Constants

$k_e = 8.99 \times 10^9 \ \frac{Nm^2}{C^2}$	$e = 1.602 \times 10^{-19} \ C$	$m_p = 1.67 \times 10^{-27} \ kg$	$m_e = 9.11 \times 10^{-31} \ kg$
$\mu_0 = 4\pi \times 10^{-7} \ \frac{Tm}{A}$	$\varepsilon_0 = 8.85 \times 10^{-12} \ \frac{C^2}{Nm^2}$		$k_e = \frac{1}{4\pi\varepsilon_0}$
$milli \ (m) = 10^{-3}$	$micro \ (\mu) = 10^{-6}$	$nano \ (n) = 10^{-9}$	$pico \ (p) = 10^{-12}$

Geometry

$A_{circle} = \pi R^2$	$V_{cylinder} = \pi R^2 h$	$V_{sphere} = \frac{4}{3}\pi R^3$	$A_{sphere} = 4\pi R^2$

Vectors

$\lvert\vec{A} \times \vec{B}\rvert = AB\sin(\theta)$	$\vec{A} \cdot \vec{B} = AB\cos(\theta)$	$\vec{A} \cdot \vec{B} = A_x B_x + A_y B_y + A_z B_z$

$$\vec{A} \times \vec{B} = (A_y B_z - A_z B_y)\hat{\imath} + (A_z B_x - A_x B_z)\hat{\jmath} + (A_x B_y - A_y B_x)\hat{k}$$

Integrals

$\int \frac{xdx}{\sqrt{x^2+y^2}} = \sqrt{x^2+y^2}$	$\int \frac{dx}{(x^2+y^2)^{3/2}} = \frac{x}{y^2\sqrt{x^2+y^2}}$	$\int \frac{xdx}{(x^2+y^2)^{3/2}} = -\frac{1}{\sqrt{x^2+y^2}}$

$$\int \frac{dx}{\sqrt{x^2+y^2}} = \ln\left(x + \sqrt{x^2+y^2}\right)$$

Electrostatics and Magnetostatics

$\vec{F}_e = \frac{k_e Q q}{r^2}\hat{r}$	$\vec{E} = \frac{k_e Q}{r^2}\hat{r}$	$U = \frac{k_e Q q}{r}$
$V = \frac{k_e Q}{r}$	$\vec{F}_e = q\vec{E}$	$\vec{E} = -\nabla V$
$\Delta V_{A\to B} = -\int_A^B \vec{E} \cdot d\vec{l}$	$\Delta U = q\Delta V$	$\vec{E}_{axis} = \frac{2k_e r}{\left(r-\frac{s}{2}\right)^2\left(r+\frac{s}{2}\right)^2}\vec{p} \approx \frac{2k_e\vec{p}}{r^3}$
$\vec{E}_{\perp} = \frac{-k_e}{\left[r^2+\left(\frac{s}{2}\right)^2\right]^{3/2}}\vec{p} \approx -\frac{k_e}{r^3}\vec{p}$	$\lvert\vec{p}\rvert = qs$ ($-$ to $+$)	
$E_{plane} = \frac{\eta}{2\varepsilon_0}$	$E_{capacitor} = \frac{\eta}{\varepsilon_0}$	$E_{\infty line} = \frac{2k_e\lvert\lambda\rvert}{r}$
$\lvert E_{ring_z}\rvert = \frac{k_e z Q}{(z^2+R^2)^{3/2}}$	$\lvert E_{disk_z}\rvert = \frac{\eta}{2\varepsilon_0}\left[1 - \frac{z}{\sqrt{R^2+z^2}}\right]$	$E_{insSphere} = \frac{k_e Q}{R^3}r, r < R$
$\Delta V_{\infty line} = 2k_e\lambda\ln\left\lvert\frac{r_A}{r_B}\right\rvert$	$V_{ring_z} = \frac{k_e Q}{\sqrt{R^2+z^2}}$	$V_{disk_z} = \frac{k_e Q}{R}\left[\sqrt{R^2+z^2} - \lvert z\rvert\right]$
Inside C: $\Delta V = 0$	$V_{inside} = \frac{k_e Q}{R}$ (C sphere)	$V_{inside} = \frac{k_e Q}{2R}\left[3 - \frac{r_A^2}{R^2}\right]$ (I sphere)
$\vec{E}_{ins} = \frac{\vec{E}_{app}}{\kappa}$	$\Delta V_{ins} = \frac{\Delta V_{vac}}{\kappa}$	$\kappa =$ dielectric constant
$\frac{\Delta U}{\Delta Volume} = \frac{1}{2}\varepsilon_0 E^2$	$E = \frac{\eta}{\varepsilon_0}$	Energy density - Capacitor

