

FIZIKA II

zapiski z avditornih vaj

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Sodelavci Blaž Potočnik, Aljoša Praznik

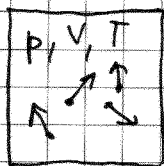
UREJANJE DOKUMENTA

VERZIJA	01	REVIZIJA	01
DATUM	24. 2. 2009		
ZADNJI POPRAVLJAL	/		
PREGLEDAL	Blaž Potočnik, Aljoša Praznik		

OPOMBE

POPRAVKI

Kinetična teorija plinov



$$p \cdot V = \frac{m}{M} R T$$

maza kilomola

splošna plinska konstanta

$N = \text{št. gradnikov}$

$R = N_A \cdot k_B$; $N_A = 6,02 \cdot 10^{26} \text{ kmol}^{-1}$

Boltzmanova konstanta $k_B = 1,38 \cdot 10^{-23} \frac{\text{J}}{\text{K}}$

$$p \cdot V = \frac{N \cdot m_1}{N_A \cdot m_1} \cdot N_A \cdot k_B \cdot T \Rightarrow p \cdot V = N \cdot k_B \cdot T$$

$\langle \vec{v} \rangle = \frac{\sum \vec{v}}{N} = 0 \Rightarrow$ povprečna hitrost je nič

$\langle v^2 \rangle \neq 0 \Rightarrow$ po smeri ni nič

$$\langle W_{k, \text{translacija}} \rangle = \frac{1}{2} m_1 \langle v^2 \rangle = \frac{1}{2} m_1 \langle v_x^2 \rangle + \frac{1}{2} m_1 \langle v_y^2 \rangle + \frac{1}{2} m_1 \langle v_z^2 \rangle = \frac{3}{2} k_B \cdot T$$

- za enoatomne molekule (točkasta oblika)

$$\langle W_{k, \text{rotacija}} \rangle = \frac{2}{2} k_B \cdot T$$

- ni točkasta oblika (prištejeno za večatomne mol.)

Primer:

kisik (O_2)



$T = 20^\circ\text{C}$

$M_{\text{O}_2} = 32 \text{ kg/kmol}$

$\langle W_k \rangle = ?$

povprečna velikost hitrosti

$\sqrt{\langle v^2 \rangle} = ?$

$$\langle W_k \rangle = \frac{5}{2} k_B \cdot T = \frac{5}{2} \cdot 1,38 \cdot 10^{-23} \frac{\text{J}}{\text{K}} \cdot 293 \text{ K} = 10^{-20} \text{ J}$$

$$\frac{1}{2} m_1 \langle v^2 \rangle = \frac{3}{2} k_B \cdot T$$

$$\langle v^2 \rangle = \frac{3 k_B \cdot T}{m_1}; \quad m_1 = \frac{M_{\text{O}_2}}{N_A}$$

$$\sqrt{\langle v^2 \rangle} \approx 470 \frac{\text{m}}{\text{s}}$$

kisik (O_2)

$$N = 2 \cdot 10^{20}$$

$$M_{O_2} = 32 \frac{\text{kg}}{\text{kmol}}$$

$$\langle v^2 \rangle = 36 \cdot 10^4 \frac{\text{m}^2}{\text{s}^2}$$

$$p = 1,28 \cdot 10^3 \text{ Pa}$$

$$V_{\text{posode}} = ?$$

$$p \cdot V = N \cdot k_B \cdot T$$

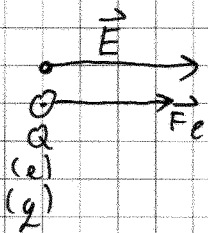
$$V = \frac{N \cdot k_B \cdot T}{p}$$

$$\frac{1}{2} m_0 \langle v^2 \rangle = \frac{3}{2} k_B \cdot T$$

$$T = \frac{M_{O_2} \langle v^2 \rangle}{3 N_A \cdot k_B}$$

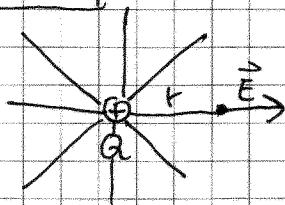
$$V = \frac{N \cdot k_B}{p} \cdot \frac{M_{O_2} \langle v^2 \rangle}{3 N_A \cdot k_B} \approx 1 \text{ dm}^3 = 1 \text{ l}$$

Električno polje



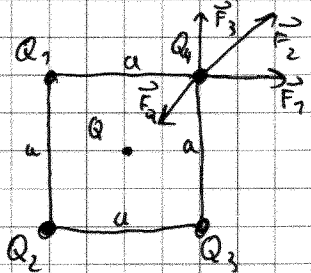
$$\vec{F} = Q \cdot \vec{E}$$

Polje točkastega naboja



$$\vec{E} = \frac{Q}{4\pi\epsilon_0 r^2} \cdot \frac{\vec{F}}{q}$$

Primer: 4 točkasti naboji v ogliščih kvadrata



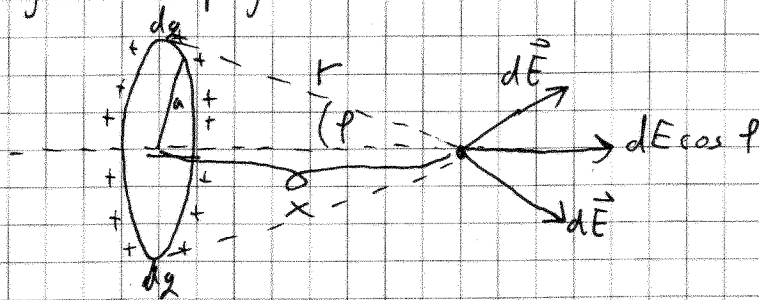
$$Q_1 = Q_2 = Q_3 = Q_4 = 1 \text{ As} = 1 \text{ C} = Q$$

$$Q_0 = ? \text{ (v pravoupsju)}$$

$$N \times \text{ smeri: } F_1 + F_2 \cos 45^\circ - F$$

Izračunaj jakost polja u osi nael. krožne zamke

$$\begin{aligned} a &= 1\text{m} \\ q &= 70^{-7}\text{As} \\ x &= 3\text{m} \\ E &=? \end{aligned}$$



$$\cos \varphi = \frac{x}{r} \quad E = \int dE \cdot \cos \varphi$$

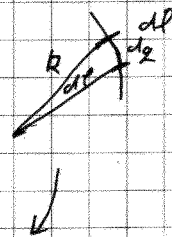
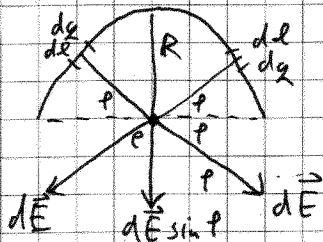
$$dE = \frac{dq}{4\pi\epsilon_0 r^2}$$

$$E = \int \frac{dq}{4\pi\epsilon_0 r^2} \cdot \frac{x}{r} = \frac{x}{4\pi\epsilon_0 r^3} \int dq = \frac{x}{4\pi\epsilon_0 r^3} \cdot q = 85 \frac{\text{V}}{\text{m}}$$

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

Tanka kovánska žica je zvitá v polkruh (R=0,7m), naelektréna je enakovno z dolžinsko enoto naboja. ($\lambda=q=10^{-4}\text{C/m}$)

$$\begin{aligned} R &= 0,7\text{m} \\ \lambda &= 10^{-4} \frac{\text{C}}{\text{m}} \\ e &= 10^{-9}\text{C} \\ E &=? \end{aligned}$$



$$E = \int dE \sin \varphi; \quad dE = \frac{dq}{4\pi\epsilon_0 r^2}; \quad dq = \lambda \cdot dl = \lambda \cdot R \cdot d\varphi$$

$$E = \int_0^\pi \frac{\lambda R d\varphi}{4\pi\epsilon_0 R^2} \sin \varphi = \frac{\lambda}{4\pi\epsilon_0 R} \int_0^\pi \sin \varphi d\varphi = \frac{\lambda}{4\pi\epsilon_0 R} (-\cos \varphi) \Big|_0^\pi = \frac{\lambda}{4\pi\epsilon_0 R} (1+1) =$$

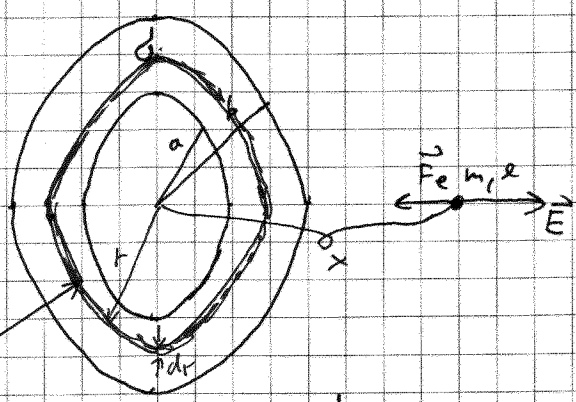
$$E = \frac{\lambda}{2\pi\epsilon_0 R}$$

$$F = e \cdot E = \frac{e\lambda}{2\pi\epsilon_0 R} = 1,8 \cdot 10^{-2}\text{N}$$

17. nal / str. 13

$m = 0,1 \text{ g}$
 $\rho = 10^{-5} \text{ As}$ } kroglica, ki se lahko giblje vzdolž tavnega ploščatega kolobarja (a, b) značka, ko jo malekost izmaknemo iz središčne lege.

$a = 5 \text{ cm}$
 $b = 10 \text{ cm}$
 $\rho = 10^{-5} \frac{\text{As}}{\text{m}^2}$
 $f_0 = ?$
 $x \ll a$



$$dq \cdot dS = \rho \cdot 2\pi \cdot r \cdot dr; \quad dE = \frac{dq \cdot x}{4\pi\epsilon_0 (r^2 + x^2)^{3/2}}$$

$$E = \int dE = \int_a^b \frac{\rho \cdot 2\pi \cdot r \cdot dr \cdot x}{4\pi\epsilon_0 (r^2 + x^2)^{3/2}} = \frac{\rho x}{2\epsilon_0} \int_a^b \frac{r \cdot dr}{(r^2 + x^2)^{3/2}} = \frac{\rho x}{2\epsilon_0} \left[\frac{du}{2u^{3/2}} \right]_{u(a)}^{u(b)}$$

$$E = -\frac{\rho x}{2\epsilon_0} \left[(b^2 + x^2)^{-1/2} - (a^2 + x^2)^{-1/2} \right]$$

$$E(x \ll 0) = \frac{\rho x}{2\epsilon_0} \left(\frac{1}{a} - \frac{1}{b} \right) \text{ — najhaji odlički}$$

$$F = m \cdot a \Rightarrow e \cdot E = m \cdot \ddot{x} \quad \boxed{\ddot{x} = -\omega^2 \cdot x}$$

$$e \cdot \frac{\rho x}{2\epsilon_0} \left(\frac{1}{a} - \frac{1}{b} \right) = m \cdot \ddot{x} \Rightarrow \omega^2$$

$$\ddot{x} = - \frac{|\rho| \left[\frac{1}{a} - \frac{1}{b} \right]}{2\epsilon_0 m} x$$

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

$$T_0 = 2\pi \cdot \sqrt{\frac{2\epsilon_0 m}{|\rho| \left(\frac{1}{a} - \frac{1}{b} \right)}} = 8,36 \cdot 10^{-3} \text{ s}$$

Prispevek gravitacije

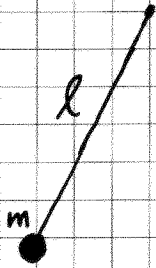
$$m_K = 0,5 \text{ kg} \quad dF_g = G \frac{dm_K \cdot m}{r^2}$$

$$T_0 = ? \quad \rho_m = \frac{m_K}{\pi(b^2 - a^2)}$$

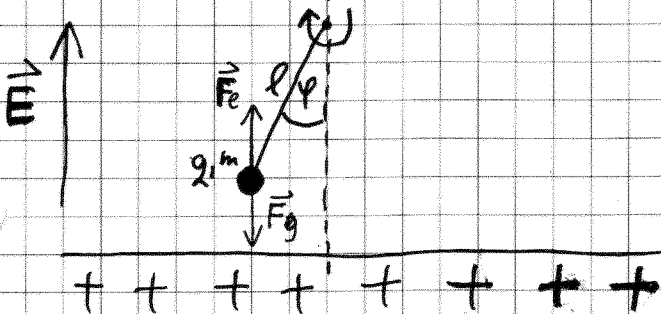
Rezultat $T_0 = 2\pi \sqrt{\frac{a \cdot b \cdot (b - a)}{G \cdot m_K}} = 77200 \text{ s}$

29.02.2008

Matematično nihalo



$$t_0 = \sqrt{\frac{l}{g}}$$



$$M = J \cdot \alpha$$

$$(F_e - F_g) \cdot l \cdot \sin \varphi = m l^2 \cdot \ddot{\varphi}$$

$$(q \cdot E - m \cdot g) \cdot l = m \cdot l \cdot \ddot{\varphi}$$

$$\ddot{\varphi} = - \underbrace{\frac{m \cdot g - q \cdot E}{m \cdot l}}_{\omega^2} \cdot \varphi$$

$$\ddot{\varphi} = - \text{konstanta} \cdot \varphi$$

sinusno nihanje

$$t_0 = \frac{2\pi}{\omega} = 2\pi \cdot \sqrt{\frac{m \cdot l}{m \cdot g - q \cdot E}}$$

$$\Rightarrow t_0 = 2\pi \sqrt{\frac{l}{g - \frac{q \cdot E}{m}}}$$

Gaussov zakon (zakon o el. pretoku)

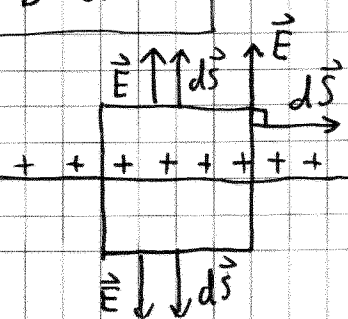
$$\oint \vec{D} \cdot d\vec{S} = e$$

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

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

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

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



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

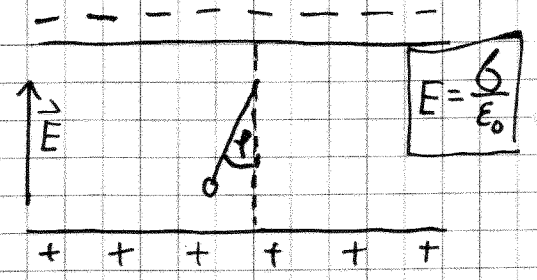
E v okolici naelektrene plosce

če je q ali E enak 0 je navadno nat. nihalo.

$$\begin{aligned}
 l &= 1 \text{ cm} \\
 q &= 20 \cdot 10^{-9} \text{ As} \\
 \tilde{m} &= 2g \\
 \delta &= \pm 5 \frac{\mu\text{As}}{\text{m}^2}
 \end{aligned}$$

$$t_0 = 2\sqrt{l} \sqrt{\frac{l}{g - \frac{q\delta}{\epsilon_0 m}}}$$

$$t_0 = 0,318$$



$$\begin{aligned}
 l &= 13 \text{ cm} \\
 m &= 0,1 \text{ g} \\
 d &= 12 \text{ cm}
 \end{aligned}$$

RAVNOVESJE:

$$\sum_i \vec{F}_i = 0 \quad \sin \rho = \frac{d}{2l}$$

$$q = ?$$

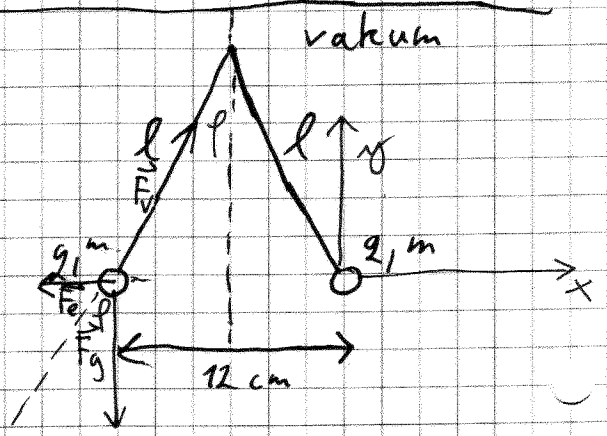
$$\begin{aligned}
 x: F_e - F_{rx} &= 0 \\
 F_{vx} &= F_v \cdot \sin \rho \\
 F_e - F_v \cdot \sin \rho &= 0
 \end{aligned}
 \left. \begin{array}{l} \\ \\ \end{array} \right\} F_v = \frac{F_e}{\sin \rho}$$

$$\begin{aligned}
 y: F_g - F_{ry} &= 0 \\
 F_g - F_v \cos \rho &= 0
 \end{aligned}$$

$$m \cdot g - \frac{F_e}{\sin \rho} \cos \rho = 0$$

$$m \cdot g - \frac{q^2}{4\pi\epsilon_0 d^2} \text{ctg} \rho = 0 \Rightarrow q = \sqrt{\frac{mg \cdot 4\pi\epsilon_0 d^2}{\text{ctg} \rho}}$$

$$q = 2,86 \cdot 10^{-8} \text{ As}$$



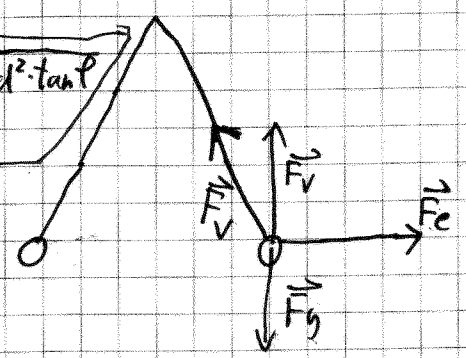
v alkoholu

$$\rho = 0,8 \cdot 10^3 \frac{\text{kg}}{\text{m}^3}$$

$$\begin{aligned}
 \epsilon &= 26 \\
 V_h &= 10^{-7} \text{ m}^3
 \end{aligned}$$

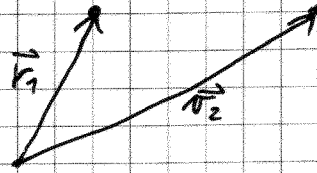
$$q = \sqrt{(m \cdot g - V \cdot \rho \cdot g) \cdot 4\pi \cdot \epsilon \cdot \epsilon_0 \cdot d^2 \cdot \tan \rho}$$

$$q = 6,52 \cdot 10^{-8} \text{ As}$$



El. napetost

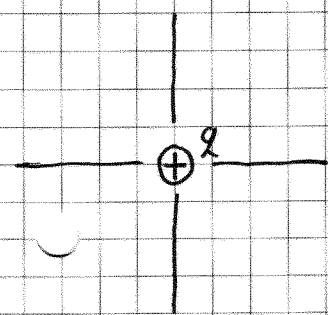
$$u(\vec{r}_2, \vec{r}_1) = - \int_{\vec{r}_1}^{\vec{r}_2} \vec{E} \cdot d\vec{s}$$



$$\begin{aligned} u(\vec{r}_2, \vec{r}_1) &= - \int_{\infty}^{\vec{r}_2} \vec{E} \cdot d\vec{s} - \left(- \int_{\infty}^{\vec{r}_1} \vec{E} \cdot d\vec{s} \right) \\ &= + V(\vec{r}_2) - V(\vec{r}_1) \end{aligned}$$

$$\Delta W_p = e \cdot u$$

$$\begin{aligned} \Delta W_p &= W_p(\vec{r}_2) - W_p(\vec{r}_1) = \\ &= e V(\vec{r}_2) - e V(\vec{r}_1) \end{aligned}$$



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

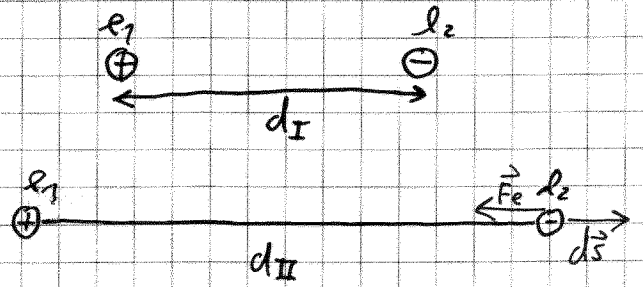
$$V(r) = - \int_{\infty}^r E dr = - \int_{\infty}^r \frac{q}{4\pi\epsilon_0 r^2} dr = - \frac{q}{4\pi\epsilon_0} \left(-\frac{1}{r} \right) \Big|_{\infty}^r$$

$$V(r) = \frac{q}{4\pi\epsilon_0 r}$$

12. naloga / stran 14 (drugi podatki)

$$\begin{aligned}
 q_1 &= +10^{-8} \text{ As} \\
 q_2 &= -2 \cdot 10^{-7} \text{ As} \\
 d_I &= 10 \text{ cm} \\
 d_{II} &= 20 \text{ cm}
 \end{aligned}$$

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



A = ?

