Formule za elektrodinamiku

$$\rho(\mathbf{r}) = \sum_\alpha q_a \delta^{(3)}(\mathbf{r} - \mathbf{r}_\alpha) \tag{1}$$

$$\boldsymbol{\nabla}\cdot\mathbf{j} + \frac{\partial \rho}{\partial t} = 0 \tag{2}$$

$$\begin{aligned}\mathbf{F} &= q(\mathbf{E} + \mathbf{v}\times\mathbf{B})\\ \mathbf{F} &= \int \rho\, \mathrm{d}^3 r\,(\mathbf{E} + \mathbf{v}\times\mathbf{B})\\ &= \int (\rho\mathbf{E} + \mathbf{j}\times\mathbf{B})\,\mathrm{d}^3 r\end{aligned} \tag{3}$$

$$\mathbf{p} = \int_V \rho(\mathbf{r})\mathbf{r}\mathrm{d}V \tag{4}$$

$$\phi = \frac{1}{4\pi\epsilon_0}\int_V \frac{\rho(\mathbf{r}')}{|\mathbf{r}-\mathbf{r}'|}\mathrm{d}V' \tag{5}$$

$$\phi = \frac{1}{4\pi\epsilon_0}\left[\frac{Q}{r} + \frac{\mathbf{r}\cdot\mathbf{p}}{r^3} + \frac{x_i D_{ij} x_j}{2r^5}\right] \tag{6}$$

$$\mathbf{E} = \frac{1}{4\pi\epsilon_0}\left(\frac{3(\mathbf{p}\cdot\mathbf{r})\mathbf{r} - r^2\mathbf{p}}{r^5} - \frac{4\pi}{3}\mathbf{p}\delta^{(3)}(\mathbf{r})\right) \tag{7}$$

$$\mathbf{E}(\mathbf{r}) = \frac{1}{4\pi\epsilon_0}\int \frac{\rho(\mathbf{r}')\,\mathrm{d}^3 r'}{|\mathbf{r}-\mathbf{r}'|^3}(\mathbf{r}-\mathbf{r}') \tag{8}$$

$$\begin{aligned}D_{ij} &= \int \rho(\mathbf{r})(3x_i x_j - \delta_{ij} r^2)\mathrm{d}V\\ D_{ij} &= \sum_\alpha q_\alpha(3x_i^{(\alpha)} x_j^{(\alpha)} - \delta_{ij}(r^{(\alpha)})^2); \quad \mathrm{Tr}\,\hat{D} = 0\end{aligned} \tag{9}$$

$$\mathbf{E} = -\boldsymbol{\nabla}\phi \tag{10}$$

$$\mathbf{j} = \rho\mathbf{v} \tag{11}$$

$$\mathbf{A}(\mathbf{r}) = \frac{\mu_0}{4\pi}\int \frac{\mathbf{j}(\mathbf{r}')}{|\mathbf{r}-\mathbf{r}'|}\mathrm{d}V' \tag{12}$$

$$\mathbf{A}(\mathbf{r}) = \frac{\mu_0}{4\pi}\frac{\mathbf{m}\times\mathbf{r}}{r^3} \tag{13}$$

$$\mathbf{B} = \frac{\mu_0}{4\pi}\left(\frac{3(\mathbf{m}\cdot\mathbf{r})\mathbf{r} - r^2\mathbf{m}}{r^5} + \frac{8\pi}{3}\mathbf{m}\delta^{(3)}(\mathbf{r})\right) \tag{14}$$

$$\mathbf{m}(\mathbf{r}) = \frac{1}{2}\int \mathbf{r}\times\mathbf{j}(\mathbf{r})\mathrm{d}V \tag{15}$$

$$\mathbf{B}(\mathbf{r}) = \boldsymbol{\nabla}\times\mathbf{A} = \frac{\mu_0}{4\pi}\int \frac{\mathbf{j}(\mathbf{r}')\times(\mathbf{r}-\mathbf{r}')}{|\mathbf{r}-\mathbf{r}'|^3}\mathrm{d}V' \tag{16}$$

$$\mathbf{E} = -\frac{\partial\mathbf{A}}{\partial t} - \boldsymbol{\nabla}\phi \tag{17}$$

