## 1. NABOJ IN TOK

$$\sum_i Q_i\Big|_{\substack{\text{znotraj}\\ \text{izoliranega}\\ \text{sistema}}} = \text{konstanta}$$

$$i = \pm\frac{\mathrm{d}Q}{\mathrm{d}t} \Leftrightarrow Q(t) = Q(t_0) \pm \int_{t_0}^{t} i\,\mathrm{d}t$$

## 2. COULOMBOV ZAKON

$$\vec{F}_{Q_2} = \vec{F}_{12} = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r_{12}^2}\vec{e}_{r_{12}}$$

## 3. ELEKTRIČNA POLJSKA JAKOST

$$\vec{E} = \frac{\vec{F}}{Q_t}$$ definicija električne poljske jakosti

$$\vec{E}_Q(r) = \frac{Q}{4\pi\varepsilon_0 r^2}\vec{e}_r$$ polje točkastega naboja

$$\vec{E} = \sum_i \vec{E}_i$$ superpozicija

## 4. PORAZDELITVE NABOJEV

$$Q = \int_V \rho\,\mathrm{d}V\,,\; Q = \int_A \sigma\,\mathrm{d}A\,,\; Q = \int_L q\,\mathrm{d}l$$

## 5. KOORDINATNI SISTEMI

**KARTEZIČNI:** $(x, y, z)$

$$\mathrm{d}\vec{l} = (\mathrm{d}x, \mathrm{d}y, \mathrm{d}z)\,,\; \mathrm{d}\vec{A}_x = \vec{e}_x\,\mathrm{d}y\cdot\mathrm{d}z$$

$$\mathrm{d}\vec{A}_y = \vec{e}_y\,\mathrm{d}x\cdot\mathrm{d}z\,,\; \mathrm{d}\vec{A}_z = \vec{e}_z\,\mathrm{d}x\cdot\mathrm{d}y$$

$$\mathrm{d}V = \mathrm{d}x\cdot\mathrm{d}y\cdot\mathrm{d}z$$

**CILINDRIČNI:** $(r, \varphi, z)$

$$\mathrm{d}\vec{l} = \vec{e}_r\,\mathrm{d}r + \vec{e}_\varphi\, r\,\mathrm{d}\varphi + \vec{e}_z\,\mathrm{d}z$$

$$\mathrm{d}\vec{A}_r = \vec{e}_r\, r\,\mathrm{d}\varphi\cdot\mathrm{d}z\,,\; \mathrm{d}\vec{A}_\varphi = \vec{e}_\varphi\,\mathrm{d}r\cdot\mathrm{d}z\,,$$

$$\mathrm{d}\vec{A}_z = \vec{e}_z\, r\,\mathrm{d}\varphi\cdot\mathrm{d}r$$

$$\mathrm{d}V = r\,\mathrm{d}\varphi\cdot\mathrm{d}r\cdot\mathrm{d}z$$

**SFERIČNI:** $(r, \vartheta, \varphi)$

$$\mathrm{d}\vec{l} = \vec{e}_r\,\mathrm{d}r + \vec{e}_\vartheta\, r\,\mathrm{d}\vartheta + \vec{e}_\varphi\, r\sin(\vartheta)\,\mathrm{d}\varphi$$

$$\mathrm{d}\vec{A}_r = \vec{e}_r\, r^2\sin(\vartheta)\,\mathrm{d}\vartheta\,\mathrm{d}\varphi,$$

$$\mathrm{d}\vec{A}_\vartheta = \vec{e}_\vartheta\, r\sin(\vartheta)\,\mathrm{d}\varphi\,\mathrm{d}r\,,$$

$$\mathrm{d}\vec{A}_\varphi = \vec{e}_\varphi\, r\,\mathrm{d}r\,\mathrm{d}\vartheta\,.$$

$$\mathrm{d}V = r^2\sin(\vartheta)\,\mathrm{d}r\,\mathrm{d}\vartheta\,\mathrm{d}\varphi$$

## 6. E PORAZDELJENIH NABOJEV

$$\vec{E} = \int_{\substack{\text{po vseh}\\ \text{Q-jih}}} \frac{\mathrm{d}Q}{4\pi\varepsilon_0 r^2}\vec{e}_r$$

$$\vec{E} = \vec{e}_r\frac{q}{2\pi\varepsilon_0 r}$$ premi naboj

$$\vec{E} = \vec{e}_z\frac{qaz}{2\varepsilon_0(a^2+z^2)^{3/2}}$$ obroč

$$\vec{E} = \vec{e}_z\frac{\sigma}{2\varepsilon_0}$$ ravnina

## 7. GAUSSOV ZAKON

$$\Phi_e = \int_A \vec{E}\cdot\mathrm{d}\vec{A} = \int_A E_n\cdot\mathrm{d}A$$ el. pretok

$$\oint_A \vec{E}\cdot\mathrm{d}\vec{A} = \frac{Q_{\text{znotraj A}}}{\varepsilon_0}$$ G.Z.

