Equation Sheet for PHYS-224 (Knight 2e)

Kinematic equations of motion (constant acceleration):

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

Electric Force between two point charges: $F_{\text{1on2}} = F_{\text{2on1}} = \dfrac{K|q_1||q_2|}{r^2}$

Electric Fields and Forces: $q\vec{E} = \vec{F}$ $\quad \vec{E} = \dfrac{\vec{F}_{\text{on q}}}{q}$ $\quad \vec{F} = m\vec{a}$ $\quad \vec{a} = \dfrac{q\vec{E}}{m}$

Electric Field Models for charge distributions

Point: $\vec{E} = \dfrac{K\,q}{r^2}\hat{r} = \dfrac{1}{4\pi\epsilon_o}\dfrac{q}{r^2}\hat{\mathbf{r}}$ $\quad$ Infinite line: $E = \dfrac{2K\lambda}{r}$ $\quad$ Infinite plane: $E = \dfrac{\eta}{2\epsilon_0}$

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

Electric flux: $\Phi_{\text{e}} = \vec{E}\cdot\vec{A} = EA\cos\theta$ $\quad \Phi_{\text{e}} = \int \vec{E}\cdot d\vec{A} = \int E_\perp\, dA$

Gauss's Law: $\Phi_{\text{net}} = \oint \vec{\mathbf{E}}\cdot d\vec{\mathbf{A}} = \dfrac{Q_{\text{in}}}{\epsilon_o}$

Work and Energy: $W = \int \vec{F}\cdot\vec{ds}$ $\quad W = \triangle K = -\triangle U$ $\quad K = \dfrac{1}{2}mv^2$

Potential Energy stored in point charge pair: $U_{\text{elec}} = \dfrac{1}{4\pi\epsilon_o}\dfrac{q_1q_2}{r}$

Electric Potential: $V = \dfrac{U}{q}$ $\quad q\triangle V = \triangle U$ $\quad$ **point charge:** $V = \dfrac{1}{4\pi\epsilon_o}\dfrac{q}{r}$

Electric field and electric potential: $\triangle V = V_f - V_i = -\int_i^f \vec{E}\cdot d\vec{s}$ $\quad E_s = -\dfrac{dV}{ds}$

Capacitors : $C = \dfrac{Q}{\triangle V_{\text{C}}}$ $\quad C = \dfrac{\kappa\epsilon_o A}{d}$ $\quad U_{\text{C}} = \dfrac{1}{2}C(\triangle V_{\text{C}})^2 = \dfrac{1}{2}Q\,\triangle V_{\text{C}} = \dfrac{1}{2}\dfrac{Q^2}{C}$

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

Current: $I = \dfrac{\triangle Q}{\triangle t}$ $\quad I = n_{\text{e}}eAv_{\text{d}}$ $\quad i = n_{\text{e}}Av_{\text{d}}$ $\quad v_{\text{d}} = \dfrac{\text{e}E}{m}\tau$ $\quad J = \dfrac{I}{A}$ $\quad J = \sigma E$

Resistors: $I = \dfrac{\triangle V}{R}$ $\quad R = \dfrac{\rho L}{A}$ $\quad \sigma = \dfrac{1}{\rho}$ $\quad P = \triangle V\, I = I^2R = \dfrac{(\triangle V)^2}{R}$

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

Circuit Analysis $\sum I_{\text{in}} = \sum I_{\text{out}}$ $\quad \sum \triangle V = 0$

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

Magnetic field: (Biot-Savart Law)

point charge: $\vec{B} = \frac{\mu_0}{4\pi}\frac{q\,\vec{v}\times\hat{r}}{r^2}$ current segment $\vec{B} = \frac{\mu_0}{4\pi}\frac{I\,\triangle\vec{s}\times\hat{r}}{r^2}$

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: $\oint \vec{B}\cdot d\vec{s} = \mu_0 I_{\text{through}}$

Magnetic force: $\vec{F}_{\text{on q}} = q\,\vec{v}\times\vec{B}$ uniform circular motion $qvB = m\frac{v^2}{r}$

$\vec{F}_{\text{wire}} = I\,\vec{l}\times\vec{B}$ $\vec{F}_{\text{parallel wires}} = I_1 l B_2 = \frac{\mu_o l I_1 I_2}{2\pi d}$

Torques on current loops: $\vec{\mu} = NIA\hat{n}$ $\vec{\tau} = \vec{\mu}\times\vec{B}$

motional emf: $\mathcal{E} = -Blv$

Magnetic flux: $\Phi_{\text{m}} = \vec{B}\cdot\vec{A} = BA\cos\theta$ $\Phi_{\text{m}} = \int \vec{B}\cdot d\vec{A}$

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

Faraday's Law (Lenz's Law): $\mathcal{E} = -\frac{d\Phi_{\text{m}}}{dt} = -L\frac{dI}{dt}$

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

Areas and Volumes:

CIRCLE	**Area:**	$A = \pi R^2$	**Circumference:**	$s = 2\pi R$
SPHERE	**Surface area:**	$A = 4\pi R^2$	**Volume:**	$V = \frac{4}{3}\pi R^3$
CYLINDER	**Surface area:**	$A = 2\pi RL + 2(\pi R^2)$	**Volume:**	$V = \pi R^2 L$

Constants:

$\text{e} = 1.602\times10^{-19}$ C	[fundamental unit of charge]
$m_{\text{e}} = 9.110\times10^{-31}$ kg	[electron mass]
$m_{\text{p}} = 1.673\times10^{-27}$ kg	[proton mass]
$K = 9.0\times10^9\ \text{Nm}^2/\text{C}^2$	[electrostatic constant]
$\epsilon_o = 8.85\times10^{-12}\ \text{C}^2/\text{Nm}^2$	[permittivity of free space]
$\mu_o = 4\pi\times10^{-7}$ T m/A	[permeability of free space]
$\text{g} = 9.8\,\text{m/s}^2$	[gravitational acceleration]
$\text{N}_\text{A} = 6.02\times10^{23}$	[Avagadro's number]
