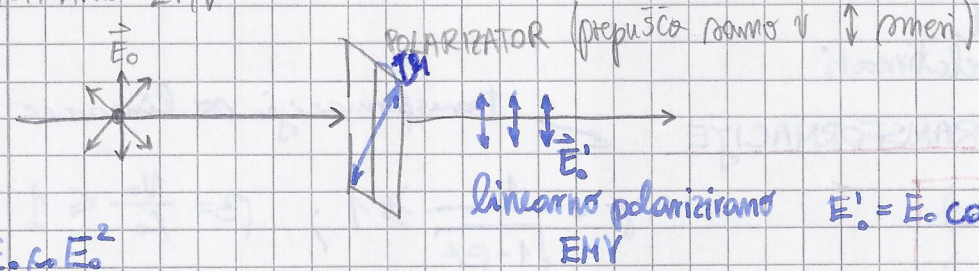


POLARIZACIJA



$\Delta t \sim 10^{-9} \text{ s}$

NEPOLARIZIRANO EMV

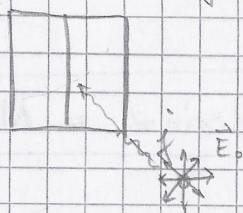
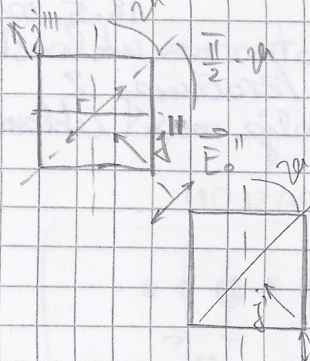


$j = \frac{1}{2} \epsilon_0 c E_0^2$
 $j' = j \cos^2 \varphi$

$j \dots \text{nepolarizirano:}$
 $j' = j \cdot \overline{\cos^2 \varphi} = \frac{1}{2} j$

$E_1 = E_0 \cos \varphi$
 $\frac{1}{2} \epsilon_0 c$

Nepol. svetloba pada na sistem treh polarizatorjev. Prvi in tretji imata os prepustanja pod pravim kotom. Os polarizacije srednje ploščice oklepa kot φ s pravokotnico 1. ploščice. Že kateri kot φ je j''' največji?



$$j''' = \max? \quad j' = \frac{1}{2} j$$

$$j'' = j' \cos^2 2\varphi$$

$$j''' = j' \cos^2 \left(\frac{\pi}{2} - 2\varphi \right) = j' \sin^2 2\varphi$$

$$j''' = \frac{1}{2} j \cos^2 \varphi \sin^2 2\varphi = \frac{1}{8} j \sin^2 (2\varphi)$$

$$\max: 2\varphi = \frac{\pi}{2}$$

$$\varphi = \frac{\pi}{4} \Rightarrow j'' = \frac{1}{2} j$$

največ kalikor pride skozi
srednji polarizator

POSEBNA TEORIJA RELATIVNOSTI

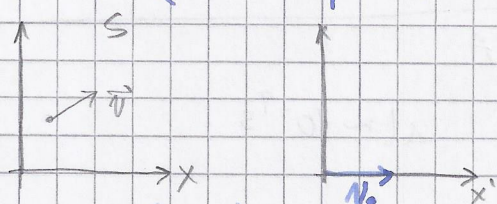
- govorimo le o neopospeševanih / inercialnih opazovalnih sistemih
- ni znatnih gravitacijskih polj (ΔW_p je majhna)

MAXWELL: svetloba je konstantna ← teorija

MICHELSON-MORLEY: eksperiment

$$c_0 = \text{konst.}$$

Klasična (Galilei-jeva) transformacija:



$$v_x' = v_x - v_0$$

• Einstein (1905)

- $c_0 = \text{konst.}$
- načelo relativnosti

LORENZOVE TRANSFORMACIJE

transformacije so linearne

$$\gamma = \frac{1}{\sqrt{1-\beta^2}} \geq 1; \quad \beta = \frac{v_0}{c_0} \leq 1$$

$$t' = \gamma \left(t - \frac{v_0}{c_0^2} x \right)$$

$$x' = \gamma \left(x - v_0 t \right)$$

$$y' = y$$

$$z' = z$$

$$v_x' = \frac{dx'}{dt'}$$

$$= \frac{\gamma (dx - v_0 dt)}{\gamma (dt - \frac{v_0}{c_0^2} dx)} = \frac{dt \left(\frac{dx}{dt} - v_0 \right)}{dt \left(1 - \frac{v_0}{c_0^2} \frac{dx}{dt} \right)} =$$

$$\frac{dx}{dt} = v_x$$

$$v_y' = \frac{dy'}{dt'} = \frac{dy}{\gamma \left(dt - \frac{v_0}{c_0^2} dx \right)}$$

$$v_x' = \frac{v_x - v_0}{1 - \frac{v_0 v_x}{c_0^2}}$$

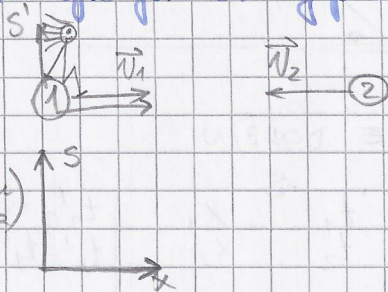
$$v_{y,z}' = \frac{v_{y,z}}{\gamma \left(1 - \frac{v_0 v_x}{c_0^2} \right)}$$

2 delca, ki se gibljeta drug proti drugemu

$$v_1 = \frac{3}{5} c_0$$

$$v_2 = -\frac{4}{5} c_0$$

$$v_2' = ? \text{ (v sistemu 1. delca)}$$



KLASIČNO:

$$v_0 \equiv v_1$$

$$v_x \equiv v_2$$

$$v_2' = v_2 - v_1 = -\frac{7}{5} c_0 > c_0 \quad ?!$$

RELATIVISTIČNO:

$$v_2' = \frac{v_2 - v_1}{1 - \frac{v_1 v_2}{c_0^2}} = \frac{-\frac{7}{5} c_0}{1 - \frac{\frac{3}{5} \cdot (-\frac{4}{5}) c_0^2}{c_0^2}} = \frac{-\frac{7}{5} c_0}{1 + \frac{12}{25}} = \frac{-\frac{7}{5} c_0}{\frac{37}{25}} = -\frac{7}{8} \cdot \frac{25}{37} \cdot c_0 = -\frac{35}{37} c_0$$

PODALJŠANJE / DILATACIJA ČASA

1. DOGODEK t_1 x_1

t_1' x_1'

2. DOGODEK t_2 $x_2 = x_1$

t_2' x_2'

$$\Delta t = t_2 - t_1 = \tau \quad \Delta t' = \gamma (\Delta t - \frac{v_0}{c_0^2} \cdot \Delta x) = \gamma \cdot \tau$$

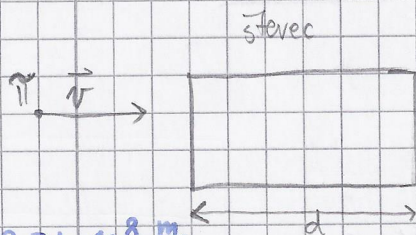
lastni čas

čas med dogodkoma, ki se zgodita na istem kraju.

