1444 FORMULA SHEET

Constants: $g = 9.80\dfrac{m}{s^2}$ $G = 6.673\times10^{-11}\,N\cdot m^2/kg^2$ $e = 1.60\times10^{-19}C$ $k_c = 9.00\times10^{9}\,N\cdot m^2/C^2$

$\varepsilon_0 = 8.85\times10^{-12}\,\dfrac{C^2}{N\cdot m^2}$ $\mu_0 = 4\pi\times10^{-7}\,\dfrac{T\cdot m}{A}$ $h = 6.63\times10^{-34}\,J\cdot s$ $\hbar = 1.055\times10^{-34}\,J\cdot s$

$m_{electron} = 9.11\times10^{-31}kg$ $m_{proton} = 1.67\times10^{-27}kg$ $c = 3.00\times10^{8}\,m/s$

Metric Multipliers: *Pico* $\mathrm{p} = 10^{-12}$ *Micro* $\mu = 10^{-6}$ *Centi* $\mathrm{c} = 10^{-2}$ *Mega* $\mathrm{M} = 10^{6}$

Nano $\mathrm{n} = 10^{-9}$ *Milli* $\mathrm{m} = 10^{-3}$ *Kilo* $\mathrm{k} = 10^{3}$ *Giga* $\mathrm{G} = 10^{9}$

Conversion Equivalents:

1.00 inch = 2.54 cm *1.00 ft. = 30.5 cm* *1.00 m = 3.28 ft. = 39.4 inches*

1.00 cm = 0.394 inches *1.00 km = 0.621 miles* *1.00 mile = 5280 ft = 1.61 km*

1 Rev = 2π rad = 360° $1eV = 1.60\times10^{-19}J$ $k_c = \dfrac{1}{4\pi\varepsilon_0}$

Trigonometric Relations:

For Right Triangles : $Sin\theta = \dfrac{Opp}{Hyp} = \dfrac{\mathrm{B}}{\mathrm{C}}$ $Cos\theta = \dfrac{Adj}{Hyp} = \dfrac{\mathrm{A}}{\mathrm{C}}$ $Tan\theta = \dfrac{Opp}{Adj} = \dfrac{B}{A}$ $A^2 + B^2 = C^2$

For All Triangles: $\dfrac{Sin(\alpha)}{A} = \dfrac{Sin(\beta)}{B} = \dfrac{Sin(\gamma)}{C}$ $C^2 = A^2 + B^2 - 2AB\cdot Cos(\gamma)$

Vector Relations *(assuming θ defined with respect to the positive x-axis)*

$$V_x = |\vec{V}|\cdot Cos\theta \qquad V_y = |\vec{V}|\cdot Sin\theta \qquad |\vec{V}| = \sqrt{V_x^2 + V_y^2} \qquad \theta = Tan^{-1}\left(\frac{V_y}{V_x}\right)$$

Vector Dot and Cross Products *(assuming θ is the angle between the vectors)*

$$\vec{A}\times\vec{B} = \det\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ A_x & A_y & A_z \\ B_x & B_y & B_z \end{vmatrix} = (A_yB_z - A_zB_y)\hat{i} + (A_zB_x - A_xB_z)\hat{j} + (A_xB_y - A_yB_x)\hat{k}$$

$$\hat{i}\times\hat{i} = 0 \quad \hat{j}\times\hat{i} = -\hat{k} \quad \hat{k}\times\hat{i} = \hat{j}$$
$$\hat{i}\times\hat{j} = \hat{k} \quad \hat{j}\times\hat{j} = 0 \quad \hat{k}\times\hat{j} = -\hat{i}$$
$$\hat{i}\times\hat{k} = -\hat{j} \quad \hat{j}\times\hat{k} = \hat{i} \quad \hat{k}\times\hat{k} = 0$$

$$|\vec{A}\times\vec{B}| = |\vec{A}||\vec{B}|\,Sin\theta \qquad \vec{A}\cdot\vec{B} = A_xB_x + A_yB_y + A_zB_z = |\vec{A}||\vec{B}|\,Cos\theta$$

