

# PH2200 Formula Sheet

## Electric Fields

$$\vec{F}_{12} = \frac{k_e q_1 q_2}{r^2} \hat{r} \quad k_e = \frac{1}{4\pi\epsilon_0}$$

$$\vec{E} = \lim_{q_o \rightarrow 0} \frac{\vec{F}_e}{q_o}$$

$$\vec{E} = \frac{k_e q}{r^2} \hat{r}$$

$$\vec{E} = \sum_i \vec{E}_i = \sum_i \frac{k_e q_i}{r_i^2} \hat{r}_i$$

$$\vec{E} = \int d\vec{E} = \int \frac{k_e dq}{r^2} \hat{r}$$

## Gauss's Law

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

$$\oint \vec{E} \cdot d\vec{A} = \frac{q_{in}}{\epsilon_0}$$

$$E = \frac{\sigma}{\epsilon_0} \text{ at conductor surface}$$

## Electric Potential

$$\Delta U = -q_o \int_A^B \vec{E} \cdot d\vec{s}$$

$$\Delta V_{A \rightarrow B} = \frac{\Delta U}{q_o} = - \int_A^B \vec{E} \cdot d\vec{s}$$

$$V(r) = \frac{k_e q}{r}$$

$$V = \sum_i \frac{k_e q_i}{r_i}$$

$$V = \int \frac{k_e dq}{r}$$

$$U = \frac{k_e q_1 q_2}{r_{12}}$$

$$E_x = -\frac{dV}{dx}$$

## Capacitance and Dielectrics

$$C = \frac{Q}{\Delta V}$$

$$C = \frac{\epsilon_0 A}{d} \text{ parallel-plate capacitor}$$

$$\frac{C}{l} = \frac{1}{2k_e \ln\left(\frac{b}{a}\right)} \text{ cylindrical capacitor}$$

$$C = \frac{4\pi\epsilon_0 ab}{b-a} \text{ spherical capacitor}$$

$$C_{eq} = C_1 + C_2 + C_3 + \dots \text{ parallel}$$

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots \text{ series}$$

$$U = \frac{Q^2}{2C} = \frac{1}{2} Q \Delta V = \frac{1}{2} C (\Delta V)^2$$

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

$$C = \kappa C_0$$

## Current and Resistance

$$I_{av} = \frac{\Delta Q}{\Delta t}$$

$$I = \frac{dq}{dt}$$

$$I_{av} = nq v_d A$$

$$\vec{J} = nq \vec{v}_d$$

$$\vec{J} = \sigma \vec{E}$$

$$R = \frac{\Delta V}{I}$$

$$\rho = \frac{l}{\sigma A}$$

$$R = \frac{\rho l}{A}$$

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

$$P = I \Delta V$$

$$P = I^2 R = \frac{(\Delta V)^2}{R}$$

## Direct Current Circuits

$$R_{eq} = R_1 + R_2 + R_3 + \dots \text{ series}$$

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots \text{ parallel}$$

$$\sum I_{in} = \sum I_{out}$$

$$\sum_{closed \ loop} \Delta V = 0$$

$$q(t) = CE(1 - e^{-t/RC}) \text{ charging}$$

$$I(t) = \frac{E}{R} e^{-t/RC} \text{ charging}$$

$$q(t) = Qe^{-t/RC} \text{ discharging}$$

$$I(t) = -\frac{Q}{RC} e^{-t/RC} \text{ discharging}$$

## Magnetic Fields

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

$$F_B = |q|vB \sin \theta$$

$$\vec{F}_B = I \vec{L} \times \vec{B}$$

$$d\vec{F}_B = Id\vec{s} \times \vec{B}$$

$$\vec{\mu} = NI\vec{A}$$

$$\vec{\tau} = \vec{\mu} \times \vec{B}$$

$$U_B = -\vec{\mu} \cdot \vec{B}$$

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

$$r = \frac{mv}{qB}, \quad \omega = \frac{qB}{m}$$

## Sources of the Magnetic Field

$$d\vec{B} = \frac{\mu_0}{4\pi} \frac{Id\vec{s} \times \hat{r}}{r^2}$$

$$B = \frac{\mu_0 I}{2\pi a} \text{ long straight wire}$$

$$\frac{F_B}{l} = \frac{\mu_0 I_1 I_2}{2\pi a}$$

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 I$$

$$B = \frac{\mu_0 NI}{2\pi r} \text{ toroid}$$

$$B = \mu_0 \frac{N}{l} I = \mu_0 n I \text{ solenoid}$$

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

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

## Faraday's Law

$$\mathcal{E} = -N \frac{d\Phi_B}{dt}$$

$$\mathcal{E} = -Blv$$

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

Need additional help? Then visit the Physics Learning Center located in 228 Fisher. Walk-in hours are Monday through Thursday 3:00 - 5:00 p.m. and 7:00 - 9:00 p.m. and Sunday 7:00 - 9:00 p.m.