1. način

$$A = - \int_{d_I}^{d_{II}} \frac{q_1 \cdot q_2}{4\pi\epsilon_0 d^2} \cdot d\vec{d}$$

$$A = - \frac{q_1 q_2}{4\pi\epsilon_0} \left(-\frac{1}{d} \right) \Big|_{d_I}^{d_{II}}$$

$$A = - \frac{q_1 q_2}{4\pi\epsilon_0} \left(\frac{1}{d_I} - \frac{1}{d_{II}} \right) \left[\frac{As}{As} \frac{V_k}{k} \right] = \left[\frac{As \cdot J}{As} \right] = [j]$$

2. način

$$A = \Delta W_p = V_{II} \cdot q_2 - V_I \cdot q_2 = \frac{q_1 q_2}{4\pi\epsilon_0 d_{II}} - \frac{q_1 q_2}{4\pi\epsilon_0 d_I} = 8,9 \cdot 10^{-5} \text{ J}$$

16. naloga / stran 17

$$\begin{aligned}
 m &= 3 \text{ g} \\
 e &= 8 \text{ mAs} \\
 a &= 3 \text{ cm} \\
 q &= 0,1 \text{ mAs} \\
 v_{00} &= 30 \text{ km/s}
 \end{aligned}$$

$x_{min} = ?$

$$\Delta W_K + \Delta W_p = 0$$

$$dV = \frac{dq}{4\pi\epsilon_0 r}$$

$$V = \frac{q}{4\pi\epsilon_0 r}$$

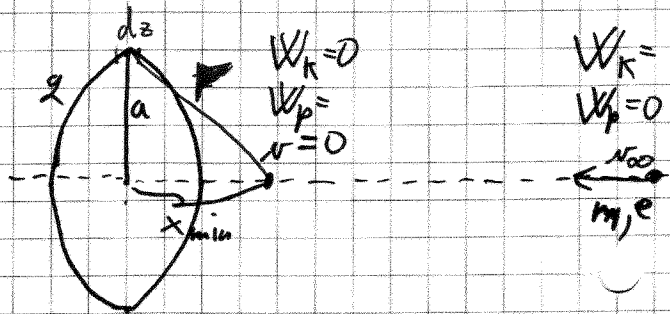
$$\frac{m \cdot v^2}{2} - 0 + \left(0 - \frac{q \cdot e}{4\pi\epsilon_0 r} \right) = 0$$

$$\frac{m v_{00}^2}{2} - \frac{q \cdot e}{4\pi\epsilon_0 r} = 0$$

$$r = \frac{q \cdot e}{2 \cdot 4\pi\epsilon_0 m v_{00}^2}$$

$$r = 6,9 \text{ cm}$$

$$x = \sqrt{r^2 - a^2} = 6,22 \text{ cm}$$



7.3.2008

20. nal. / str. 78

$$r_1 = 2 \text{ cm}$$

$$e_1 = 2 \cdot 10^{-6} \text{ As}$$

$$r_2 = 5 \text{ cm}$$

$$e_2 = 10^{-6} \text{ As}$$

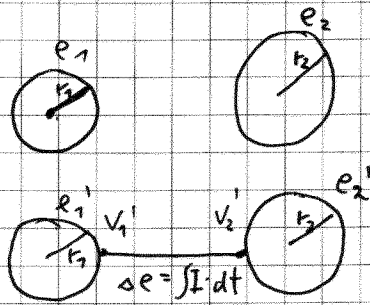
$$e_1' = ?$$

$$e_2' = ?$$

$$\delta_1' = ?$$

$$\delta_2' = ?$$

povežemo z žico



$$V_1' = V_2'$$

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

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

OHRANITEV NABOJA

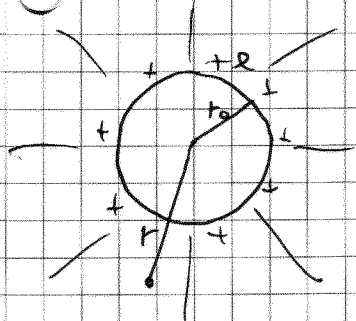
$$e_1 + e_2 = e_1' + e_2'$$

$$e_1 + e_2 = e_1' + e_1' \frac{r_2}{r_1} = e_1' \left(1 + \frac{r_2}{r_1}\right) \Rightarrow e_1' = \frac{e_1 + e_2}{\left(1 + \frac{r_2}{r_1}\right)} = 0,856 \cdot 10^{-6} \text{ As}$$

$$e_2' = 2,14 \cdot 10^{-6} \text{ As}$$

$$\delta_1' = \frac{e_1'}{4\pi r_1^2} = 1,7 \cdot 10^{-4} \text{ As/m}^2$$

$$\delta_2' = \frac{e_2'}{4\pi r_2^2} = 0,68 \cdot 10^{-4} \text{ As/m}^2$$

Izračun potenciala s pomočjo Gaussa:

$$\oint \vec{D} \cdot d\vec{S} = q$$

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

$$\epsilon_0 \oint \vec{E} \cdot d\vec{S} = q$$

$$\epsilon_0 \cdot E \cdot 4\pi r^2 = q$$

$$E = \frac{q}{4\pi\epsilon_0 r^2} \Rightarrow V = \frac{q}{4\pi\epsilon_0 r}$$

Polje \vec{E} zunaj krogle je tak, kot bi bil ves naboj v središču.

9

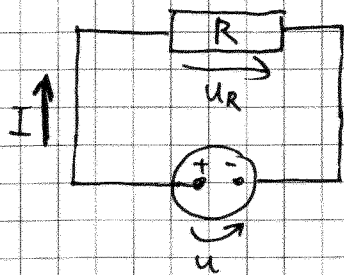
Električni tok

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

$$A = e \cdot U$$

$$P = \frac{dA}{dt} = \frac{de}{dt} U$$

$$P = U \cdot I$$



$$U = R \cdot I$$

$$U + U_R = 0$$

$$U_R = -U = -R \cdot I$$

Izkozi upor $R = 10 \Omega$, ki je potopljen v $1 \text{ dm}^3 = 1 \text{ l}$ vode, se v $7,5$ ure preteče 10^4 As naboja. Koliko se segreje voda?

$$R = 10 \Omega$$

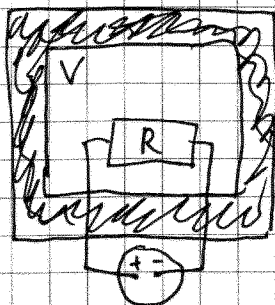
$$V = 1 \text{ dm}^3$$

$$t = 90 \text{ min}$$

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

$$t_1 = 70 \text{ min}$$

$$\Delta T = ?$$



$$P \cdot t_1 = A = Q$$

voda

$$c_v = 4200 \text{ J/kgK}$$

$$\rho = 1000 \text{ kg/m}^3$$

$$P \cdot t_1 = Q = m \cdot c_v \cdot \Delta T$$

$$R I^2 t_1 = m \cdot c_v \cdot \Delta T \Rightarrow \Delta T = \frac{R I^2 t_1}{m \cdot c_v} = 4,9 \text{ K}$$

Izkozi upor $R = 8 \Omega$ steče v dolgem času naboj $e = 30 \text{ As}$. Koliko toplote se sprosti v uporniku, če pada tok eksponentno proti nič, tako da se vsakih 24 s zmanjša za $\frac{1}{2}$.

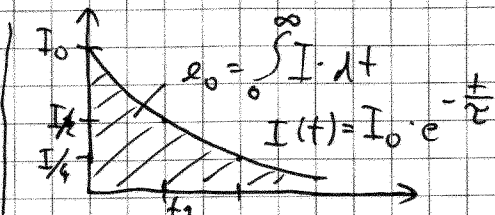
$$R = 8 \Omega$$

$$e_0 = 30 \text{ As}$$

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

$$A = Q = ?$$

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



$$Q = A = \int P \cdot dt = \int U \cdot I \cdot dt = \int I^2 \cdot R \cdot dt =$$

$$= \int_0^\infty I_0^2 e^{-\frac{2t}{\tau}} R \cdot dt = I_0^2 R \int_0^\infty e^{-\frac{2t}{\tau}} dt =$$

$$Q = I_0^2 R \left[-\frac{\tau}{2} e^{-\frac{2t}{\tau}} \right]_0^\infty = \frac{I_0^2 R \tau}{2} (e^{-\infty} - e^{-0}) = \boxed{Q = \frac{I_0^2 \cdot R \cdot \tau}{2}}$$

OB $t = t_{1/2}$:

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

$$e_0 = \int_0^\infty I dt = \int_0^\infty I_0 e^{-\frac{t}{\tau}} dt = I_0 \left[-\tau e^{-\frac{t}{\tau}} \right]_0^\infty = -I_0 \tau (e^{-\infty} - e^{-0})$$

$$e_0 = \tau \cdot I_0$$

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

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

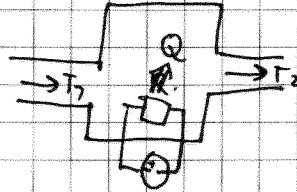
$$Q = \frac{I_0^2 \cdot R \cdot \tau}{2} = \frac{e_0^2 \cdot R \cdot t_{1/2}}{\tau^2 \cdot 2 \cdot \ln 2} = 104 \text{ J}$$

Imamo pretčni bojler skozi katerega teče volumski pretok vode 9 l/min. Voda se v bojlju segreje iz 75°C na 70°C. Bojler je priključen na $U_{ef} = 220\text{ V}$. Izkoristek grelna je 85%. Kolikšna je amplituda izmeničnega toka skozi žice?

$$\begin{aligned} \phi_v &= 9\text{ l/min} \\ T_1 &= 75^\circ\text{C} \\ T_2 &= 70^\circ\text{C} \\ U_{ef} &= 220\text{ V} \\ \eta &= 0,85 \end{aligned}$$

$$I_0 = ?$$

$$\begin{aligned} c_p &= 4200\text{ J/kgK} \\ \rho &= 1000\text{ kg/m}^3 \end{aligned}$$



$$\begin{aligned} U &= U_0 \cdot \cos(\omega t) \\ I &= I_0 \cdot \cos(\omega t + \delta) \end{aligned}$$

za upor je $\delta = 0$

$$\begin{aligned} Q &= m \cdot c_p \cdot \Delta T \\ \frac{Q}{t} &= \frac{m \cdot c_p \cdot \Delta T}{t} \end{aligned} \quad ; \quad \phi_m = P \cdot \phi_v$$

$$\eta \cdot \bar{P} = P \cdot \phi_v \cdot c_p \cdot \Delta T$$

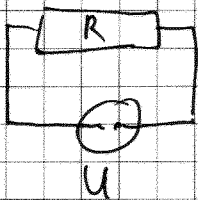
$$P = U \cdot I$$

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

$$\bar{P} = ?$$

NEKA INTEGRACIJA

$$\bar{P} = \frac{1}{2} U_0 \cdot I_0 \cdot \cos \delta = \frac{U_0}{\sqrt{2}} \cdot \frac{I_0}{\sqrt{2}} \cos \delta$$



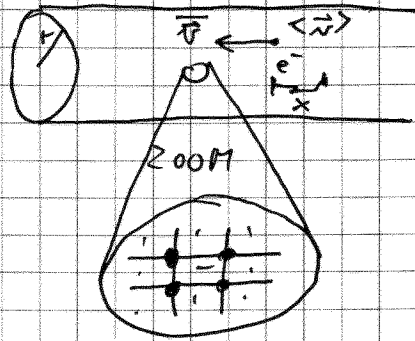
$$\begin{aligned} U &= R \cdot I \\ \delta &= 0 \Rightarrow \cos \delta = 1 \\ \bar{P} &= U_{ef} \cdot I_{ef} \end{aligned}$$

Pri uporu je fazni zamik (δ) enak 0.

$$\begin{aligned} \eta \cdot \bar{P} &= P \cdot \phi_v \cdot c_p \cdot \Delta T \\ \eta \cdot U_{ef} \cdot \frac{I_0}{\sqrt{2}} &= P \cdot \phi_v \cdot c_p \cdot \Delta T \end{aligned} \Rightarrow I_0 = \frac{\sqrt{2} \cdot P \cdot \phi_v \cdot c_p \cdot \Delta T}{U_{ef} \cdot \eta} = \underline{\underline{262\text{ A}}}$$

37. nal. / str. 32.

$N_{at} = N_e$
 $2r = 1 \text{ mm}$
 $I = 1 \text{ A}$
 $\rho = 9 \text{ g/cm}^3$
 $M = 64 \text{ kg/kmol}$



$x = \text{prepotovana razdalja}$
 $e = -e_0 = -1,6 \cdot 10^{-19} \text{ As}$
 $N_A = 6,02 \cdot 10^{26} \text{ kmol}^{-1}$

$\bar{v} = ?$

V kovinski mrezi pride povprečno na en atom en prevodniški elektron. Kakšna povp. hitrost elektr., ko po žici spustimo tok 1 A.

IZPCELJAVA
 $I = \frac{dq}{dt} = \frac{N_{e0} \cdot e}{t}$
 $I = \frac{N_{e0} \cdot e \cdot x}{s \cdot t \cdot x} = \frac{N_{e0} \cdot e \cdot \bar{v}}{s} = n \cdot e \cdot \bar{v}$

gostota nosilcev naboja $n = \frac{N_{e0}}{V}$

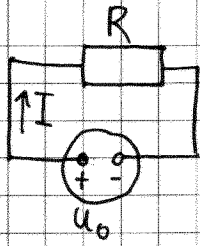
$I = \frac{I}{s} = n \cdot e \cdot \bar{v}$

$n = \frac{N_e}{V} = \frac{N_{at}}{V}$
 $n = \frac{N_e}{V} = \frac{m \cdot N_A}{V \cdot M}$
 $N_{at} = \frac{m}{m_1} = m \cdot \frac{N_A}{M}$
 $m_1 = \frac{M}{N_A}$

$\frac{I}{s} = \frac{\rho N_A}{M} \cdot e \cdot \bar{v}$

$\bar{v} = \frac{I \cdot M}{\pi \cdot r^2 \cdot \rho \cdot N_A \cdot (-e_0)} = -9,43 \cdot 10^{-5} \frac{\text{m}}{\text{s}} \approx -0,1 \frac{\text{mm}}{\text{s}}$

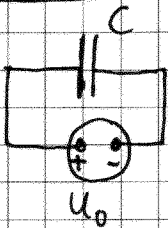
14.03.2008



$$U_0 = R \cdot I$$

$$U_0 + U_R = 0$$

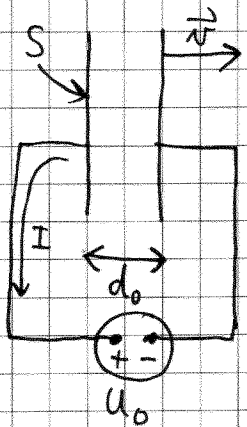
$$U_R = -R \cdot I$$



$$e = U_0 \cdot C$$

$$U_0 + U_C = 0$$

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



$$S = 150 \text{ cm}^2 \quad \vec{v} = 1 \frac{\text{m}}{\text{s}}$$

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

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

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

$$I(t_1) = ?$$

Razmakneno plošči, kak tok steče?

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

$$C = \epsilon_0 \frac{S}{d_0 + v \cdot t}$$

$$e = C \cdot U_0$$

$$I = \frac{de}{dt} = \frac{d(C \cdot U_0)}{dt} = U_0 \cdot \frac{dC}{dt}$$

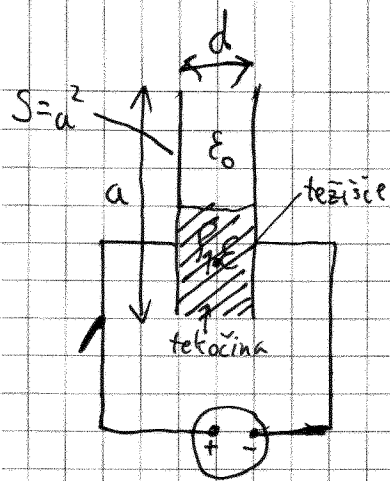
$$\frac{dC}{dt} = \epsilon_0 S \frac{0 - v}{(d_0 + v \cdot t)^2} = -\epsilon_0 S \frac{v}{(d_0 + v \cdot t)^2}$$

$$I = -\frac{U_0 \cdot \epsilon_0 \cdot S \cdot v}{(d_0 + v \cdot t)^2} = -0,4 \mu\text{A}$$

Energija kondenzatorja

$$W_e = \frac{1}{2} C U_c^2$$

13



Priključimo na napetost, nato vir odklopimo. Plošči stisnemo tako, da pride gladina tekočine do vrha. Koliko dela opravimo da plošči zbližamo?

- ① Nabijemo z U_1
- ② Izoliramo plošči $\rightarrow \varphi_1 = \varphi_2 \rightarrow U_2 = \frac{C_1 \cdot U_1}{C_2}$
- ③ Stisnemo plošči



$a = 10 \text{ cm}$
 $d = 3 \text{ mm}$
 $\rho_1 = 7 \text{ kg/dm}^3$
 $\epsilon = 80$
 $U = 800 \text{ V}$
 $A = ?$

$$A = \Delta W_p + \Delta W_e$$

$$A = m \cdot g \cdot \Delta h + \frac{1}{2} C_2 U_2^2 - \frac{1}{2} C_1 U_1^2 =$$

$$A = \rho_1 \cdot \frac{a^2 \cdot d}{2} \cdot g \cdot \frac{a}{4} + \frac{1}{2} \left(\frac{C_1^2 \cdot U_1^2}{C_2^2} - \frac{1}{2} C_1 U_1^2 \right) =$$

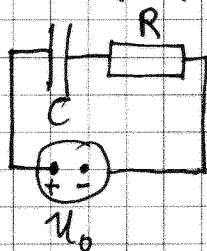
$$A = \frac{1}{8} \rho_1 a^3 \cdot d \cdot g + \frac{1}{2} C_1 U_1^2 \left(\frac{C_1}{C_2} - 1 \right)$$

$$C_2 = \epsilon \cdot \epsilon_0 \frac{a^2}{d/2} = \frac{2\epsilon\epsilon_0 a^2}{d}$$

$$C_1 = C_I + C_{II} = \epsilon_0 \frac{a^2}{2d} + \epsilon \cdot \epsilon_0 \frac{a^2}{2d} = \frac{(1+\epsilon)\epsilon_0 a^2}{2d}$$

$$A = 3,67 \cdot 10^{-3} \text{ J} - 2,86 \cdot 10^{-4} \text{ J} = \underline{\underline{3,38 \cdot 10^{-3} \text{ J}}}$$

Polnjenje kondenzatorja



$$U_0 + U_C + U_R = 0$$

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

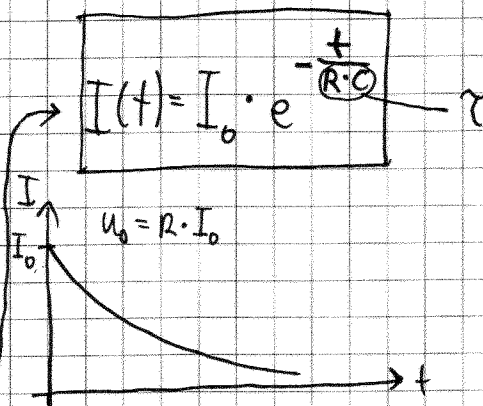
$$0 - \frac{1}{C} \left(\frac{de}{dt} \right) - R \frac{dI}{dt} = 0$$

$$-\frac{1}{C} \cdot I = R \cdot \frac{dI}{dt}$$

$$\frac{dI}{I} = -\frac{1}{R \cdot C} \cdot I$$

$$\int_{I_0}^I \frac{dI}{I} = -\frac{1}{R \cdot C} \int_0^t dt$$

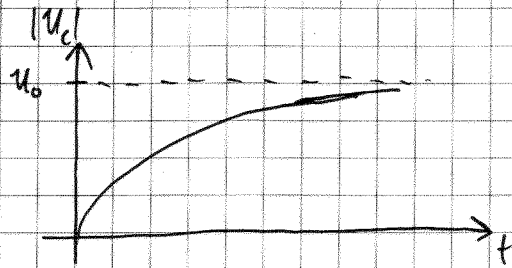
$$\ln \frac{I(t)}{I_0} = -\frac{1}{R \cdot C} \cdot t \quad / \exp$$



$$U_c = -U_0 - U_R = -U_0 + \frac{RI_0}{U_0} e^{-\frac{t}{RC}}$$

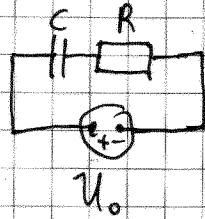
$$U_c = -U_0 (1 - e^{-\frac{t}{RC}})$$

$$|U_c| = U_0 (1 - e^{-\frac{t}{RC}})$$



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

$$R = 1000 \Omega$$



$$W_e = \frac{1}{2} C \cdot U_0^2$$

$$W_c = \frac{1}{2} C U_c^2$$

Čas, ko je energija na kond. 25% energije, ki jo lahko kondenzator prejme.

