**Constants:**

$$k_e \equiv 1/4\pi\epsilon_o = 8.98755 \times 10^9\ \mathrm{N \cdot m^2 \cdot C^{-2}}$$
$$\epsilon_o = 8.85 \times 10^{-12}\ \mathrm{C^2/N \cdot m^2}$$
$$\mu_o \equiv 4\pi \times 10^{-7}\ \mathrm{T \cdot m/A}$$
$$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}} = 2.99792 \times 10^8\ \mathrm{m/s}$$
$$e = 1.60218 \times 10^{-19}\ \mathrm{C}$$
$$m_e = 9.10938 \times 10^{-31}\ \mathrm{kg}$$

**Basic Equations:**

$$\vec{F}_{net} = \frac{d\vec{p}}{dt} = m\vec{a} \qquad \text{Newton's Second Law}$$
$$\vec{F}_{centr} = -\frac{mv^2}{r}\hat{r} \qquad \text{Centripetal}$$
$$0 = ax^2 + bx^2 + c \Longrightarrow x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$
$$|\vec{F}| = \sqrt{F_x^2 + F_y^2} \quad \text{magnitude} \qquad \theta = \tan^{-1}\left[\frac{F_y}{F_x}\right] \quad \text{direction}$$

**Magnetism**

$$|\vec{F}_B| = q|\vec{v}||\vec{B}|\sin\theta_{vB}$$
$$|\vec{F}_B| = BIl\sin\theta \quad \text{wire}$$
$$\vec{B} = \frac{\mu_0 I}{2\pi r}\hat{\theta} \quad \text{wire}$$
$$\vec{B} = \frac{\mu_0 I}{2r}\hat{\theta} \quad \text{loop}$$
$$\vec{B} = \mu_0 \frac{N}{L} I\hat{z} \equiv \mu_0 n I \hat{z} \quad \text{solenoid}$$
$$\frac{|\vec{F}_{12}|}{l} = \frac{\mu_0 I_1 I_2}{2\pi d} \quad \text{2 wires, force per length}$$

**Current/resistors/circuits:**

$$I = \frac{\Delta Q}{\Delta t} = nqAv_d$$
$$J = \frac{I}{A} = nqv_d$$
$$v_d = \frac{e\tau}{m}E \qquad \tau = \text{scattering time}$$
$$\rho = \frac{m}{ne^2\tau}$$
$$\Delta V = \frac{\rho l}{A} I = RI$$
$$R = \frac{\Delta V}{I} = \frac{\rho l}{A}$$
$$\mathscr{P} = E \cdot \Delta t = I\Delta V = I^2 R = \frac{[\Delta V]^2}{R} \quad \text{power}$$
$$R_{\text{eq, series}} = R_1 + R_2$$
$$\frac{1}{R_{\text{eq, par}}} = \frac{1}{R_1} + \frac{1}{R_2}$$
$$X_C = \frac{1}{2\pi f C} \qquad \text{"resistance" of a capacitor for ac}$$
$$X_L = 2\pi f L \qquad \text{"resistance" of an inductor for ac}$$

**Induction:**

$$\Phi_B = B_\perp A = BA\cos\theta_{BA}$$
$$\Delta V = -N\frac{\Delta\Phi_B}{\Delta t}$$
$$\Delta V = -L\frac{\Delta I}{\Delta t}$$
$$\Delta V = |\vec{v}||\vec{B}|l = |\vec{E}|l \quad \text{motional voltage}$$

**EM Waves/reflection/refraction:**

$$c = \lambda f = \frac{|\vec{E}|}{|\vec{B}|}$$
$$\mathcal{I} = \frac{\text{energy}}{\text{time} \cdot \text{area}} = \frac{E_{max}B_{max}}{2\mu_0} = \frac{\text{power }(\mathscr{P})}{\text{area}} = \frac{E_{max}^2}{2\mu_0 c}$$
$$n = \frac{\text{speed of light in vacuum}}{\text{speed of light in a medium}} = \frac{c}{v}$$
$$\frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2} = \frac{c/n_1}{c/n_2} = \frac{n_2}{n_1} \quad \text{refraction}$$
$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \quad \text{Snell's refraction}$$
$$\lambda f = c$$
$$M = \frac{h'}{h} = -\frac{q}{p}$$
$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{2}{R} \quad \text{mirror \& lens}$$
$$\frac{n_1}{p} + \frac{n_2}{q} = \frac{n_2 - n_1}{R} \quad \text{spherical refracting}$$
$$q = -\frac{n_2}{n_1}p \quad \text{flat refracting}$$
$$\frac{1}{f} = \left(\frac{n_2 - n_1}{n_1}\right)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \quad \text{lensmaker's}$$

**Electric Field, Force, Potential:**

$$\Delta PE = q\Delta V = -q|\vec{E}||\Delta\vec{x}|\cos\theta = -qE_x\Delta x \leftarrow \text{constant E field}$$
$$\vec{F}_{e,12} = q\vec{E}_{12} = \frac{k_e q_1 q_2}{r_{12}^2}\hat{r}_{12}$$
$$\vec{E} = k_e\frac{|q|}{r^2}$$
$$V_{\text{point charge}} = k_e\frac{q}{r}$$
$$PE_{\text{pair of point charges}} = k_e\frac{q_1 q_2}{r_{12}}$$

| Unit | Symbol | equivalent to |
|---|---|---|
| newton | N | kg·m/s$^2$ |
| joule | J | kg·m$^2$/s$^2$ = N·m |
| watt | W | J/s=m$^2$·kg/s$^3$ |
| coulomb | C | A·s |
| amp | A | C/s |
| volt | V | W/A = m$^2$·kg/·s$^3$·A |
| farad | F | C/V = A$^2$·s$^4$/m$^2$·kg |
| ohm | Ω | V/A = m$^2$·kg/s$^3$·A$^2$ |
| tesla | T | Wb/m$^2$ = kg/s$^2$·A |
| electron volt | eV | $1.6 \times 10^{-19}$ J |
| - | 1 T · m/A | 1 N/A$^2$ |
| - | 1 T · m$^2$ | 1 V · s |
| - | 1 N/C | 1 V/m |

| Power | Prefix | Abbreviation |
|---|---|---|
| $10^{-12}$ | pico | p |
| $10^{-9}$ | nano | n |
| $10^{-6}$ | micro | μ |
| $10^{-3}$ | milli | m |
| $10^{-2}$ | centi | c |
| $10^{3}$ | kilo | k |
| $10^{6}$ | mega | M |
| $10^{9}$ | giga | G |
| $10^{12}$ | tera | T |

**Right-hand rule #1**

1. Point the fingers of your right hand along the direction of $\vec{v}$.
2. Point your thumb in the direction of $\vec{B}$.
3. The magnetic force on a + charge points out from the back of your hand.

**Right-hand rule #2:**
Point your thumb along the direction of the current (magnetic field). Your fingers naturally curl around the direction the magnetic field (current) circulates.