$$F_E = k_e \frac{q_1 q_2}{r^2} \qquad k_e = \frac{1}{4\pi\varepsilon_0}$$

$$\vec{F} = q\vec{E}$$

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$$

$$dE = \frac{1}{4\pi\varepsilon_0}\frac{dq}{r^2}$$

$$\Phi_E = \oint_{Surface} E_\perp \, dA = \frac{Q_{enclosed}}{\varepsilon_0}$$

$$\Delta U = -q\int_a^b \vec{E}\cdot d\vec{r}$$

$$\Delta V = -\int_a^b \vec{E}\cdot d\vec{r}$$

$$\Delta V = (-)\, E\,\Delta x$$

$$V_{point\ charge} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$$

$$V = \frac{1}{4\pi\varepsilon_0}\int\frac{dq}{r}$$

$$\vec{E} = -\left(\frac{\partial V}{\partial x}\hat{i} + \frac{\partial V}{\partial y}\hat{j} + \frac{\partial V}{\partial z}\hat{k}\right) = -\vec{\nabla}V$$

$$\vec{p} = q\vec{L}$$

$$\vec{\tau}_{Dipole} = \vec{p}\times\vec{E}$$

$$\tau_{Dipole} = p\,E\,\sin\theta_{p,E}\ (RHR)$$

$$U_{Dipole} = -\vec{p}\cdot\vec{E} = -p\,E\,\cos\theta_{p,E}$$

$$Q = CV$$

$$C = \frac{\kappa\varepsilon_o A}{d}$$

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

$$\eta_E = \frac{1}{2}\varepsilon_o E^2$$

$$C_{eq} = C_1 + C_2 \cdots$$

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots$$

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

$$V = IR$$

$$R = \rho\frac{L}{A}$$

$$P = IV = I^2R = \frac{V^2}{R}$$

$$R_{eq} = R_1 + R_2 \cdots$$

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$$

$$\Sigma_n I_n = 0\ ;\ \Sigma_n I_n R_n = \Sigma_n \varepsilon_n$$

$$\vec{r} = \vec{r}_i + \vec{v}_i\, t + \frac{1}{2}\, \vec{a}\, t^2$$
$$\vec{v} = \vec{v}_i + \vec{a}\, t$$
$$v^2 = v_i^2 + 2\, \vec{a} \cdot (\vec{r} - \vec{r}_i\,)$$
$$\vec{F}_{net} = \sum \vec{F}_n = m\vec{a}$$
$$\vec{F}_{grav} = \vec{g}m$$
$$\sum \vec{F}_{EXT} = \frac{d\vec{p}}{dt}$$
$$F_x = -\frac{dU}{dx}$$
$$\sum \vec{\tau} = \frac{d\vec{L}}{dt}$$
$$\sum \vec{\tau} = I\, \vec{\alpha}$$
$$F_G = G\, \frac{m\, M}{r^2}$$
$$F_{f\,K} = \mu_K\, F_N \qquad F_{f\,S} \le \mu_S\, F_N$$
$$F_{Spring} = -\, kx$$
$$W_{NC} = \Delta K + \Delta U$$
$$K = \frac{1}{2} m\, v^2$$
$$U_{Grav} = gmy$$
$$U_{Spring} = \frac{1}{2} kx^2$$
$$U_{Electric} = qV$$
$$\vec{J}_{TOTAL} = \Delta\vec{p}$$
$$\vec{p} = m\vec{v}$$

$$\frac{d\,(e^{-a\,x})}{dx} = -ae^{-a\,x}$$
$$\int e^{-a\,x} = -\frac{e^{-a\,x}}{a}$$
$$\int \frac{dx}{x} = \ln\, x$$
$$\int \frac{dx}{x^2} = -\frac{1}{x}$$
$$\int \frac{dx}{(a^2 + x^2)^{3/2}} = \frac{x}{a^2\, \sqrt{a^2 + x^2}}$$
$$\int \frac{dx}{a^2 + x^2} = \frac{1}{a}\, \arctan(\frac{x}{a})$$
$$\int \frac{dx}{\sqrt{a^2+x^2}} = \ln(2\sqrt{a^2+x^2}+2x)$$
$$\int \frac{x\, dx}{(a^2 + x^2)^{3/2}} = \frac{-1}{\sqrt{a^2 + x^2}}$$
$$\int \frac{x\, dx}{\sqrt{a^2 + x^2}} = \sqrt{a^2 + x^2}$$

$$\vec{C} = \vec{A} \times \vec{B} \Rightarrow C = AB\ \sin\theta_{A,B}\ (RHR)$$

$$\vec{F} = q\ \vec{v} \times \vec{B} \qquad F = qvB\ \sin\theta_{v,B}\ (RHR)$$

$$\vec{F} = L\ \vec{I} \times \vec{B} \qquad F = ILB\ \sin\theta_{I,B}\ (RHR)$$

$$\vec{\mu} = NIA\ (RHR)$$

$$\vec{\tau} = \vec{\mu} \times \vec{B} \qquad \tau = \mu B\ \sin\theta_{\mu,B}\ (RHR)$$