$$\Delta t' = \gamma \cdot \tau$$

delci PIONI (π^0, π^+, π^-)

Pioni se gibljejo s hitrostjo v skozi stevec širine d , stevec šteje razpade pionov. Kolikšen del pionov razpade v stevcu, če je lastni razpadni čas teh pionov τ ?



$$N(t) = N_0 e^{-\frac{t}{\tau}}$$

$$N = 2,74 \cdot 10^8 \frac{m}{s}$$

$$d = 110 \text{ cm}$$

$$\tau = 2,6 \cdot 10^{-8} \text{ s}$$

$$\frac{N_0 - N}{N_0} = ? \text{ (DELEŽ \pi, ki razpade v STEVCU)}$$

KLASIČNO:

$$\frac{N_0 - N}{N_0} = 1 - \frac{N}{N_0} = 1 - e^{-\frac{t}{\tau}} = 1 - e^{-\frac{d}{v\tau}} = 1 - e^{-\frac{110 \text{ cm}}{2,74 \cdot 10^8 \frac{m}{s} \cdot 2,6 \cdot 10^{-8} \text{ s}}}$$

$$= 0,143 = 14,3\%$$

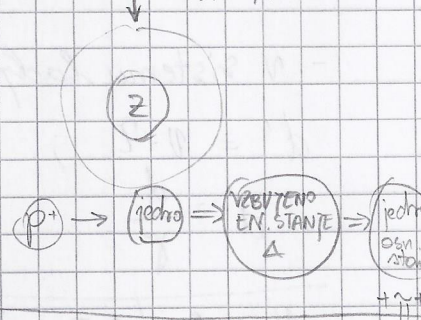
RELATIVISTIČNO: (RAČUNAHOV LAB. SISTEM)

$$\gamma_{LAB} = \gamma$$

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{1}{\sqrt{1 - \left(\frac{2,74 \cdot 10^8 \frac{m}{s}}{3,00 \cdot 10^8 \frac{m}{s}}\right)^2}} \approx 2,5$$

KOZMIČNI ŽARKI

89% PROTONI



$$\frac{N_0 - N}{N_0} = 1 - e^{-\frac{t}{\tau}} = 1 - e^{-\frac{d}{v \tau}} \approx 6\%$$

V sistemu piona:

$$\tau = \frac{d'}{v} = \frac{d}{v}$$

SKRČENJE DOLŽIN

$$\begin{array}{l} 1. \text{ DOGODEK: } t_1 \quad x_1 \quad t_1' \quad x_1' \\ 2. \text{ DOGODEK: } t_2 \quad x_2 \quad t_2' = t_1' \quad x_2' \end{array}$$

$$\Delta x = x_2 - x_1 = l$$

$$\Delta x = \gamma (\Delta x' + v_0 \Delta t') = \gamma \Delta x'$$

$$l = \gamma l', \quad l' = \frac{l}{\gamma}$$

$$\frac{N_0 - N}{N_0} = 1 - e^{-\frac{t'}{\tau}} = 1 - e^{-\frac{d}{\gamma v \tau}}$$

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4) $v = 0,95 c_0$ (gledano planet)
 $\tau = 4h$ (sistem ladje)
 d (med planetoma v sistemu planetov)

- V sistemu planetov: (S)

$$t = \gamma \cdot \tau = 3,2 \cdot 4h = 12,8h \quad \gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c_0^2}}} = \frac{1}{\sqrt{1 - (0,95)^2}} \approx 3,2$$

trajanje potovanja gledano nekoga, ki je na planetu

$$d = v \cdot t = 0,95 c_0 \cdot 12,8h = 12,16 c_0 h \approx 1,3 \cdot 10^{13} m$$

svetlobna leta, - mera za dolžino, ki jo svetlobo prepotuje v 1 uri.

- V sistemu ladje: (S')

$$d' = v \cdot \tau; \quad d = d' \gamma = \gamma \cdot v \cdot \tau = 12,16 c_0 h$$

$$d' = \frac{d}{\gamma}$$

$$N = c_0 \text{ (fotoni)}$$

$t \approx 8 \text{ min}$ (V sistemu Zemlje)

V sistemu fotona:

$$\tau = \frac{t}{\gamma} \rightarrow 0$$

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c_0^2}}} \Rightarrow \infty$$

$$\lim_{v \rightarrow c_0} \gamma \rightarrow \infty$$

$$\lim_{v \rightarrow c_0} \tau \rightarrow 0$$

za fotone čas stoji

Problem (paradoks dvojčkov):

eden ostane na Zemlji, drugi gre z vesoljsko ladjo do alfa Kentavrs

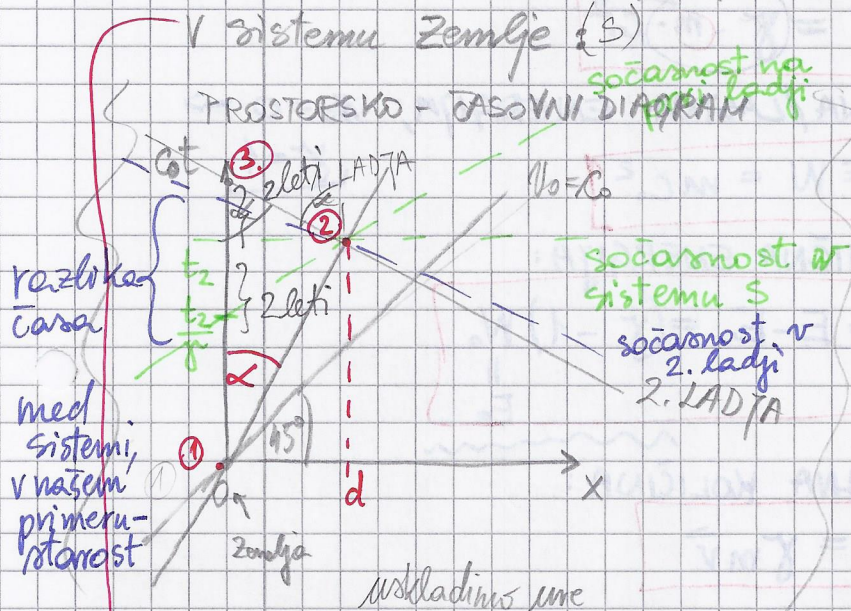
$$d \approx 4 \cdot 10^6 \text{ leta}$$

$$\frac{v_0}{c} = \frac{4}{5} \Rightarrow \beta = \frac{v_0}{c} = \frac{4}{5}$$

$$\gamma = \frac{1}{\sqrt{1-\beta^2}} = \frac{1}{\sqrt{1-\frac{16}{25}}} = \frac{5}{3}$$

1. sistemu Zemlje (S)

PROSTORSKO - ČASOVNI DIAGRAM



Vsi neuspešeni sistemi v tem sistemu so premice, $v_0 = \text{konst.}$

V SISTEMU 1. LADJE (S')