$d\vec{B} = \frac{\mu_0}{4\pi}\frac{Id\vec{s}\times\hat{r}}{r^2}$	$\vec{B} = \frac{\mu_0}{4\pi}\frac{q\vec{v}\times\hat{r}}{r^2}$	$B_{\infty wire} = \frac{\mu_0 I}{2\pi d}$
$B_{loop\ axis} = \frac{\mu_0 I R^2}{2(R^2+z^2)^{3/2}}$	$B_{solenoid} = \frac{\mu_0 NI}{L}$	$B_{wire} = \frac{\mu_0 IL}{2\pi d\sqrt{L^2+d^2}}$
$\vec{B}_{loopaxis} = \frac{\mu_0}{4\pi}\frac{2\vec{\mu}}{r^3}$	$\vec{\mu} = I\vec{A}$	$\hat{A} = \hat{B}_{loopaxis}$
$\mu_{electron} = \frac{ev}{2\pi R}\pi R^2 = \frac{1}{2}eRv$	$L_{electron} = Rmv$	$\mu_{electron} = \frac{1}{2}\frac{e}{m}L$
	Magnetic Force & Flux	
$\vec{F}_B = q\vec{v}\times\vec{B}$	$R = \frac{mv\sin(\phi)}{qB}$	$T = \frac{2\pi m}{qB}$
Relativistic: $\left\lvert\frac{d\vec{p}}{dt}\right\rvert = \lvert q\rvert vB\sin(\phi)$	$\omega = \frac{\lvert q\rvert B}{\gamma m}$	$T = \frac{2\pi m\gamma}{\lvert q\rvert B}$
$\vec{F}_{Lor} = q(\vec{E}+\vec{v}\times\vec{B})$	Cyclo: $E_K = \Delta VqN$	
$\vec{F}_{wire} = \int Id\vec{L}\times\vec{B}$	$\vec{F}_{straight} = I\vec{L}\times\vec{B}$	
Hall:	$V_H = wv_dB = \frac{IB}{dne}$	$I = v_dAne = v_dwdne$
EMF: $\Delta V = \epsilon = vLB$	$F_B = ILB = \frac{\Delta V}{R}LB = \frac{(LB)^2v}{R}$	$P = Fv = \frac{(LBv)^2}{R} = \frac{\Delta V^2}{R} = I\Delta V$
$\Phi_B = \oiint \vec{B}\cdot d\vec{A}$	$\Phi_{B,flat} = \vec{B}\cdot\vec{A}$	Unit: $1\ Wb = 1\ Tm^2$
Law of Induction:	$\epsilon = -N\frac{d\Phi_B}{dt}$	$E = -\frac{dB}{dt}\frac{r}{2}$
Torque:	$\vec{\tau} = \vec{\mu}\times\vec{B}$	$\vec{\mu} = I\vec{A}$
$\Delta U_m = \int_{\theta_i}^{\theta_f}\tau d\theta = \int_{\theta_i}^{\theta_f}\mu B\sin(\theta)d\theta$	$\Delta U_m = -\mu B\cos(\theta)\rvert_{\theta_i}^{\theta_f}$	$U_m = -\vec{\mu}\cdot\vec{B}$
$\overline{v} = uE_{net}$	$u = \frac{e}{m_e}\overline{\Delta t}$	$\vec{p} = \alpha\vec{E}$
$i_e = n_eAv_d = n_eA\frac{e\tau}{m}E$	$v_d = \overline{v_{xi}} + \frac{eE}{m}\overline{\Delta t} = \frac{e\tau}{m}E$	$i_e = \frac{N_e}{\Delta t}$
$n_e = \mathrm{e}^-$ density	$N_e =$ total # of e^-s	$I = \lvert q\rvert nAv_d$
$\lvert q\rvert =$ magnitude of single charge	$n =$ density of charges	$A =$ cross-sectional area
$\lambda = \frac{Q}{L}$	$\eta = \frac{Q}{A}$	$\rho = \frac{Q}{V}$

Maxwell's Equations		
$\Phi_E = \int\int \vec{E}\cdot d\vec{A}$		
Gauss' Law:	$\varepsilon_0 \oiint \vec{E}\cdot d\vec{A} = q_{enc}$	
Gauss' Law, Mag:	$\oiint \vec{B}\cdot d\vec{A} = 0$	
Ampere's Law:	$\oint \vec{B}\cdot d\vec{r} = \mu_0 I_{enc}$	only steady currents

$\nabla \cdot \vec{E} = \frac{\rho}{\varepsilon_0}$	$\nabla^2 V = \Delta V = -\frac{\rho}{\varepsilon_0}$	$\nabla \times \vec{B} = \mu_o \vec{J}$
$\oint \vec{B} \cdot d\vec{r} = \mu_0 i_{enc} + \mu_o \varepsilon_0 \frac{d\Phi_E}{dt}$	$\oint \vec{E} \cdot d\vec{s} = emf = -N\frac{d\Phi_B}{dt}$	$N = 1$ if free space

Remark 0.1. If $\vec{E}$ and $d\vec{A}$ are either parallel, perpendicular, or constant, one can use Gauss' Law to determine $\vec{E}$. If similar conditions apply to $\vec{B}$ and $d\vec{r}$ we can determine $\vec{B}$ by Ampere's Law.

