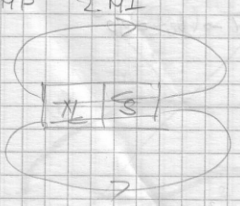
EMP 2. MI



$\mu_0 = 4\pi \cdot 10^{-7}$

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

$$I = \iint \vec{J}\vec{n}\,ds$$

mag. ind $\rightarrow \vec{B} = \mu_0 \mu_r \vec{H}$

$$\phi = \iint \vec{B}\vec{n}\,ds$$

$$\oiint \vec{B} n\,dS = 0$$

$$\nabla \vec{B} = 0$$

$$\oint \vec{H}\,d\vec{l} = \sum I$$

$$\nabla \times \vec{H} = \vec{J}$$

$$B = \nabla \times \vec{A}$$

$$\vec{A} = \frac{\mu_0}{4\pi} \int_{\gamma} \frac{I}{|\vec{R}|}\,d\vec{l} = \frac{\mu_0}{4\pi} \iiint_V \frac{\vec{J}}{|\vec{R}|}\,dV$$ - mag. potencijal

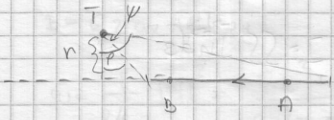
$$B = \nabla \times \vec{A}$$

$$B = \frac{\mu_0}{4\pi} \int_{\gamma} \frac{d\vec{l} \times \vec{R}}{|\vec{R}|^3} = \frac{\mu_0}{4\pi} \iiint_V \frac{\vec{J} \times \vec{R}}{|\vec{R}|^3}\,dV$$

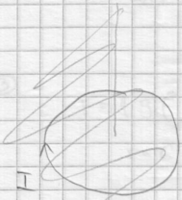
$\vec{R} = \vec{r} - \vec{r}'$ - udaljenost od mjesta u kojem tražimo, do kojeg izvori

beskonačnost → kut = 90°

$$\vec{H} = \frac{I}{4\pi r}(\sin\varphi + \sin\psi)\,\vec{a}_H$$



manji kut je negativan !



$A(x_1, y_1, z_1)$

$B(x_2, y_2, z_2)$

$T(x_3, y_3, z_3)$

$$\vec{n} = \begin{vmatrix} a_x & a_y & a_z \\ x_1 - x_2 & y_1 - y_2 & z_1 - z_2 \\ x_2 - x_3 & y_2 - y_3 & z_2 - z_3 \end{vmatrix}$$

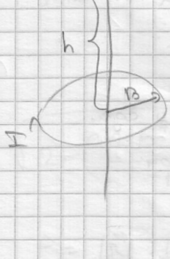
smjer kuta $\longrightarrow$

$a_x \quad a_y \quad a_z$ ili

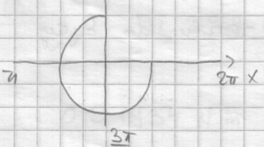
$a_z \quad a_x \quad a_y$ ili

$\underbrace{a_y \quad a_z}_{\text{u toj ravnini leži žuti dio}}, \; a_x$

$$\vec{a}_H = \frac{\vec{n}}{|\vec{n}|}$$



$$\vec{H} = \frac{I r_0}{4\pi \sqrt{r_0^2 + h^2}^{\,3}} \int \left[h\cos\varphi\,\vec{a}_x + h\sin\varphi\,\vec{a}_y + r_0\vec{a}_z\right] d\varphi$$

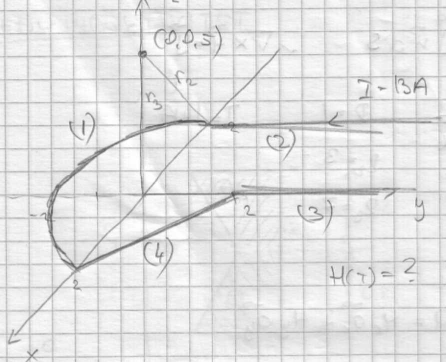


$\cancel{\int_0^{\pi/2} [\ldots]\, d\varphi}$

$\int_0^{-\frac{3\pi}{2}} [..]\, d\varphi = -\frac{3\pi}{2}$ ✓

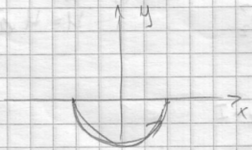
$\int_{2\pi}^{\pi/2} [..]\, d\varphi = -\frac{3\pi}{2}$ ✓

$\cancel{\int_{\pi/2}^{2\pi} [..]\, d\varphi}$



$H(T) = ? = H_1 + H_2 + H_3 + H_4$

(1)