1. DOGODEK:

$$t_1' = 0, x_1' = 0$$

2. DOGODEK:

$$t_2' = \gamma \left(t_2 - \frac{v_0}{c^2} x_2 \right) = \gamma \left(\frac{d}{v_0} - \frac{v_0}{c^2} d \right) = \gamma \frac{d}{v_0} \left(1 - \frac{v_0^2}{c^2} \right) = \gamma \frac{d}{v_0} \cdot \frac{1}{\gamma^2} = \frac{d}{\gamma v_0}$$

$$1 - \beta^2 = \frac{1}{\gamma^2}$$

$$t_2' = \frac{t_2}{\gamma} = 3 \text{ leta}$$

$$x_2' = \gamma \left(d - v_0 \frac{d}{v_0} \right) = 0$$

3. DOGODEK:

$$t_3' = \gamma (10 \text{ let} - 0) = \frac{50}{3} \text{ let}$$

$$x_3' = \gamma \left(0 - v_0 \cdot t_3 \right) = \gamma \left(0 - \frac{4}{5} \cdot \frac{50}{3} \right) = -\frac{40}{3} d$$

V SISTEMU 2. LADJE (S'')

(hoče priti nazaj na Zemljo)

2. DOGODEK (ladja se sreča pri α -Kentavri)

$$t_2'' = t_2' = 3 \text{ leta}$$

$$x_2'' = 0$$

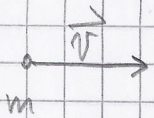
3. DOGODEK: 2. ladja pride nazaj na Zemljo

$$t_3'' = 6 \text{ let}$$

$$x_3'' = 0$$

$$\Delta t = 4 \text{ leta}$$

Dvojček, ki ostane na Zemlji ne zamenja opazovalnega sistema, drugi, pa more zamenjati sistem, da pride nazaj na Zemljo.



$$p = \left(\frac{W}{c}, \vec{p} \right)$$

$$p \cdot p = \text{konst.}$$

$$-\frac{W^2}{c^2} + p^2 = -\frac{W_0^2}{c^2} + 0$$

$$W^2 = W_0^2 + c^2 p^2$$

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

POLNA ENERGIJA

$$E \equiv W = \gamma \cdot m \cdot c^2$$

relativistična masa

m_r
mirovnna masa

MIROVNA/LASTNA ENERGIJA; $v_0 = 0 \rightarrow \gamma = 1$

$$E_0 \equiv W = m c^2$$

KINETIČNA ENERGIJA:

$$W_k = E - E_0 = (\gamma - 1) W_0$$

GIBALNA KOLIČINA:

$$\vec{p} = \gamma m \vec{v}$$

POSPEŠEVALNIK

proton: $q_p = +e$
 $W_0 = m_p c^2 = 938 \text{ MeV}$
 $m_p = 1.67 \cdot 10^{-27} \text{ kg}$
 $W_k = 5900 \text{ MeV}$

$$W_k = (\gamma - 1) E_0 \Rightarrow \gamma = \frac{W_k}{E_0} + 1 = \frac{5900 \text{ MeV}}{938 \text{ MeV}} + 1 = 7.29$$

$v = ?$

$$\gamma^2 = \frac{1}{1 - \beta^2} \Rightarrow 1 - \beta^2 = \frac{1}{\gamma^2}$$

$$\beta^2 = 1 - \frac{1}{\gamma^2} \Rightarrow \beta = \sqrt{1 - \frac{1}{\gamma^2}}$$

$$\frac{v}{c} = \sqrt{1 - \frac{1}{\gamma^2}} \approx 0.990$$

$$v \approx 0.99 \cdot 3 \cdot 10^8 \frac{\text{m}}{\text{s}} = 2.97 \cdot 10^8 \frac{\text{m}}{\text{s}}$$

KLASIČNO:

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

$$v = \sqrt{\frac{2W_k}{m_r}} \cdot \frac{c}{c} = \sqrt{\frac{2W_k}{m_p c^2}} \cdot c = 3.55 \cdot c //$$

$v > c \Rightarrow$ nekaj je narobe.

LHC

$$E = 7 \text{ TeV} = 7 \cdot 10^{12} \text{ eV}$$

proton:

RELATIVISTIČNO

$$\sigma = 27 \text{ km}$$

$$\frac{v}{c} = ?$$

$$\gamma = \frac{E}{E_0} = \frac{7 \cdot 10^{12} \text{ eV}}{938 \cdot 10^6 \text{ eV}} \approx 7462,7$$

KLASIČNO:

$$\frac{v}{c} = \sqrt{1 - \frac{1}{\gamma^2}} = 0,999999,991$$

$$W_k = \frac{1}{2} m v^2$$

$$\frac{v}{c} = \sqrt{\frac{2 W_k}{m m_0 c^2}} = \sqrt{\frac{2 E'}{E_0}} = 122$$

Kolikšna je gostota mag. polja če proton z energijo W_k , kroži po radiju r . Ravnina je pravokotna na $\vec{B}$.

$$W_k = 4 \text{ GeV}$$

$$W_0 = 938 \text{ MeV}$$

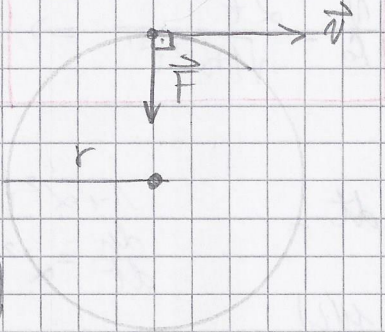


$$\vec{p} = \gamma m \vec{v}$$

$$r = 16 \text{ m}$$

$$\vec{r} \perp \vec{B}$$

$$B = ?$$



$$\vec{F} = \frac{d\vec{p}}{dt}$$

$$\vec{F} = e(\vec{E} + \vec{v} \times \vec{B})$$

$$\vec{F} = e(\vec{E} + v \vec{B})$$

$$\frac{d\vec{p}}{dt} = e(\vec{E} + v \vec{B})$$

$$\frac{d(\gamma m \vec{v})}{dt} = e(\vec{E} + v \vec{B})$$

$$\gamma(v) = \text{konst}$$

$$e v B = \gamma m \frac{d\vec{v}}{dt}$$

$$e v B = \gamma m \frac{v^2}{r}$$

$$B = \frac{\gamma m v}{e r} = \frac{p}{e r} = \frac{\sqrt{2 W_0 W_k + W_k^2}}{c e r}$$

$$(W_0 + W_k)^2 = W_0^2 + c^2 p^2$$

$$W_0^2 + 2 W_0 W_k + W_k^2 = W_0^2 + c^2 p^2$$

$$c p = \sqrt{2 W_0 W_k + W_k^2}$$

$$p = \frac{\sqrt{2 W_0 W_k + W_k^2}}{c}$$

$$B = \frac{\sqrt{2 \cdot 938 \cdot 10^6 \text{ eV} \cdot 4 \cdot 10^9 \text{ eV} + 16 \cdot 10^{18} \text{ eV}^2}}{3 \cdot 10^8 \frac{\text{m}}{\text{s}} \cdot e \cdot 16 \text{ m}} \approx 1,01 \text{ T}$$

