$\vec{F}_{E \text{ on } q_0} = q_0\vec{E}$

$\Delta U = q_0 \Delta V$

$$\vec{E} = \frac{-\partial V}{\partial x}\hat{x} + \frac{-\partial V}{\partial y}\hat{y} + \frac{-\partial V}{\partial z}\hat{z} \qquad \Delta V = -\int_{\vec{r}_a}^{\vec{r}_b} \vec{E} \bullet d\vec{\ell} \qquad \Phi_E = \oint \vec{E} \bullet d\vec{A} = \frac{Q_{enclosed}}{\varepsilon_0}$$

Charge distribution	$\vec{E}$	V
point charge q	$(kq/r^2)\hat{r}$	kq/r
general form	$\int_{charges} k(dq/r^2)\hat{r}$	$\int_{charges} k(dq/r)$
spherical shell: radius R, charge Q	$0,\ r \le R;\quad (kQ/r^2)\hat{r},\ r > R$	$kQ/R,\ r \le R;\quad kQ/r,\ r > R$
line: length L, charge Q distance d from end along line's axis	$\frac{kQ}{d(d+L)}\hat{x}$	$\frac{kQ}{L}\ln\left[\frac{d+L}{d}\right]$
infinite line: charge density λ (r_0 is a reference distance from line)	$\frac{\lambda}{2\pi\varepsilon_0 r}\hat{r}$	$\frac{\lambda}{2\pi\varepsilon_0}\ln\left[\frac{r_0}{r}\right]$
ring: radius R, charge Q (on central axis)	$\frac{kQy}{(R^2+y^2)^{3/2}}\hat{y}$	$\frac{kQ}{(R^2+y^2)^{1/2}}$
disk: radius R, charge Q (on central axis)	$\frac{2kQ}{R^2}\left(1 - \frac{y}{(R^2+y^2)^{1/2}}\right)\hat{y}$	$\frac{2kQ}{R^2}\left((R^2+y^2)^{1/2} - y\right)$
infinite sheet: charge density σ	$\frac{\sigma}{2\varepsilon_0}\hat{n}$	$-\frac{\sigma z}{2\varepsilon_0}$

in dielectric media $\varepsilon_0 \to \varepsilon = \kappa\varepsilon_0$

$$\vec{F}_{B \text{ on } q} = q\vec{v} \times \vec{B} \qquad \vec{F}_{B \text{ on } i} = i\vec{\ell} \times \vec{B} \qquad \vec{B} = \int_{current} d\vec{B} = \int_{current} \frac{\mu_0}{4\pi}\frac{i\,d\vec{\ell} \times \hat{r}}{r^2} \qquad \Phi_B = \oint \vec{B} \bullet d\vec{A} = 0$$

Current arrangement	$\lvert\vec{B}\rvert$
circular loop: radius R, current i_0, (on central axis)	$\frac{\mu_0}{2}\frac{i_0 R^2}{(R^2+y^2)^{3/2}}$
long straight wire: current i_0	$\frac{\mu_0 i_0}{2\pi r}$
solenoid: turn density n, current i_0 (inside only)	$\mu_0 n i_0$

$$\oint \vec{E} \bullet d\vec{\ell} = \Delta V_{emf} = -\frac{d\Phi_B}{dt} \text{ with } \Phi_B = \int \vec{B} \bullet d\vec{A}$$

$$\oint \vec{B} \bullet d\vec{\ell} = \mu_0\left(i_{\text{through}} + \varepsilon_0 \frac{d\Phi_E}{dt}\right) \text{ with } \Phi_E = \int \vec{E} \bullet d\vec{A}$$

*** For multiple loops, multiply fluxes by # of loops.

$$i = \frac{dQ}{dt} = nAev_{drift} \qquad \sum_{m,\text{ loop}} \Delta V_m = 0 \qquad \sum_m i_{in,m} = \sum_k i_{out,k}$$

$$C_{\parallel plate} = \kappa\varepsilon_0 A/d \qquad \Delta V = Q/C \qquad U_C = \tfrac{1}{2}Q\Delta V = \tfrac{1}{2}Q^2/C = \tfrac{1}{2}C\Delta V^2 \qquad \frac{1}{C_{eq,series}} = \sum_m \frac{1}{C_m} \qquad C_{eq,parallel} = \sum_m C_m$$

