$$\mathbf{F}_{12} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r_{12}^2}\hat{r}_{12} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r_{12}^3}\mathbf{r}_{12}$$

$$\epsilon_0 = 8.854\,10^{-12}\,C^2/(Nm^2)$$
$$K_0 = 1.113\,10^{-10}\,C^2/(Nm^2)$$
$$\frac{1}{4\pi\epsilon_0} = \frac{1}{K_0} = 9\,10^9\,Nm^2/C^2$$

$$\mathbf{E} = \frac{\mathbf{F}}{q}$$

$$\mathbf{E} = \frac{d\mathbf{F}}{dq}$$

$$\rho(x,y,z) = \frac{dq}{dV}$$
$$\sigma = \frac{dq}{dS}$$
$$\lambda = \frac{dq}{dl}$$

$$\mathcal{L}_\gamma(A \to B) = \int_{A\gamma B}\mathbf{F}\,\cdot\,d\mathbf{s} = q\int_{A\gamma B}\mathbf{E}\,\cdot\,d\mathbf{s}$$

$$\oint \mathbf{E}\,\cdot\,d\mathbf{s} = 0$$

$$\mathcal{L}(A \to B) = \int_A^B \mathbf{F}\,\cdot\,d\mathbf{s} = U_A - U_B = -\Delta U$$

$$U(r) = \int_r^\infty \frac{1}{4\pi\epsilon_0}\frac{qQ\,dr}{r^2} = \frac{1}{4\pi\epsilon_0}\frac{qQ}{r}$$

$$V(A) = \frac{U_A}{q} = \int_A^\infty \mathbf{E}\,\cdot\,d\mathbf{s} = \frac{1}{4\pi\epsilon_0}\frac{Q}{r}$$

$$\Delta V = V_A - V_B = \int_A^B \mathbf{E}\,\cdot\,d\mathbf{s} = \frac{\mathcal{L}(A \to B)}{q}$$

$$\mathbf{E} = -\boldsymbol{\nabla} V$$

$$E(0,0,z) = E_z = -\frac{\partial V}{\partial z} = \frac{\sigma}{2\epsilon_0}(1 - \frac{z}{\sqrt{R^2+z^2}})$$

$$\Delta V = V_+ - V_- = Ed = \frac{\sigma}{\epsilon_0}d$$

$$V(P) \approx \frac{q}{4\pi\epsilon_0}\frac{\mathbf{d}\cdot\mathbf{r}}{r^3} = \frac{1}{4\pi\epsilon_0}\frac{\mathbf{p}\cdot\mathbf{r}}{r^3}$$

$$\mathbf{F} = q\mathbf{E}_B - q\mathbf{E}_A = q(\mathbf{E}_B - \mathbf{E}_A)$$

$$\mathbf{F} = -\boldsymbol{\nabla}(-\mathbf{p}\cdot\mathbf{E})$$

$$U = -\mathbf{p}\cdot\mathbf{E} = -pE(x,y,z)\cos\theta$$

$$\mathbf{M} = \mathbf{p}\times\mathbf{E}$$

$$e = 1.6022\,10^{-19}\,C$$
$$1eV = 1e\cdot 1V = 1.6022\,10^{-19}\,J$$
$$1J = 6.241\,10^{18}\,eV$$

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

$$J = \frac{dq}{dt\, dS_\perp} = \frac{dq}{dt\, dS \cos\theta}$$

$$I = \Phi_S(\mathbf{J}) = \int_S \mathbf{J} \cdot \mathbf{n}\, dS$$

$$\mathbf{J} = nq\mathbf{v}$$

$$\int_S \mathbf{J} \cdot \mathbf{n}\, dS = -\frac{dQ}{dt}$$

$$Q = \int_V \rho\, dV$$

$$\int_S \mathbf{J} \cdot \mathbf{n}\, dS = -\frac{d}{dt}\int_V \rho\, dV = -\int_V \frac{\partial\rho}{\partial t}\, dV$$