KLASIČNO:

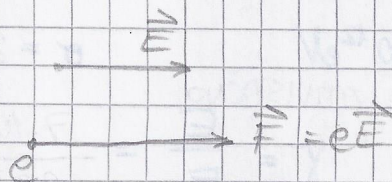
$$W_k = \frac{1}{2} m v^2$$

$$2 m W_k = m^2 v^2$$

$$B = \frac{m v}{e r} = \frac{2 m W_k}{e \cdot r} \frac{c}{c} = \frac{\sqrt{2 \cdot 938 \cdot 10^6 \text{ eV} \cdot 4 \cdot 10^9 \text{ eV}}}{3 \cdot 10^8 \frac{\text{m}}{\text{s}} \cdot e \cdot 16 \text{ m}} = 0,57 \text{ T}$$

Mirujoč pozitron damo v hom. E polje z jakostjo 3 kV/m. Kolikšno pot opravi v črni 3 pts.

$$\begin{aligned} e &= +1e \\ m &= m_{e^-} = 0,51 \text{ MeV}/c^2 \\ E &= 3 \text{ kV/m} \\ N_0 &= 0 \\ t_1 &= ? \end{aligned}$$



$$A_1 = ?$$

KLASIČNO:

$$\begin{aligned} \vec{F} &= m \cdot \vec{a} \\ a &= \frac{eE}{m} \end{aligned}$$

$$A_1 = \frac{at^2}{2} = \frac{eE}{2m} \cdot t^2 = \frac{1,6 \cdot 10^{-19} \cdot 3 \cdot 10^3}{2 \cdot 0,51 \cdot 10^{-30}} \cdot (9 \cdot 10^{-8})^2$$

$$A_1 = 2382,2 \text{ m}$$

RELATIVISTIČNO:

$$\begin{aligned} \vec{F} &= \frac{d\vec{p}}{dt} \\ e\vec{E} &= \frac{d(m\gamma\vec{v})}{dt} \\ \int_0^{t_1} eEdt &= \int_0^{t_1} d(m\gamma v) \\ \boxed{et_1} &= \gamma_1 v_1 \end{aligned}$$

$$eEt = \frac{mv}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$\frac{t}{t_0} = \frac{\alpha t}{\sqrt{1 + \alpha^2 t^2}} \Rightarrow \alpha = \frac{eE}{mc_0}$$

$$A_1 = \int_0^{t_1} v dt = c_0 \int_0^{t_1} \frac{\alpha t}{\sqrt{1 + \alpha^2 t^2}} dt =$$

$$\begin{aligned} 1 + \alpha^2 t^2 &= u \\ \frac{du}{dt} &= 2\alpha^2 t \Rightarrow \alpha t dt = \frac{du}{2\alpha} \end{aligned}$$

$$= \frac{c_0}{2\alpha} \int_{u(0)}^{u(t_1)} \frac{du}{u} = \frac{c_0}{2\alpha} \left[\ln u \right]_{1}^{\gamma_1} = \frac{c_0}{\alpha} \left(\sqrt{1 + \alpha^2 t_1^2} - 1 \right) \approx 745 \text{ m}$$

NACELO KORESPONDENCE

$$v \ll c_0$$

$$\alpha t \ll 1$$

$$\frac{(1+x)^n}{x \ll 1} = 1 + nx + \dots \approx (x^2)$$

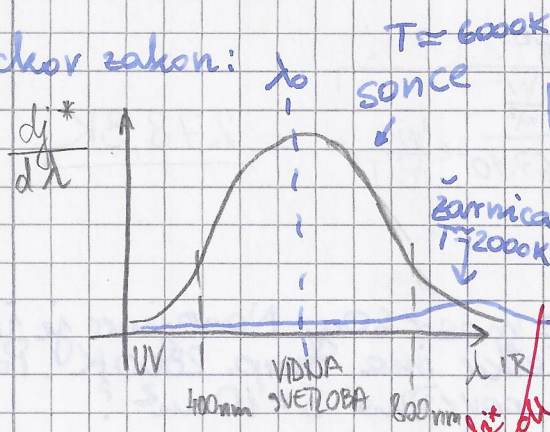
$$A_1 = \frac{c_0}{\alpha} \left(\sqrt{1 + \alpha^2 t^2} - 1 \right) = \frac{c_0}{\alpha} \left(1 + \frac{1}{2} \alpha^2 t^2 + \dots - 1 \right) =$$

$$= \frac{c_0}{\alpha} \frac{1}{2} \alpha^2 t^2 = \frac{c_0 t^2 \alpha}{2} = \frac{c_0 t^2 eE}{2mc_0} = \boxed{\frac{eEt^2}{2m} = A_1}$$

SEVANJE ČRNEGA TELESA

1.6.2011

- Planckov zakon:



$$\frac{dj^*}{d\lambda} = \frac{2Thc^2}{\lambda^5} \frac{1}{e^{\frac{hc}{\lambda k_B T}} - 1}$$

- Planckova konstanta:

$$h \approx 6,6 \cdot 10^{-34} \text{ J} \cdot \text{s}$$

- Boltzmannova konst:

$$k_B = 1,38 \cdot 10^{-23} \text{ J/K}$$

Stefanov zakon:

$$j^* = \sigma \cdot T^4$$

$$\sigma = 5,67 \cdot 10^{-8} \frac{\text{W}}{\text{m}^2 \text{K}^4}$$

WIENOV ZAKON

$$\lambda_0 T = k_W = 2,9 \cdot 10^{-3} \text{ K} \cdot \text{m}$$

SIVO TELO:

$$j^* = (1 - \alpha) \sigma T^4$$

TEMNI DELI VESOLJA:

Sevanje kot črna telesa, najmočnejše v mikrovvalnem območju EMV. Kolikšna je temperatura vesolja in svet. tok.

$$\lambda_0 = 1 \text{ mm}$$

$$T = ?$$

$$j^* = ?$$

$$\lambda_0 T = k_W$$

$$T = \frac{k_W}{\lambda_0} = \frac{2,9 \cdot 10^{-3} \text{ K} \cdot \text{m}}{1 \cdot 10^{-3} \text{ m}} = 2,9 \text{ K}$$

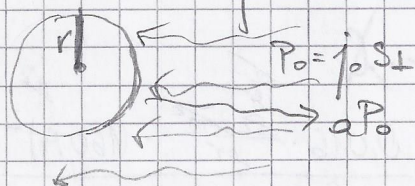
$$j^* = \sigma T^4 = 5,67 \cdot 10^{-8} \frac{\text{W}}{\text{m}^2} \cdot (2,9 \text{ K})^4 = 4,01 \mu \frac{\text{W}}{\text{m}^2}$$

Izračunaj T do katere se segreje drozgel umetni satelit, če seva kot sivo telo z odbojnostjo α .