## 8. DELO IN POTENCIALNA ENERGIJA

$$A_e = A_{12} = \int_{T_1}^{T_2}\vec{F}_e\cdot\mathrm{d}\vec{l} = Q\int_{T_1}^{T_2}\vec{E}\cdot\mathrm{d}\vec{l}$$ delo električnih sil

$$\oint_L \vec{E}\cdot\mathrm{d}\vec{l} = 0$$ zakon potencialnosti polja

$$W(T) = A_e(T\to T_\infty)$$ pot. energija

$$A(T_1\to T_2) = W(T_1) - W(T_2)$$ delo

$$A_{1\infty} = \int_{T_1}^{\infty} Q\vec{E}\cdot\mathrm{d}\vec{l} = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r_{12}}$$ Wpot. dveh nabojev

## 9. POTENCIAL IN NAPETOST

$$V(T) = \int_T^{T(V=0)=\infty}\vec{E}\cdot\mathrm{d}\vec{l}$$

$$V_Q = \frac{Q}{4\pi\varepsilon_0 r}$$ pot. točkastega naboja

$$V(T) = \frac{Q_1}{4\pi\varepsilon_0 r_1} + \ldots = \frac{1}{4\pi\varepsilon_0}\sum_{i=1}^{N}\frac{Q_i}{r_i}$$ potencial sistema točkastih nabojev

$$U_{12} = \frac{A_{Q_t}(T_1\to T_2)}{Q_t} = \int_{T_1}^{T_2}\vec{E}\cdot\mathrm{d}\vec{l}$$

KONDENZATOR:

PLAŠČNI: $\vec{E} = \vec{e}_x\frac{\sigma}{\varepsilon_0}$, $U = Ed = \frac{\sigma}{\varepsilon_0}d$

KOAKSIALNI: $\vec{E} = \vec{e}_r\frac{q}{2\pi\varepsilon_0 r}$ $U = \frac{q}{2\pi\varepsilon_0}\ln\frac{r_z}{r_n}$

$$Q(r_n) = \sigma_n 2\pi r_n l = -Q(r_z) = -\sigma_z 2\pi r_z l$$

SFERIČNI: $\vec{E} = \vec{e}_r\frac{Q}{4\pi\varepsilon_0 r^2}$ $U = \frac{Q}{4\pi\varepsilon_0}\left(\frac{1}{r_n}-\frac{1}{r_z}\right)$

$$Q = \sigma(r_n)4\pi r_n^2$$

## 10. PREVODNIK V E POLJU

$$\vec{E}_{\text{v prevodniku}} = 0\,,\; E_{t,\text{na površini}} = 0$$

$$\vec{E}_{\text{na površini}} = \vec{e}_n\frac{\sigma}{\varepsilon_0}$$

$$\vec{f}_e = \vec{e}_n\frac{\sigma^2}{2\varepsilon_0}$$ površinska sila

## 11. ZVEZA MED E IN V

$$V(T) = \int_T^{T(V=0)}\vec{E}\cdot\mathrm{d}\vec{l}\,,\quad \mathrm{d}V = -\vec{E}\cdot\mathrm{d}\vec{l}$$

$$\vec{E} = \vec{e}_n E_n = -e_n\frac{\partial V}{\partial n}$$

$$\vec{E} = \left(E_x, E_y, E_z\right) = -\left(\frac{\partial V}{\partial x}, \frac{\partial V}{\partial y}, \frac{\partial V}{\partial z}\right)$$

$$\vec{E} = \left(E_r, E_\varphi, E_z\right) = -\left(\frac{\partial V}{\partial r}, \frac{\partial V}{r\cdot\partial\varphi}, \frac{\partial V}{\partial z}\right)$$

$$\vec{E} = \left(E_r, E_\vartheta, E_\varphi\right) = -\left(\frac{\partial V}{\partial r}, \frac{\partial V}{r\cdot\partial\vartheta}, \frac{\partial V}{r\sin(\vartheta)\partial\varphi}\right)$$

$$\vec{E} = -\vec{\nabla}V = -\mathrm{grad}(V)$$ nabla, gradient

## 12. GIBANJE NABOJEV

$$m\vec{a} = Q\vec{E}$$

$$\frac{mv_2^2}{2} - \frac{mv_1^2}{2} = Q\left(V(T_1) - V(T_2)\right)$$, oziroma

$$W_{\text{kin}}(T_1) + W_{\text{pot}}(T_1) = W_{\text{kin}}(T_2) + W_{\text{pot}}(T_2)$$

