SP212 Equation Sheet, page 1 . *(draft, December 31, 2012)*

Prefixes: 10^3 kilo k , 10^6 mega M , 10^9 giga G , 10^{12} tera T , 10^{15} peta P ,
10^{-3} milli m , 10^{-6} micro μ , 10^{-9} nano n , 10^{-12} pico p , 10^{-15} femto f .

Constants: $\epsilon_0 = 8.85\times10^{-12}\ \mathrm{C^2/N{\cdot}m^2}$, $\dfrac{1}{4\pi\epsilon_0} = k = 8.99\times10^{9}\ \mathrm{N{\cdot}m^2/C^2}$, $e = 1.602\times10^{-19}$ C ,
$m_e = 9.109\times10^{-31}$ kg , $m_p = 1.673\times10^{-27}$ kg , $\mu_0 = 4\pi\times10^{-7}\ \mathrm{T{\cdot}m/A} \approx 1.26\times10^{-6}\ \mathrm{T{\cdot}m/A}$,
$c = 3.00\times10^{8}$ m/s , 1 eV $= 1.602\times10^{-19}$ J .

Electric Charge: $i = \dfrac{dq}{dt}$, $F = \dfrac{1}{4\pi\epsilon_0}\dfrac{|q_1||q_2|}{r^2}$, $q = ne$, $n = \pm1, \pm2, \pm3, ...$.

Electric Fields: $\vec{E} = \dfrac{\vec{F}}{q_0}$, $\vec{E} = \dfrac{1}{4\pi\epsilon_0}\dfrac{q}{r^2}\,\hat{r}$, $\vec{p} = q\vec{d}$, $\vec{E}(z) = \dfrac{1}{2\pi\epsilon_0}\dfrac{\vec{p}}{z^3}$, $d\vec{E}(z) = \dfrac{1}{4\pi\epsilon_0}\dfrac{dq}{r^2}\,\hat{r}$,
$dq = \lambda ds$, $dq = \sigma dA$, $dq = \rho dV$, $\vec{F} = q\vec{E}$, $\vec{\tau} = \vec{p}\times\vec{E}$, $U = -\vec{p}\cdot\vec{E}$.

Gauss' Law: $\Phi_E = \int \vec{E}\cdot d\vec{A}$, $\oint \vec{E}\cdot d\vec{A} = \dfrac{q_{\rm enc}}{\epsilon_0}$, $E = \dfrac{\sigma}{\epsilon_0}$, $E = \dfrac{\lambda}{2\pi\epsilon_0 r}$, $E = \dfrac{\sigma}{2\epsilon_0}$, $E = \dfrac{1}{4\pi\epsilon_0}\dfrac{q}{r^2}$.

Electric Potential: $\Delta V = \dfrac{\Delta U}{q}$, $V_f - V_i = -\displaystyle\int_i^f \vec{E}\cdot d\vec{s}$, $V = \displaystyle\sum_{i=1}^{n} V_i = \dfrac{1}{4\pi\epsilon_0}\sum_{i=1}^{n}\dfrac{q_i}{r_i}$, $V = \dfrac{1}{4\pi\epsilon_0}\dfrac{p\cos(\theta)}{r^2}$,
$V = \dfrac{1}{4\pi\epsilon_0}\displaystyle\int\dfrac{dq}{r}$, $E_s = -\dfrac{\partial V}{\partial s}$, $E_x = -\dfrac{\partial V}{\partial x}$, $E_y = -\dfrac{\partial V}{\partial y}$, $E_z = -\dfrac{\partial V}{\partial z}$, $U = \dfrac{1}{4\pi\epsilon_0}\dfrac{q_1 q_2}{r}$.

Capacitance: $q = CV$, $C = \dfrac{\kappa\epsilon_0 A}{d}$, $C_{\rm eq} = \displaystyle\sum_{j=1}^{n} C_j$ (parallel) , $\dfrac{1}{C_{\rm eq}} = \displaystyle\sum_{j=1}^{n}\dfrac{1}{C_j}$ (series) ,
$U = \dfrac{q^2}{2C} = \dfrac{1}{2}CV^2$, $u = \dfrac{1}{2}\epsilon_0 E^2$.

