Áramkiszorítás

$R_0 = \frac{l}{\sigma \cdot A}$

$R_\sim = \frac{l}{\sigma K \delta}$ $\delta = \sqrt{\frac{2}{\omega \mu \sigma}}$ $J(z) = J(0) e^{-\frac{z}{\delta}}$

$\delta_{Cu}^{[m]} = \frac{6{,}67 \cdot 10^{-2}}{\sqrt{f_{Hz}}}$

$R_{koax\sim} = R_{b\sim} + R_{K\sim}$

$R' = R/l$

$\mu = \mu_r \mu_0$ $\mu_0 = 4\pi \cdot 10^{-7} \frac{Vs}{Am}$

$\varepsilon = \varepsilon_r \varepsilon_0$ $\varepsilon_0 = 8{,}85 \cdot 10^{-12} \frac{As}{Vm}$

$\varepsilon_0 = \frac{1}{\mu_0 c^2}$; $c = 3 \cdot 10^8 \frac{m}{s}$

$\delta = \frac{1}{Re\{\gamma\}} = \frac{1}{\alpha}$

$\omega = 2\pi f$; $\lambda = c/f$

Elektrosztatika

MAX. IV: $div \bar{D} = \rho$

$\updownarrow$

$\oint_a \bar{D} da = \int_v \rho dv \xrightarrow[\bar{D} = \varepsilon \bar{E}]{MAX. V}$

pont/gömb: $\rho V = Q$; $A = 4r^2\pi$

$\varepsilon E \cdot 4r^2\pi = Q \rightarrow E = \frac{Q}{4\pi\varepsilon} \cdot \frac{1}{r^2} \rightarrow U = -\frac{Q}{4\pi\varepsilon} \int \frac{1}{r^2} dr = \frac{Q}{4\pi\varepsilon} \cdot \frac{1}{r}$

$\int \frac{1}{r^2} = -\frac{1}{r}$

$\xrightarrow[U = -\int E dr]{E = -grad U}$

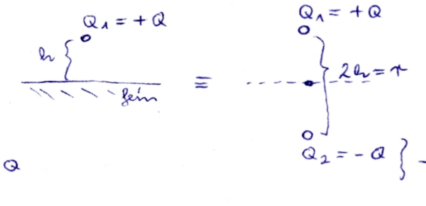
vonal/heng.: $\rho V = q \cdot l$; $A = 2r\pi \cdot l$

$\varepsilon E \cdot 2r\pi \cdot l = q l \rightarrow E = \frac{q}{2\pi\varepsilon} \cdot \frac{1}{r} \rightarrow U = -\frac{q}{2\pi\varepsilon} \int \frac{1}{r} dr = -\frac{q}{2\pi\varepsilon} \cdot ln(r)$

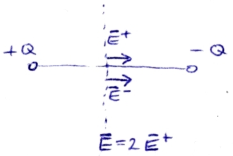
$\int \frac{1}{r} = ln(r)$

$U_{12} = U_1 - U_2$

$F = Q \cdot E$ pl:

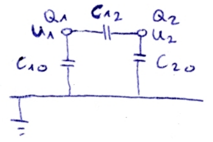


$F_1 = Q_1 \cdot E_2 = Q_1 \cdot \frac{Q_2}{4\pi\varepsilon} \cdot \frac{1}{r^2} = \frac{1}{4\pi\varepsilon} \frac{|Q_1 Q_2|}{r^2}$



$\bar{E} = 2\bar{E}^+$

kapacitás $C = Q/U$

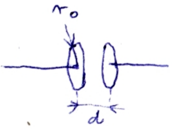


részkapac: $Q_1 = C_{10} U_1 + C_{12} (U_1 - U_2)$

$(Q = CU)$ $Q_2 = C_{20} U_2 + C_{12} (U_2 - U_1)$

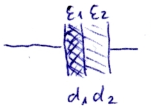
kapac: $\begin{bmatrix} Q_1 \\ Q_2 \end{bmatrix} = \begin{bmatrix} c_{11} & c_{12} \\ c_{12} & c_{22} \end{bmatrix} \begin{bmatrix} U_1 \\ U_2 \end{bmatrix}$

energia:



$W = wV = \frac{1}{2} C U^2$

krit. fesz:



$U_{kr} = min(\varepsilon_1 E_{1kr}; \varepsilon_2 E_{2kr}) \cdot \left(\frac{d_1}{\varepsilon_1} + \frac{d_2}{\varepsilon_2}\right)$

