$\vec{F}_{12} = k_e \frac{q_1 q_2}{r^2}\hat{r}_{12} \quad \vec{E} = \frac{\vec{F}_e}{q_o} = k_e \frac{q}{r^2}\hat{r}; \quad \vec{E} = k_e \sum_i \frac{q_i}{r_i^2}\hat{r}_i$

$\vec{E} = k_e \lim_{\Delta q_i \to 0} \sum_i \frac{\Delta q_i}{r_i^2}\hat{r}_i = k_e \int \frac{dq}{r^2}\hat{r}; \quad \vec{a} = \frac{q\vec{E}}{m}$

$\Phi_E \equiv \int_{\text{surface}} \vec{E}\cdot d\vec{A};\ \Phi_E = \oint \vec{E}\cdot d\vec{A} = \frac{q_{\text{in}}}{\varepsilon_0};\ E = \frac{\sigma}{2\varepsilon_0};\ E = \frac{\sigma}{\varepsilon_0}$

$C = \frac{Q}{V};\ C = \frac{\varepsilon_0 A}{d};\ C = \frac{ab}{k_e(b-a)};\ C = \frac{\ell}{2k_e \ln\ (b/a)}$

$C_{\text{eq}} = C_1 + C_2 + C_3 + \ldots$ (parallel combination)

$\frac{1}{C_{\text{eq}}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots$ (series combination)

$U = \frac{Q^2}{2C} = \frac{1}{2}Q\Delta V = \frac{1}{2}C(\Delta V)^2;\ \sigma_p = \sigma\left(1 - \frac{1}{\kappa}\right)$

$I \equiv \frac{dQ}{dt};\ I_{avg} = \frac{\Delta Q}{\Delta t} = nqv_d A;\ J \equiv \frac{I}{A} = nqv_d$

$J = \sigma E;\ R \equiv \frac{\Delta V}{I};\ R = \rho\frac{\ell}{A}; J = nqv_d = \frac{nq^2 E}{m_e}\tau$

$\rho = \rho_0[1 + \alpha(T - T_0)];\quad \rho = \frac{1}{\sigma};\ \wp = I\Delta V$

$\wp = I^2 R = \frac{(\Delta V)^2}{R};\ \sum_{junction} I = 0;\ \sum_{\substack{\text{closed}\\ \text{loop}}} \Delta V = 0$

$\tau = RC;\ q(t) = C\varepsilon(1 - e^{-t/RC}) = Q(1 - e^{-t/RC});\ q(t) = Qe^{-t/RC};$

$U = ½\, Q\varepsilon = ½\, C\varepsilon^2 \quad \Delta U = -q_0\int_A^B \vec{E}\cdot d\vec{s};\ V = \frac{U}{q_0};\ \Delta U = q\Delta V$

$dV = k_e\frac{dq}{r};\quad \Delta V = -E\int_A^B ds = -Ed$

$\Delta V = -\int_A^B \vec{E}\cdot d\vec{s} = -\vec{E}\cdot\int_A^B d\vec{s} = -\vec{E}\cdot\vec{s};\ \Delta K + \Delta U = 0$

$U = k_e\frac{q_1 q_2}{r_{12}};\ V = k_e\frac{q}{r};\ E_x = -\frac{dV}{dx};\ E_r = -\frac{dV}{dr}$

$E_x = -\frac{\partial V}{\partial x} \quad E_y = -\frac{\partial V}{\partial y} \quad E_z = -\frac{\partial V}{\partial z}$

$\vec{F}_B = q\vec{v}\times\vec{B};\ \vec{F} = q\vec{E} + q\vec{v}\times\vec{B};\ F_B = |q|\ v\,B\sin\theta$

$K = \frac{1}{2}mv^2 = \frac{q^2B^2R^2}{2m};\ d\vec{B} = \frac{\mu_0}{4\pi}\frac{I\,d\vec{s}\times\hat{r}}{r^2};\ B = \frac{\mu_0 I}{2\pi a}$

$B = \frac{\mu_0 I}{4\pi a}(\sin\theta_1 - \sin\theta_2);\ B = \frac{\mu_0 I}{4\pi a}\theta;\ B_x = \frac{\mu_0 I a^2}{2(a^2+x^2)^{3/2}}$