Kinematic Equations in 1 Dimension: $x = x_0 + \bar{v}t$ $\bar{v} = \dfrac{\Delta x}{\Delta t} = \dfrac{x - x_0}{t - t_0}$ $\bar{a} = \dfrac{\Delta v}{\Delta t} = \dfrac{v - v_0}{t - t_0}$

$$\mathrm{v_{inst}} = \lim_{\Delta t\to0}\frac{\Delta x}{\Delta t} = \frac{dx}{dt} \qquad \mathrm{a_{inst}} = \lim_{\Delta t\to0}\frac{\Delta v}{\Delta t} = \frac{dv}{dt} = \frac{d^2x}{dt^2} \qquad \int a\cdot dt = v \qquad \int v\cdot dt = x$$

Kinematic Equations in 1 Dimension with Constant Acceleration:

$$v = v_0 + at \qquad \mathrm{x} = x_0 + \frac{1}{2}(v + v_0)t \qquad x = x_0 + v_0t + \frac{1}{2}at^2 \qquad v^2 = v_0^2 + 2a(x - x_0) \qquad \bar{v} = \frac{1}{2}(v + v_0)$$

Kinematic Equations in 2 Dimensions: $\vec{r} = \vec{r}_0 + \vec{v}_{avg}t$ $\vec{v}_{avg} = \dfrac{\Delta\vec{r}}{\Delta t} = \dfrac{\vec{r} - \vec{r}_0}{t - t_0}$ $\bar{a} = \dfrac{\Delta\vec{v}}{\Delta t} = \dfrac{\vec{v} - \vec{v}_0}{t - t_0}$

$$\vec{\mathrm{v}}_{\mathrm{inst}} = \lim_{\Delta t\to0}\frac{\Delta\vec{r}}{\Delta t} = \frac{d\vec{r}}{dt} \qquad \vec{\mathrm{a}}_{\mathrm{inst}} = \lim_{\Delta t\to0}\frac{\Delta\vec{v}}{\Delta t} = \frac{d\vec{v}}{dt} = \frac{d^2\vec{r}}{dt^2} \qquad \int\vec{a}\cdot dt = \vec{v} \qquad \int\vec{v}\cdot dt = \vec{r}$$

***Kinematics in 2 Dimensions with Constant Acceleration*:**

$$v_x = v_{0x} + a_x t \qquad x = x_0 + \frac{1}{2}(v_x + v_{0x})t \qquad x = x_0 + v_{0x}t + \frac{1}{2}a_x t^2 \qquad {v_x}^2 = v_{0x}^2 + 2a_x(x - x_0) \qquad \bar{v}_x = \frac{1}{2}(v_x + v_{0x})$$

$$v_y = v_{0y} + a_y t \qquad y = y_0 + \frac{1}{2}(v_y + v_{0y})t \qquad y = y_0 + v_{0y}t + \frac{1}{2}a_y t^2 \qquad {v_y}^2 = v_{0y}^2 + 2a_y(y - y_0) \qquad \bar{v}_y = \frac{1}{2}(v_y + v_{0y})$$

***Forces*:** $\sum \vec{F} = m\vec{a}$ $\quad \sum \mathrm{F_x} = ma_x$ $\quad \sum \mathrm{F_y} = ma_y$ $\quad \vec{W} = m\vec{g}$ $\quad \vec{g}_{Apparent} = \vec{g} - \vec{a}_{Frame}$

***Work*:** $W = \vec{F} \cdot \vec{s} = F \cdot s \cdot Cos(\theta)$ ***Translational Kinetic Energy*:** $KE = \frac{1}{2}mv^2$

***Gravitational PE*:** $U_{GRAV} = mgh$ ***Conservation on Energy*:** $W_{NC} = \Delta KE + \Delta U$ ***Power*:** $P = \frac{W}{t}$