$$\boldsymbol{\nabla} \cdot \mathbf{J} + \frac{\partial\rho}{\partial t} = 0$$

$$I = \frac{V_1 - V_2}{R}$$

$$V_1 - V_2 = RI$$

$$R = \rho_c \frac{l}{S}$$

$$\mathbf{E} = \rho_c \mathbf{J} = \rho_c nq\mathbf{v}$$

$$\mathbf{J} = \gamma_c \mathbf{E}$$

$$W = \frac{d\mathcal{L}}{dt} = I(V_1 - V_2) = \frac{(V_1 - V_2)^2}{R} = I^2 R$$

$$\mathcal{L} = q(V_1 - V_2) = I^2 R\, \Delta t$$

$$\sum_{k=1}^{N} I_K = 0$$

$$\sum_{k=1}^{N} \mathcal{E}_K = \sum_{k=1}^{N} R_K I_K$$

$$d\Phi\mathbf{E} = \mathbf{E} \cdot \mathbf{n}\, dS = E_n\, dS$$

$$\Phi_S(\mathbf{E}) = \int_S \mathbf{E} \cdot \mathbf{n}\, dS = \frac{1}{\epsilon_0}\int_V dq = \frac{1}{\epsilon_0}\int_V \rho\, dx\, dy\, dz$$

$$\boldsymbol{\nabla} \cdot \mathbf{E} = \frac{\rho}{\epsilon_0}$$

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

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

$$C = \frac{Q}{V_+ - V_-} = \frac{Q}{\Delta V}$$

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

$$C = \frac{2\pi\epsilon_0 l}{\ln\frac{R_2}{R_1}}$$

$$C = 4\pi\epsilon_0 \frac{R_1 R_2}{R_2 - R_1}$$

$$U = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}QV = \frac{1}{2}CV^2$$

$$\sigma_P = \mathbf{P} \cdot \mathbf{n}$$

$$\boldsymbol{\nabla} \cdot \mathbf{P} = -\rho_P$$

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

$$\boldsymbol{\nabla} \cdot \mathbf{D} = \rho$$

$$\mathbf{P}_0 = \chi\epsilon_0 \mathbf{E} = (\epsilon_r - 1)\epsilon_0 \mathbf{E}$$

$$u = \frac{1}{2}\mathbf{D} \cdot \mathbf{E}$$

$$div\, \mathbf{F} = \boldsymbol{\nabla} \cdot \mathbf{F} = \frac{\partial F_x}{\partial x} + \frac{\partial F_y}{\partial y} + \frac{\partial F_z}{\partial z}$$

$$gradU = \boldsymbol{\nabla} U = \frac{\partial U}{\partial x}\mathbf{u_x} + \frac{\partial U}{\partial y}\mathbf{u_y} + \frac{\partial U}{\partial z}\mathbf{u_z} =$$
$$= \frac{\partial U}{\partial r}\mathbf{u_r} + \frac{1}{r}\frac{\partial U}{\partial \theta}\mathbf{u}_\theta + \frac{1}{r\sin\phi}\frac{\partial U}{\partial \phi}\mathbf{u}_\phi$$

$$rot\mathbf{F} = \boldsymbol{\nabla} \times \mathbf{F} = \begin{vmatrix} \mathbf{u}_x & \mathbf{u}_y & \mathbf{u}_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ F_x & F_y & F_z \end{vmatrix} = \left(\frac{\partial F_z}{\partial y} - \frac{\partial F_y}{\partial z}\right)\mathbf{u}_x +$$
$$+ \left(\frac{\partial F_x}{\partial z} - \frac{\partial F_z}{\partial x}\right)\mathbf{u}_y + \left(\frac{\partial F_y}{\partial x} - \frac{\partial F_x}{\partial y}\right)\mathbf{u}_z$$

$$\int_S \mathbf{F} \cdot \mathbf{n}\, dS = \int_V \boldsymbol{\nabla} \cdot \mathbf{F}\, dV$$

$$\oint_\gamma \mathbf{F} \cdot d\mathbf{s} = \int_S \boldsymbol{\nabla} \times \mathbf{F} \cdot \mathbf{n}\, dS$$