$$\begin{aligned}\boldsymbol{\nabla}\cdot\mathbf{A} + \frac{1}{c^2}\frac{\partial\phi}{\partial t} &= 0\\ \nabla^2\phi - \frac{1}{c^2}\frac{\partial^2\phi}{\partial t^2} &= -\frac{\rho}{\epsilon_0}\\ \nabla^2\mathbf{A} - \frac{1}{c^2}\frac{\partial^2\mathbf{A}}{\partial t^2} &= -\mu_0\mathbf{j}\end{aligned} \tag{18}$$

$$\langle\rho\rangle = \frac{1}{T}\int_0^T \rho dt \tag{19}$$

$$\begin{aligned}D_{2n} - D_{1n} &= \sigma\\ B_{2n} - B_{1n} &= 0\\ P_{2n} - P_{1n} &= -\sigma_{vez}\\ E_{2n} - E_{1n} &= \frac{1}{\epsilon_0}\sigma\\ E_{2t} - E_{1t} &= 0\\ \mathbf{n}\times(\mathbf{H}_2 - \mathbf{H}_1) &= \mathbf{i}\\ M_{2t} - M_{1t} &= \mathbf{i}_{vez}\times\mathbf{n}\end{aligned} \tag{20}$$

$$\begin{aligned}\boldsymbol{\nabla}\cdot\mathbf{E} &= \frac{\rho}{\epsilon_0}\\ \boldsymbol{\nabla}\cdot\mathbf{B} &= 0\\ \boldsymbol{\nabla}\times\mathbf{E} &= -\frac{\partial\mathbf{B}}{\partial t}\\ \boldsymbol{\nabla}\times\mathbf{B} &= \mu_0\left(\mathbf{j} + \epsilon_0\frac{\partial\mathbf{E}}{\partial t}\right)\end{aligned} \tag{21}$$

$$\begin{aligned}\boldsymbol{\nabla}\cdot\mathbf{D} &= \rho + \rho_{ext}\\ \boldsymbol{\nabla}\cdot\mathbf{B} &= 0\\ \boldsymbol{\nabla}\times\mathbf{E} &= -\frac{\partial B}{\partial t}\\ \boldsymbol{\nabla}\times\mathbf{H} &= \mathbf{j} + \mathbf{j}_{ext} + \frac{\partial D}{\partial t}\end{aligned} \tag{22}$$

$$\boldsymbol{\nabla}\cdot\mathbf{P} = -\rho_{\mathrm{vez}} \tag{23}$$

$$q = UC = U\epsilon_0\frac{S}{d} \tag{24}$$

$$\begin{aligned}&\frac{d}{dt}\left(\sum_n \varepsilon_n + \underbrace{\int_V \mathrm{d}^3 r\left(\frac{1}{2}\mathbf{D}\cdot\mathbf{E} + \frac{1}{2}\mathbf{H}\cdot\mathbf{B}\right)}_{W_{em}}\right)\\ &= -\oint_{\partial S}\mathbf{S}_p d\mathbf{S}\\ &\frac{\mathrm{d}}{\mathrm{d}t}(\sum_n \varepsilon_n) = \int \mathrm{d}^3 r\,\mathbf{j}\cdot\mathbf{E}\end{aligned} \tag{25}$$

$$\begin{aligned}\mathbf{S}_p &= \mathbf{E}\times\mathbf{H}\\ \mathbf{g} &= \frac{\mathbf{S}_p}{c^2} \quad \text{- gustina impulsa}\end{aligned} \tag{26}$$

$$\begin{aligned}\frac{\mathrm{d}}{\mathrm{d}t}\left(\mathbf{L}_{\mathrm{meh}} + \int_V \mathrm{d}^3 r\,(\mathbf{r}\times\mathbf{g})\right) &= \oint_{\partial V}(\mathbf{r}\times\hat{T}\,\mathrm{d}\mathbf{S})\\ \mathbf{L}_f &= \epsilon_0\int_V \mathrm{d}^3 r\,(\mathbf{r}\times(\mathbf{E}\times\mathbf{B}))\end{aligned} \tag{27}$$

