Constants: $e = 1.6 \times 10^{-19}$ C $\quad m_p = 1.67 \times 10^{-27}$ kg $\quad m_e = 9.1 \times 10^{-31} kg \quad c = 3 \times 10^8 m/s \quad$ micro $= 10^{-6}$

$\epsilon_o = 8.85 \times 10^{-12} C^2/N \cdot m^2 \qquad k = 1/(4\pi\epsilon_o) = 9 \times 10^9\, N \cdot m^2/C^2 \qquad \mu_o = 4\pi \times 10^{-7} T \cdot m/A \qquad$ nano $= 10^{-9}$

Coulomb's Law: $|\vec{F}| = \frac{|q_1||q_2|}{4\pi\epsilon_o r^2}$ (point charge)

Electric field: $\vec{E} = \frac{\vec{F}}{q} \qquad \vec{E} = \frac{q}{4\pi\epsilon_o r^2}\hat{r}$ (point charge) $\qquad \vec{E} = \int \frac{dq}{4\pi\epsilon_o r^2}\hat{r}$ (general) $\qquad E = \frac{\sigma}{2\epsilon_o}$ (plane)

Gauss' law: $\Phi = \hat{n} \cdot \vec{E}\, A = \oint \hat{n} \cdot \vec{E}\, dA = \frac{q_{enc}}{\epsilon_o}$

Energy: $W = \int \vec{F} \cdot d\vec{s} = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = K_f - K_i$

For conservative forces $U_f - U_i = -\int \vec{F} \cdot d\vec{s} \rightarrow K_i + U_i = K_f + U_f$

Electric potential: $V = \frac{U}{q} \qquad V = \frac{q}{4\pi\epsilon_o r}$ (point charge) $\qquad V = \int \frac{dq}{4\pi\epsilon_o r}$ (general)

$V_b - V_a = -\int_a^b E_x dx = -\int_a^b \vec{E} \cdot d\vec{s} \qquad E_x = -\frac{\partial V}{\partial x}, \qquad E_y = -\frac{\partial V}{\partial y}, \qquad E_z = -\frac{\partial V}{\partial z}$

Capacitors: $q = CV \qquad C = \frac{K\epsilon_o A}{d}$ (parallel-plate) $\qquad C = C_1 + C_2$ (parallel)

$U = \frac{q^2}{2C} \qquad u = \frac{1}{2}\epsilon_o E^2 \qquad \frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$ (series)

Resistors: $i = \frac{dq}{dt} = jA \qquad R = \frac{V}{i} \qquad R = \frac{\rho L}{A}$ (wire) $\qquad P = iV \qquad R = R_1 + R_2$ (series)

$q = CV(1 - e^{-t/RC})$ (charging) $\qquad q = q_o e^{-t/RC}$ (discharging) $\qquad \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$ (parallel)

Magnetism: $\vec{F} = q\vec{v} \times \vec{B} \qquad \vec{F} = i\vec{L} \times \vec{B} \qquad \mu = NiA \qquad \vec{\tau} = \vec{\mu} \times \vec{B} \qquad U = -\vec{\mu} \cdot \vec{B} \qquad \frac{F}{l} = \frac{\mu_o i_1 i_2}{2\pi r}$

$d\vec{B} = \frac{\mu_o}{4\pi}\frac{i d\vec{s} \times \hat{r}}{r^2} \qquad \oint \vec{B} \cdot d\vec{s} = \mu_o i_{enc} \qquad B = \frac{\mu_o i}{2\pi R}$, (wire) $\frac{\mu_o i}{2R}$ (loop center), $\frac{\mu_o i N}{L}$ (solenoid)

Induction: $\Phi_B = \hat{n} \cdot \vec{B}\, A = \oint \hat{n} \cdot \vec{B}\, dA \qquad \mathcal{E} = \oint \vec{E} \cdot d\vec{s} = -\frac{d\Phi_B}{dt}$