$\frac{F_B}{\ell} = \frac{\mu_0 I_1 I_2}{2\pi a};\ \oint \vec{B}\cdot d\vec{s} = \mu_0 I;\ B = \left(\frac{\mu_0 I}{2\pi R^2}\right)r$ (for $r < R$)

$B = \frac{\mu_0 N I}{2\pi r};\ B = \mu_0\frac{N}{\ell}I = \mu_0 n I;\ \mu = \left(\frac{e}{2m_e}\right)L;\ \mu_{\text{spin}} = \frac{e\hbar}{2m_e};$

$\mu_B = \frac{e\hbar}{2m_e} = 9.27\times10^{-24}$ J/T;

$\vec{F}_B = I\vec{L}\times\vec{B};\ d\vec{F}_B = I\ d\vec{s}\times\vec{B};\ \vec{\tau} = I\vec{A}\times\vec{B};$

$\vec{\tau} = \vec{\mu}\times\vec{B};$

$\Delta V_H = E_H d = v_d B d;\ \Delta V_H = \frac{I\,B}{nqt} = \frac{R_H\,I\,B}{t}$

$U_E = (\varepsilon_o E^2)/2;\ C = \kappa C_o;\ \tau = p\times E;\ U = p\,.\,E;\ E = E_o/\kappa$

$\varepsilon = -N\frac{d\Phi_B}{dt};\ \Delta V = E\ell = B\ell v;\ \varepsilon = -B\ell v\ \oint \vec{E}\cdot d\vec{s} = -\frac{d\Phi_B}{dt}$

$\varepsilon_L = -L\frac{dI}{dt};\ L = \frac{N\Phi_B}{I};\ L = -\frac{\varepsilon_L}{\frac{dI}{dt}};\ L = \frac{N\Phi_B}{I} = \mu_0\frac{N^2}{\ell};\ L = \mu\,\ell\ln(b/a)/2\pi$

$L = \mu_0\frac{(n\ell)^2}{\ell}A = \mu_0 n^2 A\ell = \mu_0 n^2 V;\ I = \frac{\varepsilon}{R}\left(1 - e^{-t/\tau}\right);\ \tau = \frac{L}{R}$

$I = \frac{\varepsilon}{R}e^{-t/\tau} = I_i e^{-t/\tau};\ U = \frac{1}{2}LI^2;\ u_B = \frac{U}{V} = \frac{B^2}{2\mu_0};\ M_{12} = \frac{N_2\Phi_{12}}{I_1}$

$\varepsilon_1 = -M_{21}\frac{dI_2}{dt} \qquad U = U_C + U_L = \frac{Q^2}{2C} + \frac{1}{2}LI^2$

$\omega = \frac{1}{\sqrt{LC}};\ Q = Q_{max}\,e^{\left(-\frac{Rt}{2L}\right)}\cos(\omega_d\,t);\ \omega_d = \left[\frac{1}{LC} - \left(\frac{R}{2L}\right)^2\right]^{1/2}$

$i_C = \omega C\,\Delta V_{max}\ \sin\left(\omega t + \frac{\pi}{2}\right);\ q = C\,\Delta V_{max}\sin(\omega t);\ X_c \equiv 1/c\omega;$

$\Delta v_C = I_{max}X_C\sin\left(\omega t - \frac{\pi}{2}\right) = -\Delta V_C\cos(\omega t);\ I_{max} = \frac{\Delta V_{max}}{X_C}$

$\Delta v_R = I_{max}\,R\,\sin(\omega t) = \Delta V_R\sin(\omega t);\quad I_{max} = \frac{\Delta V_{max}}{Z}$

$\Delta v_L = I_{max}X_L\sin\left(\omega t + \frac{\pi}{2}\right) = \Delta V_L\cos(\omega t);\ X_L \equiv \omega L;\ R = Z.\cos($

$I_{max} = \frac{\Delta V_{max}}{\sqrt{R^2 + (X_L - X_C)^2}};\ R_{\text{eq}} = \left(\frac{N_1}{N_2}\right)^2 R_L;\ \wp_{\text{avg}} = \frac{1}{2}\ I_{max}\Delta V_{max}\cos(\emptyset)$

$\Delta v_2 = \frac{N_2}{N_1}\Delta v_1;\ I_1\Delta V_1 = I_2\Delta V_2;\ I_d = \varepsilon_o\frac{d\Phi_E}{dt};\ c = \frac{1}{\sqrt{\mu_o\varepsilon_o}};\ c = \frac{E}{B}$

