

# Electricity & Magnetism Equation Sheet

Think about how to set up the problem first, then apply the needed principles and formulas.

## **Electric Field & Force**

$$F = \frac{kq_0q}{r^2}$$

$$E = \frac{F}{q} = \frac{kq_0}{r^2}$$

$$E_{ring} = \frac{kQx}{(x^2+a^2)^{3/2}}$$

$$E_{line} = \frac{\lambda}{2\pi\epsilon_0 r}$$

$$E_{disk} = \frac{\sigma}{2\epsilon_0} \left[ 1 - \frac{z}{R^2+z^2} \right]$$

$$E_{sheet} = \frac{\sigma}{2\epsilon_0}$$

$$E_{para.\ plates} = \frac{\sigma}{\epsilon_0}$$

$$p = qd \text{ (dipole moment)}$$

$$\vec{\tau}_{dipole} = \vec{p} \times \vec{E}$$

$$\tau_{dipole} = pE \sin \phi$$

$$U = -pE \cos \phi$$

$$\Phi_E = EA \cos \phi$$

$$\Phi_E = \int \vec{E} \cdot d\vec{A}$$

$$\oint \vec{E} \cdot d\vec{A} = \frac{Q_{enc}}{\epsilon_0}$$

## **Electric Potential**

$$W = \int \vec{F} \cdot d\vec{l} = -\Delta U$$

$$U = \frac{kq_0q}{r}$$

$$V = \frac{U}{q} = \frac{kq_0}{r}$$

$$\Delta V = -\int \vec{E} \cdot d\vec{l}$$

$$V_{cyl} = \frac{\lambda}{2\pi\epsilon_0} \ln \left( \frac{R}{r} \right)$$

$$V_{ring} = \frac{kQ}{x^2+a^2}$$

$$\vec{E} = -\vec{\nabla}V$$

## **Capacitance**

$$C = \epsilon_0 \frac{A}{d} = \frac{Q}{V}$$

$$E = \frac{\sigma}{\epsilon_0} = \frac{Q}{\epsilon_0 A}$$

$$V = Ed = \frac{Qd}{\epsilon_0 A}$$

$$U = \frac{Q^2}{2C} = \frac{1}{2}CV^2 = \frac{1}{2}QV$$

$$u = \frac{1}{2}\epsilon_0 E^2$$

$$C_{new} = \kappa C_{old}$$

$$E_{new} = \frac{E_{old}}{\kappa}$$

$$\varepsilon = \kappa \epsilon_0$$

$$C_{eq} = C_1 + C_2 + \dots \text{ (parallel)}$$

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \dots \text{ (series)}$$

## **Circuits**

$$I = \frac{dQ}{dt} = nqv_d A$$

$$J = \frac{I}{A}$$

$$\rho = \frac{E}{J}$$

$$\sigma = \rho^{-1}$$

$$\rho(T) = \rho_0[1 + \alpha(T - T_0)]$$

$$V = IR$$

$$V_{term.} = \varepsilon - Ir$$

$$P = IV = I^2 R = \frac{V^2}{R}$$

$$R_{eq} = R_1 + R_2 + \dots \text{ (series)}$$

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \dots \text{ (parallel)}$$

$$\sum I_{junction} = 0$$

$$\sum V_{closed\ loop} = 0$$

$$\tau = RC$$

$$Q(t) = Q(1 - e^{-t/\tau}) \text{ (charging)}$$

$$Q(t) = Qe^{-t/\tau} \text{ (discharging)}$$

$$I(t) = I_0 e^{-t/\tau} \text{ (charging)}$$

$$I(t) = -I_0 e^{-t/\tau} \text{ (discharging)}$$

$$I_0 = -\frac{Q_0}{\tau}$$

## **Magnetism**

$$\vec{F} = q\vec{v} \times \vec{B}$$

$$\Phi_B = BA \cos \phi$$

$$\Phi_B = \vec{B} \cdot d\vec{A}$$

$$\oint \vec{B} \cdot d\vec{A} = 0$$

$$\vec{F} = Il \times \vec{B}$$

$$\vec{\tau}_{mag.\ dipole} = \vec{\mu} \times \vec{B}$$

$$\vec{\mu} = IA$$

$$U = -\mu B \cos \phi$$

$$nq = -\frac{J_z B_y}{E_z}$$

$$\vec{B} = \frac{\mu_0}{4\pi} \frac{q\vec{v} \times \hat{r}}{r^2}$$

$$B_{wire} = \frac{\mu_0 I}{2\pi r}$$

$$F = \frac{\mu_0 I_1 I_2 L}{2\pi r}$$

$$B_{loop} = \frac{\mu_0 I a^2}{2(x^2+a^2)^{3/2}}$$

$$B_{solenoid} = \mu_0 n I$$