$$\begin{aligned}&\frac{d}{dt}\left[\sum_\alpha \mathbf{p}_\alpha + \int \mathrm{d}^3 r\,(\mathbf{D}\times\mathbf{B})\right]\\ &-\frac{1}{2}\int \mathrm{d}^3 r\,(\epsilon_0\mathbf{E}^2\boldsymbol{\nabla}\epsilon_r + \mu_0\mathbf{H}^2\boldsymbol{\nabla}\mu_r) = \oint_S \hat{T}d\mathbf{S}\\ &\hat{T} = |\mathbf{E}\rangle\langle\mathbf{D}| + |\mathbf{H}\rangle\langle\mathbf{B}| - \frac{1}{2}(\mathbf{E}\cdot\mathbf{D} + \mathbf{H}\cdot\mathbf{B})\hat{I}\end{aligned} \tag{28}$$

$$V^\mu = \begin{pmatrix}\frac{c}{\sqrt{1-\frac{v^2}{c^2}}}\\ \frac{\mathbf{v}}{\sqrt{1-\frac{v^2}{c^2}}}\end{pmatrix} \tag{29}$$

$$P^\mu = mV^\mu = \begin{pmatrix}\frac{E}{c}\\ \mathbf{p}\end{pmatrix} \tag{30}$$

$$\mathcal{A}^\mu = \frac{\mathrm{d}V^\mu}{\mathrm{d}\tau} = \begin{pmatrix}c\gamma\frac{\mathrm{d}\gamma}{\mathrm{d}t}\\ \gamma\frac{\mathrm{d}\gamma}{\mathrm{d}t}\mathbf{v} + \gamma^2\mathbf{a}\end{pmatrix} \tag{31}$$

$$\mathcal{F}^\mu = \begin{pmatrix}\frac{\mathbf{v}\cdot\mathbf{F}}{c\sqrt{1-\frac{v^2}{c^2}}}\\ \frac{\mathbf{F}}{\sqrt{1-\frac{v^2}{c^2}}}\end{pmatrix} \tag{32}$$

$$\begin{aligned}\mathbf{E'}_\parallel &= \mathbf{E}_\parallel \quad \mathbf{E'}_\perp = \frac{\mathbf{E}_\perp + \mathbf{v}\times\mathbf{B}_\perp}{\sqrt{1-\frac{v^2}{c^2}}}\\ \mathbf{B'}_\parallel &= \mathbf{B}_\parallel \quad \mathbf{B'}_\perp = \frac{\mathbf{B}_\perp - \frac{1}{c^2}\mathbf{v}\times\mathbf{E}_\perp}{\sqrt{1-\frac{v^2}{c^2}}}\end{aligned} \tag{33}$$

$$\begin{pmatrix}x'^0\\ x'^1\\ x'^2\\ x'^3\end{pmatrix} = \underbrace{\begin{pmatrix}\gamma & -\beta\gamma & 0 & 0\\ -\beta\gamma & \gamma & 0 & 0\\ 0 & 0 & 1 & 0\\ 0 & 0 & 0 & 1\end{pmatrix}}_{\Lambda^\mu{}_\nu}\begin{pmatrix}x^0\\ x^1\\ x^2\\ x^3\end{pmatrix} \tag{34}$$

$$g_{\mu\nu} = \begin{pmatrix}1 & 0 & 0 & 0\\ 0 & -1 & 0 & 0\\ 0 & 0 & -1 & 0\\ 0 & 0 & 0 & -1\end{pmatrix} \tag{35}$$

$$\frac{\partial}{\partial x^\mu} = \left(\frac{1}{c}\frac{\partial}{\partial t}, \boldsymbol{\nabla}\right) \tag{36}$$

$$j^\mu = (c\rho, \mathbf{j} = \rho\mathbf{v}) \tag{37}$$

$$A^\mu = (\frac{\phi}{c}, \mathbf{A}) \tag{38}$$

$$\Box A^\mu = \mu_0 j^\mu \tag{39}$$

$$F^{\mu\nu} = \partial^\mu A^\nu - \partial^\nu A^\mu \tag{40}$$

$$F^{\mu\nu} = \begin{pmatrix}0 & -\frac{E_x}{c} & -\frac{E_y}{c} & -\frac{E_z}{c}\\ \frac{E_x}{c} & 0 & -B_z & B_y\\ \frac{E_y}{c} & B_z & 0 & -B_x\\ \frac{E_z}{c} & -B_y & B_x & 0\end{pmatrix} \tag{41}$$

