# PH-214 Cheat Sheet

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## Constants

$$\mu_0 = 12.57 * 10^7 \, \frac{\mathrm{T} \cdot \mathrm{m}}{\mathrm{A}} \qquad \epsilon_0 = 8.85 * 10^{-12} \frac{\mathrm{C}^2}{\mathrm{N} \cdot \mathrm{m}^2} \qquad m_{\text{Proton}} = 1.67 * 10^{-27} \text{ kg}$$

$$m_{\text{Electron}} = 9.11 * 10^-31 \text{ kg} \qquad q = 1.60 * 10^{-19} \text{ C}$$

## Vector Derivatives

$$\text{Gradient: } \nabla t = \frac{\partial t}{\partial x}\hat{\mathbf{x}} + \frac{\partial t}{\partial y}\hat{\mathbf{y}} + \frac{\partial t}{\partial z}\hat{\mathbf{z}} \qquad \text{Divergence: } \nabla \cdot \mathbf{v} = \frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} + \frac{\partial v_z}{\partial z} \qquad \text{Laplacian: } \nabla^2 t = \frac{\partial^2 t}{\partial x^2} + \frac{\partial^2 y}{\partial y^2} + \frac{\partial^2 z}{\partial z^2}$$

$$\text{Curl: } \nabla \times \mathbf{v} = \left(\frac{\partial v_z}{\partial y} - \frac{\partial v_y}{\partial z}\right)\hat{\mathbf{x}} + \left(\frac{\partial v_x}{\partial z} - \frac{\partial v_z}{\partial x}\right)\hat{\mathbf{y}} + \left(\frac{\partial v_y}{\partial x} - \frac{\partial v_x}{\partial y}\right)\hat{\mathbf{z}}$$

## Vector Identities

$$\mathbf{A} \cdot (\mathbf{B} \times \mathbf{C}) = \mathbf{B} \cdot (\mathbf{C} \times \mathbf{A}) = \mathbf{C} \cdot (\mathbf{A} \times \mathbf{B}) \qquad \mathbf{A} \times (\mathbf{B} \times \mathbf{C}) = \mathbf{B}(\mathbf{A} \cdot \mathbf{C}) - \mathbf{C}(\mathbf{A} \cdot \mathbf{B})$$

## Maxwell's Equations

| | | | | |
|---|---|---|---|---|
| **Integral Form** | $\oint \vec{E} \cdot d\vec{A} = \frac{q_{\text{enc}}}{\epsilon_0}$ | $\oint \vec{B} \cdot d\vec{A} = 0$ | $\oint \vec{E} \cdot d\vec{s} = -\frac{d\phi_B}{dt}$ | $\oint \vec{B} \cdot d\vec{s} = \mu_0\epsilon_0 \frac{d\phi_B}{dt} + \mu_0 i_{\text{enc}}$ |
| **Differential Form** | $\nabla \cdot \vec{E} = 0$ | $\nabla \cdot \vec{B} = 0$ | $\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$ | $\nabla \times \vec{B} = \mu_0\epsilon_0 \frac{\partial \vec{E}}{\partial t}$ |

### Wave Equations for $\vec{E}$ and $\vec{B}$

$$\vec{E} = \vec{E_0} e^{i(k \cdot r - \omega t)} = \vec{E_0} \cos(\omega t - kx) \qquad \vec{B} = \vec{B_0} e^{i(k \cdot r - \omega t)} = \vec{B_0} \cos(\omega t - kx)$$

$$\frac{1}{c_0} \frac{\partial^2 \vec{E}}{\partial t^2} = \frac{\partial^2 \vec{E}}{\partial x^2} \qquad \frac{1}{c_0} \frac{\partial^2 \vec{B}}{\partial t^2} = \frac{\partial^2 \vec{B}}{\partial x^2} \qquad \omega = ck$$

### Energy Density

$$u_E = \frac{1}{2}\epsilon_0 \left|\vec{E}\right|^2 \qquad u_B = \frac{1}{2\mu_0}\epsilon_0 \left|\vec{B}\right|^2 \qquad u_T = \epsilon_0 \left|\vec{E}\right|^2 = \frac{1}{\mu_0} \left|\vec{B}\right|^2$$

## Radiation

$$\vec{s} = \frac{1}{\mu_0} \vec{E} \times \vec{B} \qquad \frac{E}{B} = c \qquad P = \frac{q^2 a^2}{6\pi\epsilon_0 c^3} \qquad \sigma_{\text{Th}} = \frac{8\pi}{3} \left(\frac{q^2}{4\pi\epsilon_0 m_e c^2}\right)^2 \qquad \langle P \rangle = \frac{q^4 E_0^2}{12\pi\epsilon_0 m^2 c^3}$$

$$E_\theta = \frac{a \sin\theta \, q}{4\pi \, c^2 \epsilon_0 R} \qquad E_R = \frac{a \, T \sin\theta \, q}{4\pi c \, \epsilon_0 R^2} \qquad \sigma_{\text{Ray}} = \sigma_{\text{Th}} \left(\frac{\omega^2}{\omega^2 - \omega_0^2}\right)^2$$

## Potential for a Dipole

$$\phi_E = \frac{1}{4\pi\epsilon_0} * \frac{qdr\cos\theta}{r^3}$$