$$\alpha = 0,52 \text{ (odbojnost)}$$

$$T = ?$$

$$j_0^* = 1360 \frac{\text{W}}{\text{m}^2}$$

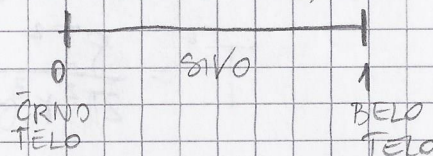


$$j = \frac{P}{S}$$

Stacionarno stanje?

$$P_{\text{ABS}} = P^*$$

$$\alpha \neq \alpha(\lambda) \rightarrow \text{sivo}$$



$$P_{ABS} = P^*$$

$$P_0 - \alpha P_0 = P^* = j^* S$$

$$(1-\alpha) j_0 T^4 = (1-\alpha) \sigma T^4$$

$$j_0 = \frac{1360 \frac{W}{m^2}}{5,67 \cdot 10^{-8} \frac{W}{m^2 K^4}} = 278,3 K$$

str. 81 / vol. 17

V vakuumu se nahaja črno telo z maso 60g. Novejšino je iz snovi, ki ima spec. toplota c . Na začetku ima temp. 2500K. Po kolikšnem času pade temp. na T_1 , če je površina $S = 10 cm^2$?

$$m = 60g$$

$$c = 200 J/kgK$$

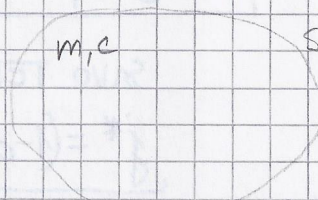
$$T_0 = 2500 K$$

$$T_1 = 1422 K$$

$$S = 10 cm^2$$

$$t_1 = ?$$

VAKUUM



$$P^* = - \frac{dW_m}{dt}$$

$$j^* \cdot S = - \frac{dW_m}{dt}$$

$$\sigma T^4 \cdot S = - \frac{mc \frac{dT}{dt}}{dt}$$

$$\int_0^{t_1} dt = - \frac{mc}{\sigma S} \int_{T_0}^{T_1} \frac{dT}{T^4} = \frac{mc}{3\sigma S} \left(T^{-3} \right) \Big|_{T_0}^{T_1}$$

$$t_1 = \frac{mc}{3\sigma S} (T_1^{-3} - T_0^{-3}) = \frac{60 \cdot 10^{-3} kg \cdot 200 J/kgK \cdot 10^{-4} m^2}{3 \cdot 5,67 \cdot 10^{-8} \frac{W}{m^2 K^4} \cdot 10 \cdot 10^{-4} m^2} \left(\frac{1}{1422^3} - \frac{1}{2500^3} \right) =$$

$$t_1 = 20 s$$

$$0,7055 \cdot 10^{11} s \cdot 2,838 \cdot 10^{-10}$$

mal. 12 / str 78

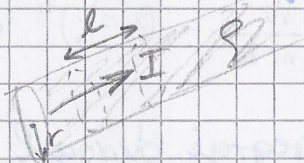
Dolga črna žica polmera r in spec. uporom ρ greje s tokom I . Žica se nahaja v vakuumu. Kolikšna je temp. žice na površini v stacionarnem stanju?

$$r = 4 mm$$

$$\rho = 0,016 \frac{\Omega mm^2}{m}$$

$$I = 160 A$$

$$T = ?$$



$$P_R = P^*$$

$$RI^2 = j^* S$$

$$\frac{\rho}{\pi r^2} I^2 = \sigma T^4 \pi r \cdot l$$

$$T^4 = \frac{\rho I^2}{2\pi^2 r^3 \sigma} = \frac{0,016 \cdot \frac{\Omega mm^2}{m} \cdot (160 A)^2}{2\pi^2 (4 mm)^3 \cdot 5,67 \cdot 10^{-8} \frac{W}{m^2 K^4}} =$$

$$T = 275 K$$

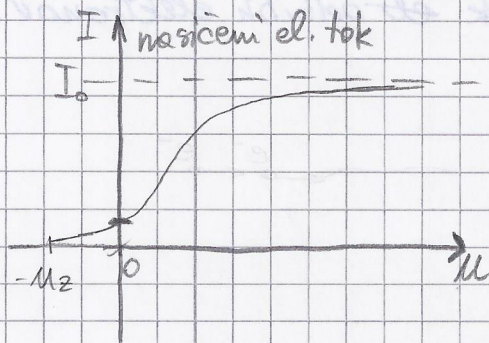
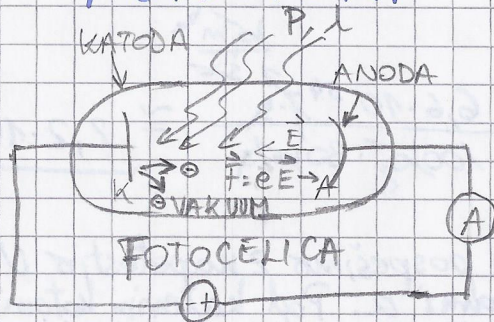
FOTOEFEKT

(na svetnem)

FOTONI (γ):

$$E_\gamma = h \cdot \nu = \frac{h \cdot c}{\lambda}$$

$$c = \nu \cdot \lambda$$



Večamo napetost, manjša tok, pade je večje, več elektronov k anodi, izbitih

na koncu anode posrka vse izbite elektrone, nasičenje

napetost damo na 0, vendar tok še nič, ker imajo elektroni še nekaj energije in lahko dosežejo anodo

Na katodo pada svetloba, vsak 6. foton izbiye elektron. Kolikšen nasičen el. tok teče skozi fotocelico, če pada na katodo svet. tok P z valovno dolžino λ ?

$$I_0 = \frac{dQ}{dt} = \frac{dN_{e^-} \cdot e_0}{dt} = \frac{1}{6} \frac{dN_\gamma}{dt} \cdot e_0$$

$$N_{e^-} = \frac{1}{6} N_\gamma$$

$$P = 10 \text{ W}$$

$$\lambda = 105 \text{ nm}$$

$$I_0 = ?$$

$$P = \frac{dE}{dt} = \frac{dN_\gamma E_\gamma}{dt}$$

$$\frac{dN_\gamma}{dt} = \frac{P}{E_\gamma} = \frac{P \lambda}{h c_0} = \frac{10 \text{ W} \cdot 105 \cdot 10^{-9} \text{ m}}{6,6 \cdot 10^{-34} \text{ J s} \cdot 3 \cdot 10^8 \frac{\text{m}}{\text{s}}} = 5,3 \cdot 10^{18} / \text{s}$$

$$I_0 = \frac{1}{6} \cdot 5,3 \cdot 10^{18} / \text{s} \cdot 1,6 \cdot 10^{-19} \text{ A s} \approx 141 \text{ mA}$$

$$E_\gamma = 0$$

GIB. KOL.