$$F'^{\mu\nu} = (\Lambda F\Lambda^T)^{\mu\nu} \tag{42}$$

$$\begin{aligned}\frac{\mathrm{d}\mathbf{p}}{\mathrm{d}t} &= q(\mathbf{E} + \mathbf{v}\times\mathbf{B})\\ \frac{\mathrm{d}}{\mathrm{d}t}\underbrace{\left(\frac{mc^2}{\sqrt{1-\frac{v^2}{c^2}}}\right)}_{E} &= \mathbf{v}\cdot\mathbf{F} = q\mathbf{v}\cdot\mathbf{E}\end{aligned} \tag{43}$$

$$E^2 = c^2 p^2 + m^2 c^4 \tag{44}$$

$$\frac{\mathrm{d}}{\mathrm{d}\tau}\left(\frac{\partial\tilde{L}}{\partial u^\alpha}\right) - \frac{\partial\tilde{L}}{\partial x^\alpha} = 0 \tag{45}$$

$$H = p_i\dot{q}_i - L \tag{46}$$

$$\begin{aligned}\frac{\partial u^\mu}{\partial u^\alpha} &= \delta^\mu{}_\alpha\\ \frac{\partial u^\mu}{\partial u_\alpha} &= g^{\mu\alpha}\end{aligned} \tag{47}$$

$$\begin{aligned}S &= \int(-mc\mathrm{d}s - qA^\mu\mathrm{d}x_\mu) + S_f\\ \mathrm{d}s &= \sqrt{g_{\mu\nu}\frac{\mathrm{d}x^\mu}{\mathrm{d}\tau}\frac{\mathrm{d}x^\nu}{\mathrm{d}\tau}}\mathrm{d}\tau\\ \mathrm{d}s &= c\mathrm{d}\tau = c\sqrt{1-\frac{v^2}{c^2}}\mathrm{d}t\\ A^\mu\mathrm{d}x_\mu &= (\phi - \mathbf{A}\cdot\mathbf{v})\mathrm{d}t\end{aligned} \tag{48}$$

$$j^\mu_{\mathrm{vez}} = (c\rho_{\mathrm{vez}}, \mathbf{j}_{\mathrm{vez}}) = (-c\boldsymbol{\nabla}\cdot\mathbf{P}, \boldsymbol{\nabla}\times\mathbf{M} + \frac{\partial\mathbf{P}}{\partial t}) \tag{49}$$

$$\begin{aligned}\mathbf{P}'_\parallel &= \mathbf{P}_\parallel \quad \mathbf{P}'_\perp = \frac{\mathbf{P}_\perp - \frac{1}{c^2}\mathbf{v}\times\mathbf{M}}{\sqrt{1-\frac{v^2}{c^2}}}\\ \mathbf{M}'_\parallel &= \mathbf{M}_\parallel \quad \mathbf{M}'_\perp = \frac{\mathbf{M}_\perp - \mathbf{v}\times\mathbf{P}}{\sqrt{1-\frac{v^2}{c^2}}}\end{aligned} \tag{50}$$

$$\begin{aligned}\mathbf{D}'_\parallel &= \mathbf{D}_\parallel \quad \mathbf{D}'_\perp = \frac{\mathbf{D}_\perp - \frac{1}{c^2}\mathbf{v}\times\mathbf{H}}{\sqrt{1-\frac{v^2}{c^2}}}\\ \mathbf{H}'_\parallel &= \mathbf{H}_\parallel \quad \mathbf{H}'_\perp = \frac{\mathbf{H}_\perp - \mathbf{v}\times\mathbf{D}}{\sqrt{1-\frac{v^2}{c^2}}}\end{aligned} \tag{51}$$

$$\begin{aligned} \sin(\alpha \pm \beta) &= \sin\alpha\cos\beta \pm \cos\alpha\sin\beta \\ \cos(\alpha \pm \beta) &= \cos\alpha\cos\beta \mp \sin\alpha\sin\beta \\ \tan(\alpha \pm \beta) &= \frac{\tan\alpha \pm \tan\beta}{1 \mp \tan\alpha\tan\beta} \end{aligned} \tag{52}$$