## Inductance

$$E_L = -N \frac{d\Phi_B}{dt} = -L \frac{dI}{dt}$$

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

$$L = \frac{\mu_o N^2 A}{l} \quad \text{solenoid}$$

$$I = \frac{E}{R} (1 - e^{-Rt/L}) \quad \text{rising current}$$

$$I = \frac{E}{R} e^{-Rt/L} \quad \text{decaying current}$$

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

$$u_B = \frac{B^2}{2\mu_o}$$

$$M_{12} = \frac{N_2 \Phi_{12}}{I_1} = M_{21} = \frac{N_1 \Phi_{21}}{I_2} = M$$

$$E_2 = -M_{12} \frac{dI_1}{dt} \quad \text{and} \quad E_1 = -M_{21} \frac{dI_2}{dt}$$

$$Q = Q_{\max} \cos(\omega t + \phi)$$

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

$$U = U_C + U_L$$

$$= \frac{Q_{\max}^2}{2C} \cos^2 \omega t + \frac{LI_{\max}^2}{2} \sin^2 \omega t$$

## Alternating Current Circuits

$$I_{rms} = 0.707 I_{\max}$$

$$\Delta V_{rms} = 0.707 V_{\max}$$

$$X_L = \omega L$$

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

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

$$\phi = \tan^{-1} \left( \frac{X_L - X_C}{R} \right)$$

$$P_{av} = I_{rms} \Delta V_{rms} \cos \phi$$

$$P_{av} = I_{rms}^2 R$$

$$I_{rms} = \frac{\Delta V_{rms}}{\sqrt{R^2 + (X_L - X_C)^2}}$$

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

$$I_1 \Delta V_1 = I_2 \Delta V_2$$

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## Electromagnetic Waves

$$\oint_S \vec{E} \cdot d\vec{A} = \frac{Q}{\epsilon_o}$$

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

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

$$\oint \vec{B} \cdot d\vec{s} = \mu_o I + \epsilon_o \mu_o \frac{d\Phi_E}{dt}$$

$$c = \frac{1}{\sqrt{\epsilon_o \mu_o}}$$

$$f\lambda = c$$

$$\frac{E_{\max}}{B_{\max}} = \frac{E}{B} = c$$

$$\vec{S} = \frac{\vec{E} \times \vec{B}}{\mu_o}$$

$$I = S_{av} = \frac{E_{\max} B_{\max}}{2\mu_o} = c u_{av}$$

$$u_B = u_E = \frac{1}{2} \epsilon_o E^2 = \frac{B^2}{2\mu_o}$$

$$u_{av} = \frac{1}{2} \epsilon_o E_{\max}^2 = \frac{B_{\max}^2}{2\mu_o}$$

$$p = \frac{U}{c} \quad P = \frac{S}{c} \quad \text{complete absorption}$$

$$p = \frac{2U}{c} \quad P = \frac{2S}{c} \quad \text{complete reflection}$$

## The Nature of Light and the Laws of Geometric Optics

$$\theta'_1 = \theta_1$$

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

$$n = \frac{c}{v}$$

$$\lambda_n = \frac{\lambda}{n}$$

$$\sin \theta_c = \frac{n_2}{n_1} \quad (\text{for } n_1 > n_2)$$

## Geometric Optics

$$M = \frac{h'}{h} = \frac{-q}{p}$$

$$\frac{1}{p} + \frac{1}{q} = \frac{2}{R} = \frac{1}{f}$$

$$\frac{n_1}{p} + \frac{n_2}{q} = \frac{n_2 - n_1}{R}$$

$$\frac{1}{f} = (n-1) \left( \frac{1}{R_1} - \frac{1}{R_2} \right)$$

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

## Physical Constants

$$k_e = 8.988 \times 10^9 \text{ N} \cdot \text{m}^2 / \text{C}^2$$

$$\epsilon_o = 8.854 \times 10^{-12} \text{ C}^2 / \text{N} \cdot \text{m}^2$$

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

$$m_{\text{electron}} = 9.109 \times 10^{-31} \text{ kg}$$

$$m_{\text{proton}} = 1.672 \times 10^{-27} \text{ kg}$$

$$\mu_o = 4\pi \times 10^{-7} \text{ T} \cdot \text{m} / \text{A}$$

$$c = \frac{1}{\sqrt{\epsilon_o \mu_o}} = 2.998 \times 10^8 \text{ m} / \text{s}$$

## Useful Geometry

### Circle

$$\text{Area} = \pi r^2$$

$$\text{Circumference} = 2\pi r$$

### Sphere

$$\text{Surface area} = 4\pi r^2$$

$$\text{Volume} = \frac{4}{3} \pi r^3$$

### Cylinder

$$\text{Lateral surface}$$

$$\text{area} = 2\pi rL$$

$$\text{Volume} = \pi r^2 L$$