$$B_{toroid} = \frac{\mu_0 N I}{2\pi r}$$

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{enc}$$

## **Induction**

$$\varepsilon = -\frac{d\Phi}{dt}$$

$$\varepsilon = vBL$$

$$\varepsilon = \oint (\vec{v} \times \vec{B}) \cdot d\vec{l}$$

$$\oint \vec{E} \cdot d\vec{l} = -\frac{d\Phi_B}{dt}$$

$$i_D = \varepsilon_0 \frac{d\Phi_E}{dt}$$

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 (I + \epsilon_0 \frac{d\Phi_E}{dt})$$

$$M = \frac{N_1 \Phi_{B1}}{i_2}$$

$$\varepsilon_1 = -M \frac{di_2}{dt}$$

$$L = \frac{N\Phi_B}{i}$$

$$\varepsilon = -L \frac{di}{dt}$$

$$U = \frac{1}{2}LI^2$$

$$u_0 = \frac{B^2}{2\mu_0}$$

$$u = \frac{B^2}{2\mu}$$

$$\tau = \frac{L}{R}$$

$$i = I_0 e^{-t/\tau}$$

$$\varepsilon i = i^2 R + Li \frac{di}{dt}$$

$$\omega = \sqrt{\frac{1}{LC}}$$

$$\omega = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$$

## **AC Circuits**

$$i = I \cos(\omega t)$$

$$I_{rms} = \frac{I}{\sqrt{2}}$$

$$v_{rms} = \frac{v}{\sqrt{2}}$$

$$X_C = \frac{1}{\omega C}$$

$$X_L = \omega L$$

$$V_C = IX_C$$

$$V_L = IX_L$$

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$\tan \phi = \frac{X_L - X_C}{R}$$

$$P_{av} = \frac{1}{2}IV \cos \phi$$

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

$$\frac{V_2}{V_1} = \frac{N_2}{N_1}$$

$$I_1 V_1 = I_2 V_2$$

**EM Waves**

$$E = cB$$

$$B = \epsilon_0 \mu_0 c E$$

$$c = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$$

$$\vec{E}(x, t) = E_{max} \cos(kx \pm \omega t) \hat{j}$$

$$\vec{B}(x, t) = B_{max} \cos(kx \pm \omega t) \hat{k}$$

$$v = \frac{1}{\sqrt{\epsilon \mu}} = \frac{c}{\sqrt{\kappa \kappa_m}}$$

$$\vec{S} = \frac{1}{\mu_0} \vec{E} \times \vec{B}$$

$$I = S_{av} = \frac{1}{2} \epsilon_0 c E_{max}^2$$

$$\frac{1}{A} \frac{dp}{dt} = \frac{S}{c} = \frac{EB}{\mu_0 c}$$

**Constants**

$$\epsilon_0 = 8.854 \times 10^{-12} \frac{C^2}{N \cdot m^2}$$

$$k = \frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \frac{N \cdot m^2}{C^2}$$

$$m_p = 1.67 \times 10^{-27} kg$$

$$m_e = 9.11 \times 10^{-31} kg$$

$$e = 1.602 \times 10^{-19} C$$

$$1eV = 1.602 \times 10^{-19} J$$

$$\mu_0 = 4\pi \times 10^{-7} \frac{Wb}{A \cdot m}$$

$$c = 2.998 \times 10^8 \frac{m}{s}$$

$$1u = 1.66 \times 10^{-27} kg$$

**Miscellaneous**

$$\vec{A} \cdot \vec{B} = AB \cos \theta$$

$$\vec{A} \cdot \vec{B} = (A_y B_z - A_z B_y) \hat{i} + (A_z B_x - A_x B_z) \hat{j} + (A_x B_y - A_y B_x) \hat{k}$$

$$A_{sphere} = 4\pi r^2$$

$$V_{sphere} = \frac{4}{3}\pi r^3$$

$$Circum. \ of \ circle = 2\pi r$$

$$A_{circle} = \pi r^2$$

Scientific Notation Prefixes		
Factor	Prefix	Symbol
$10^{-12}$	pico-	p
$10^{-9}$	nano-	n
$10^{-6}$	micro-	$\mu$
$10^{-3}$	milli-	m
$10^{-2}$	centi-	c
$10^3$	kilo-	k
$10^6$	mega-	M
$10^9$	giga-	G

Young, H. D., Freedman, R. A., & Sears, F. W. (2016). Sears and Zemansky's University physics. Harlow: Pearson Education.