## 13. ELEKTRIČNI DIPOL

$$\vec{p} = Q\vec{d}$$ el. dipolni moment

$$\vec{M} = \vec{r}\times\vec{F} = \vec{p}\times\vec{E}$$ navor

$$V(T) = \frac{Qd\cos(\vartheta)}{4\pi\varepsilon_0 r^2} = \frac{p\cos(\vartheta)}{4\pi\varepsilon_0 r^2}$$

$$\vec{E}(R,\vartheta,\varphi) = \left(\frac{p\cos(\vartheta)}{2\pi\varepsilon_0 r^3}, \frac{p\sin(\vartheta)}{4\pi\varepsilon_0 r^3}, 0\right)$$

$$\vec{F} = -\left(\frac{\partial W}{\partial x}, \frac{\partial W}{\partial y}, \frac{\partial W}{\partial z}\right)$$

$$\vec{F} = \left(\vec{p}\cdot\vec{\nabla}\right)\vec{E}\,,\; W = -\vec{p}\cdot\vec{E}$$

## 14. OKOVINJENJE

$$V(T) = \frac{q}{2\pi\varepsilon_0}\ln\left(\frac{r_{-q}}{r_{+q}}\right)$$ +q in –q naboja

$$U = \frac{q}{\pi\varepsilon_0}\ln\left(\frac{s+d/2-r_0}{s-d/2+r_0}\right),\; s = \sqrt{(d/2)^2 - r_0^2}$$

## 15. ZRCALJENJE

$$U = \frac{q}{2\pi\varepsilon_0}\ln\left(\frac{d-r_0}{r_0}\right)$$ premi naboj nad zemljo

$$V_{+q} = \frac{+q}{2\pi\varepsilon_0}\ln\left(\frac{1}{r_0}\right) + \frac{-q}{2\pi\varepsilon_0}\ln\left(\frac{1}{d}\right)$$

$$\frac{Q_1}{Q_2} = -\frac{d}{r_0}\,,\; e = \frac{r_0^2}{d}$$ točast naboj $Q_1$ ob prevodni krogli

## 16. KAPACITIVNOST

$$Q = CU\,,\; C = \frac{Q}{U}$$

$$C = \varepsilon_0\frac{A}{d}$$ ploščni kond.

$$C = \frac{2\pi\varepsilon_0 l}{\ln\frac{r_z}{r_n}}$$ koaks. kond.

$$C = \frac{Q}{U} = \frac{4\pi\varepsilon_0}{\left(\frac{1}{r_n}-\frac{1}{r_z}\right)}$$ sferični kond.

$$C = \frac{2\pi\varepsilon_0 l}{\ln\left(\frac{d-r_0}{r_0}\right)}$$ valj nad zemljo

$$C = \frac{\pi\varepsilon_0 l}{\ln\left(\frac{d-r_0}{r_0}\right)}$$ dva valja

$$\left.\begin{aligned}\sum_i U_i\big|_{\text{v zanki}} &= 0\\ \sum_i Q_i\big|_{\text{spojišča}} &= 0\end{aligned}\right\}$$ za kondezatorsko vezje

**17. DIELEKTRIK**

$C_{\text{diel}} = \varepsilon_r C_{zrak}$

$\vec{P} = \lim_{\Delta v\to 0}\frac{\sum_i \vec{p}_i}{\Delta V} = \frac{\mathrm{d}\vec{p}}{\mathrm{d}V}$ vektor polarizacije

$\sigma_P = P_n$ , $Q_P = \int_A \vec{P}\cdot\mathrm{d}\vec{A}$ površinski vezan naboj

$\vec{P} = \chi\varepsilon_0\vec{E}$ (χ je električna susceptibilnost)

$\vec{D} = \varepsilon_0\vec{E} + \vec{P}$

$\oint_A \vec{D}\cdot\mathrm{d}\vec{A} = Q_{\substack{\text{prosti,}\\ \text{znotraj A}}}$ modificiran Gaussov zakon