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

$$t_1 = ?$$

$$\frac{1}{2} C U_c^2 = \frac{1}{4} \cdot \frac{1}{2} C \cdot U_0^2 / \sqrt{\quad}$$

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

$$U_0 \cdot (1 - e^{-\frac{t}{\tau}}) = \frac{1}{2} U_0$$

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

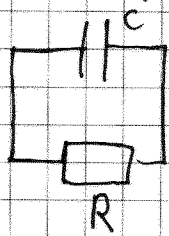
$$\ln \frac{1}{2} = -\frac{t}{\tau}$$

$$t_1 = -\tau \cdot \ln \frac{1}{2} = \boxed{R \cdot C \cdot \ln 2 = t_1}$$

$$t_1 = 1000 \frac{\text{V}}{\text{A}} \cdot 100 \cdot 10^{-6} \frac{\text{As}}{\text{V}} \cdot \ln 2 =$$

$$t_1 = 0,07 \text{ s}$$

Praznjenje kondenzatorja



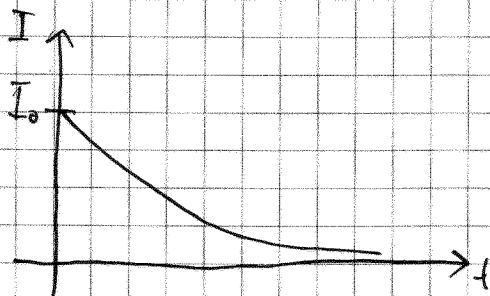
$$U_c + U_R = 0$$

$$-\frac{q}{c} - R \cdot I = 0 \quad / \frac{d}{dt}$$

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

$$-\frac{1}{c} I = R \frac{dI}{dt} \Rightarrow$$

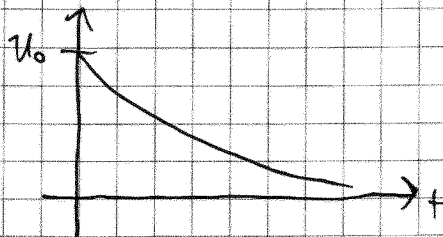
$$I(t) = I_0 e^{-\frac{t}{R \cdot c}}$$



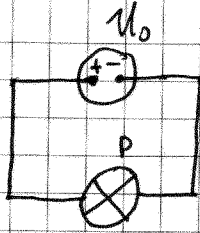
$$U_c = -U_R = +R \cdot I$$

$$U_c = R \cdot I_0 \cdot e^{-\frac{t}{R \cdot c}}$$

$$U_c = U_0 \cdot e^{-\frac{t}{R \cdot c}}$$



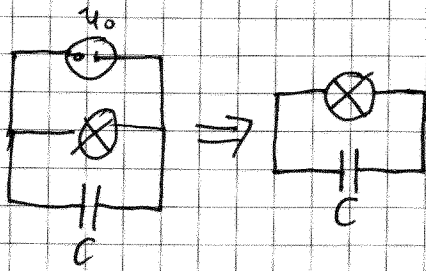
Žarnica
 $P = 100 \text{ W}$
 $U_0 = 110 \text{ V}$



$$P = U_0 \cdot I_0 = \frac{U_0^2}{R}$$

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

Kakšen kondenzator moramo priključiti, da bo žarnica svetila še 10 s, najmanjša napetost, da še svetli je 20 V.



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

$$t_2 = 10 \text{ s}$$

$C = ?$

$$U_c(t_2) = U_{\min}$$

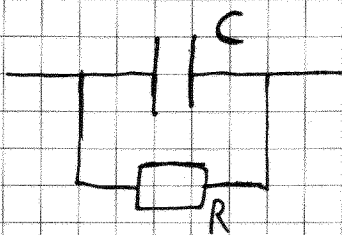
$$U_{\min} = U_0 e^{-\frac{t}{R \cdot C}}$$

$$\frac{U_{\min}}{U_0} = e^{-\frac{t}{R \cdot C}} / \ln$$

$$\ln \frac{U_{\min}}{U_0} = -\frac{t_2 P}{U_0^2 C}$$

$$C = \frac{t_2 P}{U_0^2 \cdot \ln \frac{U_{\min}}{U_0}}$$

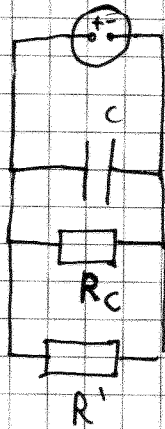
$$C = 0,05 \text{ F}$$



Realni kondenzator

$$\begin{aligned}
 C &= 25 \mu\text{F} \\
 U_0 &= 60 \text{ V} \\
 U &= 50 \text{ V} \\
 t_1 &= 10 \text{ ms} \\
 R' &= 500 \Omega
 \end{aligned}$$

$$U_c(t_1) = ?$$



Zaradi slabe izolacije pade napetost na kondenzatorju na 50 V v 10 ms.

Do katere napetosti se bo spraznil kond., če nanj priključimo R' v istem času.

$$U_c(t_1) = U_0 \cdot e^{-\frac{t_1}{R \cdot C}}$$

$$\frac{1}{R} = \frac{1}{R_c} + \frac{1}{R'}$$

$$R = 407,2 \Omega$$

$$\frac{U_c(t_1)}{U_0} = e^{-\frac{t_1}{R \cdot C}}$$

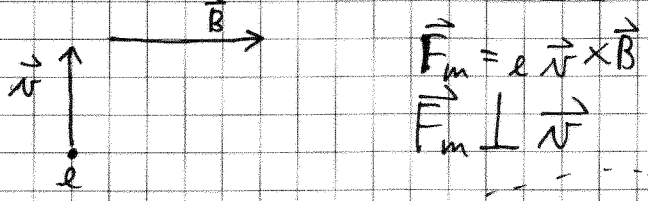
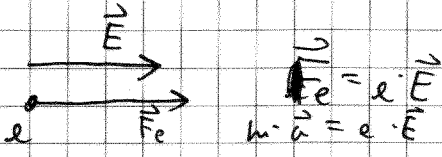
$$\ln \frac{U_c(t_1)}{U_0} = -\frac{t_1}{R \cdot C}$$

$$R = + \frac{t_1}{C \cdot \left(\ln \frac{U_0}{U_c(t_1)} \right)^{-1}} = 2200 \Omega$$

$$U_c(t_1) = U_0 \cdot e^{-\frac{t_1}{R \cdot C}} = 22,5 \text{ V}$$

~~$$\begin{aligned}
 \frac{U_c(t_1)}{U_0} &= e^{-\frac{t_1}{R \cdot C}} \\
 \ln \frac{U_c(t_1)}{U_0} &= -\frac{t_1}{R \cdot C}
 \end{aligned}$$~~

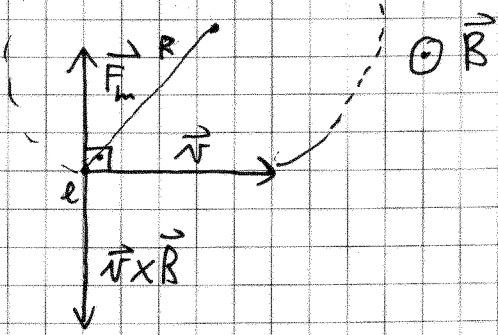
~~$$t_1 = \ln \frac{U_0}{U_c(t_1)} \cdot R \cdot C = 22,5$$~~



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

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

$m_e = 0,51 \frac{\text{MeV}}{c_0^2}$



$R = ?$
 $t_0 = ?$

$F_m = e_0 \cdot v \cdot B$
 $m \cdot a_r = e_0 \cdot v \cdot B$
 $m \cdot \frac{v^2}{R} = e_0 v \cdot B$
 $R = \frac{m \cdot v}{e_0 \cdot B}$

$|a_r| = \frac{v^2}{R} = \omega^2 R$

$W_k = \frac{1}{2} m_e v^2$

$v = \sqrt{\frac{2 W_k}{m_e}} = \sqrt{\frac{2 \cdot 10 \text{ eV} \cdot c_0^2}{0,511 \text{ MeV}}} = 0,0063 \cdot c_0$

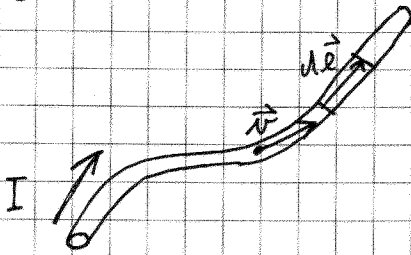
$v = 1,89 \cdot 10^6 \frac{\text{m}}{\text{s}}$

$R = \frac{m_e \cdot v}{e \cdot B} = \underline{\underline{11 \text{ cm}}}$

$t_0 = \frac{2\pi R}{v} = \frac{2\pi R}{v} = 3,6 \cdot 10^{-7} \text{ s}$

21.03.2008

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



$$I = \frac{dq}{dt} \Rightarrow q = \int I \cdot dt$$

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

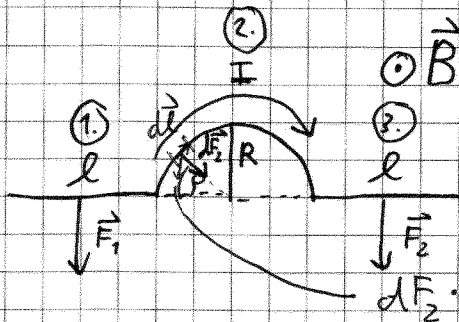
$$\boxed{\vec{F} = I \int d\vec{l} \times \vec{B}}$$

Imamo vodič.

l, R, I, B

$F = ? \quad d\vec{l} \perp \vec{B}$

$F_1 = F_3$



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

$$F_1 = F_2 = I \int dl B = I l B$$

$$F_2 = \int dF_2 \cdot \sin \varphi \quad d\varphi = \frac{dl}{R}$$

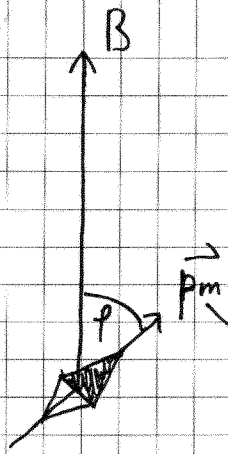
$$dF_2 = I \cdot dl \cdot B = I R d\varphi \cdot B$$

$$F_2 = I \cdot R \cdot B \int_0^\pi \sin \varphi d\varphi = I \cdot R \cdot B (-\cos \varphi) \Big|_0^\pi = I \cdot R \cdot B (-\cos \pi + \cos 0)$$

$$\boxed{F_2 = 2 \cdot I \cdot R \cdot B} \quad \text{kot če bi imeli raven vodič z dolžino } 2R.$$

$$F = F_1 + F_2 + F_3 = 2 \cdot I \cdot l \cdot B + 2 \cdot I \cdot R \cdot B$$

$$\underline{\underline{F = 2 \cdot I \cdot B (l + R)}}$$



Magnetni dipolni moment

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

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

Zemljsko mag. polje. U njenih vlakama magnetnica okoli horizontalne osi s frekvencijom 0,02 Hz. Kakva je gustoća mag. polja, čija vlakna s frekvencijom 0,8 Hz.

$$B_0 = 2 \cdot 10^{-4} \text{ T}$$

$$\nu_0 = 0,02 \text{ Hz}$$

$$\nu_1 = 0,8 \text{ Hz}$$

$$B_1 = ?$$

$$M = J \cdot \alpha$$

$$-p_m \cdot B \cdot \sin \varphi = J \cdot \ddot{\varphi}$$

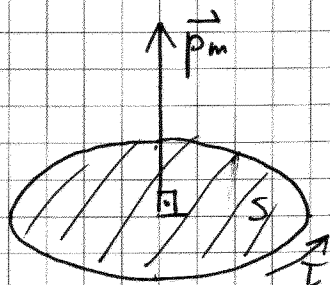
$$\ddot{\varphi} = - \frac{p_m \cdot B}{J} \cdot \varphi$$

ω^2

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

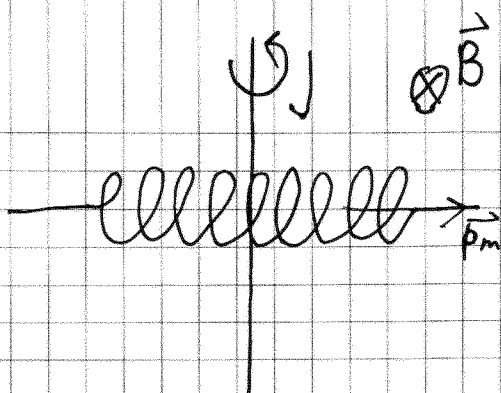
$$\frac{\nu_1^2}{\nu_0^2} = \frac{\frac{1}{4\pi^2} \frac{p_m B_1}{J}}{\frac{1}{4\pi^2} \frac{p_m B_0}{J}}$$

$$B_1 = B_0 \cdot \frac{\nu_1^2}{\nu_0^2} = 2 \cdot 10^{-4} \text{ T} \cdot \frac{64 \cdot 10^{-2} \text{ Hz}^2}{4 \cdot 10^{-4} \text{ Hz}^2} = 0,32 \text{ T}$$



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

taljava $\vec{p}_m = N \cdot I \cdot \vec{S}$



Tuljava s 40 ovojji, $S = 70 \text{ cm}^2$ se nahaja v homogenem mag. polju. Kakšen je kotni pospešek, ko skozi spustimo tok.

$$N = 40$$

$$S = 70 \text{ cm}^2$$

$$B = 0,8 \text{ T} \quad I = 0,2 \text{ A}$$

$$I = 0,0015 \text{ kg m}^2$$

$$\alpha = ?$$

$$f = 0: \vec{p}_m \perp \vec{B}$$

$$\sin \varphi = 1$$

$$\varphi = 90^\circ$$

$$M = J \cdot \alpha$$

$$p_m \cdot B = J \cdot \alpha$$

$$\alpha = \frac{p_m \cdot B}{J} = \frac{N \cdot I \cdot S \cdot B}{J} = 4,27 \text{ s}^{-2}$$

$$A = \int_{p_1}^{p_2} M \cdot dp = \int_{p_1}^{p_2} p_m \cdot B \cdot \sin \varphi \, dp = -p_m B \cos \varphi \Big|_{p_1}^{p_2}$$

$$A = \underbrace{-p_m \cdot B \cdot \cos \varphi_2}_{W_m(p_2)} - \underbrace{(-p_m \cdot B \cdot \cos \varphi_1)}_{W_m(p_1)}$$

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

$N = 100$
 $r = 5 \text{ cm}$
 $I = 0,1 \text{ A}$
 $B = 1,5 \text{ T}$
 $\varphi = 0$
 $\varphi_1 = 180^\circ$

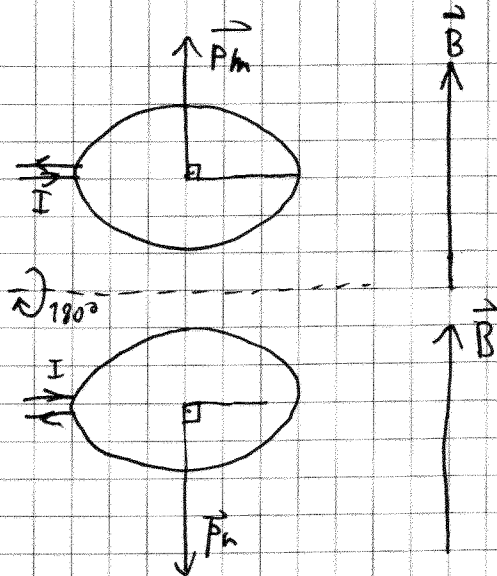
$A = ?$

$$A = \Delta W_m = W_m(\varphi_1) - W_m(\varphi_2)$$

$$A = -\mu_0 B \cos 180^\circ + \mu_0 B \cos 0^\circ$$

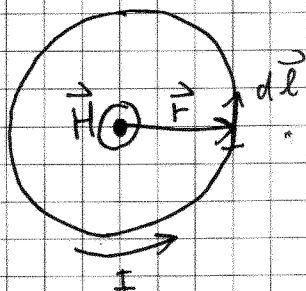
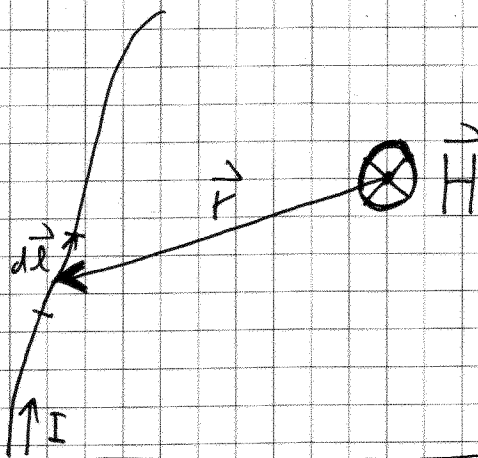
$$A = 2 \cdot \mu_0 \cdot B$$

$$A = 2 \cdot N \cdot I \cdot \pi r^2 \cdot B = 0,24 \text{ J}$$



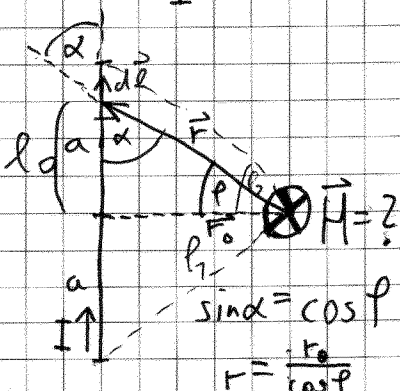
Biot-Savartov zakon

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



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

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



$$H = \frac{I}{4\pi} \int \frac{r \cdot dl \cdot \sin \alpha}{r^3} = \frac{I}{4\pi} \int \frac{r_0 \cdot \cos^2 \varphi \cdot \cos \varphi}{\frac{r_0^3}{\cos^3 \varphi}} d\varphi$$

$$H = \frac{I}{4\pi r_0} \int \cos \varphi \cdot d\varphi$$

$$H = \frac{I}{4\pi r_0} (\sin \varphi_2 - \sin \varphi_1)$$

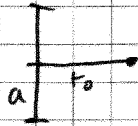
$$\sin \varphi_2 = \frac{a}{\sqrt{a^2 + r_0^2}}$$

$$\sin \varphi_1 = \frac{-a}{\sqrt{a^2 + r_0^2}}$$

$$l = r_0 \cdot \tan \varphi$$

$$dl = r_0 \frac{d\varphi}{\cos^2 \varphi}$$

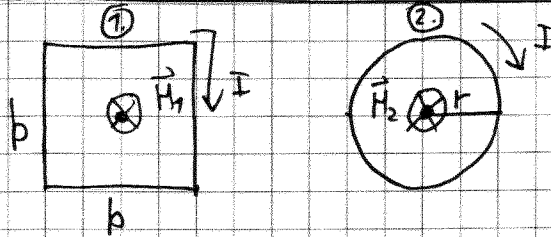
$$H = \frac{I}{2\pi r_0} \frac{a}{\sqrt{a^2 + r_0^2}}$$



$$l_1 = l_2 \Rightarrow 4 \cdot b = 2\pi r$$

$$N_1 = N_2$$

$$I_1 = I_2$$



Kakšno je razmerje mag. poljskih jakosti v središču zank?