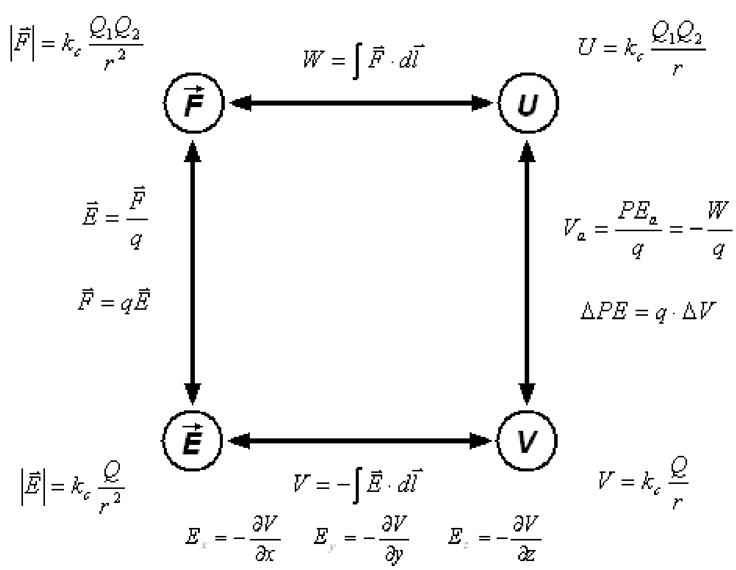
Coulomb's Law: $\left|\vec{F}\right| = k_c \frac{|Q_1||Q_2|}{r^2}$ **Electric Field**: $\vec{E} = \frac{\vec{F}}{q}$ $\quad \vec{F} = q\vec{E}$

E (Point Charge): $\left|\vec{E}\right| = k_c \frac{|Q|}{r^2}$ **Electric Potential**: $V_{ab} = \frac{U_{ab}}{q} = -\frac{W_{ab}}{q}$ $\quad \Delta U = q \cdot \Delta V$

Electric Potential (Point Charge): $V = k_c \frac{Q}{r}$ **Electric Potential (in uniform E field)**: $\Delta V = -Ed$

Electric Fields and Potentials: $V = -\int \vec{E} \cdot d\vec{l}$ $\quad E_x = -\frac{\partial V}{\partial x}$ $\quad E_y = -\frac{\partial V}{\partial y}$ $\quad E_z = -\frac{\partial V}{\partial z}$

Electric Potential Energy (Point Charges): $U = k_c \frac{Q_1 Q_2}{r}$ **Gauss's Law**: $\Phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{Q_{Enclosed}}{\varepsilon_0}$



Capacitance: $Q = CV$ **Capacitor Energy Storage**: $PE = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{Q^2}{2C}$

Parallel Plate Capacitor: $C = \frac{k_d \varepsilon_0 A}{d} = \frac{\varepsilon A}{d}$ **E Field Energy Density**: $\frac{PE}{volume} = \frac{1}{2}\varepsilon_0 E^2$

Electric Current: $I = \frac{dq}{dt}$ **Ohm's Law**: $V = IR$ **Resistance**: $R = \rho \frac{L}{A}$ $\quad R = R_0[1 + \alpha(T - T_0)]$

Electric Power: $P = IV = I^2 R = \frac{V^2}{R}$ **Battery Terminal Voltage**: $V_T = \mathcal{E} - Ir$

Capacitors In Parallel: $C_{EQ} = C_1 + C_2$ **Capacitors In Series**: $\frac{1}{C_{EQ}} = \frac{1}{C_1} + \frac{1}{C_2}$ or $C_{EQ} = \frac{C_1 \cdot C_2}{C_1 + C_2}$

Resistors In Series: $R_{EQ} = R_1 + R_2$ **Resistors In Parallel**: $\frac{1}{R_{EQ}} = \frac{1}{R_1} + \frac{1}{R_2}$ or $R_{EQ} = \frac{R_1 \cdot R_2}{R_1 + R_2}$

Kirchoff's Junction Rule: At any junction point, the sum of all currents entering a junction must equal the sum of all currents leaving the junction.

Kirchoff's Loop Rule: The sum of the changes in potential around any closed path of a circuit must be zero.