$$d\mathbf{F} = i\, d\mathbf{s} \times \mathbf{B}$$

$$\mathbf{F} = i \int d\mathbf{s} \times \mathbf{B}$$

$$1\, T = 1\, Wb/(m^2) = 1\, N/(A\, m)$$

$$1\, gauss = 1\, G = 10^{-4}\, T$$

$$\boldsymbol{\mu} = iS\, \mathbf{n}$$

$$\mathbf{M} = \boldsymbol{\mu} \times \mathbf{B}$$

$$U = -\boldsymbol{\mu} \cdot \mathbf{B}$$

$$B = \frac{\mu_0}{2\pi}\frac{i}{R}$$

$$\frac{\mu_0}{2\pi} = 2\, 10^{-7}\, Wb/(Am) = 2\, 10^{-7}\, N/A^2$$

$$d\mathbf{B} = \frac{\mu_0}{4\pi} i \frac{d\mathbf{s} \times \mathbf{r}}{r^3}$$

$$\mathbf{B}(\mathbf{r}) = \frac{\mu_0}{4\pi} i \int_\gamma \frac{d\mathbf{r}' \times (\mathbf{r} - \mathbf{r}')}{|\mathbf{r} - \mathbf{r}'|^3}$$

$$\mathbf{B} = \frac{\mu_0}{4\pi} i \mathbf{u}_z \int_{pi/2}^{\pi/2} \frac{\cos\theta}{R}\, d\theta = \frac{\mu_0 i}{2\pi R}\mathbf{u}_z$$

$$\mathbf{B} = \frac{\mu_0}{4\pi} i \frac{1}{r^3} \oint d\mathbf{s} \times \mathbf{R} = \frac{\mu_0}{4\pi} i \frac{R}{r^3} \mathbf{u}_z \int_0^{2\pi} ds = \\ = \frac{\mu_0 i}{2} \frac{R^2}{(R^2 + z^2)^{3/2}} \mathbf{u}_z$$

$$\mathbf{B} \approx \frac{\mu_0 i}{2} \frac{R^2}{z^3} \mathbf{u}_z = \frac{\mu_0}{2\pi} \frac{\boldsymbol{\mu}}{z^3} \;\; (R \ll z)$$

$$B = \mu_0 i n = \mu_0 i \frac{N}{l}$$

$$\Phi_S(\mathbf{B}) = \oint_S \mathbf{B} \cdot \mathbf{n}\, dS = 0$$

$$\boldsymbol{\nabla} \cdot \mathbf{B} = 0$$

$$\frac{F}{l} = \frac{\mu_0}{2\pi} \frac{i_1 i_2}{R}$$

$$\mathbf{F} = q(\mathbf{E} + \mathbf{v} \times \mathbf{B})$$

$$\oint_c \mathbf{B} \cdot d\mathbf{s} = \mu_0 \sum_r i_r$$

$$\mathcal{E}_I = -\frac{d\Phi_\gamma(\mathbf{B})}{dt}$$

$$\boldsymbol{\nabla} \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\Phi(\mathbf{B}) = Li$$

$$1\, Wb/A = 1\, henry = 1\, H = 1\, Vs/A = 1\, \Omega\, s$$

$$\begin{aligned} \Phi_{\gamma_1}(\mathbf{B}) &= L_1 i_1 + M i_2 \\ \Phi_{\gamma_2}(\mathbf{B}) &= M i_1 + L_2 i_2 \end{aligned}$$

$$M = k\sqrt{L_1 L_2} \quad -1 \le k \le 1$$

$$\mathbf{j}_{ms} = \mathbf{M} \times \mathbf{n}$$

$$\mathbf{j}_m = \boldsymbol{\nabla} \times \mathbf{M}$$

$$\mathbf{H} = \frac{1}{\mu_0}\mathbf{B} - \mathbf{M}$$

$$\boldsymbol{\nabla} \times \mathbf{H} = \mathbf{j}$$

$$B_{1n} = B_{2n} \quad H_{1t} = H_{2t}$$

$$\frac{\tan i}{\tan r} = \frac{\mu_1}{\mu_2} = \frac{\mu_{r,1}}{\mu_{r,2}} = cost$$

$$\mathcal{R} = \oint \frac{ds}{\mu S}$$

$$f.m.m. = \Phi_S(\mathbf{B})\mathcal{R}$$

$$u = \frac{1}{V} \int d\mathcal{L} = \frac{1}{V} \int_0^B VH\, dB = \int_0^B \mathbf{H} \cdot d\mathbf{B}$$