Current and Resistance: $i = \dfrac{dq}{dt}$, $i = \displaystyle\int \vec{J}\cdot d\vec{A}$, $i = nAev_d$, $\vec{J} = (ne)\vec{v}_d$, $R = \dfrac{V}{i}$, $\vec{E} = \rho\vec{J}$,
$R = \rho\dfrac{L}{A}$, $\rho - \rho_0 = \rho_0\alpha(T - T_0)$, $P = iV = i^2R = \dfrac{V^2}{R}$.

Circuits: $\mathscr{E} = \dfrac{dW}{dq}$, $i = \dfrac{\mathscr{E}}{R + r}$, $P = iV$, $P_r = i^2 r$, $P_{\rm emf} = i\mathscr{E}$, $R_{\rm eq} = \displaystyle\sum_{j=1}^{n} R_j$ (series) ,
$\dfrac{1}{R_{\rm eq}} = \displaystyle\sum_{j=1}^{n}\dfrac{1}{R_j}$ (parallel) , $q = C\mathscr{E}\left(1 - e^{-t/RC}\right)$, $C\mathscr{E} = q_0$, $RC = \tau$, $i = \dfrac{dq}{dt} = \left(\dfrac{\mathscr{E}}{R}\right)e^{-t/RC}$,
$V_C = \mathscr{E}\left(1 - e^{-t/RC}\right)$, $q = q_0 e^{-t/RC}$, $i = \dfrac{dq}{dt} = -\left(\dfrac{q_0}{RC}\right)e^{-t/RC}$.

SP212 Equation Sheet, page 2 . *(draft, December 30, 2012)*

Magnetic Fields: $\vec{F}_B = q\vec{v}\times\vec{B}$, $F_B = |q|vB\sin(\phi)$, $|q|vB = \frac{mv^2}{r}$, $\omega = \frac{2\pi}{T} = 2\pi f = \frac{|q|B}{m}$,
$\vec{F}_B = i\vec{L}\times\vec{B}$, $d\vec{F}_B = id\vec{L}\times\vec{B}$, $\vec{\mu} = Ni\vec{A}$, $\vec{\tau} = \vec{\mu}\times\vec{B}$, $U = -\vec{\mu}\cdot\vec{B}$.

Magnetic Fields Due to Currents: $d\vec{B} = \frac{\mu_0}{4\pi}\frac{id\vec{s}\times\hat{r}}{r^2}$, $B = \frac{\mu_0 i}{2\pi R}$, $B = \frac{\mu_0 i\phi}{4\pi R}$, $F_{ba} = \frac{\mu_0 L i_a i_b}{2\pi d}$,
$\oint \vec{B}\cdot d\vec{s} = \mu_0 i_{\text{enc}}$, $B = \mu_0 i n$, $n = N/L$, $B = \frac{\mu_0 i N}{2\pi}\frac{1}{r}$, $B = \frac{\mu_0 i R^2}{2(R^2+z^2)^{3/2}}$, $\vec{B}(z) = \frac{\mu_0}{2\pi}\frac{\vec{\mu}}{z^3}$.

Induction and Inductance: $\Phi_B = \int \vec{B}\cdot d\vec{A}$, $\mathscr{E} = -\frac{d\Phi_B}{dt}$, $\mathscr{E} = -N\frac{d\Phi_B}{dt}$, $\mathscr{E} = BLv$, $\mathscr{E} = \oint \vec{E}\cdot d\vec{s}$,
$\oint \vec{E}\cdot d\vec{s} = -\frac{d\Phi_B}{dt}$, $L = \frac{N\Phi_B}{i}$, $\frac{L}{l} = \mu_0 n^2 A$, $\mathscr{E}_L = -L\frac{di}{dt}$, $i = \frac{\mathscr{E}}{R}\left(1 - e^{-t/\tau_L}\right)$, $\tau_L = L/R$,
$i = i_0 e^{-t/\tau_L}$, $U_B = \frac{1}{2}Li^2$, $u_B = \frac{B^2}{2\mu_0}$, $M_{21} = \frac{N_2\Phi_{21}}{i_1}$, $M_{21} = M_{12} = M$, $\mathscr{E}_2 = -M\frac{di_1}{dt}$, $\mathscr{E}_1 = -M\frac{di_2}{dt}$.