RC Circuit (Charging): $V_C = V_{SS}\left(1 - e^{\frac{-t}{RC}}\right)$ $Q_C = Q_{SS}\left(1 - e^{\frac{-t}{RC}}\right)$ $I_C = I_0 e^{\frac{-t}{RC}}$

RC Circuit (Discharging): $V_C = V_0 e^{\frac{-t}{RC}}$ $Q_C = Q_0 e^{\frac{-t}{RC}}$ $I_C = I_0 e^{\frac{-t}{RC}}$ **Time Constant**: $\tau = RC$

Magnetic Force On Moving Charge: $F = qvB\sin\theta$ $\vec{F} = q\vec{v} \times \vec{B}$

Circular Motion of Charged Particle in B Field: $r = \frac{mv}{qB}$ **Biot-Savart**: $d\vec{B} = \frac{\mu_0 I}{4\pi} \cdot \frac{d\vec{l} \times \hat{r}}{r^2}$

Magnetic Force On Current Carrying Wire: $F = ILB\sin\theta$ $\vec{F} = I\vec{L} \times \vec{B}$

Magnetic Field From Current Carrying Wire: $B = \frac{\mu_0 I}{2\pi r}$ **Ampere's Law**: $\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{ENC}$

Magnetic Force Between Two Parallel Wire: $\frac{F}{L} = \frac{\mu_0 I_1 I_2}{2\pi d}$

Magnetic Field in Solenoid: $B = \mu_0 In = \mu_0 I \frac{N}{L}$ **Torque On Current Loop**: $\tau = NIAB\sin\theta$

Magnetic Flux: $\Phi_B = \vec{B} \cdot \vec{A} = BA\cos\theta$ **Faraday's Law of Induction**: $\mathcal{E} = -N\frac{d\Phi_B}{dt}$

EMF in Moving Conductor: $\mathcal{E} = BLv$ **Electric Generators:** $\mathcal{E} = \omega NBA\sin(\omega t)$

Transformers: $\frac{V_s}{V_P} = \frac{N_s}{N_P}$ $\frac{I_s}{I_P} = \frac{N_P}{N_S}$ **Inductance:** $\mathcal{E} = -L\frac{dI}{dt}$

Solenoid Inductance: $L = \mu_0 n^2 Al = \frac{\mu_0 N^2 A}{l}$ **Inductor Energy:** $U = \frac{1}{2}LI^2$

RL Circuit (Charging): $I_L = I_{SS}\left(1 - e^{\frac{-Rt}{L}}\right)$ $V_L = V_0 e^{\frac{-Rt}{L}}$

RL Circuit (Discharging): $V_L = V_0 e^{\frac{-Rt}{L}}$ $I_L = I_0 e^{\frac{-Rt}{L}}$ **Time Constant**: $\tau = L/R$

Complex Numbers: $z = a + bi = |z|\angle\theta$ $a = |z|Cos\theta$ $\text{b} = |z|Sin\theta$ $|z| = \sqrt{a^2 + b^2}$ $\theta = \text{Tan}^{-1}\left(\frac{b}{a}\right)$

$$z_1 z_2 = |z_1||z_2|\angle(\theta_1 + \theta_2) \qquad \frac{z_1}{z_2} = \frac{|z_1|}{|z_2|}\angle(\theta_1 - \theta_2)$$

General AC Circuits: $V_0 = I_0|z|$ $V_{RMS} = I_{RMS}|z|$ $P = V_{RMS}I_{RMS} = \frac{1}{2}V_0 I_0$ $V_{RMS} = \frac{V_0}{\sqrt{2}}$ $I_{RMS} = \frac{I_0}{\sqrt{2}}$

Inductors in AC Circuits: $X_L = \omega L = 2\pi fL$ $Z_L = iX_L$ $V_L = IX_L$

Capacitors in AC Circuits: $X_C = \frac{1}{\omega C} = \frac{1}{2\pi fC}$ $Z_C = -iX_C$ $V_C = IX_C$

Series RLC AC Circuit: $z = R + (X_L - X_C)i \qquad |z| = \sqrt{R^2 + (X_L - X_C)^2} \qquad \theta = Tan^{-1}\left(\frac{X_L - X_C}{R}\right)$

Index of Refraction: $c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}} = \lambda f \qquad v_{EM} = \frac{1}{\sqrt{\varepsilon\mu}} = \lambda' f = \frac{\lambda f}{n} = \frac{c}{n} \qquad \lambda' = \frac{\lambda}{n}$