$$P_\gamma = \frac{E_\gamma}{c_0} = \frac{h}{\lambda}$$

$$E^2 = E_0^2 + c^2 P^2$$

$$E_0 = m c_0^2$$

$$E_\gamma = c_0 P_\gamma$$

DE BROGLIE :

$$\lambda_0 = \frac{h}{P}$$

$$m = 100 \text{ kg}$$

$$v = 30 \text{ m/s}$$

NERELATIVISTIČNO:

$$p = mv$$

$$\lambda_D = ?$$

$$\lambda_D = \frac{h}{p} = \frac{h}{mv} = \frac{6,6 \cdot 10^{-34} \frac{\text{kg} \cdot \text{m}^2}{\text{s}}}{100 \text{ kg} \cdot 30 \text{ m/s}} \approx 2,2 \cdot 10^{-37} \text{ m}$$

CUREK "počarnih" elektronov, ki jih pospešimo z napetostjo U , pošljemo jih skozi kristalno mrežo z razdaljami a . Pod katerim kotom na normalo na površino kristala se pojavi prvi ojačen curek odbitih elektronov?

$$U = 54 \text{ V}$$

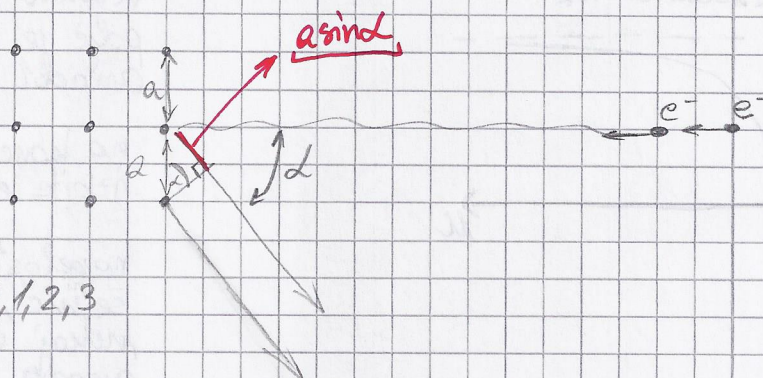
$$a = 0,215 \text{ nm}$$

$$\alpha_1 = ?$$

OJAČITEV:

$$a \sin \alpha = N \lambda$$

$$N = 0, 1, 2, 3$$



$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

$$= \frac{h}{\sqrt{2meU}}$$

$$W_k = eU$$

$$\frac{1}{2}mv^2 = eU$$

$$mv^2 = 2eU$$

$$mv = \sqrt{2meU}$$

$$\lambda = \frac{6,6 \cdot 10^{-34} \text{ J} \cdot \text{s}}{\sqrt{2 \cdot 9,1 \cdot 10^{-31} \text{ kg} \cdot 1,6 \cdot 10^{-19} \text{ As} \cdot 54 \text{ V}}} = 0,166 \text{ nm}$$

$$\sin \alpha_1 = \frac{\lambda}{a} = \frac{0,166 \text{ nm}}{0,215 \text{ nm}} \approx 0,772$$

$$\alpha_1 = 50,54^\circ$$

2. KOLOKVIJ 2008

3.) vesoljska jedrnica:

$$Q = 1 \text{ (odbojnost)}$$

$$S = 1000 \text{ m}^2$$

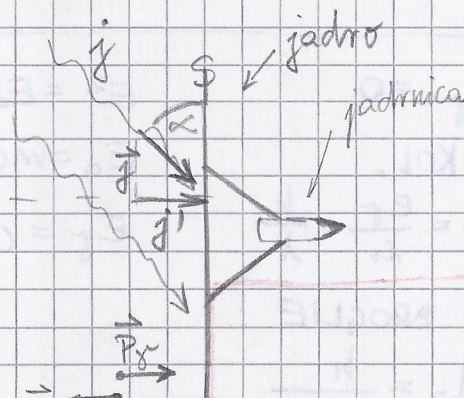
$$j = 6 \frac{\text{KW}}{\text{m}^2} \text{ (osvetljenost)}$$

$$F = ?$$

$$j' = j \cdot \cos \alpha$$

$$\Delta P_y = |\Delta \vec{P}_y| = -\vec{P}_y \text{ foton}$$

$$= 2P_y$$



$$F = \frac{dP}{dt} = \frac{dN_{\gamma}}{dt} \cdot 2P_{\gamma} \leftarrow \text{gib. kol.}$$

$$\frac{dN_{\gamma}}{dt} = \frac{P_{\text{sv. l.}}}{h \cdot \nu_0} = \frac{j' \cdot S \cdot l}{h \cdot \nu_0} \leftarrow \text{svet. tok}$$

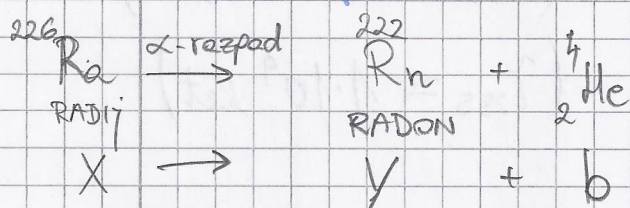
$$F = \frac{j' \cdot S \cdot l}{h \cdot \nu_0} \cdot 2 \cdot \frac{h \cdot \nu_0}{c} = 2 \frac{j' \cdot S}{c} \leftarrow \text{odvisno od odbojnosti}$$

$$F = 2 \frac{j' \cdot S}{c} \leftarrow \text{svetlobni tlak}$$

$$F = 2 \cdot \frac{6 \cdot 10^2 \text{ W}}{\text{m}^2} \cdot \frac{1000 \text{ m}^2}{3 \cdot 10^8 \text{ m/s}} = 4 \cdot 10^{-2} \frac{\text{N}}{\text{m}} = 0,04 \text{ N}$$

7.6.2011

Razpad radija:



Mirajoče jedro radija preide v jedro radona.
masa radona, radija in delca α so:

1. $M_X = 226,02536 \text{ ame}$
2. $m_Y = 222,01753 \text{ ame}$
3. $m_b = 4,00260 \text{ ame}$

Kolikšna je hitrost delca α po razpadu?

$v_b = ?$

- OHRANITEV ENERGIJE:

$$M_X c^2 = m_Y c^2 + m_b c^2 + \frac{1}{2} m_Y v_Y^2 + \frac{1}{2} m_b v_b^2$$

$$(M_X - m_Y - m_b) c^2 = \frac{1}{2} m_Y v_Y^2 + \frac{1}{2} m_b v_b^2$$

- OHRANITEV GIB. KOL.

