PHYS-224, Electricity and Magnetism
Formulas and Constants

Kinematic equations of motion (constant acceleration):

$$x_f = x_i + v_{ox}(\triangle t) + \tfrac{1}{2}a_x(\triangle t)^2 \qquad v_f = v_i + a\triangle t \qquad v_v^2 = v_i^2 + 2a_x(x_f - x_i)$$

Electric field and force (for point charges):

$$\vec{\mathbf{F}}_{1\text{on}2} = \frac{kq_1q_2}{r^2}\hat{\mathbf{r}} \qquad \vec{\mathbf{F}} = q\vec{\mathbf{E}} \qquad \vec{\mathbf{E}} = \frac{kq}{r^2}\hat{\mathbf{r}} \qquad d\vec{\mathbf{E}} = \frac{k\,dq}{r^2}\hat{\mathbf{r}}$$

Charge Densities: $\lambda = Q/L \qquad \eta = Q/A \qquad \rho = Q/V$

Line of charge: $E = \dfrac{2k\lambda}{r}$ **Plane of charge:** $E = \dfrac{\eta}{2\epsilon_0}$ **dipole:** $\vec{\mathbf{p}} = q\vec{\mathbf{s}} \quad \vec{\tau} = \vec{\mathbf{p}}\times\vec{\mathbf{E}}$

Electric flux: $\Phi_{\text{e}} = \displaystyle\int \vec{\mathbf{E}}\cdot d\vec{\mathbf{A}} = \int E_\perp\, dA$ **Gauss's Law:** $\Phi_{\text{net}} = \displaystyle\oint \vec{\mathbf{E}}\cdot d\vec{\mathbf{A}} = \frac{Q_{\text{inside}}}{\epsilon_o}$

Current and conductivity: $I = \dfrac{dQ}{dt} \qquad I = nev_dA \qquad J = \dfrac{I}{A} \qquad \vec{\mathbf{J}} = \sigma\vec{\mathbf{E}}$

Work and Energy: $W = \displaystyle\int \vec{F}\cdot\vec{ds} \qquad W = \triangle K = -\triangle U$

Potential Energy stored in point charge pair: $U_{q_1+q_2} = \dfrac{kq_1q_2}{r_{12}}$

Electric Potential: $V = \dfrac{U_{\text{source}+q}}{q}$ **Potential due to a point charge:** $V = \dfrac{kq}{r}$

Electric field and electric potential: $\triangle V = V_b - V_a = -\displaystyle\int_a^b \vec{\mathbf{E}}\cdot d\vec{\mathbf{s}} \qquad E_s = -\frac{dV}{ds}$

Capacitors : $C = \dfrac{Q}{\triangle V} \qquad C = \dfrac{\epsilon_o A}{d} \qquad U_C = \tfrac{1}{2}C(\triangle V)^2 = \tfrac{1}{2}Q\,\triangle V = \tfrac{1}{2}\dfrac{Q^2}{C} \qquad u = \tfrac{1}{2}\epsilon_o E^2$

Parallel: $C_{\text{eq}} = C_1 + C_2 + C_3 + \cdots$ **Series:** $C_{\text{eq}} = \left(\dfrac{1}{C_1} + \dfrac{1}{C_2} + \dfrac{1}{C_3} + \cdots\right)^{-1}$

CurrentandResistance : $E = \dfrac{\triangle V}{L} \qquad I = \dfrac{\triangle V}{R} \qquad R = \dfrac{\rho L}{A} \qquad P = \triangle V\, I = I^2R = \dfrac{(\triangle V)^2}{R}$

Series: $R_{\text{eq}} = R_1 + R_2 + R_3 + \cdots$ **Parallel:** $R_{\text{eq}} = \left(\dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3} + \cdots\right)^{-1}$

Discharging a Capacitor: $Q = Q_o e^{-t/RC} \qquad I = I_o e^{t/RC} \qquad \tau = RC$

Magnetic field: (Biot-Savart Law)

$$\vec{\mathbf{B}} = \frac{\mu_0}{4\pi}\frac{q\,\vec{\mathbf{v}} \times \hat{\mathbf{r}}}{r^2} \qquad d\vec{\mathbf{B}} = \frac{\mu_0}{4\pi}\frac{I\,d\vec{\mathbf{s}} \times \hat{\mathbf{r}}}{r^2}$$

long straight wire: $B = \frac{\mu_0 I}{2\pi r}$

center of circular loop: $B = \frac{\mu_0 I}{2r}$

long solenoid: $B = \mu_0 \frac{N}{l} I$

Ampere's Law: $\oint \vec{\mathbf{B}}\cdot d\vec{\mathbf{s}} = \oint B_{\parallel}\, ds = \mu_0 I_{\text{net}}$

Magnetic force: $\vec{\mathbf{F}} = q\vec{\mathbf{v}}\times\vec{\mathbf{B}}$

$\vec{\mathbf{F}} = I\,\vec{\mathbf{L}} \times \vec{\mathbf{B}}$

uniform circular motion: $qvB = m\frac{v^2}{r}$

cyclotron frequency: $f_{\text{cyc}} = \frac{qB}{2\pi m}$

Torques on current loops: $\vec{\boldsymbol{\mu}} = NIA\hat{\mathbf{n}}$ $\qquad \vec{\boldsymbol{\tau}} = \vec{\boldsymbol{\mu}}\times\vec{\mathbf{B}}$ $\qquad U = -\vec{\boldsymbol{\mu}}\cdot\vec{\mathbf{B}}$

Magnetic flux: $\Phi_{\text{m}} = \vec{\mathbf{B}}\cdot\vec{\mathbf{A}} = BA\cos\theta$ $\qquad \Phi_{\text{m}} = \int \vec{\mathbf{B}}\cdot d\vec{\mathbf{A}} = \int B_{\perp}\, dA$

Gauss's Law for B: $\oint \vec{\mathbf{B}} \cdot d\vec{\mathbf{A}} = 0$

Faraday's Law (Lenz's Law): $\mathscr{E} = -\frac{d\Phi_{\text{m}}}{dt} = -L\frac{dI}{dt}$ $\qquad$ **motional emf:** $\mathscr{E} = -Blv$

Inductors: $L = \frac{N\Phi_{\text{m}}}{I} = \mu_0 \frac{N^2}{l} A$ $\qquad U_{\text{B}} = \frac{1}{2}LI^2$ $\qquad u_{\text{B}} = \frac{B^2}{2\mu_0}$

Areas and Volumes:

Area – circle: $A = \pi R^2$ $\qquad$ **Circumference – circle:** $s = 2\pi R$

Surface area – sphere: $A = 4\pi R^2$ $\qquad$ **Volume – sphere:** $V = \frac{4}{3}\pi R^3$

Surface area – cylinder: $A = 2\pi RL + 2(\pi R^2)$ $\qquad$ **Volume – cylinder:** $V = \pi R^2 L$

CONSTANTS:

$e = 1.602 \times 10^{-19}$ C	[fundamental unit of charge]
$m_e = 9.110 \times 10^{-31}$ kg	[electron mass]
$m_p = 1.673 \times 10^{-27}$ kg	[proton mass]
$k = 9.0 \times 10^9$ Nm^2/C^2	[electrostatic constant]
$\epsilon_o = 8.85 \times 10^{-12}$ C^2/Nm^2	[permittivity of free space]
$\mu_o = 4\pi \times 10^{-7}$ T m/A	[permeability of free space]
g $= 9.8$ m/s^2	[gravitational acceleration]
$\mathrm{N_A} = 6.02 \times 10^{23}$	[Avagadro's number]