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

$$H_2 = \frac{N \cdot I}{2r}$$

$$H_1 = 4 \cdot H_b = 4 \cdot \frac{NI}{2 \cdot \pi \cdot \frac{b}{2}} \cdot \frac{\frac{b}{2}}{\sqrt{(\frac{b}{2})^2 + (\frac{b}{2})^2}} = 2 \cdot \frac{N \cdot I}{\pi \sqrt{\frac{b^2}{4} + \frac{b^2}{4}}}$$

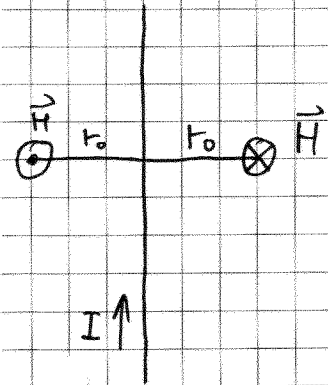
$$H_1 = \frac{2 \cdot N \cdot I \cdot \sqrt{2}}{\pi b}$$

$$\frac{H_1}{H_2} = \frac{2 \cdot N \cdot I \cdot \sqrt{2}}{\pi \cdot b} \cdot \frac{2 \cdot \pi \cdot \frac{2b}{\pi}}{N \cdot I} \quad r = \frac{2b}{\pi}$$

$$\frac{H_1}{H_2} = \frac{8\sqrt{2}}{\pi^2} = 1,15$$

Amperov zakon (zakon o mag. napetosti)

$$\oint \vec{H} \cdot d\vec{s} = I$$



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

$$\oint H ds = I$$

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

$$R = 7 \text{ cm}$$

$$I = 7000 \text{ A}$$

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

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

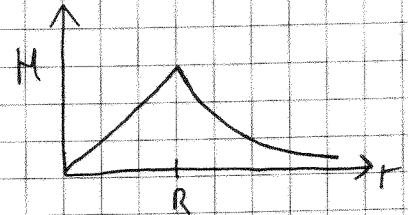
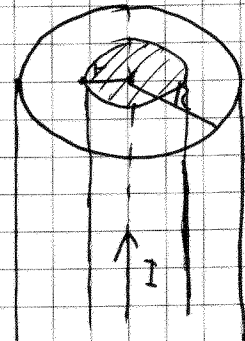
$$H(r) = ?$$

$$\oint \vec{H} \cdot d\vec{s} = \int_0^{2\pi} j \cdot r^2 \pi \vec{H} \parallel d\vec{s}$$

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

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

$$H = \frac{I \cdot r}{2\pi R^2} = 7958 \frac{\text{A}}{\text{m}}$$



Gaussov zakon (zakon o el. pretoku)

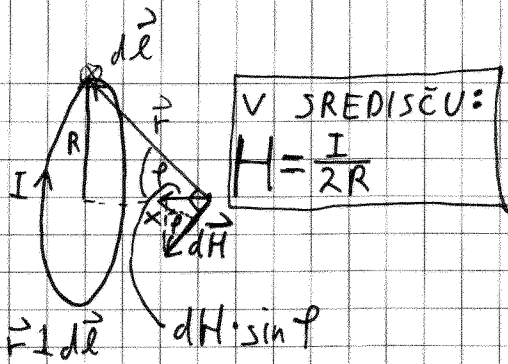
$$\oint \vec{D} \cdot d\vec{S} = q$$

Zakon o mag. pretoku.

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

$$\epsilon_0 = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$$

27.03.2008



$$\vec{H} = \frac{I}{4\pi} \int \frac{\vec{F} \times d\vec{l}}{r^3} \Rightarrow dH = \frac{I}{4\pi} \frac{r \cdot dl}{r^3}$$

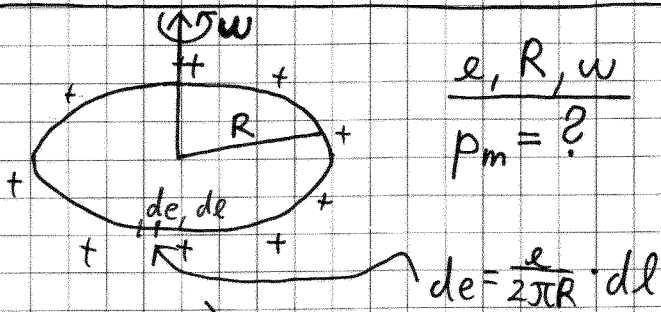
$$H = \int dH \cdot \sin \varphi$$

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

NA OSI

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

$$H = \frac{I R^2}{2 r^3} = \frac{I R^2}{2 \sqrt{R^2 + x^2}^3}$$



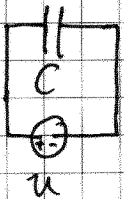
Obtoci vrtimo okoli osi.

$$de = \frac{e}{2\pi R} \cdot dl$$

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

$$p_m = \frac{de}{dt} \cdot S \Rightarrow p_m = \frac{e}{2\pi R} \left(\frac{d\varphi}{dt} \right) \cdot S = \frac{e}{2\pi R} \cdot \omega \cdot R \cdot \pi R^2$$

$$\Rightarrow p_m = \frac{e \cdot \omega \cdot R^2}{2}$$



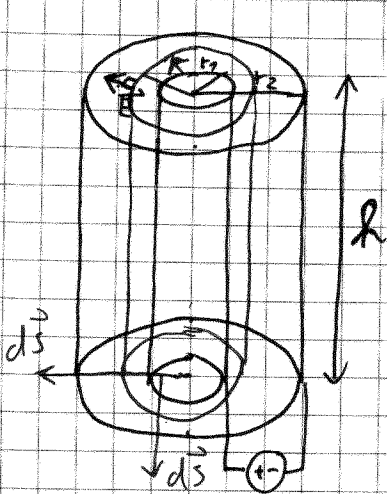
$$e = C \cdot U$$

$$U + U_c = 0$$

$$U_c = -\frac{e}{C}$$

$$C = -\frac{e}{U_c}$$

VALJAST KOND.



$$U_c = - \int_{r_1}^{r_2} \vec{E} \cdot d\vec{r}$$

$$\oint \vec{D} \cdot d\vec{S} = q$$

$$\epsilon \epsilon_0 \oint \vec{E} \cdot d\vec{S} = q$$

$$\epsilon \epsilon_0 E \cdot 2\pi R h = q$$

$$E = \frac{q/h}{2\pi \epsilon \epsilon_0 R}$$

$$U_c = - \int_{r_1}^{r_2} E \cdot dr$$

$$U_c = - \int_{r_1}^{r_2} \frac{q/h}{2\pi \epsilon \epsilon_0 R} dr = \frac{q/h}{2\pi \epsilon \epsilon_0} \ln \frac{r_2}{r_1} = U_c$$

$$C = \frac{2\pi \epsilon \epsilon_0 h}{\ln \frac{r_2}{r_1}}$$

KROGELNI KONDENZATOR

$$C = - \frac{q}{U_c} \quad E = \frac{q}{4\pi \epsilon \epsilon_0 r^2}$$

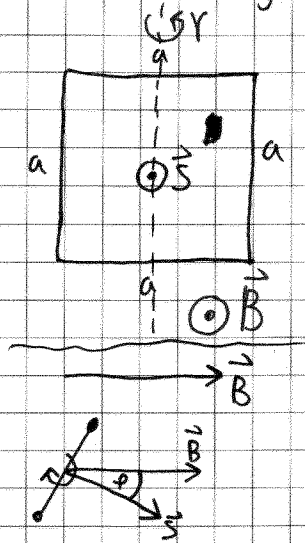
$$U_c = - \int_{r_1}^{r_2} E \cdot dr = - \frac{q}{4\pi \epsilon \epsilon_0} \int_{r_1}^{r_2} \frac{dr}{r^2} = \frac{q}{4\pi \epsilon \epsilon_0} \left(\frac{1}{r_1} - \frac{1}{r_2} \right) = U_c$$

$$C = \frac{4\pi \epsilon \epsilon_0}{\frac{1}{r_1} - \frac{1}{r_2}}$$

Indukcija

$$U_i = \frac{d\Phi_m}{dt} \quad \Phi_m = \int \vec{B} \cdot d\vec{S}$$

str. 52/86. naloga



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

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

$$S = 121 \text{ cm}^2$$

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

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

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

$$I_0 = ?$$

okvir vrtno okrog njegove simetrale.

Kolikšna je amplituda toka, ki teče po okvirju?

$$\varphi = \omega \cdot t \quad \Phi_m = \vec{B} \cdot \vec{S} = B \cdot S \cdot \cos \varphi = B \cdot S \cdot \cos(\omega \cdot t)$$

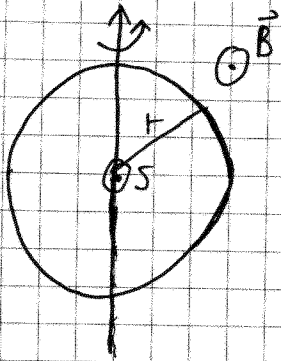
$$U_i = \frac{d\Phi_m}{dt} = -B \cdot S \cdot \omega \cdot \sin(\omega \cdot t) = U_i$$

$$I = \frac{U_i}{R} = \frac{B \cdot S \cdot \omega}{R} \sin(\omega \cdot t) = I$$

I_0

$$I_0 = \frac{B \cdot a^2 \cdot 2\pi V}{\rho \cdot \frac{4a}{S_0}} = \frac{B \cdot a \cdot \pi \cdot V \cdot S_0}{2\rho} = 115 \text{ A}$$

str. 52 / 87. nal.



$$\begin{aligned} \rho &= 0,1 \frac{\Omega \cdot \text{mm}^2}{\text{m}} \\ r &= 10 \text{ cm} \\ S_0 &= 1 \text{ mm}^2 \\ B &= 0,1 \text{ T} \\ \nu &= 10 \text{ Hz} \\ \langle M \rangle &= ? \end{aligned}$$

Kakšen navor je potreben, da se obrat zavrti z $\nu = 10 \text{ Hz}$

$$\begin{aligned} \vec{p}_m &= I \cdot \vec{S} \\ \vec{M} &= \vec{p}_m \times \vec{B} \end{aligned}$$

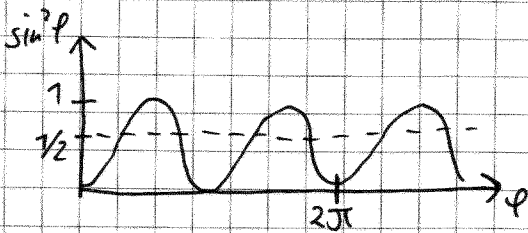
$$M = p_m B \cdot \sin \varphi$$

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

INDUKCIJA

$$I = - \frac{B \cdot S \cdot \omega}{R} \cdot \sin(\omega t)$$

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



$$\langle \sin^2 \varphi \rangle = \frac{1}{2\pi} \int_0^{2\pi} \sin^2 \varphi \cdot d\varphi = \frac{1}{2}$$

$$\langle M \rangle = - \frac{B^2 \cdot S^2 \cdot \omega}{R} \langle \sin^2 \varphi \rangle = - \frac{B^2 \cdot S^2 \cdot \omega}{2 \cdot \frac{2\pi \cdot \nu}{S_0}} = - \frac{B^2 \cdot \pi^2 \cdot r^3 \cdot \nu \cdot S_0}{2 \cdot \rho}$$

$$\langle M \rangle =$$

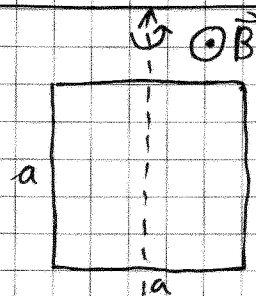
88. nal. / str. 53

Koliko dela opravimo za en obrat okvirja?

$$\begin{aligned} \rho &= 0,1 \frac{\Omega \cdot \text{mm}^2}{\text{m}} \\ S_0 &= 1 \text{ mm}^2 \\ a &= 10 \text{ cm} \\ B &= 0,1 \text{ T} \\ \nu &= 60 \text{ Hz} \end{aligned}$$

$$A = \int_0^{2\pi} M \cdot d\varphi = \int_0^{2\pi} \frac{B^2 \cdot S^2 \cdot \omega}{R} \cdot \sin^2 \varphi \cdot d\varphi =$$

$$A = \frac{B^2 \cdot S^2 \cdot \omega}{R} \cdot \int_0^{2\pi} \sin^2 \varphi \cdot d\varphi =$$



delo za en obrat, $\geq a$ večkrat N .

$$A = \frac{\pi \cdot B^2 \cdot S^2 \cdot \omega}{R}$$

2. način

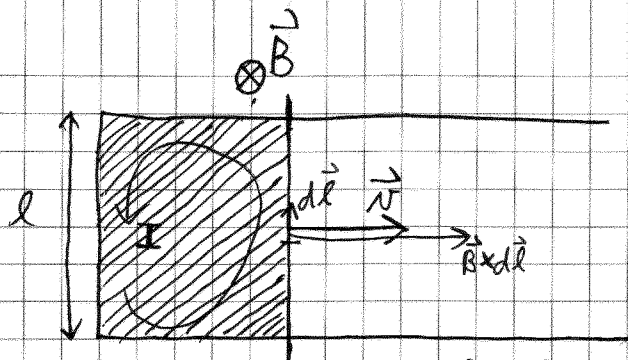
$$A = \int_0^{t_0} P \cdot dt = \int_0^{t_0} U \cdot I \cdot dt = \Delta N =$$

$$A = \frac{\pi \cdot B^2 \cdot a^4 \cdot \nu}{\rho \cdot \frac{4a}{S_0}} =$$

3. način

$$A = \langle M \rangle \cdot 2\pi$$

$$A = \frac{\pi^2 \cdot B^2 \cdot a^3 \cdot \nu \cdot S_0}{2 \cdot \rho} = 3 \cdot \pi \cdot 10^{-3} \text{ J} = 0,03 \text{ J}$$

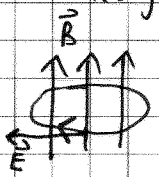


$$U_i = \int \vec{v} \cdot (\vec{B} \cdot d\vec{l})$$

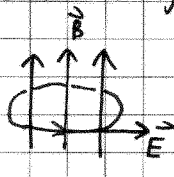
$$U_i = v \cdot B \cdot l \quad \begin{matrix} \vec{B} \perp d\vec{l} \\ (\vec{B} \times d\vec{l}) \parallel \vec{v} \end{matrix}$$

LENZOVO PRAVILO

Indukcija nasprotuje vzroku svojega nastanka.

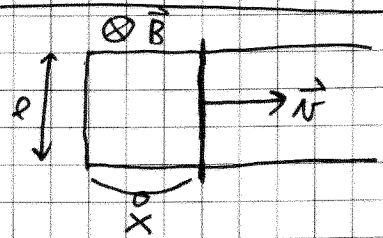
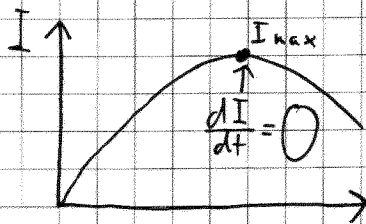


$$\frac{dB}{dt} > 0$$



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

- $l = 5 \text{ cm}$
- $B = 1 \text{ T}$
- $x(t=0) = 0$
- $v = \text{enakomerno pospejeno} = a \cdot t$
- $a = \text{konst.}$



$$x = ? \quad (I = \text{max})$$

$$I = \frac{U_i}{R}$$

$$U_i = a \cdot t \cdot B \cdot l$$

$$R = \rho \cdot \frac{2l + 2x}{S_0} \quad ; \quad x = \frac{a \cdot t^2}{2}$$

$$R = \rho \cdot \frac{2l + at^2}{S_0}$$

$$I = \frac{U_i}{R} = \frac{a \cdot B \cdot l \cdot S_0}{\rho} \cdot \frac{t}{2l + at^2}$$

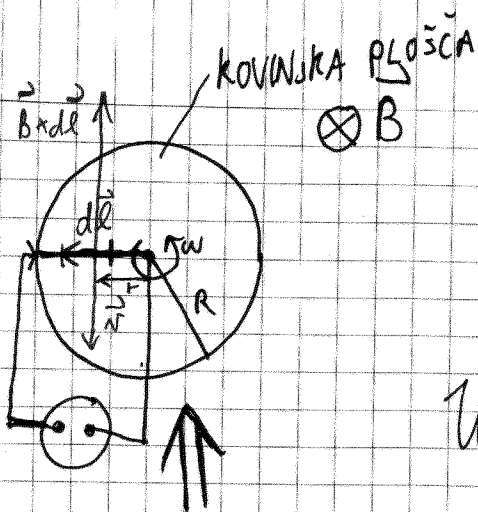
$$\frac{dI}{dt} = \frac{a \cdot B \cdot l \cdot S_0}{\rho} \cdot \frac{1 \cdot (2l + at^2) - t \cdot (0 + 2at)}{(2l + at^2)^2} = 0$$

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

$$2l = at^2$$

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

$$x = l = 5 \text{ cm}$$



$$R = 20 \text{ cm}$$

$$\omega = 200 \text{ s}^{-1}$$

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

$$U_i = ?$$

$$U_i = - \int v \cdot B \cdot dl$$

$$v = \omega \cdot r$$

$$U_i = - \int_0^R \omega \cdot r \cdot B \cdot dr$$

$$U_i = - \omega \cdot B \cdot \frac{R^2}{2} = -200 \text{ s}^{-1} \cdot 0,1 \text{ T} \cdot \frac{0,2^2 \text{ m}^2}{2} = \underline{\underline{-0,4 \text{ V}}}$$

93. naloga / str. 54

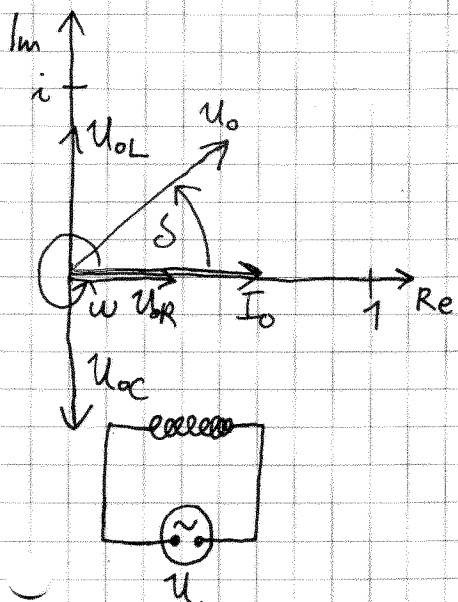
$$U_i = \frac{d\Phi_m}{dt} = 0 \quad \text{V TEM PRIMERU NE VELJA}$$