$$\begin{aligned} \sin(2\alpha) &= 2\sin\alpha\cos\alpha \\ \cos(2\alpha) &= \cos^2\alpha - \sin^2\alpha \\ \tan(2\alpha) &= \frac{2\tan\alpha}{1-\tan^2\alpha} \\ \cot(2\alpha) &= \frac{\cot^2\alpha - 1}{2\cot\alpha} \end{aligned} \tag{53}$$

$$\begin{aligned} \sin\alpha \pm \sin\beta &= 2\sin\frac{\alpha\pm\beta}{2}\cos\frac{\alpha\mp\beta}{2} \\ \cos\alpha + \cos\beta &= 2\cos\frac{\alpha+\beta}{2}\cos\frac{\alpha-\beta}{2} \\ \cos\alpha - \cos\beta &= -2\sin\frac{\alpha+\beta}{2}\sin\frac{\alpha-\beta}{2} \\ \tan\alpha \pm \tan\beta &= \frac{\sin(\alpha\pm\beta)}{\cos\alpha\cos\beta} \\ \cot\alpha \pm \cot\beta &= \frac{\sin(\alpha\pm\beta)}{\sin\alpha\sin\beta} \\ \sin\alpha\cos\beta &= \frac{1}{2}(\sin(\alpha+\beta)+\sin(\alpha-\beta)) \\ \cos\alpha\cos\beta &= \frac{1}{2}(\cos(\alpha+\beta)+\cos(\alpha-\beta)) \\ \sin\alpha\sin\beta &= -\frac{1}{2}(\cos(\alpha+\beta)+\cos(\alpha-\beta)) \end{aligned} \tag{54}$$

$$\begin{aligned} \sin\frac{\alpha}{2} &= \pm\sqrt{\frac{1-\cos\alpha}{2}} \\ \cos\frac{\alpha}{2} &= \pm\sqrt{\frac{1+\cos\alpha}{2}} \\ \tan\frac{\alpha}{2} &= \pm\sqrt{\frac{1-\cos\alpha}{1+\cos\alpha}} \end{aligned} \tag{55}$$

$$\begin{aligned} \sin(\mathrm{acos}(x)) = \cos(\mathrm{asin}(x)) &= \sqrt{1-x^2} \\ \sin(\mathrm{atan}(x)) &= \frac{x}{\sqrt{1+x^2}} \\ \cos(\mathrm{atan}(x)) &= \frac{1}{\sqrt{1+x^2}} \\ \tan(\mathrm{asin}(x)) = \cot(\mathrm{acos}(x)) &= \frac{x}{\sqrt{1-x^2}} \\ \tan(\mathrm{acos}(x)) = \cot(\mathrm{asin}(x)) &= \frac{\sqrt{1-x^2}}{x} \end{aligned} \tag{56}$$

$$\int_0^b \sin\frac{k\pi y}{b}\sin\frac{m\pi y}{b} = \frac{b}{2}\delta_{km} \tag{57}$$

$$\phi(r,\theta) = \sum_{l=0}^{\infty}\left(A_l r^l + \frac{B_l}{r^{l+1}}\right)P_l(\cos\theta) \tag{58}$$

$$\begin{aligned} V(\mathbf{r}) &= \int_V G(\mathbf{r},\mathbf{r}')\rho(\mathbf{r}')\mathrm{d}V' + \\ \epsilon_0 \oint_{\partial V} \mathrm{d}S' &\left(G(\mathbf{r},\mathbf{r}')\frac{\partial V(\mathbf{r}')}{\partial n'} - V(\mathbf{r}')\frac{\partial G(\mathbf{r},\mathbf{r}')}{\partial n'}\right) \end{aligned} \tag{59}$$

$$\mathbf{D} = \epsilon_0\mathbf{E} + \mathbf{P} \tag{60}$$

$$\mathbf{P} = \epsilon_0(\hat{\epsilon}-1)\mathbf{E} = \epsilon_0\hat{\chi}_e\mathbf{E} \tag{61}$$