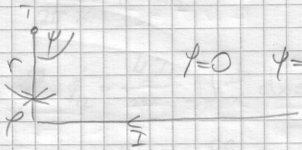


$r_0 = 2$

$h = 5$

$\int_{\pi}^{2\pi} [\ldots] dl$

(2) $r_2 = \sqrt{29}$



$\varphi = 0 \quad \psi = 90^\circ$

$A(-2, 2, 0)$

$B(-2, 0, 0)$

(3) $r_3 = 5$

$\sin \varphi = \frac{-2}{\sqrt{29}} \Rightarrow \varphi =$

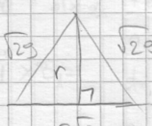
$\psi = 90^\circ$

$A(0, 2, 0)$

$B(0, 4, 0)$

$\vec{a_4} = \vec{a_2}$

(4)

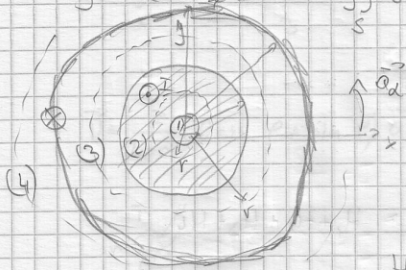


$r = \sqrt{27}$

$\sin \varphi = \sin \psi = \frac{\sqrt{2}}{\sqrt{29}}$

$A(2, 0, 0) \quad B(0, 2, 0)$

$\oint \vec{H} d\vec{l} = \cancel{\Sigma} I = I = \iint_S \vec{J} \vec{n} dS \qquad \nabla \times \vec{H} = \vec{J}$



$R_1 = 1 \qquad I = 14A$

$R_2 = 3$

$R_3 = 7$

$H = H_x \vec{a}_x + H_y \vec{a}_y$

$\vec{J} = J \vec{a}_z \qquad \vec{H} = H \vec{a}_\alpha$

$H \cdot O_{sic} = I$

$H = \frac{I}{O_{sic}} \cdot \vec{a}_\alpha$

(2) $\quad H = \frac{\Sigma I}{2\pi r} \vec{a}_\alpha$

$\Sigma I = \iint J \vec{n} dS$

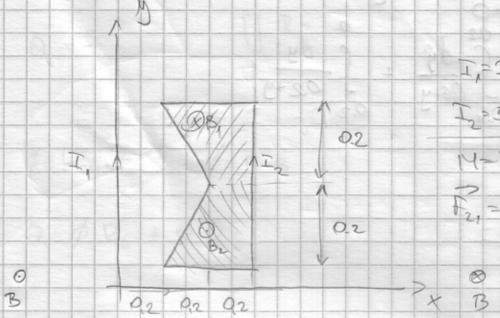
$\Sigma I = I \frac{r^2\pi - R_1^2\pi}{R_2^2\pi - R_1^2\pi}$

(3) $\quad \vec{H}_3 = \frac{I}{2\pi r}$

(4) $\quad \Sigma I = 0$

$\vec{H}_4 = 0$

MEĐUINDUKTIVITET



$I_1 = 3A$

$I_2 = 5A$

$M = ?$

$\vec{F}_{21} = ?$

$$M = L_{12} = L_{21} = \frac{\phi_{12}}{I_1} = \frac{\phi_{21}}{I_2}$$

$$\phi_{12} = \iint_{S_2} \vec{B}_1 \, n \, ds$$

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

$$B_1 = \frac{\mu_0 I_1}{2\pi x} (-\vec{a}_z)$$

$$\phi_{12} = \frac{\mu_0 I_1}{2\pi} \iint \frac{1}{x} \, dx \, dy$$

$$M = \frac{\mu_0}{2\pi} \left[\int_0^{0.2} dy \int_{y+0.2}^{0.6} \frac{dx}{x} + \int_{0.2}^{0.4} dy \int_{0.6-y}^{0.6} \frac{dx}{x} \right]$$

sila na petlju $- F_{12} = I_2 \int_\gamma d\vec{l} \times \vec{B}_1$

$$= - \vec{F}_{21}$$

$$d\vec{l} = dx \, \vec{a}_x + dy \, \vec{a}_y + dz \, \vec{a}_z$$

$$d\vec{l} \times B_1 = \begin{vmatrix} a_x & a_y & a_z \\ dx & dy & dz \\ 0 & 0 & \frac{-I_1 \mu_0}{2\pi r} \end{vmatrix} = - \frac{\mu_0 I_1}{2\pi x} \left[dy \, \vec{a}_x - \cancel{dx} \, \vec{a}_y \right]$$

$$F_{12} = \frac{\mu_0 I_1 I_2}{2\pi}\Big[\underbrace{\int_{\gamma_2} \frac{1}{x}\,dx\,a_y}_{=0} - \int_{\gamma_2}\frac{1}{x}\,dy\,a_x\Big]$$