INDUKCIJSKI ZAKON

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

17.04.2008

KAZALČNI DIAGRAM



$$I = I_0 \cdot e^{i\omega t} \quad ; \quad e^{i\omega t} = \cos\omega t + i \sin\omega t$$

$$U = U_0 \cdot e^{i\omega t}$$

$$U_0 = Z \cdot I_0$$

↑
impedanca

$$\tan \delta = \frac{\text{Im} Z}{\text{Re} Z}$$

$$P = U \cdot I$$

$$\bar{P} = \frac{1}{2} |I_0| |U_0| \cos \delta = |U_{\text{eff}}| |I_{\text{eff}}| \cos \delta$$

če imamo samo upor je napetost v fazi s tokom.
 če imamo kondenzator napetost zaostaja za $\frac{1}{4}$ nihaja
 če imamo faljno napetost prehiteva za $\frac{1}{4}$ nihaja.

$$Z_R = R$$

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

$$Z_L = i\omega L$$

i je kompleksen, predstavlja fazi zamik

$$|Z| = \sqrt{(\text{Re} Z)^2 + (\text{Im} Z)^2}$$

FIZ II (UNI) 6.6.2006 3. naloga

$$R = 50 \Omega$$

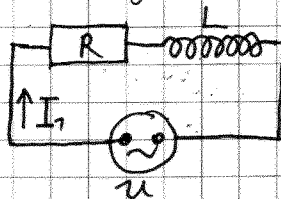
$$L = 1 \text{ mH}$$

$$\omega = 50\,000 \text{ s}^{-1}$$

$$I_{\text{eff}1} = 0,7071 \text{ A}$$

$$I_{\text{eff}2} = 0,8575 \text{ A}$$

$$C = ?$$

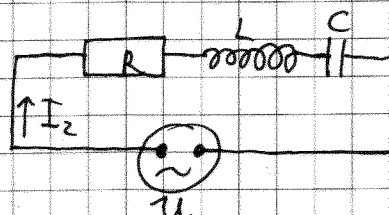


$$U_0 = Z_1 \cdot I_{01} = (Z_R + Z_L) \cdot I_{01}$$

$$U_0 = (R + i\omega L) \cdot I_{01} / \sqrt{2}$$

$$|U_0| = \sqrt{R^2 + \omega^2 L^2} \cdot I_{01} / \sqrt{2}$$

$$|U_{\text{eff}}| = \sqrt{R^2 + \omega^2 L^2} \cdot I_{\text{eff}1}$$



$$U_0 = Z_2 \cdot I_{02} = (Z_R + Z_L + Z_C) \cdot I_{02}$$

$$U_0 = (R + i\omega L - i\frac{1}{\omega C}) \cdot I_{02} / \sqrt{2}$$

$$|U_0| = \sqrt{R^2 + (\omega L - \frac{1}{\omega C})^2} \cdot I_{02} / \sqrt{2}$$

$$|U_{\text{eff}}| = \sqrt{R^2 + (\omega L - \frac{1}{\omega C})^2} \cdot I_{\text{eff}2}$$

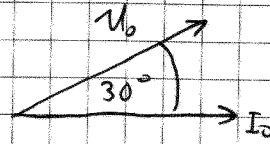
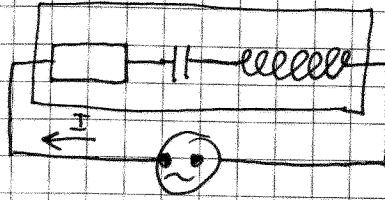
$$\frac{|U_{\text{eff}}| = |U_{\text{eff}}|}{\sqrt{R^2 + \omega^2 L^2} I_{\text{eff}1} = \sqrt{R^2 + (\omega L - \frac{1}{\omega C})^2} I_{\text{eff}2}}$$

$$C_{1/2} = \begin{cases} 1 \mu\text{F} \\ \frac{1}{4} \mu\text{F} \end{cases}$$

56. naloga / stran 42

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

$$|Z| = ?$$



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

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

$$|Z| = \frac{\bar{P}}{I_{ef}^2 \cos \delta} = \frac{3 \cdot 10^{-3} \text{ W} \cdot 2}{0,3 \text{ A}^2 \cdot \sqrt{3}} = 0,0385 \Omega$$

2. način

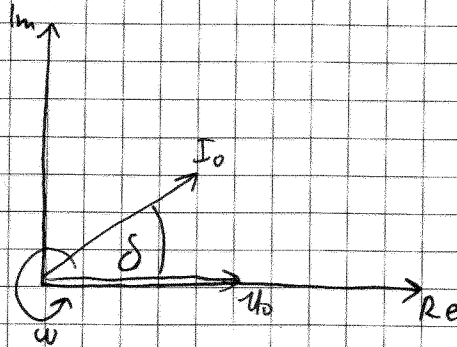
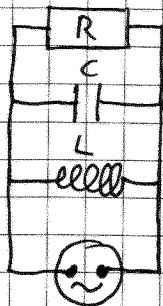
moč se uporablja samo za uporn $\delta = 0$.

$$\bar{P} = U_{Rof} \cdot I_{ef} = R \cdot I_{ef}^2 \Rightarrow R = \frac{\bar{P}}{I_{ef}^2} = \frac{1}{30} \Omega$$

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

$$\tan \delta = \frac{\text{Im } Z}{\text{Re } Z} = \frac{\omega L - \frac{1}{\omega C}}{R} \Rightarrow \omega L - \frac{1}{\omega C} = 0,07924 \Omega$$

$$\begin{aligned} u &= U_0 \cdot e^{i\omega t} \\ I &= I_0 \cdot e^{i\omega t} \\ U_0 &= Z \cdot I_0 \\ \frac{U_0}{Z} &= I_0 \\ \left| \frac{1}{Z} \right| \cdot U_0 &= |I_0| \end{aligned}$$



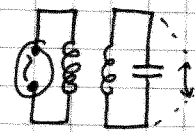
$$\frac{1}{Z} = \frac{1}{Z_R} + \frac{1}{Z_C} + \frac{1}{Z_L} = \frac{1}{R} + i\omega C + \frac{1}{i\omega L}$$

$$\frac{1}{Z} = \frac{1}{R} + i\left(\omega C - \frac{1}{\omega L}\right)$$

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

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

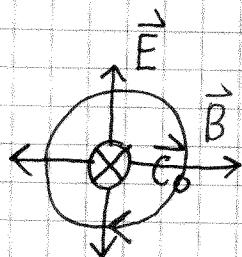
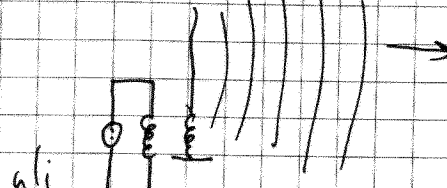
EM valovanje



⇒



→



$$c_0 = \frac{1}{\sqrt{\epsilon_0 \mu_0}} = 3,00 \cdot 10^8 \frac{m}{s}$$

$$c = \frac{1}{\sqrt{\epsilon \epsilon_0 \mu \mu_0}} \leq c_0$$

$$\vec{E} \perp \vec{B} \perp \vec{c}_0$$

$$\vec{E} = \vec{B} \times \vec{c}_0$$

$$E = B \cdot c_0$$

$$w_e = \frac{1}{2} \epsilon_0 E^2 \quad \left(\frac{W_e}{V} \right)$$

gostota el. ener.

$$w_m = \frac{1}{2} \frac{B^2}{\mu_0} = \frac{1}{2} \epsilon_0 E^2$$

gostota mag.

$$w = w_e + w_m = \epsilon_0 E^2 = \epsilon_0 E_0^2 \cos^2(\omega t + kx)$$

ENERGIJSKI TOK:

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

$$\bar{w} = \frac{1}{2} \epsilon_0 E_0^2$$

POV. GOSTOTA EN. TOKA:

$$\vec{j} = \frac{P}{S}$$

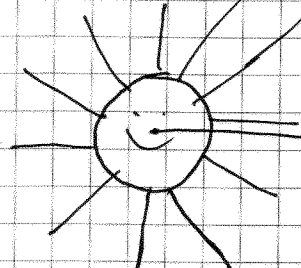
$$\vec{j} = \vec{w} \cdot \vec{c} = \frac{1}{2} \epsilon_0 c_0 E_0^2 = \frac{1}{2} E_0 H_0$$

POYNTINGOV VEKTOR
gostota en. toka

$$\vec{P} = \vec{E} \times \vec{H}$$

SONCE

SEVA IZOTROPNO



$$d = c_0 \cdot t = 3 \cdot 10^8 \frac{m}{s} \cdot 8 \text{ min} \cdot 60 \text{ s} = 1,5 \cdot 10^{11} \text{ m}$$

$$\vec{j} = 1360 \frac{W}{m^2}$$

$$P = ?$$

$$\vec{j} = \frac{P}{S} \Rightarrow P = \vec{j} \cdot S = \vec{j} \cdot 4\pi d^2 = 1360 \frac{W}{m^2} \cdot 4 \cdot \pi \cdot (1,5 \cdot 10^{11} \text{ m})^2$$

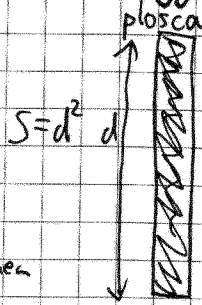
$$P \approx 4 \cdot 10^{22} \text{ W}$$

$$W = m \cdot c_0^2$$

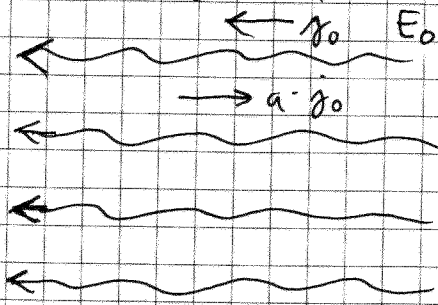
$$P = \frac{dW}{dt} = \frac{dm \cdot c_0^2}{dt} \Rightarrow \frac{dm}{dt} = \frac{P}{c_0^2} \approx 0,4 \cdot 10^{10} \frac{kg}{s} = 4000000 \frac{ton}{s}$$

52 naloga / stran 77

$d = 1 \text{ m}$
 $E_0 = 100 \frac{\text{V}}{\text{m}}$
 $a = 0,6$ (ODBOJNOST, ALBEDO)



VAKUUM



$P_{\text{izsevan}} = ?$ v stacionarni stanju

izsevan tok = absorpiranemu toku

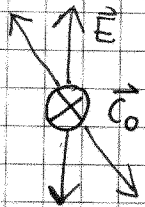
$$P_{\text{izs}} = P_{\text{abs}} = j_{\text{abs}} \cdot S = j_{\text{abs}} \cdot d^2$$

$$j_0 = \frac{1}{2} \epsilon_0 c_0 E_0^2$$

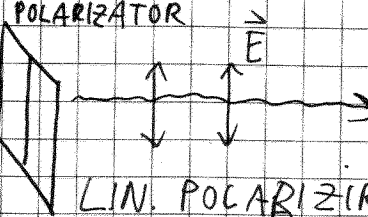
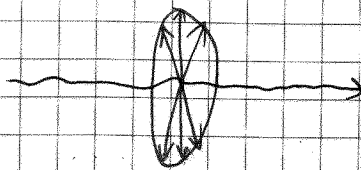
$$j_{\text{abs}} = j_0 - a j_0 = (1-a) j_0$$

$$P_{\text{abs}} = \frac{(1-a)}{2} \epsilon_0 c_0 E_0^2 \cdot d^2 = 5,3 \text{ W}$$

Polarizacija

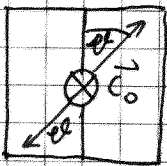


NEPOLARIZIRANO EM VAL



LIN. POLARIZIRANO EM VAL

$$j' = j \cdot \cos^2 \varphi = \frac{1}{2} j$$

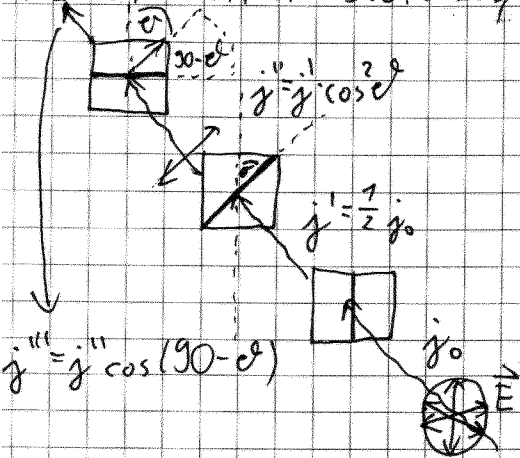


$$E' = E \cdot \cos \varphi$$

$$j' = \frac{1}{2} \epsilon_0 c_0 E'^2 = \frac{1}{2} \epsilon_0 c_0 E_0^2 \cos^2 \varphi$$

$$j' = j \cdot \cos^2 \varphi$$

NEPOLARIZIRANA SVETLOBA, TRIJE POLARIZATORJI



$\varphi = ?$, da bo največ svet. prišlo skozi

$$j'' = j' \cdot \cos^2(90 - \varphi) = j' \cdot \sin^2 \varphi$$

$$j''' = \frac{1}{2} j_0 \cos^2 \varphi \cdot \cos^2(90 - \varphi)$$

$$j''' = \frac{1}{2} j_0 \cos^2 \varphi \cdot \sin^2 \varphi$$

$$j''' = \frac{1}{2} j_0 \frac{1}{4} \sin^2(2\varphi) = \max$$

$$\sin(2\varphi) = 1$$

$$\sin(2\varphi) = 2 \sin \varphi \cos \varphi$$

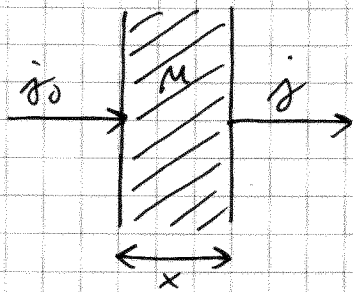
$$2\varphi = \pm 90^\circ + k\pi$$

$$\varphi = \pm \frac{\pi}{4} + k\frac{\pi}{2}$$

36

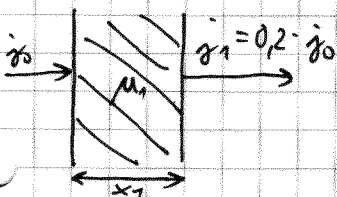
24.04.2008

Absorbicija



$$j = j_0 \cdot e^{-\mu \cdot x}$$

μ - absorpcijski koeficient



$$j_1 = 0.2 \cdot j_0$$

$$j_2 = 0.75 \cdot j_0$$

$$\mu_1 = \mu_2 = \mu$$

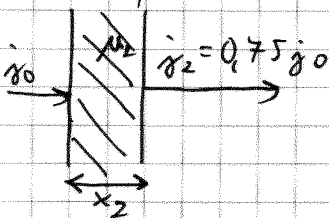
$$x_1 : x_2 = ?$$

$$j_1 = j_0 \cdot e^{-\mu_1 \cdot x_1}$$

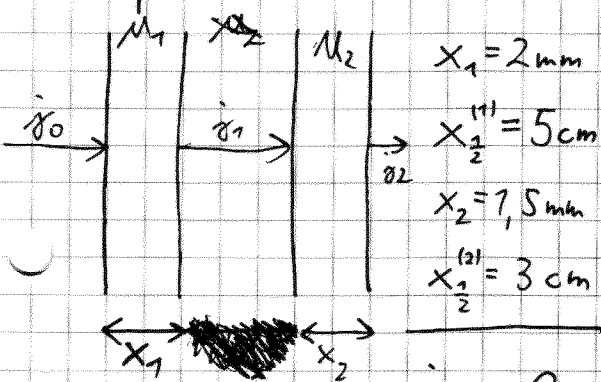
$$\frac{j_1}{j_0} = e^{-\mu_1 \cdot x_1}$$

$$-\ln \frac{j_1}{j_0} = \mu_1 \cdot x_1$$

$$\frac{x_1}{x_2} = \frac{\ln 0.2}{\ln 0.75} = 5.6$$



Šipa



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

$$x_2^{(1)} = 5 \text{ cm}$$

$$x_2 = 7.5 \text{ mm}$$

$$x_2^{(2)} = 3 \text{ cm}$$

$$j = j_0 \cdot e^{-\mu x}$$

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

$$e^{\mu x_{1/2}} = 2$$

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

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

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

$$j = j_0 \cdot 2^{-\frac{x}{x_{1/2}}}$$

$$j \cdot e^{\ln 2} = 2$$

$$j_2 = j_0 \cdot 2^{-\frac{x_1}{x_{1/2}}} \cdot 2^{-\frac{x_2^{(2)}}{x_{1/2}}}$$

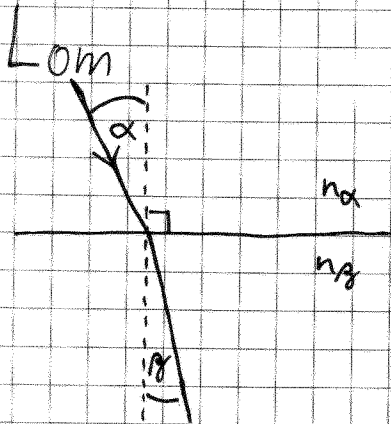
$$j_{\text{ABS}} = j_0 - j_2 \Rightarrow \frac{j_{\text{ABS}}}{j_0} = \frac{j_0 - j_2}{j_0} = 1 - 2^{-\frac{x_1}{x_{1/2}}} \cdot 2^{-\frac{x_2^{(2)}}{x_{1/2}}} = 0.06 = 6\%$$

Optika

1) $d \gg \lambda$: geometrijska optika

2) $d \approx \lambda$: valovna optika

VIDNA SVETLOBA
 $\lambda = 400 \text{ nm}$ $\lambda = 800 \text{ nm}$

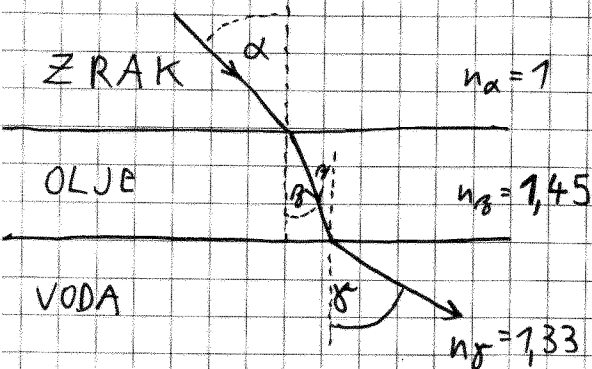


LOMNI KOLIČNIK

$$n = \frac{c_0}{c} = \frac{\sqrt{\epsilon_0 \epsilon_0}}{\sqrt{\epsilon_0 \mu_0}} = \sqrt{\epsilon_r \mu_r}$$

LOMNI ZAKON

$$\frac{\sin \alpha}{\sin \beta} = \frac{n_y}{n_x}$$



$$\alpha = 45^\circ$$

$$\gamma = ?$$

$$\frac{\sin \alpha}{\sin \beta} = \frac{n_y}{n_x}$$

$$\frac{\sin \beta}{\sin \gamma} = \frac{n_x}{n_y}$$

$$\sin \beta = \frac{\sin \alpha \cdot n_x}{n_y}$$

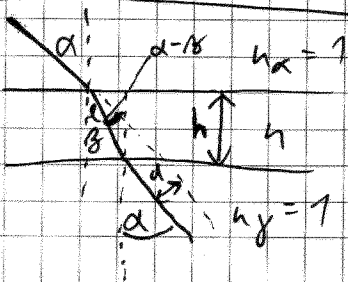
$$\sin \gamma = \frac{\sin \beta \cdot n_x}{n_y}$$

$$\sin \gamma = \frac{\sin \alpha \cdot n_x \cdot n_x}{n_y \cdot n_y}$$

$$\sin \gamma = \frac{\sin \alpha \cdot n_x}{n_y}$$

$$\gamma = 32^\circ$$

KOT DA OLJA NEBI BILO



$$d = l \cdot \sin(\alpha - \beta)$$

$$\cos \beta = \frac{h}{l}$$

$$l = \frac{h}{\cos \beta}$$

$$d = \frac{h}{\cos \beta} \cdot \sin(\alpha - \beta)$$

$$d = h \sin \alpha \left[1 - \frac{\cos \alpha}{\sqrt{n^2 - \sin^2 \alpha}} \right]$$