$$u = \frac{1}{2}\mu H^2 = \frac{1}{2}\mathbf{H}\cdot\mathbf{B}$$

$$\mathbf{F}_i^{(M)} = -(\boldsymbol{\nabla}_i U_M)_{\Phi=cost} = (\boldsymbol{\nabla}_i U_M)_{i=cost}$$

$$\boldsymbol{\nabla}\times\mathbf{B} = \mu_0\mathbf{j}_{tot} + \epsilon_0\mu_0\frac{\partial\mathbf{E}}{\partial t}$$

$$\boldsymbol{\nabla}\times\mathbf{E} = -\frac{\partial\mathbf{B}}{\partial t}$$

$$\boldsymbol{\nabla}\cdot\mathbf{E} = \frac{\rho_{tot}}{\epsilon_0}$$

$$\boldsymbol{\nabla}\cdot\mathbf{B} = 0$$

$$\boldsymbol{\nabla}\times\mathbf{H} = \mathbf{j}_C + \frac{\partial\mathbf{D}}{\partial t}$$

$$\boldsymbol{\nabla}\cdot\mathbf{D} = \rho_L$$

$$\mathbf{E} = c\mathbf{B}\times\mathbf{u}_x$$

$$\mathbf{E} = \mathbf{E}_0\sin(kx-\omega t)$$
$$\mathbf{B} = \mathbf{B}_0\sin(kx-\omega t)$$

$$\mathbf{E} = E_0[\pm\mathbf{u}_y\sin(kx-\omega t) + \mathbf{u}_z\cos(kx-\omega t)]$$

$$\mathbf{B} = \frac{1}{c}\mathbf{u}_x\times\mathbf{E} = \frac{1}{c}E_0[-\mathbf{u}_y\cos(kx-\omega t) \pm \mathbf{u}_z\sin(kx-\omega t)]$$

$$I = cu = c\epsilon_0 E^2 = \frac{E^2}{Z}$$

$$Z = \sqrt{\frac{\mu_0}{\epsilon_0}} = 376.7\,\Omega$$

$$\mathbf{S} = \mathbf{E}\times\mathbf{H}$$

$$\boldsymbol{\nabla}\cdot\mathbf{S} + \frac{\partial u}{\partial t} = -\mathbf{E}\cdot\mathbf{j}$$

$$\mathbf{I} = \frac{\mathcal{L}}{c}\mathbf{u}_x$$

$$\mathbf{p} = \frac{\mathbf{S}}{c^2}$$

$$\mathbf{L} = \mathbf{r}\times\mathbf{p} = \frac{1}{c^2}\mathbf{r}\times\mathbf{S}$$

$$\mathbf{S} = \mathbf{E}\times\mathbf{H} = \frac{\omega^4 p_0^2\sin^2\theta\sin^2\omega\left(t-\frac{r}{c}\right)}{16\pi^2\epsilon_0 c^3 r^2}\mathbf{u}_r$$

$$I(\theta) = |\mathbf{S}|_m = \frac{\omega^4 p_0^2\sin^2\theta}{32\pi^2\epsilon_0 c^3 r^2}\mathbf{u}_r$$

$$n_{vetro} = 1.5 \qquad n_{acqua} = 1.3$$

$$\phi = r$$

$$n \sin \phi = n^{'} \sin \phi^{'}$$

$$\sin \phi_C = \frac{n^{'}}{n}$$

$$n = \frac{\sin \frac{A+\delta_m}{2}}{\sin \frac{A}{2}} \approx \frac{A + \delta_m}{A}$$

$$\omega = \frac{n_F - n_C}{n_D - 1} = \frac{\delta_F - \delta_C}{\delta_D}$$

$$\frac{1}{p} + \frac{1}{q} = \frac{2}{R} = \frac{1}{f}$$

$$G_y = -\frac{q}{p}$$

$$\frac{n_1}{p} + \frac{n_2}{q} = \frac{n_2 - n_1}{R}$$

$$f^{'} = \frac{n_1}{n_2 - n_1} R$$

$$f^{''} = \frac{n_2}{n_2 - n_1} R$$

$$G_y = -\frac{n_1 q}{n_2 p}$$

$$\frac{1}{p} + \frac{1}{q} = (n_{12} - 1) \left(\frac{1}{R'} - \frac{1}{R''} \right) = \frac{1}{f}$$

$$G_y = -\frac{q}{p}$$