$\frac{\partial^2 E}{\partial x^2} = \mu_o\varepsilon_o\frac{\partial^2 E}{\partial t^2};\ \frac{\partial B}{\partial x} = -\mu_o\varepsilon_o\frac{\partial E}{\partial t};\ \frac{\partial E}{\partial x} = -\frac{\partial B}{\partial t};\ \vec{S} \equiv \frac{1}{\mu_o}\vec{E}\times\vec{B}$

$E = E_{max}\cos(kx - \omega t);\ B = B_{max}\cos(kx - \omega t);\ k = 2\pi/\lambda;\ \omega = 2\pi f$

$\lambda = c\,T = \frac{c}{f};\ u_B = u_E = \frac{1}{2}\varepsilon_o E^2 = \frac{B^2}{2\mu_o};\ I = S_{\text{avg}} = \frac{E_{\max}B_{\max}}{2\mu_o} = \frac{E_{\max}^2}{2\mu_o c} = \frac{cB_{\max}^2}{2\mu_o}$

$P = \frac{F}{A} = \frac{1}{A}\frac{dp}{dt} = \frac{1}{c}\frac{\left(\frac{dT_{ER}}{dt}\right)}{A} = (1+f)\frac{S}{c}$; *f is the fraction of the reflected light*

$m_\alpha = 6.644657\times10^{-27}kg = 4.00151\,u = 3727.409\frac{MeV}{c^2}$

$e = 1.6\times10^{-19}C$; $N = 6.02\times10^{23}$ particles/mole

$c = 3.00\times10^8\frac{m}{s}$; $k_e = 8.9876\times10^9\ N\,m^2/C^2;\ k_e = 1/(4\pi\epsilon_o)$

$\varepsilon_0 = 8.8542\times10^{-12}\ \frac{C^2}{N.m^2};\quad \mu_0 = 4\pi\times10^{-7}\frac{T.m}{A};\quad 1T = 10^4 G$

1 u = 931.502 MeV/c^2

1 eV = 1.602×10^{-19} J

$m_p = 1.672\times10^{-27}$ kg

= 1.0073 u = 938.280 MeV/c^2

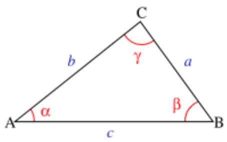
$m_n = 1.674\times10^{-27}$ kg

= 1.0087 u = 939.57 MeV/c^2

$m_e = 9.11\times10^{-31}$ kg

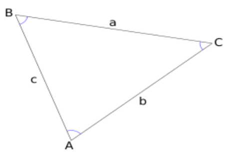
= 5.486×10^{-4} u = 0.511 MeV/c^2

Law of cosines



$c^2 = a^2 + b^2 - 2ab\cos(\gamma)$

Law of sines



$\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$

Quadratics:

$ax^2 + bx + c = 0$

$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

Trigonometric Identities:

$cos^2\boldsymbol{\theta} + sin^2\boldsymbol{\theta} = \mathbf{1}$

$\sin(a \pm b) = \sin a \cos b \pm \cos a \sin b$

$\cos(a \pm b) = \cos a \cos b \mp \sin a \sin b$

$\tan(a \pm b) = \frac{\tan a \pm \tan b}{1 \mp \tan a \tan b}$

$V = \frac{4}{3}\pi r^3$; $A = 4\pi r^2$; $A = \pi r^2$;

$(x - y)(x + y) = x^2 - y^2$

$v_f = v_i + a\,\Delta t$

$x_f = x_i + v_i\,\Delta t + \frac{1}{2} a\,\Delta t^2$

${v_f}^2 = {v_i}^2 + 2\,a\,\Delta x$

$x_f = x_i + \frac{1}{2}(v_f + v_i)\,\Delta t$

$\omega_f = \omega_i + \alpha\,\Delta t$

$\theta_f = \theta_i + \omega_i\,\Delta t + \frac{1}{2}\alpha\,\Delta t^2$

${\omega_f}^2 = {\omega_i}^2 + 2\,\alpha\,\Delta\theta$

$\theta_f = \theta_i + \frac{1}{2}(\omega_f + \omega_i)\,\Delta t$