$\leftarrow$ ni suma zunanjih sil

$$0 = m_Y \vec{v}_Y + m_b \vec{v}_b \Rightarrow \vec{v}_Y = -\frac{m_b}{m_Y} \vec{v}_b$$

$$Q = \frac{1}{2} m_Y \frac{m_b^2}{m_Y^2} v_b^2 + \frac{1}{2} m_b v_b^2 = \frac{1}{2} m_b v_b^2 \left(1 + \frac{m_b}{m_Y}\right)$$

$$v_b = \sqrt{\frac{2Q}{m_b \left(1 + \frac{m_b}{m_Y}\right)}} \approx 1,5 \cdot 10^7 \frac{\text{m}}{\text{s}}$$

$$v_b = \sqrt{\frac{2 \cdot (226,02536 - 222,01753 - 4,00260) \cdot 931,5 \text{ MeV}}{4,00260 \cdot 931,5 \text{ MeV} \left(1 + \frac{4,00260}{222,01753}\right)}}$$

MIROVNA EN.: $E_0 = mc^2$

$$E_0 = mc^2$$

POLNA ENERGIJA:

$$E = \gamma \cdot E_0$$

KIN. EN.:

$$W_k = (\gamma - 1) E_0$$

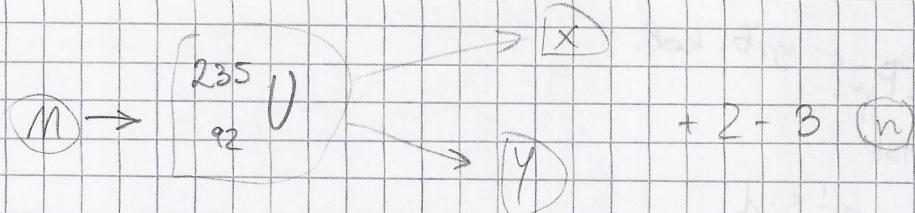
$$v \ll c$$

$$W_k \approx \frac{1}{2} m v^2$$

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

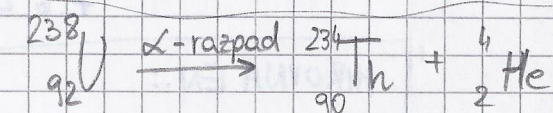
$$\vec{P} = \gamma m \vec{v}$$

ame - atomske masne enote
 $\rightarrow 931,5 \text{ MeV} / c^2$

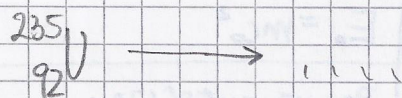


$$M = \frac{N_{235}}{N_{\text{vseh izotopov}}} \approx \frac{N_{235}}{N_{238}} \approx 0,7\%$$

$(M \sim 3\%)$ za veržno reakcijo



$(\tau_{238} \approx 6,5 \cdot 10^9 \text{ let})$



$(\tau_{235} \approx 1 \cdot 10^9 \text{ let})$

Delež ^{235}U pred 2 milijardami let:

$t = 2 \cdot 10^9 \text{ let}$
 $M_0 = ?$

$N(t) = N_0 e^{-\frac{t}{\tau}}$

$N e^{\frac{t}{\tau}} = N_0$

$M_0 \approx \frac{235}{238} \frac{N_0}{N_0}$

$M_0 = \frac{235}{238} \frac{N e^{\frac{t}{\tau_{235}}}}{N e^{\frac{t}{\tau_{238}}}} = n \frac{e^{\frac{t}{\tau_{235}}}}{e^{\frac{t}{\tau_{238}}}} = n e^{\frac{t}{\tau_{238}} - \frac{t}{\tau_{235}}} = 0,7\% \cdot e^{\frac{1,68}{1}} = \underline{\underline{3,8\%}}$

$2 \cdot 10^9$ let nazaj - Gabon, Afrika; naravni jedrski fizijski reaktor.

danes: 0,71%

$t_0 \sim 3h$

$t \sim 100\,000 \text{ let}$

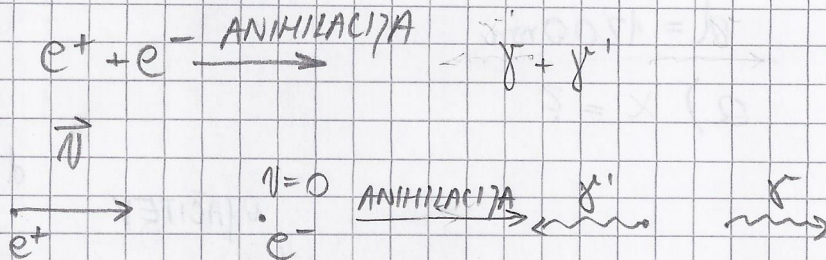
$P \sim 100 \text{ kW}$

DELEC + ANTIDELEC $\xrightleftharpoons[\text{TVORBA PARA}]{\text{ANIHILACIJA}}$ $\begin{matrix} (EMV) \\ \gamma^- + \gamma^+ \\ \text{FOTON} \end{matrix}$

$E_T = \sqrt{W_k^2 + 2E_0 W_k}$

Pozitron e^+ s $W_k = 20 \text{ MeV}$ sreča mirujoči elektron in se z njim anihilira. Kolikšna je val. dolžina nastalih žarkov γ od katerih eden sledi v smeri pozitrona, drugi pa v nasprotni smeri.

e^+ (POZITRON):
 $E_0 = 0,51 \text{ MeV}$
 $W_k = 20 \text{ MeV}$
 mirujoči e^- (elektron)
 $\lambda = ?$
 $\lambda' = ?$



OHRANITEV EN.:

$$W_k + 2 \cdot E_0 = E_\gamma + E_{\gamma'}$$

$$W_k + 2 \cdot E_0 = \frac{hc}{\lambda} + \frac{hc}{\lambda'} \quad (2)$$

OHRANITEV GIB. EN.:

$$p_{e^+} = \frac{h}{\lambda} - \frac{h}{\lambda'} \quad / \cdot c$$

$$\sqrt{W_k^2 + 2E_0 W_k} = \frac{hc}{\lambda} - \frac{hc}{\lambda'} \quad (1)$$

① + ② :

$$(W_k + 2E_0) + \sqrt{W_k^2 + 2E_0 W_k} = 2 \frac{hc}{\lambda}$$

$$\hbar \omega = \frac{h}{2\pi} \omega = 200 \text{ MeV fm}$$

$$\lambda = \frac{2hc}{(W_k + 2E_0) + \sqrt{W_k^2 + 2E_0 W_k}} = \frac{2 \cdot 400 \pi \text{ MeV fm}}{20 \text{ MeV} + 1,02 \text{ MeV} + \sqrt{400 + 2 \cdot 0,51 \cdot 20 \text{ MeV}}}$$

$$\lambda = \underline{60 \text{ fm}}$$

2. KOL. FIZ 2.

2010

① $n_2 = 2n_1$

$$\frac{\epsilon_2}{\epsilon_1} = ?$$

$$m = \frac{\epsilon_0}{c}$$

$$c_0 = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$$

$$c = \frac{1}{\sqrt{\epsilon \epsilon_0 \mu \mu_0}}$$

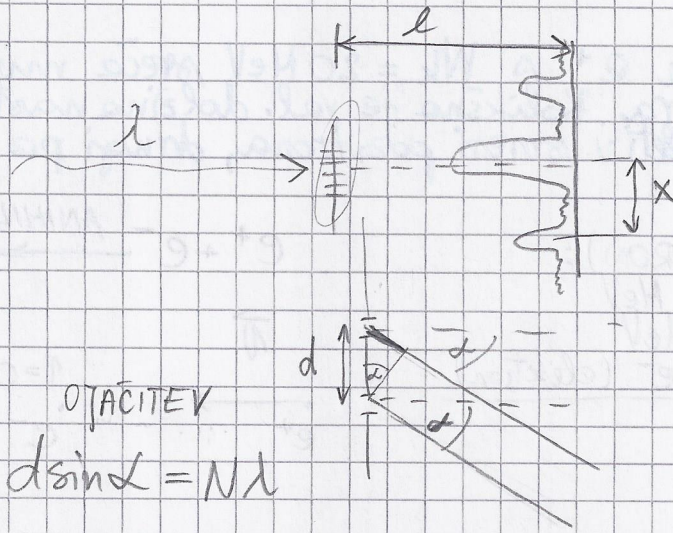
$$m = \sqrt{\epsilon \mu}$$

$$n^2 = \epsilon \mu$$

(F) 4x večja

2) $\lambda = 500 \text{ nm}$
 $\varphi = 90^\circ$
 $l = 2 \text{ m}$
 $d = 1200 \text{ nm}$