$$R = \rho L/A \qquad \Delta V = iR \qquad P = \frac{d(\Delta U)}{dt} = i\Delta V = \Delta V^2/R = i^2 R \qquad R_{eq,series} = \sum_m R_m \qquad \frac{1}{R_{eq,parallel}} = \sum_m \frac{1}{R_m}$$

$$L_{solenoid} = \frac{\mu_0 N^2 A}{\ell} \qquad \Delta V = -L\frac{di}{dt} \qquad U_L = \tfrac{1}{2}Li^2 \qquad M = \frac{N_2\Phi_{B2}}{i_1} \qquad \Delta V_2 = -M\frac{di_1}{dt};\ \Delta V_1 = -M\frac{di_2}{dt}$$

$$Q_{RC}(t) = C\Delta V(1 - e^{-t/(RC)}) \qquad i_{RC}(t) = \frac{\Delta V}{R}e^{-t/(RC)} \qquad \tau = RC \qquad Q_{RC}(t) = C\Delta V e^{-t/(RC)} \qquad i_{RC}(t) = \frac{-\Delta V}{R}e^{-t/(RC)}$$

$$i_{LR}(t) = i_{0,LR}(1 - e^{-t/(L/R)}) \qquad i_{LR}(t) = i_{0,LR}e^{-t/(L/R)} \qquad \tau = L/R \qquad i_{0,LR} = \Delta V/R$$

$$Q_{LC}(t) = Q_{\max}\cos(\omega_0 t + \phi) \qquad i_{LC}(t) = -Q_{\max}\omega_0\sin(\omega_0 t + \phi) \qquad \omega_0 = \sqrt{1/(LC)}$$

$$V_{AC}(t) = V_0\sin(\omega t) \qquad V_{rms} = \sqrt{\left\langle V_{AC}^2(t)\right\rangle} = V_0/\sqrt{2} \qquad V_{AC,s}/N_s = V_{AC,p}/N_p \qquad i_{AC,s}N_s = i_{AC,p}N_p$$

$$c=\sqrt{\frac{1}{\mu_0\varepsilon_0}} \qquad v=c/n \qquad \lambda=\lambda_0/n \qquad \left|E_{0,\text{ EM wave}}\right|=v\left|B_{0,\text{ EM wave}}\right| \qquad \vec{S}=\frac{1}{\mu_0}\vec{E}\times\vec{B}$$

$$I=\frac{P}{A}=\langle S\rangle=\frac{E_{rms}B_{rms}}{\mu_0}=\frac{E_0B_0}{2\mu_0}=\frac{vB_0^2}{2\mu_0}=\frac{E_0^2}{2v\mu_0} \qquad P=E_{photon}\left(\frac{dN}{dt}\right)_{photons} \qquad I_{\text{omni.}}=\frac{P_0}{4\pi r^2}$$

$$n_1\sin\theta_1=n_2\sin\theta_2 \qquad \theta_C=\sin^{-1}(n_2/n_1) \qquad \theta_B=\tan^{-1}(n_2/n_1) \qquad I_{\text{after pol.}}=I_0\cos^2\theta$$

$$\Delta\phi_{constr}=m2\pi;\ \ \Delta\phi_{destr}=\left(m+\tfrac{1}{2}\right)2\pi;\ \ m=0,1,2,3,\ldots \quad \text{where}\ \ \phi=2\pi\frac{x}{\lambda}\mp 2\pi\frac{t}{T}+\phi_0$$

$$\sin\theta_{dark\ fringe}=m\frac{\lambda}{w} \quad \sin\theta_R=1.22\frac{\lambda}{D} \quad NA=n\sin\alpha \quad \Delta y_R=d\sin\theta_R=\frac{1.22\lambda d}{D}=\frac{1.22\lambda}{2\sin\alpha}=\frac{0.61\lambda n}{NA}=\frac{0.61\lambda_0}{NA}$$

$$f_{mirror}=\frac{r}{2} \qquad \frac{1}{f_{lens}}=(n-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right) \qquad \frac{1}{d_O}+\frac{1}{d_I}=\frac{1}{f} \qquad m=\frac{h_I}{h_O}=-\frac{d_I}{d_O} \qquad P=\frac{1}{f}$$