Circuits		
$\sum I_{in} = \sum I_{out}$	$\sum\limits_{loop} \Delta V = 0$	
$\lvert\Delta V_{battery}\rvert = E_C s = \frac{F_{NC} s}{e}$	$\lvert\Delta V_{resistor}\rvert = EL$	$i = nA\overline{v} = nAuE$
$i(t) = \frac{dq}{dt}$	$q = \int\limits_0^t i(t)dt$	$i = \int \vec{J} \cdot d\vec{A}$
$q_{tot} = (nAL)e$	$i = q/t = (nAL)e/(L/v_d) = nAev_d$	
For uniform current:	$i = JA$	$\lvert\vec{J}\rvert = (ne)\lvert\vec{v}_d\rvert$
$n = density \times \frac{N_A z}{Molar\ Mass}$		
$R = \frac{V}{i}$	$\rho = \frac{E}{J}$	$\sigma = \frac{1}{\rho}$
$R = \rho\frac{L}{A}$	$\rho = \frac{m}{e^2 n\tau}$	$\rho = \rho_0(1 + \alpha(T - T_0))$
$\frac{dU}{dt} = P = iV$		
$R_{eq,s} = \sum\limits_{i=1}^{n} R_i$	$\frac{1}{R_{eq,p}} = \sum\limits_{i=1}^{n} \frac{1}{R_i}$	

Capacitors and Resistors		
$q = C\Delta V$		a inner, b outer:
$C_{plate} = \frac{\varepsilon_0 A}{d}$	$C_{cylinder} = \frac{2\pi L\varepsilon_0}{\ln\left\lvert\frac{b}{a}\right\rvert}$	$C_{sphere} = \frac{4\pi\varepsilon_0}{\frac{1}{a} - \frac{1}{b}}$
$\frac{1}{C_{eq,s}} = \sum\limits_{i=1}^{n} \frac{1}{C_i}$	$C_{eq,p} = \sum\limits_{i=1}^{n} C_i$	
External: $U = \frac{q^2}{2C} = \frac{1}{2}CV^2$	Density: $u = \frac{U}{Ad} = \frac{CV^2}{2Ad}$	

Charging:	$q(t) = \varepsilon C\left(1 - e^{-t/RC}\right)$	$V_C(t) = \varepsilon\left(1 - e^{-t/RC}\right)$
Discharging:	$q(t) = \varepsilon C e^{-t/RC}$	$V_C(t) = \varepsilon e^{-t/RC}$

Inductors		
$L = \frac{N\Phi_B}{i}$	$L = \mu_0 n^2 l A$	$n = N/l$
$\varepsilon_L = -N\frac{d\Phi_B}{dt} = -L\frac{di}{dt}$		
$\frac{dU_B}{dt} = Li\frac{di}{dt}$	$U_B = \frac{1}{2}Li^2$	$u_B = \frac{U_B}{Al} = \frac{Li^2}{2lA} = \frac{1}{2}\mu_0 n^2 i^2$
Solenoid:	$B = \mu_0 in$	$u_B = \frac{B^2}{2\mu_0}$
	LC Circuit	
$q(t) = Q_0\cos(\omega t + \phi_0)$	$i(t) = i_{max}\sin(\omega t + \phi_0)$	
$\omega = \frac{1}{\sqrt{LC}}$	$\phi_0 = 0, q(0) = Q_0$	$i_{max} = Q_0\omega$
	RLC Circuit	
$i(t) = i_0\sin(\omega t + \phi_0)$	$\omega = \frac{1}{\sqrt{LC}}$	
$V_R(t) = Ri(t)$	$V_L = -Li_0\omega\cos(\omega t + \phi_0)$	$V_C = \frac{i_0}{\omega}\cos(\omega t + \phi_0)$

Definition 0.2 (Accelerated Charges)**.** If a charge q is accelerated briefly by $\vec{a}$, then at an angle θ around the particle relative to the acceleration vector, we have electric radiation of

$$\vec{E}_{rad} = k_e\frac{-q\vec{a}_\perp}{c^2 r} \tag{0.1}$$

where $a_\perp = a\sin(\theta)$ and points in the direction $\vec{a} - proj_{\vec{r}}(\vec{a})$ (making a right triangle with one angle equal to θ).