Electromagnetic Oscillations: $L\frac{d^2q}{dt^2} + \frac{1}{C}q = 0$, $q = Q\cos(\omega t + \phi)$, $\omega = \frac{1}{\sqrt{LC}}$,
$i = \omega Q\sin(\omega t + \phi)$, $L\frac{d^2q}{dt^2} + R\frac{dq}{dt} + \frac{1}{C}q = 0$, $q = Qe^{-Rt/2L}\cos(\omega' t + \phi)$, $\omega' = \sqrt{\omega^2 - \left(\frac{R}{2L}\right)^2}$.

Maxwell's Equations: $\oint \vec{E}\cdot d\vec{A} = \frac{q_{\text{enc}}}{\epsilon_0}$, $\oint \vec{B}\cdot d\vec{A} = 0$, $\oint \vec{E}\cdot d\vec{s} = -\frac{d\Phi_B}{dt}$, $\oint \vec{B}\cdot d\vec{s} = \mu_0\epsilon_0\frac{d\Phi_E}{dt} + \mu_0 i_{\text{enc}}$,
$i_d = \epsilon_0\frac{d\Phi_E}{dt}$, $\oint \vec{B}\cdot d\vec{s} = \mu_0 i_{d,\text{enc}} + \mu_0 i_{\text{enc}}$.

Electromagnetic Waves: $E = E_m\sin(kx - \omega t)$, $B = B_m\sin(kx - \omega t)$, $c = \frac{E}{B} = \frac{1}{\sqrt{\mu_0\epsilon_0}}$, $\vec{S} = \frac{1}{\mu_0}\vec{E}\times\vec{B}$,
$S_{\text{ave}} = I = \frac{1}{c\mu_0}E_{\text{rms}}^2$, $E_{\text{rms}} = \frac{E_m}{\sqrt{2}}$, $I = \frac{P_S}{4\pi r^2}$, $p_r = \frac{I}{c}$, $p_r = \frac{2I}{c}$, $I = \frac{1}{2}I_0$, $I = I_0\cos^2\theta$,
$n_2\sin(\theta_2) = n_1\sin(\theta_1)$, $\theta_c = \sin^{-1}\frac{n_2}{n_1}$, $\theta_{\text{B}} = \tan^{-1}\frac{n_2}{n_1}$.

Images: $\frac{1}{p} + \frac{1}{i} = \frac{1}{f} = \frac{2}{r}$, $\frac{n_1}{p} + \frac{n_2}{i} = \frac{n_2 - n_1}{r}$, $\frac{1}{p} + \frac{1}{i} = \frac{1}{f} = (n-1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$, $m = -\frac{i}{p}$, $|m| = \frac{h'}{h}$.

Interference: $\lambda_n = \frac{\lambda}{n}$, $d\sin\theta = m\lambda$, $m = 0,1,2,....$, $d\sin\theta = \left(m + \frac{1}{2}\right)\lambda$, $m = 0,1,2,....$,
$I = 4I_0\cos^2\left(\frac{1}{2}\phi\right)$, $\phi = \frac{2\pi d}{\lambda}\sin\theta$, $2L = \left(m + \frac{1}{2}\right)\frac{\lambda}{n_2}$, $m = 0,1,2,....$, $2L = m\frac{\lambda}{n_2}$, $m = 0,1,2,....$.

Diffraction: $a\sin(\theta) = m\lambda$, $m = 1,2,3,....$, $I(\theta) = I_m\left(\frac{sin\alpha}{\alpha}\right)^2$, $\alpha = \frac{\pi a}{\lambda}\sin\theta$, $\sin\theta = 1.22\frac{\lambda}{d}$,
$\theta_{\text{R}} = 1.22\frac{\lambda}{d}$, $I(\theta) = I_m(\cos^2\beta)\left(\frac{sin\alpha}{\alpha}\right)^2$, $\beta = \frac{\pi d}{\lambda}\sin\theta$, $d\sin\theta = m\lambda$, $m = 0,1,2,....$.