$$(1+x)^\alpha = \sum_{n=0}^{\infty}\binom{\alpha}{n}x^n, |x| < 1 \tag{62}$$

$$\int_V \mathrm{d}V(\phi\nabla^2\psi - \psi\nabla^2\phi) = \oint_{\partial V}\mathrm{d}\mathbf{S}(\phi\boldsymbol{\nabla}\psi - \psi\boldsymbol{\nabla}\phi) \tag{63}$$

$$\Delta \ln r = 2\pi\delta(r) \tag{64}$$

$$\begin{aligned} \mathbf{p} &= \beta\mathbf{E} \\ \mathbf{p} &= -e\mathbf{r} \end{aligned} \tag{65}$$

$$\omega = \frac{q}{2m}\mathbf{B_{sp}} \tag{66}$$

$$W = \frac{1}{2}I_1 I_2 M_{1,2} = \frac{1}{2}I_1 I_2 \underbrace{\int \frac{\mathrm{d}\mathbf{l_1}\mathrm{d}\mathbf{l_2}}{|\mathbf{r_1}-\mathbf{r_2}|}\frac{\mu_0}{4\pi}}_{M_{1,2}} \tag{67}$$

$$W_{int} = q\phi \tag{68}$$

$$\langle X\rangle = \frac{\int X e^{-\frac{W_{int}}{kT}}\,\mathrm{d}V}{\int e^{-\frac{W_{int}}{kT}}\,\mathrm{d}V} \tag{69}$$

$$W_{\mathrm{int}} = Q\phi(0) - \mathbf{p}\cdot\mathbf{E}(0) + \ldots \tag{70}$$

$$\mathbf{F} = Q\mathbf{E}(0) + (\mathbf{p}\cdot\nabla)\mathbf{E}(0) + \ldots \tag{71}$$

$$\mathbf{M} = \mathbf{p}\times\mathbf{E}(0) + \ldots \tag{72}$$

$$W_{\mathrm{int}} = \mathbf{m}\cdot\mathbf{B}(0) + \ldots \tag{73}$$

$$\mathbf{F} = (\mathbf{m}\cdot\nabla)\mathbf{B}\Big|_0 \tag{74}$$

$$I = \frac{1}{4\pi\epsilon_0}\left(|\ddot{\mathbf{p}}(\tau)|^2\frac{2}{3c^2} + \frac{2}{3c^5}|\dddot{\mathbf{m}}(\tau)|^2 + \frac{1}{180c^5}|\dddot{D}(\tau)|^2\right) \tag{75}$$

$$\frac{\mathrm{d}I}{\mathrm{d}\Omega} = \frac{1}{(4\pi)^2\epsilon_0 c^3}\Big[\ddot{\mathbf{p}}(\tau)\times\mathbf{n} + \frac{1}{c}(\ddot{\mathbf{m}}(\tau)\times\mathbf{n})\times\mathbf{n} \tag{76}$$

$$+\frac{1}{6c}\dddot{D}(\tau)\mathbf{n}\times\mathbf{n}\Big]^2 \tag{77}$$

$$\underbrace{\frac{\mathrm{d}\epsilon}{\mathrm{d}t}}_{\text{izračena}} = \frac{1}{6\pi\epsilon_0 c^3}\frac{e^2}{m^2}\frac{\mathbf{F}^2 - \frac{1}{c^2}(\mathbf{F}\cdot\mathbf{v})^2}{1-\frac{v^2}{c^2}} \tag{78}$$

$$\hat{\epsilon}_r = \hat{I} + \frac{N}{\epsilon_0}\hat{\beta} \tag{79}$$

$$v_f = c\sqrt{\frac{\sin^2\theta}{\epsilon_\parallel} + \frac{\cos^2\theta}{\epsilon_\perp}} \tag{80}$$

$$\begin{aligned} \epsilon'(\omega) - 1 &= \frac{1}{\pi}P\int_{-\infty}^{\infty}\mathrm{d}x\frac{\epsilon''(x)}{x-\omega} \\ \epsilon''(\omega) &= -\frac{1}{\pi}P\int_{-\infty}^{\infty}\mathrm{d}x\frac{\epsilon'(x)_1}{x-\omega} \end{aligned} \tag{81}$$