a) $x = ?$



OTACITEV
 $d \sin \alpha = N \lambda$

$N=0, \alpha_0=0$

$N=1 \quad \alpha_1 = \arcsin \frac{\lambda}{d} = 24,62^\circ$

$\tan \alpha_1 = \frac{x}{l}$

$x = l \cdot \tan \alpha_1 \approx 2 \text{ m} \cdot \tan 24,6^\circ = 917 \text{ mm} \quad (c)$

b) $P = 40 \text{ W}$
 $\lambda = 500 \text{ nm}$

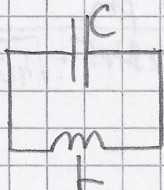
koliko fotonov v povprečju pade na uklonsko mrežico vsako sekundo

$\frac{dN_r}{dt} = ?$

$P = \frac{dE}{dt} = \frac{dN_r E_f}{dt}$

$\frac{dN_r}{dt} = \frac{P \lambda}{hc} \approx \frac{40 \text{ W} \cdot 500 \cdot 10^{-9} \text{ m}}{6,6 \cdot 10^{-34} \text{ J} \cdot 3 \cdot 10^8 \frac{\text{m}}{\text{s}}} = 1 \cdot 10^{20} \frac{1}{\text{s}} \quad (b)$

3.)



$t_0 = 2\pi \sqrt{LC}$

$L_1 = 2L \rightarrow t_0 \rightarrow \sqrt{2} t_0 \quad (d)$

4.) $\lambda_0 = 490 \text{ nm}$

a) $T = ?$

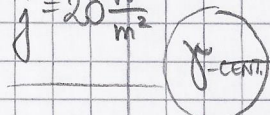
$\lambda_0 \cdot T = k_B \Rightarrow T = \frac{k_B}{\lambda_0} = \frac{2,9 \cdot 10^{-21} \text{ J} \cdot 10^9}{490 \cdot 10^{-9} \text{ m}} = 5918 \text{ K} \quad (c)$

b) $P^* = ?$

$j^* = \sigma T^4 \quad P^* = j^* S$

$\underline{P^* \propto T^4} \quad (d)$

5. $r = 2 \cdot 10^6 \text{ m}$
 $j = 20 \frac{\text{W}}{\text{m}^2}$



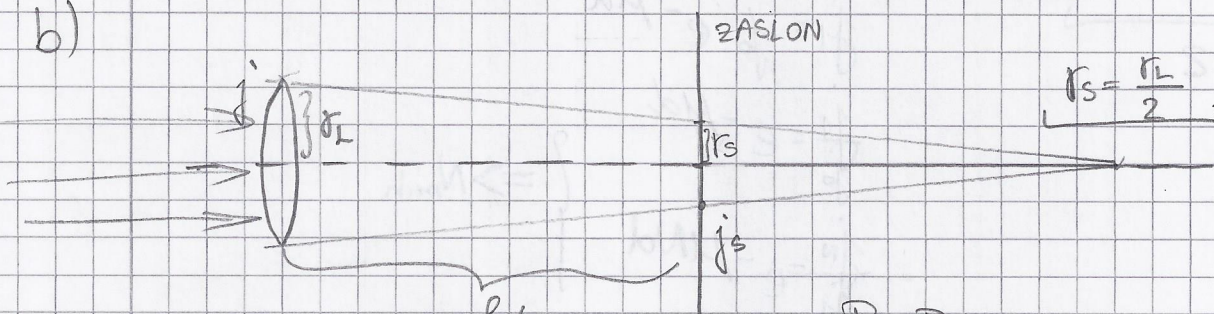
a) $P^* = ?$

izotropno sevanje

$f/2$

$$P^* = j \cdot 4\pi r^2 = 20 \frac{\text{W}}{\text{m}^2} \cdot 4 \cdot \pi \cdot 10^{12} \cdot 10^6 = 4 \cdot 10^{21} \text{ W} \quad (c)$$

b)



$$j_s = \frac{P_s}{S_s} = \frac{P_s}{\pi r_s^2} = \frac{j \cdot 4\pi r_L^2}{\pi r_s^2} = \frac{j \cdot 4 r_L^2}{r_s^2} = 4 j' = 80 \frac{\text{W}}{\text{m}^2} \quad (c)$$

c)

$\tau_{\text{SAM}} = 70 \text{ h}$

$t_z = 25 \text{ dni} = 600 \text{ h}$

$v \text{ (v sistema zemlje)} = ?$

$t_z = \gamma \tau_{\text{SAM}}$

$\gamma = \frac{t_z}{\tau_{\text{SAM}}} \approx 8,57 = 8,6$

$\gamma = \frac{1}{\sqrt{1 - \frac{v_0^2}{c^2}}} = >$

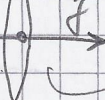
$1 - \frac{v_0^2}{c^2} = \frac{1}{\gamma^2}$
 $\frac{v_0^2}{c^2} = 1 - \frac{1}{\gamma^2}$

$v_0 = c \sqrt{1 - \frac{1}{\gamma^2}} = 2,98 \cdot 10^8 \frac{\text{m}}{\text{s}} \quad (c)$

ZASLON

tomka zb. leča

r



ZASLON

$r_s = \frac{r_L}{2}$

j_s

$f/2$

$P_s = P_L$

$j \cdot 4 r_L^2$

$= 4 j' = 80 \frac{\text{W}}{\text{m}^2} \quad (c)$

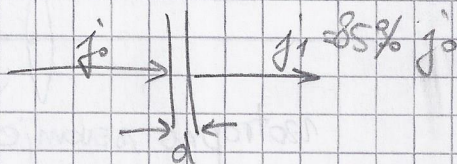
$\gamma\text{-CENT.}$

SAM.



6. siva plomparalelna ploščica:

$$\frac{I_1}{I_0} = 0,85$$



koliko ploščic, da bodo prepustile manj kot 9% vpadne svetlobe?

$$\frac{I_N}{I_0} < 9\%$$

$N = ?$

$$I_1 = I_0 e^{-\mu d}$$

$$\frac{I_1}{I_0} = e^{-\mu d}$$

$$\frac{I_N}{I_1} = e^{-\mu N d}$$

$\Rightarrow N_{min}$