$$\int_{\gamma_2}\frac{dy}{x} = \int_0^{0.4}\frac{dy}{0.6} + \int_{0.4}^{0.2}\frac{dy}{0.6-y} + \int_{0.2}^{0}\frac{dy}{0.2+y}$$

$$F = \mu_0 \frac{I_1 I_2 l}{2\pi r}$$

$W = \dfrac{\vec{B}\cdot\vec{H}}{2}$ - gustoća energije

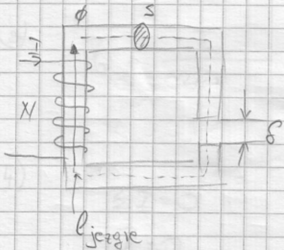
$$W = \frac{1}{2}\iiint_V \vec{B}\cdot\vec{H}\,dV \qquad \vec{B} = \mu_0\mu_r\vec{H}$$

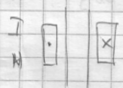
$$= \frac{1}{2}I_1^2 L_1 + \frac{1}{2}I_2^2 L_2 + I_1 I_2 M$$

$$W_M = I_1 I_2 M$$

Uvjeti na granici

MAGNETSKI KRUGOVI



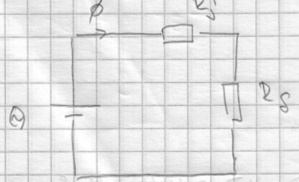


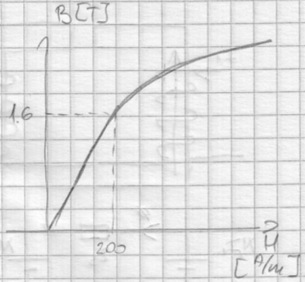
MMS

$$\Theta = N\cdot I \sim E$$

$$\phi \sim I$$

R_m - mag otpor $= \dfrac{1}{\mu_0\mu_r}\dfrac{l}{s}$





$\phi = \text{konst.}$ $\qquad \phi = B \cdot S$

$\Theta = \phi \cdot R_j + \phi \cdot R_\delta$

$\oint \vec{H}\, d\vec{l} = \Sigma I$

$NI = l_j H_j + \delta H_\delta$

Npr.

jezgru $1,6 \times 0,5\,m$

$\delta = 2\,mm$

$N = 150$

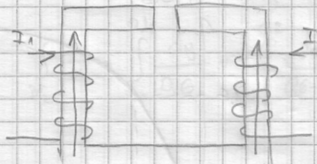
$W = 20\,mJ$

$B_j = B_\delta = \text{konst}$

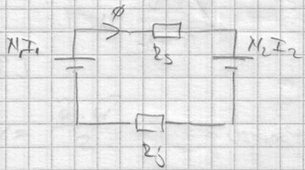
$B_\delta = \mu_0 H_\delta$

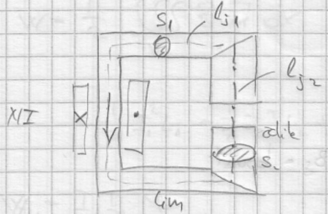
$W_s = \frac{1}{2} B_\delta H_\delta \cdot S \delta$

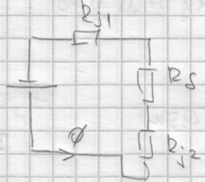
$W_s = \frac{B_\delta^2}{2\mu_0} S \delta$



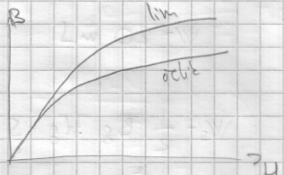
$$N_1 I_1 - N_2 I_2 = H_j l_j + H_\delta \delta$$







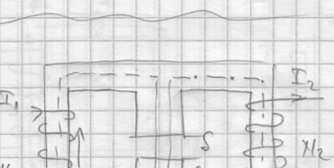
$$\phi = konst = B \cdot S$$

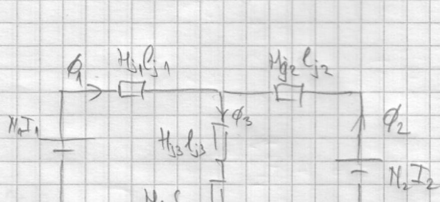


$$B_1 S_1 = B_2 S_2$$

$$B_2 - B_{2j} = B_\delta$$

$$NI = H_{j1} l_{j1} + H_{j2} l_{j2} + H_\delta \delta$$





$$\phi_1 + \phi_2 = \phi_3$$

$$N_1 I_1 = H_{j1} l_{j1} + H_{j3} l_{j3} + H_\delta \delta$$

$$N_2 I_2 = H_{j2} l_{j2} + H_{j3} l_{j3} + H_\delta \delta$$