$$\frac{1}{\lambda}=R_H\left(\frac{1}{n^2}-\frac{1}{m^2}\right);\ n \text{ and } m \text{ are integers; } m>n \quad r_n=\frac{n^2}{Z}a_0;\ n=1,2,3,\ldots \quad E_n=-\frac{Z^2}{n^2}E_0;\ n=1,2,3,\ldots$$

$$K_{\max}=hf-\Phi_0=eV_{Stop} \qquad \lambda_{deBroglie}=h/p \qquad E_{photon}=hc/\lambda=hf$$

$$\gamma=\frac{1}{\sqrt{1-\frac{V^2}{c^2}}} \qquad \begin{array}{ll} x'=\gamma(x-Vt) & y'=y \\ t'=\gamma\left(t-Vx/c^2\right) & z'=z \end{array} \qquad \ell=\frac{\ell_{proper}}{\gamma} \qquad \Delta t=\gamma\ \Delta t_{proper}$$

Constants and Units

$$k=\frac{1}{4\pi\varepsilon_0}=8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2 \qquad \varepsilon_0=8.85\times10^{-12}\ \text{C}^2/(\text{N}\cdot\text{m}^2) \qquad \mu_0=4\pi\times10^{-7}\ \text{T}\cdot\text{m/A} \qquad e=1.602\times10^{-19}\ \text{C}$$

$$c=3.00\times10^8\ \text{m/s}=300\ \text{m}/\mu\text{s} \qquad N_A=6.02\times10^{23} \qquad h=6.63\times10^{-34}\ \text{J}\cdot\text{s}=4.14\times10^{-15}\ \text{eV}\cdot\text{s} \qquad \hbar=h/(2\pi)$$

$$a_0=\frac{\hbar^2}{m_eke^2}=0.529\times10^{-10}\ \text{m} \qquad E_0=\frac{m_e(ke^2)^2}{2\hbar^2}=13.6\ \text{eV} \qquad R_H=\frac{E_0}{hc}=1.10\times10^7\ \text{m}^{-1} \qquad r_0=1.2\ \text{fm}$$

$$m_p=1.672622\times10^{-27}\ \text{kg}=\ 938.2720\ \text{MeV}/c^2 \qquad m_n=1.674927\times10^{-27}\ \text{kg}=\ 939.5654\ \text{MeV}/c^2$$

$$m_e=9.109382\times10^{-31}\ \text{kg}=\ 0.5109989\ \text{MeV}/c^2$$

1 V/m = 1 N/C   1 V = 1 J/C   1 A = 1 C/s = 1 V/Ω   1 F = 1 C/V   1 W = 1 J/s

1 T = 1 N/(A·m)   1 Wb = 1 V·s = 1 T·m^2 = 1 J/A   1 H = 1 T·m^2/A = 1 Wb/A

1 eV = $(1.602\times10^{-19}$ C)(1 V) = 1.602×10^{-19} J   1 D = 1 m^{-1} 1 u = 1.66×10^{-27} kg = 931.494 MeV / c^2

Integrals that might be of use

$$\int x^n\,dx=\frac{x^{n+1}}{n+1}+C \quad \text{for } n\neq -1 \qquad \int\frac{dx}{x}=\ln[x]+C$$

$$\int\frac{dx}{\sqrt{x^2\pm a^2}}=\ln\left[x+\sqrt{x^2\pm a^2}\right]+C \qquad \int\frac{xdx}{\sqrt{x^2\pm a^2}}=\sqrt{x^2\pm a^2}+C$$

$$\int\frac{dx}{x^2\pm a^2}=\pm\frac{1}{a}\tan^{-1}\left[\frac{x}{a}\right]+C \qquad \int\frac{xdx}{x^2\pm a^2}=\tfrac{1}{2}\ln\left[x^2\pm a^2\right]+C$$

$$\int\frac{dx}{\left(x^2\pm a^2\right)^{3/2}}=\frac{x}{\pm a^2\sqrt{x^2\pm a^2}}+C \qquad \int\frac{xdx}{\left(x^2\pm a^2\right)^{3/2}}=\frac{\pm1}{\sqrt{x^2\pm a^2}}+C$$

SI unit prefixes

giga	G	10^9
mega	M	10^6
kilo	k	10^3
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}