$$U_{Dipole} = -\vec{\mu} \cdot \vec{B} = -\mu B\ \cos\theta_{\mu,B}$$

$$dB = \frac{\mu_0}{4\pi} \frac{dl\ I}{r^2} \sin\theta_{I,\ r}\ (RHR)$$

$$\oint_{Surface} B_{\perp}\ dA = 0$$

$$\oint_{Loop} B_{\parallel}\ dl = \mu_0\ I_{Enclosed}$$

$$B_{Center\ of\ Loop} = \frac{\mu_0\ I}{2R}$$

$$B_{Wire} = \frac{\mu_0\ I}{2\pi R}$$

$$B_{Solenoid} = \mu_0\ nI$$

$$B_{Toroid} = \frac{\mu_0\ NI}{2\pi r}$$

$$\varphi_m = \int B \perp dA$$

$$\mathcal{E} = \oint_{Loop} \vec{E} \cdot d\vec{l} = (-)N \frac{d\varphi_m}{dt}$$

$$\mathcal{E}_L = (-)L\ \frac{dI}{dt}$$

$$\frac{V_P}{V_S} = \frac{N_P}{N_S}$$

$$U_L = \tfrac{1}{2} L I^2$$

$$\eta_B = \frac{B^2}{2\mu_0}$$

$$\tau_C = RC$$

$$Q(t) = CV_o\ e^{-t/RC}$$

$$V_C(t) = V_o\ e^{-t/RC}$$

$$I(t) = \frac{\mathcal{E}}{R}\ e^{-t/RC}$$

------

$$Q(t) = C\mathcal{E}\ (1 - e^{-t/RC})$$

$$V_C(t) = \mathcal{E}\ (1 - e^{-t/RC})$$

$$I(t) = (-)\ \frac{\mathcal{E}}{R}\ e^{-t/RC}$$

---

$$\tau_L = L\ /R$$

$$I(t) = \frac{\mathcal{E}}{R}\ (1 - e^{-Rt/L})$$

------

$$I(t) = \frac{\mathcal{E}}{R}\ e^{-Rt/L}$$

---

$$I_{rms} = \sqrt{(I^2)_{ave}}$$

$$I_{rms} = \frac{I_{\max}}{\sqrt{2}}\ (sinusoidal)$$

$$P_{av} = \tfrac{1}{2}\ \mathcal{E}_{\max}\ I_{\max}\ \cos\varphi$$

$$P_{av} = I^2{}_{rms}\ R = \frac{V_{R\ rms}^2}{R}$$

$$\frac{V_1}{V_2} = \frac{N_1}{N_2}$$

$$\chi_L = \omega L$$

$$\chi_C = \frac{1}{\omega C}$$

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

$$\mathcal{E}_{\max} = I_{\max} Z$$

$$Z = \sqrt{R^2 + (\chi_L - \chi_C)^2}$$

$$\tan \varphi = \frac{\chi_L - \chi_C}{R}$$

$$the\ Q = \frac{\omega_0}{\Delta\omega} = \frac{\omega_0 L}{R}$$

$$\varphi_E = \oint E_\perp \, dA = \frac{Q_{enclosed}}{\varepsilon_o}$$

$$\varphi_M = \oint B_\perp \, dA = 0$$

$$\mathcal{E} = \oint_{Loop} E_\parallel \, dl = -\frac{d\varphi_M}{dt}$$

$$\oint_{Loop} B_\parallel \, dl = \mu_0 I + \mu_0 \varepsilon_0 \frac{d\varphi_E}{dt}$$

$$\frac{\partial^2 \vec{E}}{\partial x^2} = \frac{1}{c^2} \frac{\partial^2 \vec{E}}{\partial t^2}$$

$$\frac{\partial^2 \vec{B}}{\partial x^2} = \frac{1}{c^2} \frac{\partial^2 \vec{B}}{\partial t^2}$$

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$$

$$E = cB$$

$$\eta_{av} = \frac{E_0 \, B_0}{2\mu_0 c}$$

$$P = \frac{F}{A}$$

$$P = P_o + \rho g h$$

$$B = \rho_{Fluid}\, g V_{Displaced}$$

$$Rate = vA = const$$

$$Rate = \frac{(P_1 - P_2)\pi r^4}{8 L \eta}$$

$$P + \tfrac{1}{2}\rho v^2 + \rho g y = const$$

---

$$\Delta L = \alpha L_o \Delta T$$

$$\Delta V = \beta V_o \Delta T$$

$$\beta \approx 3\alpha$$

---

$$\frac{F}{A} = Y \frac{\Delta L}{L_o}$$

$$\frac{F}{A} = S \frac{\Delta x}{h}$$

$$\frac{F}{A} = B \frac{\Delta V}{V_o}$$

---

$$H = \frac{k_{Thermal} A}{L} \Delta T$$

$$H = e \sigma_{SB} A T^4$$

$$\lambda_{Peak} = \frac{0.003}{T}$$

$$T_A = T_B = T_C$$
$$Q = \Delta U + W$$
$$\delta W = PdV$$
$$U_{AVE} = \tfrac{1}{2} k_B T\_(for\_each\_type\_of\_motion)$$
$$Q_P = nc_{MP}\Delta T$$
$$Q_V = nc_{MV}\Delta T$$
$$Q = mL_F ; Q = mL_V$$
$$for\_gases:$$
$$PV = nRT$$
$$c_{MV} + R = c_{MP}$$
$$\gamma = \frac{c_{MP}}{c_{MV}}$$
$$PV = const\_(isothermal)$$
$$PV^{\gamma} = const\_(adiabatic)$$
$$TV^{\gamma - 1} = const\_(adiabatic)$$
$$for\_solids:$$
$$c_{MP} \approx c_{MV}$$
$$-----------$$
$$dS = \frac{\delta Q}{T}$$
$$S = k_B \ln(g)$$