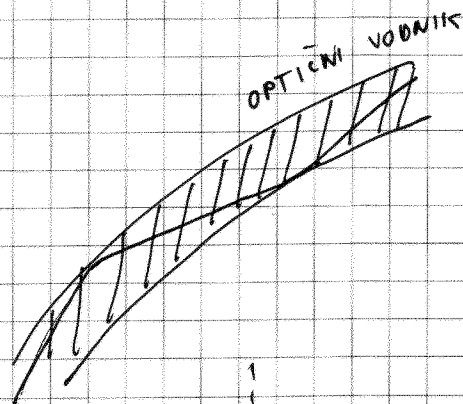
Totalni odboj (ko lomni zakon ni izpolnjen)

$$\sin \beta = \sin \alpha \left(\frac{n_\alpha}{n_\beta} \right) > 1$$

ko je $n_\alpha > n_\beta$

Mejni kot: $\sin \alpha_M \frac{n_\alpha}{n_\beta} = 1$

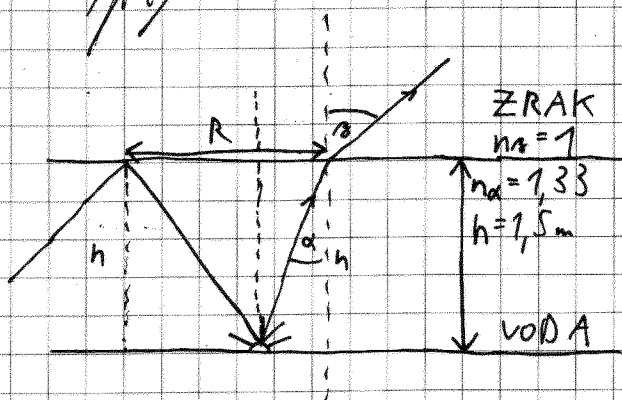
$$\sin \alpha_M = \frac{n_\beta}{n_\alpha}$$



4 nal. / str. 56

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

$$R = ?$$



$$\sin \alpha_M = \frac{n_\beta}{n_\alpha}$$

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

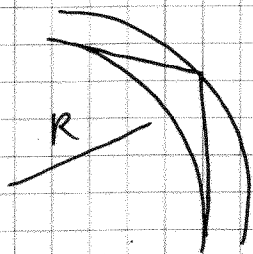
$$\tan \alpha_M = \frac{R}{h}$$

$$R = h \cdot \tan \alpha_M$$

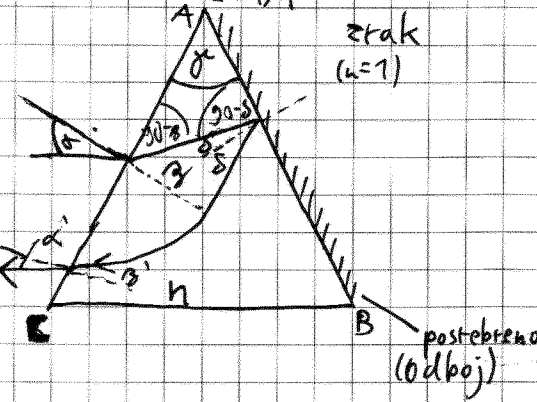
$$R = \underline{\underline{1,77 \text{ m}}}$$

UKRIVLJENOST:

$$C = \frac{1}{R}$$



PRIZMA

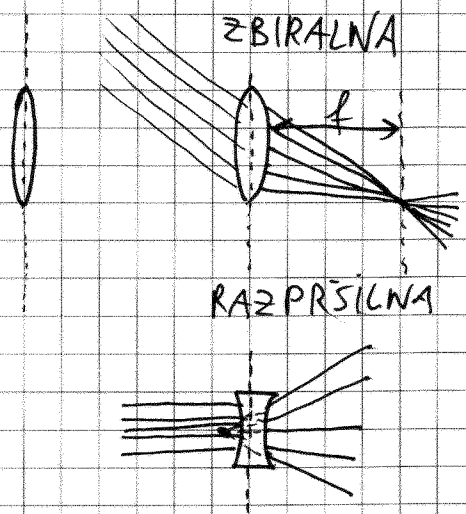


$$\begin{aligned} \gamma &= 30^\circ \\ \alpha &= 40^\circ \\ \hline \alpha' &= ? \end{aligned}$$

$$\gamma + (90^\circ - \delta) + (90^\circ - \delta) = 180^\circ$$

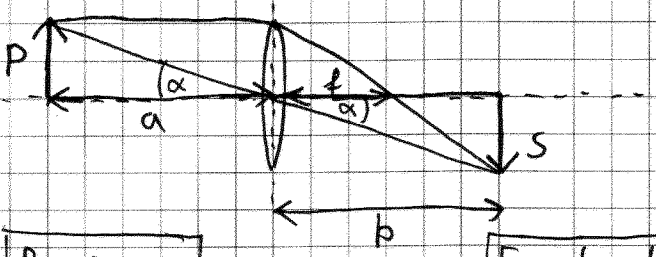
$$\alpha' = 66,78^\circ$$

Tanke leče



- BIKONVEKSNA
- KONKAVNA
- BIKONKAVNA
- KONVEKSNA

ZBIRALNA LEČA



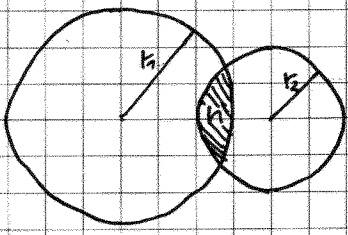
Povečava:

$$\frac{P}{a} = \frac{S}{b}$$

Enačba leče:

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

f - goriščna razdalja



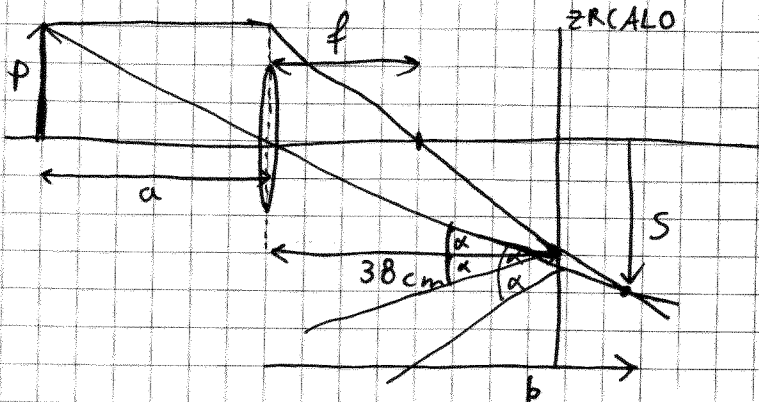
$$\frac{1}{f} = (n-1) \cdot \left(\frac{1}{r_1} + \frac{1}{r_2} \right)$$

16. nal. / str. 59

- $P = 1,5 \text{ cm}$
- $a = 30 \text{ cm}$
- $f = 20 \text{ cm}$
- $s = 38 \text{ cm}$

kako velika je slika predmeta?

$S = ?$



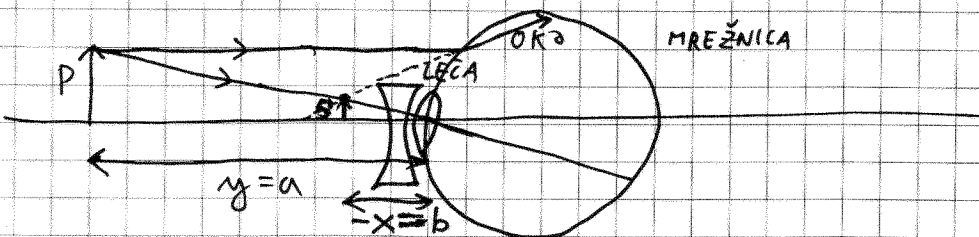
$$\frac{1}{a} + \frac{1}{b} = \frac{1}{f}$$

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

$$b = \left(\frac{1}{f} - \frac{1}{a} \right)^{-1}$$

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

$$S = P \cdot \frac{b}{a} = \underline{\underline{3 \text{ cm}}}$$



19. nal. / str. 60

KRATKOVIDNO OKO

- $x = 1 \text{ m}$ (DO TE MERE VIDIMO JASNO)
- $y = 5 \text{ m}$ (DO TE MERE VIDIMO JASNO Z OČALI)

$D = ?$ (DIOPTRIJA)

$D = \frac{1}{f}$

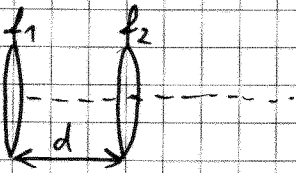
$$\frac{1}{f} = \frac{1}{a} + \frac{1}{b}$$

$$D = \frac{1}{f} = \frac{1}{y} + \frac{1}{-x} = \frac{1}{5 \text{ m}} - \frac{1}{1 \text{ m}} = 0,2 \text{ m}^{-1} - 1 \text{ m}^{-1} = \underline{\underline{-0,8 \text{ m}^{-1}}}$$

$$\underline{\underline{D = -0,8}}$$

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Več leč



$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$$

očala oko



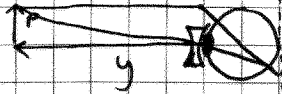
OKO:

$$\frac{1}{f_{\text{oko}}} = \frac{1}{x} + \frac{1}{b}$$



OČALA:

$$\frac{1}{f_{\text{oko}}} + \frac{1}{f_{\text{leča}}} = \frac{1}{y} + \frac{1}{b}$$



$$\frac{1}{f_{\text{leča}}} = \frac{1}{y} + \frac{1}{b} - \frac{1}{f_{\text{oko}}}$$

$$\frac{1}{f_{\text{leča}}} = \frac{1}{y} + \frac{1}{b} - \frac{1}{x} - \frac{1}{b}$$

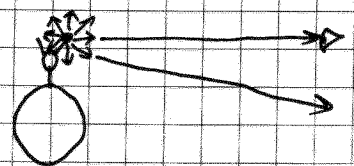
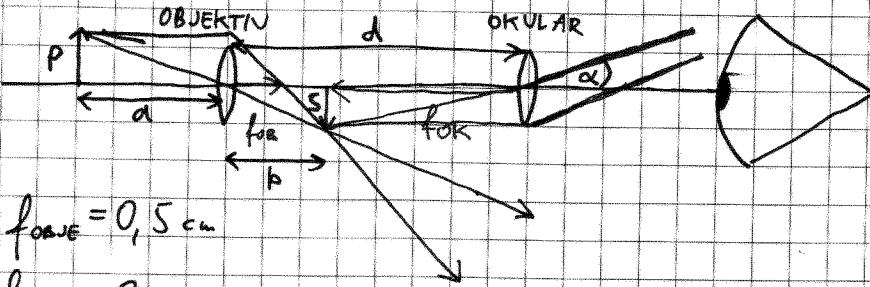
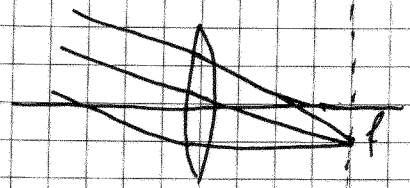
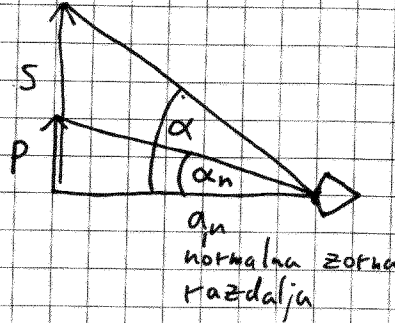
$$\frac{1}{f_{\text{leča}}} = \frac{1}{y} - \frac{1}{x} = -0,8/m$$

08.05.2008

Mikroskop

Povečava:

$$M = \frac{\text{tg } \alpha}{\text{tg } \alpha_n}$$



1 del) $f_{OBJE} = 0,5 \text{ cm}$

$f_{OKU} = 2 \text{ cm}$

$d = 22 \text{ cm}$

$a = ?$ (DA BO SLIKA NAVIDEZNO V NESKONČNOSTI)

$$\frac{1}{a} + \frac{1}{b} = \frac{1}{f_{OB}}$$

$$d = b + f_{OK} \Rightarrow b = d - f_{OK}$$

$b = 20 \text{ cm}$

$$\frac{1}{a} = \frac{1}{f_{OB}} - \frac{1}{b} = \frac{b - f_{OB}}{f_{OB} \cdot b}$$

$$a = \frac{f_{OB} \cdot b}{b - f_{OB}} = \frac{0,5 \text{ cm} \cdot 20 \text{ cm}}{19,5 \text{ cm}} = 0,51 \text{ cm}$$

2 del) $a_n = 25 \text{ cm}$

$M = ?$

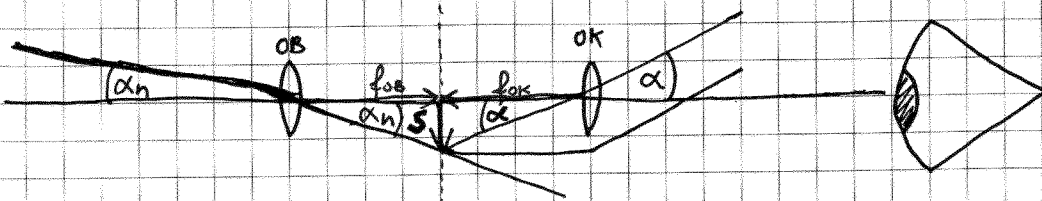
$$M = \frac{\frac{S}{f_{OK}}}{\frac{S}{P}} = \frac{S \cdot a_n}{P \cdot f_{OK}}$$

$$\frac{P}{a} = \frac{S}{b} \Rightarrow \frac{S}{P} = \frac{b}{a}$$

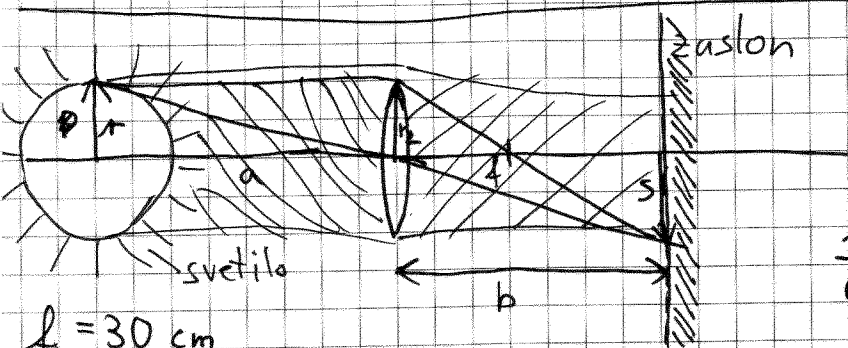
$$\frac{S}{P} = \frac{b}{a} = \frac{b}{f_{OB} \cdot \frac{b}{b - f_{OB}}} = \frac{b - f_{OB}}{f_{OB}} = \frac{d - f_{OK} - f_{OB}}{f_{OB}} = \frac{S}{P}$$

$$M = \frac{(d - f_{OK} - f_{OB}) \cdot a_n}{f_{OB} \cdot f_{OK}} = \frac{19,5 \text{ cm} \cdot 25 \text{ cm}}{0,5 \text{ cm} \cdot 2 \text{ cm}} \approx \underline{\underline{488}}$$

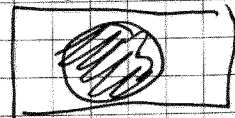
Daljnogled (astronomski)



$$M = \frac{\tan \alpha}{\tan \alpha_n} = \frac{\frac{S}{f_{ok}}}{\frac{S}{f_{ob}}} = \boxed{\frac{f_{ob}}{f_{ok}} = M}$$



ZASLON



$$\frac{1}{a} + \frac{1}{b} = \frac{1}{f} \quad \frac{r}{a} = \frac{s}{b} \Rightarrow S = r \cdot \frac{b}{a}$$

- $f = 30 \text{ cm}$
- $a = 1,5 \text{ m}$
- $r = 3 \text{ cm}$
- $P = 10 \text{ W}$
- $r_2 = 1 \text{ cm}$

$j_{NA} = ?$
 $j_{SLIKI} = ?$

$$j_{NA} = \frac{P_L}{\pi S^2} = \frac{j_L \cdot \pi \cdot r_2^2}{\pi S^2}$$

$$j_{NA} = \frac{P}{4\pi a^2} \cdot \frac{r_2^2}{S^2}$$

$$j_{NA} = \frac{P r_2^2 (a-f)^2}{4\pi a^2 r^2 f^2} = 0,63 \frac{\text{W}}{\text{m}^2}$$

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

$$S = r \cdot \frac{a \cdot f}{(a-f) \cdot a}$$

$$S = \frac{r \cdot f}{(a-f)}$$

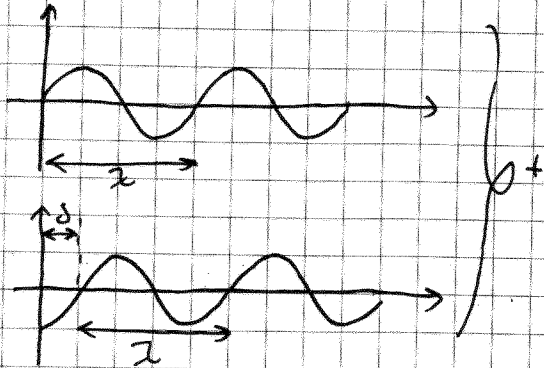
$$S = \frac{P \cdot f}{(a-f)}$$

r je radij P

15.05.2008

Valovna optika

INTERFERENCA



OJAČITEV:

$$\delta = N \cdot \lambda \quad N = 0, 1, 2, \dots$$

OSLABITEV:

$$\delta = N \frac{\lambda}{2} \quad N = 1, 3, 5, \dots \text{ liha št.}$$

$$\delta = (2N+1) \frac{\lambda}{2} \quad N = 0, 1, 2, \dots$$

NAL. 33 / STR 67

$$\lambda_0 = 500 \text{ nm}$$

$$n' = 1$$

$$n = 1,2$$

$$n'' = 1,5$$

OSLABITEV

$$\delta = (2N+1) \cdot \frac{\lambda}{2} \quad N = 0, 1, 2, \dots$$

$$2h = (2N+1) \cdot \frac{\lambda}{2} \quad N = 0, 1, 2$$

$f_v = ?$

fazlika poti

$$n = \frac{c_0}{v}$$

$$v = v_0$$

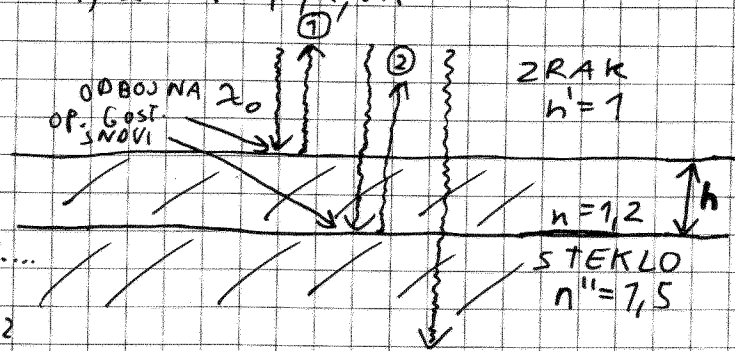
$$c = \lambda \cdot v$$

$$\lambda = \frac{c}{v} = \frac{c_0}{n v_0} = \frac{\lambda_0}{n} = \lambda$$

$$2h = (2N+1) \cdot \frac{\lambda_0}{n} \cdot \frac{1}{2} \quad N = 0, 1, 2$$

$$N = 0:$$

$$h = \frac{\lambda_0}{4n} = \frac{500 \text{ nm}}{4 \cdot 1,2} = 0,1 \mu\text{m}$$