Térbeli áramlás

analógia:

el. sztat.	D	ε	E	Q
stac. ár.	J	σ	E	I

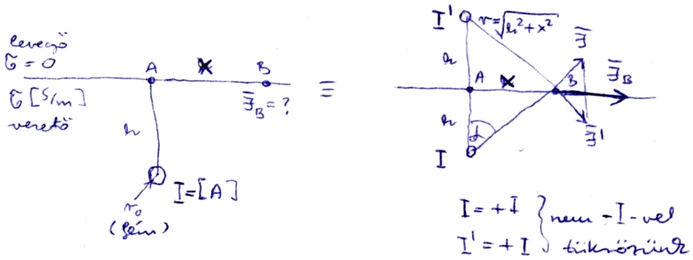
$D[\frac{As}{m^2}]$; $\varepsilon[\frac{As}{Vm}]$; $E[\frac{V}{m}]$; $Q[C = As]$

$J[\frac{A}{m^2}]$; $\sigma[\frac{S}{m} = \frac{A}{Vm}]$; $E[\frac{V}{m}]$; $I[A]$

példa: pont/gömb: $E = \frac{1}{4\pi\sigma} \cdot \frac{1}{r^2} \rightsquigarrow U = \frac{1}{4\pi\sigma} \cdot \frac{1}{r} \rightsquigarrow P = U \cdot I = 4\pi\sigma \cdot r \cdot U^2$; $R = \frac{U}{I} = \frac{1}{4\pi\sigma} \cdot \frac{1}{r}$

$I = J \cdot A$

$|J| = |I| / A$ pl.



$I = +I$, $I' = +I$ } nem -I-vel tükrözünk!

$$\bar{J}_B = \underbrace{\frac{1}{4\pi \underbrace{(h^2 + x^2)}_{r^2}}}_{|\bar{J}| = |\bar{J}'|} \cdot \underbrace{\frac{x}{\sqrt{h^2 + x^2}}}_{sin\alpha} \cdot 2 \cdot \bar{e}_x \left[\frac{A}{m^2}\right]$$

Mágneses tér

MAX I. $rot \bar{H} = \bar{J} + \cancel{\frac{\partial \bar{D}}{\partial t}}$

$\updownarrow$

$\oint_l \bar{H} dl = \int_a \bar{J} da = \bar{I}$

egyéb: $B = \mu H$

$Hl = N \cdot I$

$N\phi = L \cdot I \rightarrow L = \frac{N\phi}{I} = \frac{NBA}{I} = \frac{N\mu HA}{I} = \frac{N\mu HA}{\frac{Hl}{N}} = \frac{N^2 \mu A}{l} = L_{ön}$

$\phi = B \cdot A$

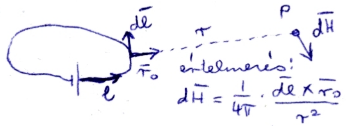
$L_{12} = \frac{\phi_{21}}{I_1} = \frac{\phi_{12}}{I_2} = L_{21}$ (kölcs.)

(fluxus: $\phi = \int B dA = \oint_l \bar{A} d\bar{l}$ $[Vs = Wb]$

$\bar{A}$: mágneses vektorpot.)

Biot-Savart

$\bar{H} = \frac{1}{4\pi} \oint_l \frac{d\bar{l} \times \bar{r}_0}{r^2}$



értelmezés: $d\bar{H} = \frac{1}{4\pi} \cdot \frac{d\bar{l} \times \bar{r}_0}{r^2}$

de csak zárt ák. egészének hatását adja meg

∞. vezetőre: $\bar{H} = \frac{1}{2\pi} \cdot \frac{1}{r}$

(2 párhuzamos vez.: $|F| = B_2 I_1 \cdot l =$

$= \mu H_2 I_1 \cdot l = \dots$)

szab. n szög kp.-ja:

$H = n \frac{1}{4\pi r} \cdot [sin\beta]_{-\pi/n}^{+\pi/n}$

légréses vasmag:

$H_v l_v + H_l l_l = N \cdot I$; $H_v \cdot \mu_r = H_l$

$w = \frac{1}{2} BH = \frac{1}{2} \mu H^2 [\frac{J}{m^3}]$

MAXWELL-EGYENLETEK

I. Általános gerjesztési tv.

$$\boxed{\text{rot}\,\bar{H} = \bar{J} + \frac{\partial \bar{D}}{\partial t}}$$

II. Faraday-féle indukció tv.

$$\boxed{\text{rot}\,\bar{E} = -\frac{\partial \bar{B}}{\partial t}}$$

III. Mágneses Gauss tv.

$$\boxed{\text{div}\,\bar{B} = 0}$$

IV. Elektrosztatikai Gauss-tv.

$$\boxed{\text{div}\,\bar{D} = \rho}$$

V. Közegjellemző törvények

Mágneses indukció vektora

$$\boxed{\bar{B} = \mu \bar{H}}$$

Elektromos eltolódás vektora

$$\boxed{\bar{D} = \varepsilon \bar{E}}$$

Differenciális Ohm-tv.