MEJNI POGOJI

$\vec{e}_{\text{n}}\cdot\left(\vec{D}_1 - \vec{D}_2\right) = \sigma_{\text{prosti}}$ za normalno komponento

$E_{\text{t1}} = E_{\text{t2}}$ za tangencialno komponento

$\frac{\tan(\alpha_1)}{\tan(\alpha_2)} = \frac{\varepsilon_1}{\varepsilon_2}$ lomni zakon

**13. ENERGIJA**

$W = Q_2 V = Q_2\frac{Q}{4\pi\varepsilon_0 r}$ dva naboja

$W = \frac{1}{2}\sum_{i=1}^{n} Q_i V_i$ več nabojev

$V_i = \frac{1}{4\pi\varepsilon_0}\sum_{\substack{j=1\\ i\neq j}}^{n}\frac{Q_j}{r_{ij}}$ potencial na mestu $Q_i$

$A(T_1\to T_2) = W(T_1) - W(T_2)$

$W = \frac{Q^2}{2C} = \frac{CU^2}{2} = \frac{QU}{2}$ W kondenzatorja

$W = \int_{\mathbf{v}} \frac{1}{2}\varepsilon E^2\mathrm{d}\mathcal{V}$

$w = \frac{1}{2}\varepsilon E^2$ gostota energije

$\vec{F}_e = \pm\left(\frac{\partial W_e}{\partial x}, \frac{\partial W_e}{\partial y}, \frac{\partial W_e}{\partial z}\right)$

$F_x = \frac{\partial W}{\partial x} = \frac{\partial}{\partial x}\frac{Q^2}{2C} = \frac{Q^2}{2}\frac{\partial}{\partial x}\left(\frac{1}{C}\right)$

$F_x = \frac{\partial W}{\partial x} = \frac{\partial}{\partial x}\frac{CU^2}{2} = \frac{U^2}{2}\frac{\partial C}{\partial x}$

**20. ČASOVNO KONSTANTNO TOK. POLJE**

$I = \int_A \vec{J}\cdot\mathrm{d}\vec{A}$

$\frac{\mathrm{d}Q}{\mathrm{d}t} = -\oint_A \vec{J}\cdot\mathrm{d}\vec{A}$ kontinuitetna enačba

$\vec{J} = \rho\vec{v}$ gostota toka

$\vec{v} = \mu\vec{E}$ (μ je mobilnost)

$\vec{J} = \gamma\vec{E}$ konduktivni tok (Ohmov zakon)

$R = \frac{l}{\gamma A}$ upornost vodnika dolžine *l*

$R(T) = R(T_0)\left(1+\alpha\left(T-T_0\right)\right)$

$P = \frac{\mathrm{d}W_t}{\mathrm{d}t} = \frac{\mathrm{d}Q}{\mathrm{d}t}U = IU$ moč

$P = IU = I^2R = U^2G$

$p = \vec{J}\cdot\vec{E} = \gamma E^2$ gostota moči

$P = \int_V p\mathrm{d}V = \int_V \vec{J}\cdot\vec{E}\mathrm{d}V$

MEJNI POGOJI

$\vec{e}_{\text{n}}\cdot\left(\vec{D}_1 - \vec{D}_2\right) = \sigma_{\text{prosti}}$

$J_{n1} = J_{n2}$ , $E_{\text{t1}} = E_{\text{t2}}$ : $\left(\frac{\varepsilon_1}{\gamma_1} - \frac{\varepsilon_2}{\gamma_2}\right)J_n = \sigma$

$RC = \rho\varepsilon$ dualnost

**22. ENOSMERNA VEZJA**

1. KZ: $\sum_{i=1}^{N} I_i\Big|_{\text{V SPOJIŠČU}} = 0$

2. KZ: $\sum_{i=1}^{M} U_i\Big|_{\text{V ZANKI}} = 0$

**25. MOČ**

$P = UI = RI^2 = U^2/R$

$P_{\text{b}} = R_{\text{b}}I^2 = R_{\text{b}}\left(\frac{U_{\text{g}}}{R_{\text{b}}+R_{\text{g}}}\right)^2$ moč na bremenu

$R_{\text{b}} = R_{\text{g}}$ pogoj za max moč (0.g)

$P_{\text{b,max}} = \frac{U_{\text{g}}^2}{4R_{\text{b}}}$ max moč na bremenu

**MATEMATIČNI DEL (DOPOLNITE SAMI!)**