ODBOJ NA:

Ⓐ optično gostejši snovi

$\vec{E} \uparrow \rightarrow \downarrow \vec{E}$ dodatni fazi zamik

$$S_{00} = \frac{\lambda}{2}$$

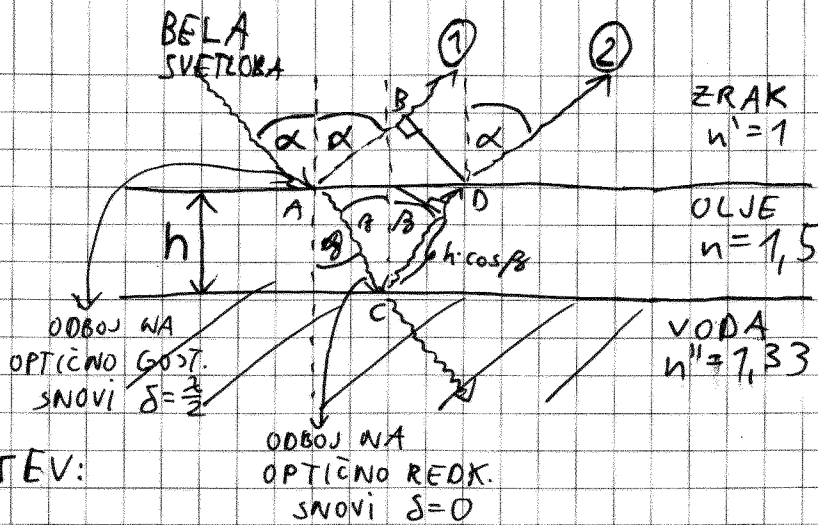
Ⓑ optično redkejši snovi

$\vec{E} \uparrow \rightarrow \uparrow \vec{E}$ $S_{00} = 0$

LOMNI KOLIČNIK:

$$n = \frac{c_0}{c} \quad n = 1 - \text{vakuum}$$

$$\overline{ACD} - \overline{AB} \approx 2h \cdot \cos \beta$$



$$h = 0,1 \mu\text{m}$$

$$\alpha = 30^\circ$$

$$n'' = 1,33$$

$$n = 1,5$$

$$n' = 1$$

$$\lambda_0 = ? \text{ (OJAČITEV)}$$

OJAČITEV:

$$\Delta = N \cdot \lambda \quad N = 0, 1, 2, \dots$$

$$2h \cos \beta + \frac{\lambda}{2} = N \cdot \lambda$$

razlika poti

$$2h \cos \beta = (N - \frac{1}{2}) \lambda_0$$

$$\frac{2h \cdot \sqrt{n^2 - \sin^2 \alpha}}{N - \frac{1}{2}} = \lambda_0 \quad ; \quad N = 0, 1, 2, \dots$$

$$\lambda = \frac{\lambda_0}{n}$$

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

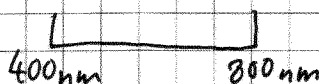
$$\Downarrow$$

$$h \cdot \cos \beta = \sqrt{n^2 - \sin^2 \alpha}$$

N=0: NI REŠITVE

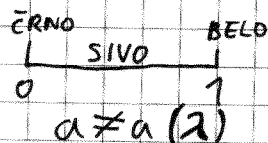
$$N=1: \lambda_0 = \frac{4h \cdot \sqrt{n^2 - \sin^2 \alpha}}{1} = 565 \text{ nm (rumena)}$$

$$N=2: \lambda_0 = \frac{565 \text{ nm}}{3} = \text{ni v vidnem delu spektra}$$



Sevanje črnega telesa

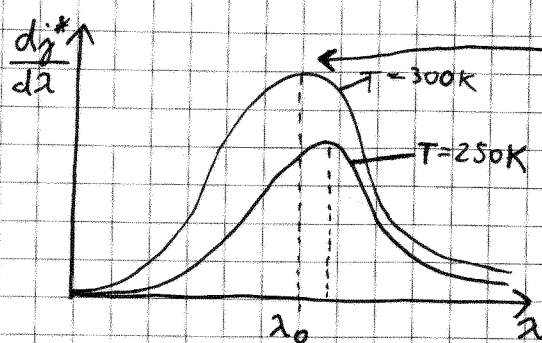
(sivega)
ODBOJNOST (a)



STEFANOV ZAKON:

$$j^* = (1-a) \sigma \cdot T^4$$

$$\sigma = 5,67 \cdot 10^{-8} \frac{\text{W}}{\text{m}^2 \text{K}^4} \text{ - STEFANOVA KONSTANTA}$$



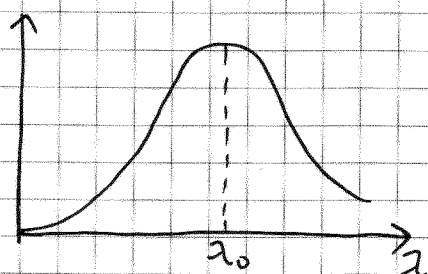
Planckov zakon
(58 nal. / str 49)

WIENOV ZAKON:

$$\lambda_0 \cdot T = k_w \quad k_w = 2,9 \cdot 10^{-3} \text{ mK}$$

$$j_{\text{SONCA NA ZEMLJI}} = 1360 \frac{\text{W}}{\text{m}^2} \text{ - gostota sv. toka sonca na zemlji}$$

TEMNI DELI VESOLJA



$$\begin{aligned} \lambda_0 &= 1 \text{ mm} \\ T &= ? \\ j &= ? \end{aligned}$$

$$\lambda_0 \cdot T = k_w$$

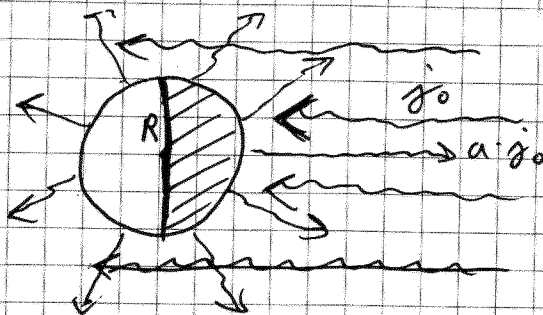
$$T = \frac{k_w}{\lambda_0} = \frac{2,9 \cdot 10^{-3} \text{ mK}}{1 \cdot 10^{-3} \text{ m}} = 2,9 \text{ K}$$

$$j^* = \sigma \cdot T^4 = 5,67 \cdot 10^{-8} \frac{\text{W}}{\text{m}^2 \text{K}^4} \cdot (2,9 \text{ K})^4 = 4,01 \cdot 10^{-6} \frac{\text{W}}{\text{m}^2}$$

$$a = 0,52$$

$$j_0 = 1360 \frac{\text{W}}{\text{m}^2}$$

$T = ?$ (RAVNOVESNO STANJE)



$$P_{\text{ABS}} = P_{\text{IZS}}^*$$

$$(1-a) \cdot j_0 \cdot 4\pi R^2 = (1-a) \cdot \sigma \cdot T^4 \cdot 4\pi R^2$$

$$T = \sqrt[4]{\frac{j_0}{\sigma}}$$

$$T = 278 \text{ K}$$

54 nal./str 79

$$r = 4 \text{ mm}$$

$$P = 0,076 \frac{\text{W}}{\text{m}}$$

$$I = 160 \text{ A}$$

$T = ?$ (RAVNOVESNO STANJE)

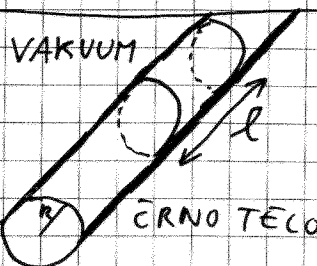
$$P_R = P^*$$

$$I^2 R = (1-a) \cdot j_0^* \cdot 2\pi r \cdot l$$

$$I^2 \cdot P \cdot \frac{l}{\pi r^2} = (1-0) \sigma \cdot T^4 \cdot 2\pi r \cdot l$$

$$T = \sqrt[4]{\frac{I^2 \cdot P}{2\pi^2 r^3 \sigma}}$$

$$T = 275 \text{ K}$$

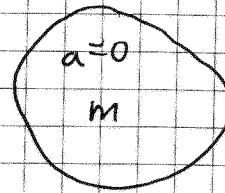


59. nal / str. 81

ČRNO TELO

VAKUUM

$$\begin{aligned}
 m &= 60 \text{ g} \\
 a &= 0 \\
 c_v &= 200 \frac{\text{J}}{\text{kgK}} \\
 T_1 &= 2500 \text{ K} \\
 S &= 10 \text{ cm}^2 \\
 T_2 &= 1422 \text{ K} \\
 t &=?
 \end{aligned}$$



$$\begin{aligned}
 P^* &= - \frac{dW_n}{dt} \\
 \delta \cdot S &= - \frac{m \cdot c_v \cdot dT}{dt} \\
 \delta \cdot S \cdot \frac{dT}{T^4} &= - \frac{m \cdot c_v}{T^4} dt \\
 \int_{T_2}^{T_1} \frac{dT}{T^4} &= - \int_0^t \frac{\delta \cdot S}{m \cdot c_v} dt \\
 \frac{T^{-3}}{-3} \Big|_{T_2}^{T_1} &= - \frac{\delta \cdot S}{m \cdot c_v} t
 \end{aligned}$$

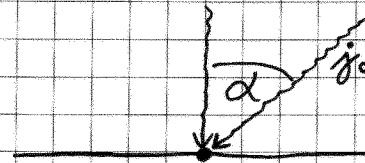
$$t = \frac{m \cdot c_v}{3\delta S} \left(\frac{1}{T_2^3} - \frac{1}{T_1^3} \right)$$

$$\underline{t = 20 \text{ s}}$$

Fotometrija

OSVETLJENOST (j'):

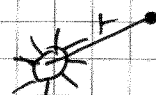
$$j' = j_0 \cdot \cos \alpha$$



SVETILNOST (I):

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

Izotropno svetilo:

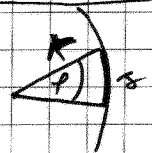


$$\begin{aligned}
 I &= \frac{P^*}{4\pi} = \left[\frac{\text{W}}{\text{sterad}} \right] \\
 j &= \frac{P^*}{4\pi r^2} = \frac{I}{r^2}
 \end{aligned}$$

KOT

$$p = \frac{A}{r^2} \text{ [rad]}$$

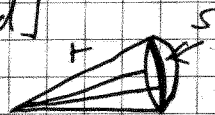
$$p_0 = \frac{2\pi r}{r} = 2\pi$$



PROSTORSKI KOT

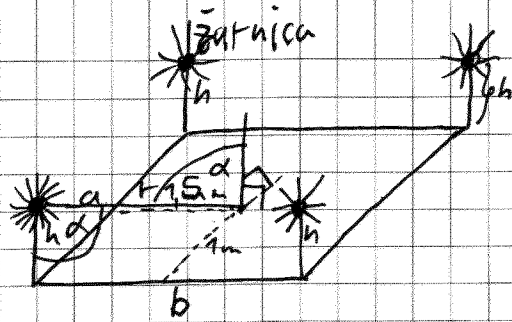
$$\Omega = \frac{S}{r^2} \text{ Esterad}$$

$$\Omega = \frac{4\pi r^2}{r^2} = 4\pi$$



49

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



$j' = ?$ (na sredini)

~~$$j' = 4 \cdot j_0 \cdot \cos \alpha$$~~

$$j' = 4 \cdot \frac{P}{\pi r^2} \cdot \frac{h}{r} \quad i \quad \cos \alpha = \frac{h}{r}$$

$$r^2 = h^2 + \left(\frac{a}{2}\right)^2 + \left(\frac{b}{2}\right)^2$$

$$j' = \frac{P \cdot h}{\pi r^3}$$

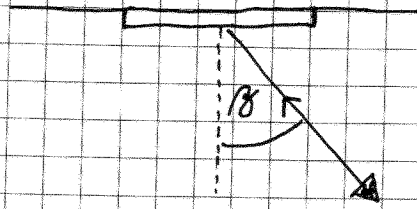
$$j' = \frac{P \cdot h}{\pi \left(h^2 + \frac{a^2}{4} + \frac{b^2}{4}\right)^{3/2}}$$

$$j' = 2,78 \frac{\text{W}}{\text{m}^2}$$

22.05.2008

SVETLOST:

$$B_{\perp} = \frac{I}{S}$$



$$I(\beta) = B \cdot S \cdot \cos \beta$$

LAMBERTOV ZAKON:

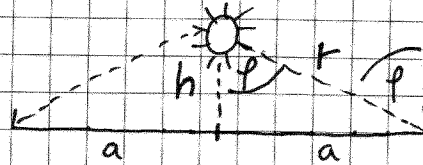
$$B \neq B(\beta)$$

48. nal. / str. 75

$$2a = 15 \text{ m}$$

$$h = ? \left(\begin{array}{l} \text{OSVETLEJENOST} \\ \text{NA ROBU} \\ \text{MAKSIMALNA} \end{array} \right)$$

$$h \left(j_{\text{robu}}^{\text{na}} = \max \right)$$



$$j_{\text{robu}}^{\text{na}} = j \cdot \cos \varphi = \frac{I}{r^2} \cdot \frac{h}{r}, \cos \varphi = \frac{h}{r}, r = \sqrt{a^2 + h^2}$$

$$= \frac{I \cdot h}{(a^2 + h^2)^{\frac{3}{2}}}$$

$$\frac{dj_{\text{robu}}^{\text{na}}}{dh} = \frac{I \cdot (a^2 + h^2)^{-\frac{3}{2}} - h \cdot \frac{3}{2} (a^2 + h^2)^{-\frac{5}{2}} \cdot 2h}{(a^2 + h^2)^3} = 0$$

$$(a^2 + h^2)^{\frac{3}{2}} \cdot ((a^2 + h^2)^{-1} - 3h^2) = 0$$

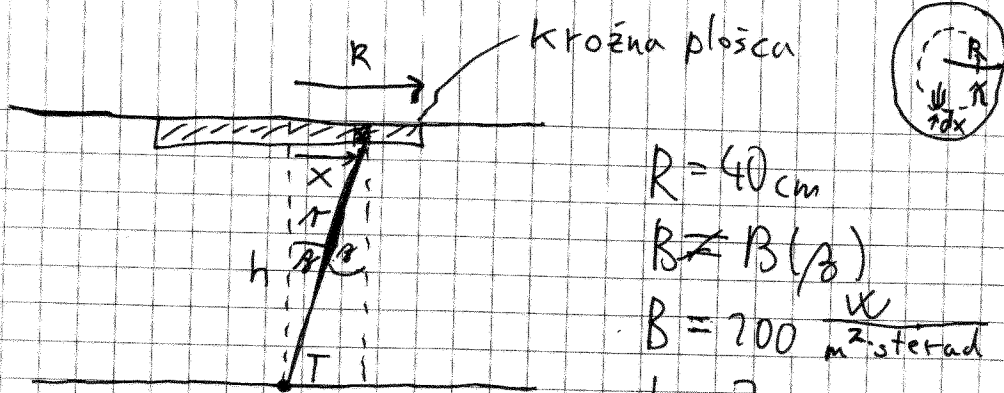
$$a^2 + h^2 - 3h^2 = 0$$

$$a^2 - 2h^2 = 0$$

$$h = \frac{a}{\sqrt{2}} = 5,3 \text{ m}$$

$$\tan \varphi = \frac{a}{h} = \sqrt{2}$$

$$\varphi = \arctan(\sqrt{2}) = 55^\circ$$



$$R = 40 \text{ cm}$$

$$B \neq B(\beta)$$

$$B = 200 \frac{\text{W}}{\text{m}^2 \cdot \text{sterad}}$$

$$h = 2 \text{ m}$$

$$j'(T) = ?$$

$$dj' = \frac{dI}{r^2} \cdot \cos \beta \quad ; \quad dI = B \cdot dS \cdot \cos \beta \quad ; \quad \cos \beta = \frac{h}{r} \quad ; \quad r^2 = h^2 + x^2$$

$$dj' = \frac{B \cdot 2\pi x dx \cdot \cos^2 \beta}{r^2} = \frac{B \cdot 2\pi x dx}{r^4} h^2$$

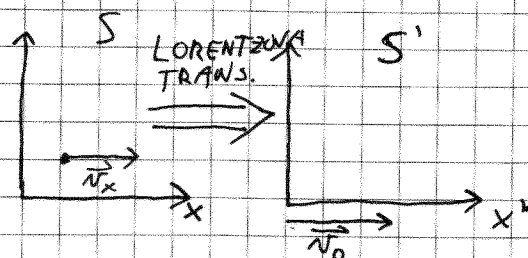
$$j' = \int dj' = 2\pi B h^2 \int_0^R \frac{x dx}{(h^2 + x^2)^2} = \boxed{2\pi B h^2 \left(\frac{1}{h^2} - \frac{1}{h^2 + R^2} \right)}$$

$$j' = 12,08 \frac{\text{W}}{\text{m}^2}$$

Posebna teorija relativnosti

- NI GRAVITACIJE
- NEPOSPEŠENI (INERCIALNI) OP. SIST.

$$\text{MAXWELL} \Rightarrow c_0 = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$$



DOGODEK:

$$\begin{bmatrix} ct \\ x \\ y \\ z \end{bmatrix}$$

SVETOVNI
ČETVEREC

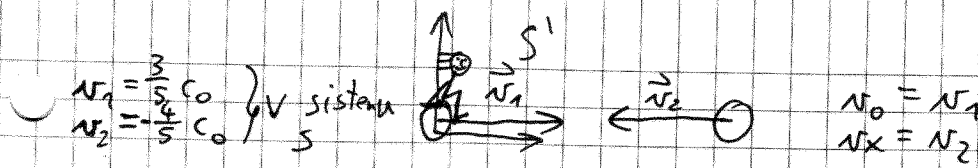
$$\begin{aligned} y' &= y & x' &= \gamma(x - v_0 t) & ; & \gamma = \frac{1}{\sqrt{1 - \frac{v_0^2}{c_0^2}}} \\ z' &= z & t' &= \gamma\left(t - \frac{v_0}{c_0^2} x\right) \end{aligned}$$

$$v_x = \frac{dx}{dt}$$

$$v_x' = \frac{dx'}{dt'}$$

$$dx' = \gamma(dx - v_0 dt) \quad ; \quad dt' = \gamma\left(dt - \frac{v_0}{c_0^2} dx\right)$$

$$v_x' = \frac{v_x - v_0}{1 - \frac{v_0 v_x}{c_0^2}} \quad \text{transformacija hitrosti}$$



$v_2 = ?$ (v sistemu
 1. delcu S')

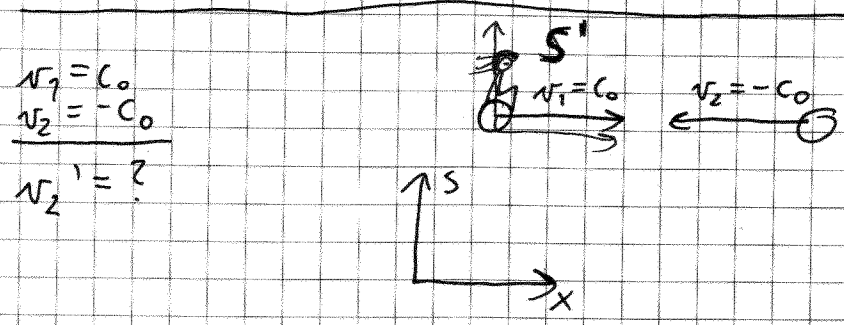
KLASIČNO:

$$v_2' = v_2 - v_1 = -\frac{4}{5}c_0 - \frac{3}{5}c_0 = -\frac{7}{5}c_0 //$$

RELATIVISTIČNO:

$$v_2' = \frac{v_2 - v_1}{1 - \frac{v_1 v_2}{c_0^2}} = \frac{-\frac{4}{5}c_0 - \frac{3}{5}c_0}{1 - \frac{(-\frac{4}{5}c_0)(\frac{3}{5}c_0)}{c_0^2}} = \frac{-\frac{7}{5}c_0}{1 + \frac{12}{25}}$$

$$v_2' = -\frac{7}{5} \cdot \frac{25}{37} c_0 = -\frac{35}{37} c_0$$



KLASIČNO:

$$v_2' = v_2 - v_1 = -c_0 - c_0 = -2c_0 //$$

RELATIVISTIČNO:

$$v_2' = \frac{-c_0 - c_0}{1 - \frac{c_0(-c_0)}{c_0^2}} = \frac{-2c_0}{1 + 1} = -c_0 \checkmark$$

4. nal. 22.06.2004.