Law of Reflection: $\theta_i = \theta_R$ **Snell's Law**: $n_1 Sin\theta_1 = n_2 Sin\theta_2$ **Total Int. Refl.**: $Sin\theta_1 = \frac{n_2}{n_1}$

Energy Density: $\frac{\vec{E}\ Energy}{Volume} = \frac{1}{2}\varepsilon_0 E^2 \qquad \frac{\vec{B}\ Energy}{Volume} = \frac{B^2}{2\mu_0}$

Electromagnetic Waves: $E_0 = cB_0 \qquad E_{RMS} = cB_{RMS} \qquad \frac{Total\ Energy}{Volume} = \frac{1}{2}\varepsilon_0 E_{RMS}^2 + \frac{1}{2\mu_0}B_{RMS}^2 = \varepsilon_0 E_{RMS}^2 = \frac{B_{RMS}^2}{\mu_0}$

Doppler Effect for EM Waves: $f_0 = f_s\left(1 \pm \frac{V_{REL}}{c}\right)$ **Polarization**: $|E| = E_0 Cos\theta$

Mirrors/Lenses: $|f| = \frac{R}{2} \qquad \frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_0}$ **Magnification**: $M = \frac{h_i}{h_O} = -\frac{d_i}{d_O}$

Lens Sign Conventions: Focal Length (f): "+" for converging, "-" for diverging
Object Distance (d_O): "+" on left (real), "-" on right (virtual)
Image Distance (d_i): "+" on right (real), "-" on left (virtual)
Magnification (M): "+" upright, "-" inverted

Double Slit Interference: $d\sin\theta = \begin{cases} m\lambda & Constructive \\ (m+1/2)\lambda & Destructive \end{cases}$

Small Angle Approximation $\mathrm{Sin}\,\theta = \frac{\mathrm{Y}}{\mathrm{L}}$

Single Slit Interference: $d\sin\theta = \begin{cases} (m+1/2)\lambda & Constructive \\ m\lambda & Destructive \end{cases}$

Thin Film Interference: $2t + \underbrace{\left\{\frac{1}{2}\lambda_F\right\}}_{\text{Difference in Reflected Phase Shift}} = \begin{cases} m\lambda_F & Constructive \\ (m+1/2)\lambda_F & Destructive \end{cases}$ with $\lambda_F = \frac{\lambda}{n}$

Bragg (X-Ray) Diffraction: $2d\sin\theta = \begin{cases} m\lambda & Constructive \\ (m+1/2)\lambda & Destructive \end{cases}$

Special Relativity: $\gamma = \frac{1}{\sqrt{1 - v^2/c^2}} \qquad \Delta t = \gamma \Delta t_0 \qquad L = \frac{1}{\gamma}L_0 \qquad m = \gamma m_0 \qquad p = mv = \gamma m_0 v$

$$V_{AC} = \frac{V_{AB} + V_{BC}}{1 + \frac{V_{AB} \cdot V_{BC}}{c^2}} \qquad E^2 = p^2c^2 + m_0^2c^4 \qquad E_0 = m_0c^2 \qquad E = \gamma m_0 c^2 \qquad KE = (\gamma - 1)m_0c^2$$

Quantum Energy/Momentum: $E = hf = \frac{hc}{\lambda} = pc \qquad p = \frac{h}{\lambda}$

Photoelectric Effect: $KE_{Max} = hf - W_0$ **Compton Effect**: $\lambda' - \lambda = \frac{h}{m_e c}(1 - Cos\theta)$

Bohr Radius/Energy: $r_0 = \frac{\varepsilon_0 h^2}{\pi m_e e^2} \qquad r_n = n^2 r_0 \qquad E_0 = -\frac{e^4 m_e}{8\varepsilon_0^2 h^2}Z^2 = -(13.6eV)Z^2 \qquad E_n = \frac{E_0}{n^2}$

Heisenberg Uncertainty: $(\Delta x)(\Delta p) \geq \frac{h}{4\pi} = \frac{\hbar}{2} \qquad (\Delta E)(\Delta t) \geq \frac{h}{4\pi} = \frac{\hbar}{2}$