$$\boxed{\bar{J} = \sigma \cdot \bar{E}}$$

VI. Energia

$$\boxed{w = \frac{1}{2}\bar{H}\bar{B} + \frac{1}{2}\bar{E}\cdot\bar{D}}$$

differenciális alak →	integrális alak
$\text{rot}\,\bar{X}$	$\oint_l \bar{X}\,dl$
$\text{div}\,\bar{X}$	$\oint_a \bar{X}\,da$

peremfeltételek:

el. sztat $\boxed{D} = \varepsilon \boxed{E}$

stac. ár $\boxed{J} = \sigma \boxed{E}$

mágneses $\boxed{B} = \mu \boxed{H}$

1-2 határon: ↓ norm. ↓ tang.

pl. $E_{1t} = E_{2t}$

$D_{1n} = D_{2n}$

↑ 1. közeg ↑ 2. közeg

// Φ skalárpotra a hom. Dirichlet peremfeltétel: $\underline{n} \times \nabla\Phi \equiv 0$ //

Az elektrodinamika felosztása: Időben állandó EM tér:

Magnetosztatika

I. $\text{rot}\,\bar{H} = 0$

III. $\text{div}\,\bar{B} = 0$

V. $\bar{B} = \mu \cdot \bar{H}$

H | E

B | D

μ | ε

↔

Elektrosztatika

II. $\text{rot}\,\bar{E} = 0$

IV. $\text{div}\,\bar{D} = \rho$

V. $\bar{D} = \varepsilon \bar{E}$

↑ E D ε (Q)

↓ E J σ (I)

Stac. mágn. tér

I. $\text{rot}\,\bar{H} = \bar{J}$

III. $\text{div}\,\bar{B} = 0$

V. $\bar{B} = \mu \bar{H}$

Stac. ár. tér

II. $\text{rot}\,\bar{E} = 0$

IV. $\text{div}\,\bar{J} = 0$

V. $\bar{J} = \sigma \cdot \bar{E}$

tétel

sztatikus töltéselosztás létrehozhat elektromos teret ⇔ ha $\text{rot}\,\bar{E} \equiv 0$ (örvénymentes)

MATEK

$$\text{grad}\,\phi = \frac{\partial \phi}{\partial x}\bar{e}_x + \frac{\partial \phi}{\partial y}\bar{e}_y + \frac{\partial \phi}{\partial y}\bar{e}_z$$

$$\text{div}\,\vec{v} = \frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} + \frac{\partial v_z}{\partial z}$$

$$\bar{B} = \text{rot}\,\bar{A} = \begin{vmatrix} \bar{e}_x & \bar{e}_y & \bar{e}_z \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ A_x & A_y & A_z \end{vmatrix}$$

, ahol $\bar{A}$: vektorpotenciál (U_m: skalárpot.)

$$\Delta U = \left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}\right) \cdot U$$ (Laplace-operátor)

---

integrálok:

$$\int \frac{1}{r^2}\,dr = -\frac{1}{r} \qquad \int \frac{1}{r}\,dr = \ln(r)$$

EGYÉB GYÖNYÖRŰSÉGEK

MAGIC FORMULA a fluxusra

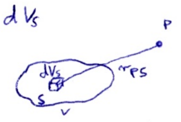
$$\infty \text{ vez: } \Phi_{AB} = \underset{be}{\overset{ki}{\pm}} \frac{\mu_0 I l}{2\pi}\left(\ln\frac{1}{A\,\text{távolság}} - \ln\frac{1}{B\,\text{távolság}}\right)$$

$$\text{gömb: } \Phi_{AB} = \frac{\mu_0 I}{4\pi}\left(\frac{1}{A..} - \frac{1}{B..}\right)$$

Poisson

skaláris P. + mo.

$$\Delta U = -\frac{\rho}{\varepsilon} \Rightarrow \varphi(P) = \frac{1}{4\pi\varepsilon}\int_V \frac{\rho(s)}{r_{PS}}\,dV_s$$



vektoriális P. + mo.

$$\Delta \bar{A} = -\mu \bar{J} \Rightarrow \bar{A}(P) = \frac{\mu}{4\pi}\int_V \frac{\bar{J}(s)}{r_{PS}}\,dV_s$$