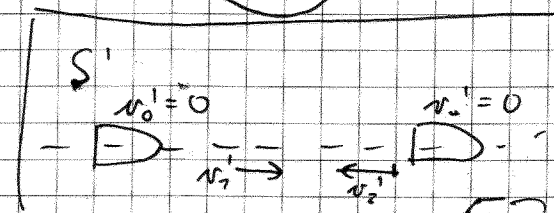
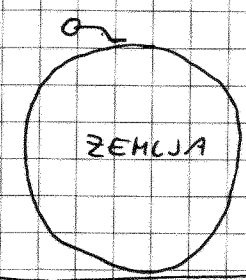
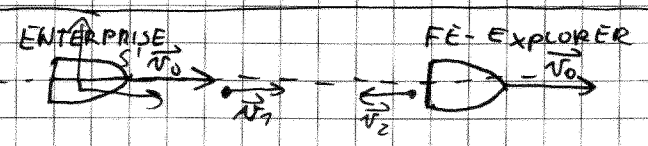
$v_0 = 0,85c_0$ (v sist. ZEMLJE S)
 $v_1 = 0,85c_0$
 $v_2 = 0,85c_0$ (v sist. LADU S')

$$v_x = \frac{v_x' + v_0}{1 + \frac{v_0 v_x'}{c_0^2}}$$

$$v_1 = \frac{v_1' + v_0}{1 + \frac{v_0 v_1'}{c_0^2}} = 0,987c_0$$

$$v_2 = \frac{v_2' + v_0}{1 + \frac{v_0 v_2'}{c_0^2}} = 0$$

$v_1 = ?$
 $v_2 = ?$ (v sist. ZEMLJE)



	S	S'
1. DOGODEK	$t_1=0 \quad x_1=0$	$t_1' = \gamma(t_1 - \frac{v_0}{c^2}x_1) = 0 \quad x_1' = \gamma(x_1 - v_0 t_1) = 0$
2. DOGODEK	$t_2 = \tau \quad x_2 = 0$	$t_2' = \gamma(t_2 - \frac{v_0}{c^2}x_2) = \gamma t_2 \quad x_2' = -\gamma v_0 t_2$
	$\Delta t = t_2 - t_1 = \tau$	$\Delta t' = t_2' - t_1' = \gamma t_2 = \gamma \cdot \tau$
		$\Delta t' = \gamma \cdot \Delta t$

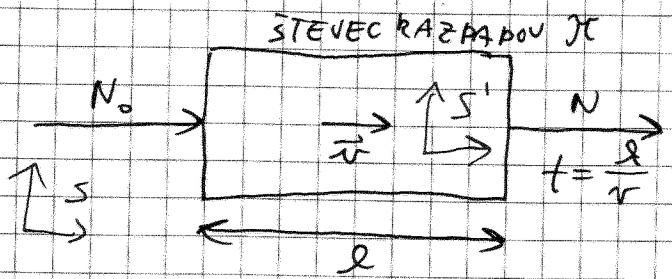
DOGODKA SE VS
ZGODITA NA ISTEM
KRAJU
 τ - lastni čas

PODALJŠANJE (DILATACIJA) ČASA

$$\gamma \geq 1$$

PIONI (π)
 $\tau = 2,6 \cdot 10^{-8} \text{ s}$ (LASTNI RAZPADNI ČAS)
 $v = 2,74 \cdot 10^8 \text{ m/s}$ V LAB. SIST. S
 $l = 110 \text{ cm}$

$$N = N_0 \cdot e^{-\frac{t}{\tau}}$$



$$\frac{N_0 - N}{N_0} = 1 - \frac{N}{N_0} = ?$$

DELEŽ
RAZPADLIH
DELECEV

KLASIČNO:

$$1 - \frac{N}{N_0} = 1 - e^{-\frac{t}{\tau}} = 1 - e^{-\frac{l}{v \cdot \tau}} = 0,143 \approx 14\%$$

RELATIVISTIČNO: RAČ. V LAB. SISTEMU

$$1 - \frac{N}{N_0} = 1 - e^{-\frac{l}{v \cdot \gamma \tau}} = 6,1\%$$

RAZPADNI ČAS PIONA V SISTEMU S JE $\gamma \tau$.

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{1}{\sqrt{1 - \frac{(2,74 \cdot 10^8)^2}{(3 \cdot 10^8)^2}}} = 2,456$$

- V SIST. PIONA:
- RAZPADNI ČAS JE τ
 - MITROŠT ŠTEVCA JE $N \cdot l$
 - DOLŽINA ŠTEVCA JE $\frac{l}{\gamma}$

SKRČENJE DOLŽIN (D.W.)

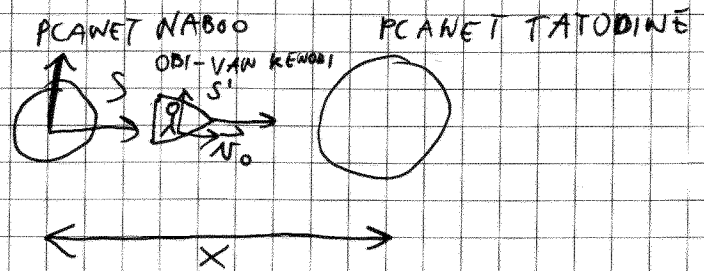
$$l' = \frac{l}{\gamma}$$

2005. 13. 6.

4. nal.

$$v_0 = 0,95 c_0 \text{ (glede na planeta)}$$

$$t' = 4 \text{ h (v sistemu LADJE)}$$



$$x = ? \text{ (v sistemu PLANETOV)}$$

RACUNAMO V SISTEMU S:

$$x = v_0 \cdot t$$

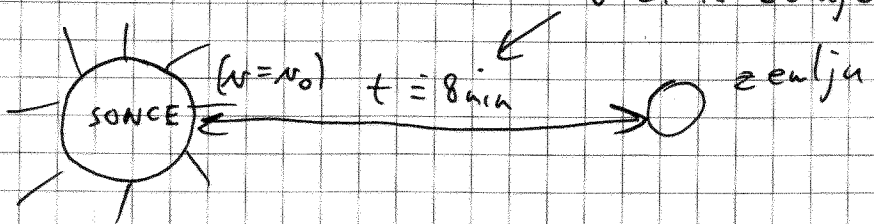
$$t = \gamma \cdot t' = 3,2 \cdot 4 \text{ h} = 12,8 \text{ h}$$

LASTNI ČAS OBIDA

$$\gamma = \frac{1}{\sqrt{1 - \left(\frac{0,95 c_0}{c_0}\right)^2}} = 3,2$$

$$x = 0,95 \cdot c_0 \cdot 12,8 \text{ h} = 12,16 c_0 \text{ h} \rightarrow \text{svetlobna ura}$$

FOTONI



Koliko časa mine za foton(γ)

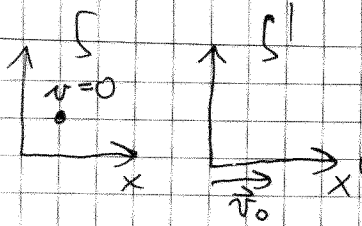
$$t = \gamma \cdot \tau$$

$$\gamma = \frac{t}{\tau} \Rightarrow \gamma = \frac{1}{\sqrt{1 - \frac{c_0^2}{c_0^2}}} \Rightarrow \infty$$

$$\tau = \frac{8 \text{ min}}{\infty} = \underline{\underline{0}}$$

ZA FOTONE
ČAS STOJI

29.05.2008



Mirovna / lastna energija

$$E_0 = m \cdot c_0^2$$

Polna energija

$$E = \gamma \cdot m \cdot c_0^2$$

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c_0^2}}}$$

Kinetična energija

$$T = E - E_0 = (\gamma - 1) m c_0^2$$

Gibalna količina

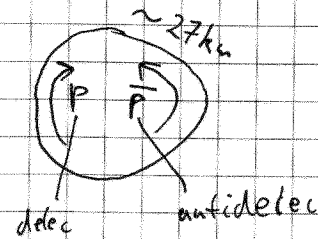
$$\vec{P} = \gamma m \vec{v}$$

$$E^2 = c_0^2 P^2 + E_0^2$$

LARGE HADRON COLLIDER (LHC) - cern - Ženeva

Proton ($E_0 = m_p \cdot c_0^2 = 938 \text{ MeV}$)

$$E = 7 \text{ TeV} = 7 \cdot 10^{12} \text{ eV}$$



$$\frac{v}{c_0} = ?$$

$$E = \gamma E_0$$

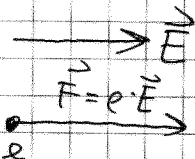
$$\frac{1}{\gamma} = \frac{E_0}{E}$$

$$\sqrt{1 - \frac{v^2}{c_0^2}} = \frac{E_0}{E} \quad |^2$$

$$1 - \frac{v^2}{c_0^2} = \frac{E_0^2}{E^2} \quad | \cdot (-1)$$

$$\frac{v^2}{c_0^2} = 1 - \frac{E_0^2}{E^2} \quad | \sqrt{\quad}$$

$$\frac{v}{c_0} = \sqrt{1 - \frac{E_0^2}{E^2}} = 0,9999999999$$



pozitron (antielektron)

$$\vec{F} = e \cdot \vec{E}$$

$$\frac{dP}{dt} = e \cdot \vec{E}$$

$$\gamma \cdot m \cdot \vec{v} = e \vec{E} \cdot t$$

$$\frac{m \cdot \vec{v}}{\sqrt{1 - \frac{v^2}{c_0^2}}} = e \cdot \vec{E} \cdot t \Rightarrow$$

$$\frac{v}{c_0} = \frac{\alpha \cdot t}{\sqrt{1 + \alpha^2 t^2}} \quad \alpha = \frac{e E}{m c_0} \quad 5b$$

$$e^+ = +e_0$$

$$E_0 = m_0 \cdot c_0^2 = m_e \cdot c_0^2 = 0,51 \text{ MeV}$$

$$E = 3 \text{ kV}$$

$$t_1 = 3 \mu\text{s}$$

$$s(t_1) = ?$$

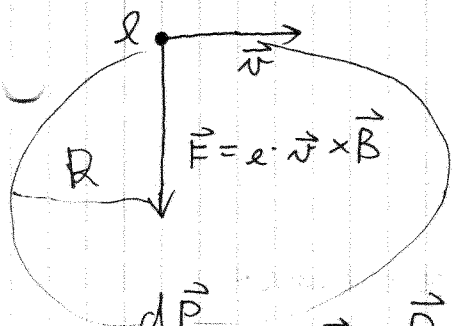
$$\frac{d(\gamma m \vec{v})}{dt} = e \vec{E}$$

$$s = \int_0^{t_1} v \cdot dt = \dots = \frac{c_0}{\alpha} \cdot [\sqrt{\alpha^2 t^2 + 1} - 1]$$

$$s = 445 \text{ m}$$

$\odot \vec{B}$

Magnetno polje



$$\frac{d\vec{p}}{dt} = e \cdot \vec{v} \times \vec{B}$$

$$\frac{d(\gamma \cdot m \cdot \vec{v})}{dt} = e \cdot \vec{v} \times \vec{B} ; |\vec{v}| = v = \text{konst.} \Rightarrow \gamma = \text{konst.}$$

$$\gamma \cdot m \cdot \left(\frac{d\vec{v}}{dt} \right) = e \cdot \vec{v} \times \vec{B}$$

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

$$\gamma \cdot m \cdot v = e \cdot R \cdot B$$

$$\Rightarrow \boxed{P = e \cdot R \cdot B}$$

Proton
 $E_0 = 938 \text{ MeV}$
 $T = 4 \text{ GeV}$
 $R = 16 \text{ m}$

$B = ?$

1. možnost

2. možnost

$$B = \frac{P}{e \cdot R}$$

$$T = (\gamma - 1) \cdot E_0 \Rightarrow \frac{T}{E_0} = \gamma - 1 \Rightarrow P = \gamma \cdot m \cdot v$$

$$(E_0 + T)^2 = c_0^2 p^2 + E_0^2$$

$$\cancel{E_0^2} + 2E_0 T + T^2 = c_0^2 p^2 + \cancel{E_0^2}$$

$$\boxed{c_0 \cdot P = \sqrt{2E_0 T + T^2}}$$

$$B = \frac{\sqrt{2E_0 T + T^2}}{c_0 \cdot e_0 \cdot R} = 1,07 \text{ T}$$

FOTON (γ):

$$m_\gamma = 0 \Rightarrow E_{0\gamma} = 0$$

$$E = c_0 \cdot p$$
$$E = h \cdot \nu$$

h - Planckova konstanta

$$h = 6,62 \cdot 10^{-34} \text{ Js}$$

$$c = \lambda \cdot \nu \Rightarrow E = h \cdot \frac{c_0}{\lambda}$$

$$p = \frac{h}{\lambda}$$

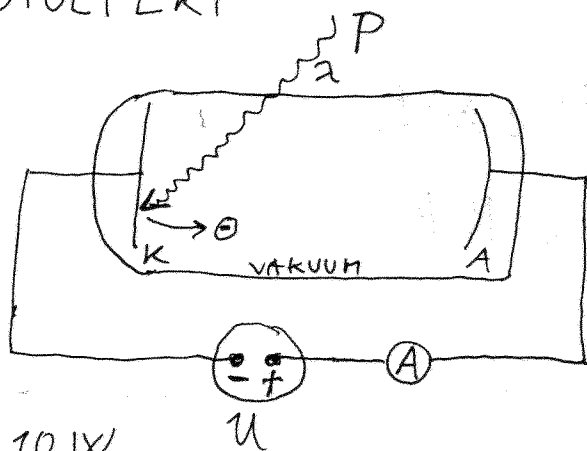
DĚLEC \Leftrightarrow VALOVANJE

$$\lambda = \frac{h}{p}$$



DE BROGLIĚ - VA. VAL. DOLŽIWA

FOTOEFEKT



FOTOCELICA

$$P = 10 \text{ W}$$

U

$$\lambda = 705 \text{ nm}$$

(vsak šestí foton izbije e^-)

$$N_{e^-} = \frac{1}{6} N_\gamma$$

$$I = \frac{dQ}{dt} = \frac{d(N_{e^-} \cdot e_0)}{dt} = \frac{1}{6} \frac{dN_\gamma}{dt} \cdot e_0$$

$$E_\gamma = \frac{h \cdot c_0}{\lambda}$$

$$E = \frac{h \cdot c_0}{\lambda} \cdot N_\gamma$$

$$P = \frac{dE}{dt} = \frac{dN_\gamma}{dt} \frac{h \cdot c_0}{\lambda}$$

$$\frac{dN_\gamma}{dt} = \frac{P \cdot \lambda}{h \cdot c_0}$$

$$I = ? \text{ (NASIČEN)}$$

\Downarrow

vsak izbiti e^-
pride do anode

$$I = \frac{1}{6} \frac{P \cdot \lambda}{h \cdot c_0} \cdot e_0 = \underline{\underline{0,74 \text{ A}}}$$

MOPEDIST

$$m = 100 \text{ kg}$$

$$v = 10 \frac{\text{km}}{\text{s}}$$

$$\lambda = ?$$

$$\lambda = \frac{h}{m \cdot v} = \frac{6,6 \cdot 10^{-34} \text{ J} \cdot \text{s}}{100 \text{ kg} \cdot 10 \text{ m/s}} = \underline{\underline{6,6 \cdot 10^{-37} \text{ m}}}$$

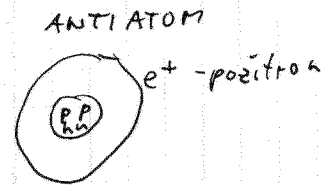
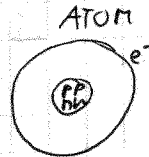
$$E_0 = m \cdot c_0^2$$

ENERGIJA \leftrightarrow MASA

DELEC + ANTIDELEC $\Rightarrow \gamma$ (svetloba)

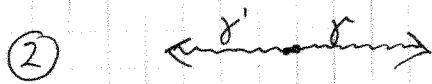
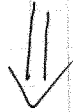
ANIHILACIJA

←
TVORBA
PARA



ANTISNOV + SNOV $\Rightarrow \gamma$ nastane 2. žarka

$$e^+ + e^- \Rightarrow \gamma + \gamma$$



$$T = 20 \text{ MeV}$$

$$E_0 = m_e c_0^2 = 0,51 \text{ MeV}$$

$$\lambda' = ?$$

$$\lambda = ? \quad \left(\begin{array}{l} \text{VAL. DOLŽINA} \\ \text{SVETLOBE} \end{array} \right)$$

OHRANITEV ENERGIJE:

$$T + E_0 + E_0 = \frac{h c_0}{\lambda'} + \frac{h c_0}{\lambda}$$

POZITRON ELEKTRON

$$T + 2E_0 = h \cdot c_0 \left(\frac{1}{\lambda'} + \frac{1}{\lambda} \right)$$

$$\lambda, \lambda' \quad \underline{\underline{D.W.}}$$

OHRANITEV GIB. KOLIČINE:

$$p_{e^+} = -\frac{h}{\lambda'} + \frac{h}{\lambda}$$

$$\frac{\sqrt{2E_0 T + T^2}}{c_0} = -\frac{h}{\lambda'} + \frac{h}{\lambda}$$

$$\sqrt{2E_0 T + T^2} = h c_0 \left(-\frac{1}{\lambda'} + \frac{1}{\lambda} \right)$$

4. naloga

$R_{zvezde} = 1,5 \cdot 10^9 \text{ m}$ (SEVA kot ČRNO TELO)

$T = 6000 \text{ K}$

$r = 10^{11} \text{ m}$ (vesoljska jadrnico) črno telo

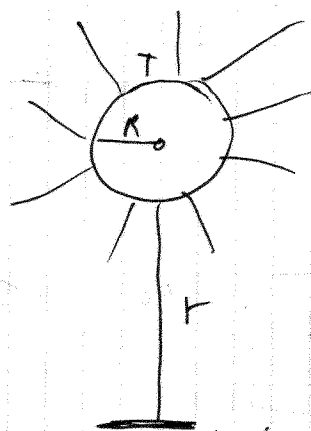
$S = 100 \text{ m}^2$
 $m = 1 \text{ kg}$

$a = ?$

$F = m \cdot a$

$a = \frac{F}{m} = \frac{1}{m} \frac{dP}{dt}$

$P_{\gamma} = \frac{h}{\lambda}$



VEČIKI VESOLJNIK

ZVEZDA SEVA:

$P^* = j^* \cdot S_2 = \sigma \cdot T^4 \cdot S_2$
 $= \sigma T^4 \cdot 4\pi R^2$

SVETLOBNI TOR, KI PADE NA JADRO:

$P_{ABS} = j_{ABS} \cdot S = \frac{P^*}{4\pi r^2} \cdot S$

$P_{ABS} = \sigma T^4 \frac{4\pi R^2}{4\pi r^2} \cdot S$

$P_{ABS} = \sigma T^4 \cdot \frac{R^2}{r^2} \cdot S$

$P_{ABS} = \frac{dE}{dt} = c_0 \cdot P$
 $= c_0 \cdot \frac{dP}{dt}$

$a = \frac{1}{m} \frac{dP}{dt} = \frac{1}{m} \cdot \frac{P_{ABS}}{c_0} = \frac{1}{m c_0} \cdot \sigma T^4 \frac{R^2}{r^2} \cdot S$

$a = 5,5 \cdot 10^{-3} \frac{\text{m}}{\text{s}^2}$