$L = N\Phi_B/i$ (definition) $\qquad L = \mu_o n^2 Al$ (solenoid) $\qquad \mathcal{E} = -L\frac{di}{dt} \qquad \mathcal{E}_1 = -M\frac{di_2}{dt} \qquad L = L_1 + L_2$ (series)

$U_B = \frac{1}{2}Li^2 \qquad u_B = \frac{B^2}{2\mu_o} \qquad i = i_o e^{-t/\tau_L} \qquad \tau_L = L/R \qquad \frac{V_s}{V_p} = \frac{N_s}{N_p} \qquad \frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2}$ (parallel)

AC Circuits: $\omega = \frac{1}{\sqrt{LC}}$ (LC circuit) $\qquad \mathcal{E} = \mathcal{E}_m \sin(\omega t) \qquad i = I\sin(\omega t - \phi)$ (driven RLC) $\quad P_{avg} = \frac{1}{2}I\mathcal{E}_m \cos\phi$

$\tan\phi = \frac{X_L - X_C}{R} \qquad I = \frac{\mathcal{E}_m}{Z} \qquad Z = \sqrt{R^2 + (X_L - X_C)^2} \qquad X_L = \omega L, \quad X_C = \frac{1}{\omega C}, \quad v_L = L\frac{di}{dt}, \quad v_C = \frac{q}{C}$

$q = Q_o e^{-Rt/(2L)}\cos(\omega' t + \phi) \qquad \omega' = \left(\omega^2 - (R/(2L))^2\right)^{1/2}$

Last 2 Maxwell's Eqs.: $\oint \vec{B} \cdot \hat{n} dA = 0 \qquad \oint \vec{B} \cdot d\vec{s} = \mu_o\epsilon_o\frac{d\Phi_E}{dt} + \mu_o i_{enc} \qquad i_d = \epsilon_o\frac{d\Phi_E}{dt}$

EM Waves: $c = \frac{E}{B} = \frac{1}{\sqrt{\mu_o \epsilon_o}}$ $\vec{S} = \frac{1}{\mu_o}\vec{E} \times \vec{B}$ $I = S_{avg} = \frac{1}{c\mu_o}E_{rms}^2$ $E_{rms} = \frac{E_m}{\sqrt{2}}$ $I = \frac{P_s}{4\pi r^2}$

$I = I_o \cos^2\theta$ $n_1 \sin\theta_1 = n_2 \sin\theta_2$ $\theta_c = \sin^{-1}\frac{n_2}{n_1}$ $\theta_B = \tan^{-1}\frac{n_2}{n_1}$ $p_r = \frac{I}{c}$ (absorp.), $\frac{2I}{c}$ (refl.)

$\vec{E} = \vec{E}_m \sin(\vec{k}\cdot\vec{r} - \omega t)$ $\vec{B} = \vec{B}_m \sin(\vec{k}\cdot\vec{r} - \omega t)$ $\vec{E}_m \perp \vec{B}_m \perp \vec{k}$ $c = \omega/k = f\lambda$

Images: $\frac{1}{p} + \frac{1}{i} = \frac{1}{f} = \frac{2}{r}$ $\frac{n_1}{p} + \frac{n_2}{i} = \frac{n_2 - n_1}{r}$ $\frac{1}{p} + \frac{1}{i} = \frac{1}{f} = (n-1)(\frac{1}{r_1} - \frac{1}{r_2})$ $m = -\frac{i}{p}$

Interference: $\Delta L = m\lambda_n$ (constructive) $\Delta L = (m + \frac{1}{2})\lambda_n$ (destructive) $\lambda_n = \lambda/n$ $n = 1$ in air

$\Delta L = d\sin(\theta)$ (2-slit), $2L_1 - 2L_2$ (interferometer), $2t$ (thin film) with extra $\lambda/2$ when reflecting off higher index

Diffraction: $d\sin(\theta) = m\lambda$ (grating) $2d\sin(\theta) = m\lambda$ (X-ray) $\sin\theta = 1.22\lambda/d$ (aperture)