## **PHYSICS 4B EQUATION SHEET**

$\mathbf{E} = \frac{\mathbf{F}}{q}$ $\mathbf{E} = k \frac{q}{r^2} \hat{\mathbf{r}}$ $\mathbf{E} = k \int \frac{dq}{r^2} \hat{\mathbf{r}}$ $\mathbf{E} = k \int \frac{dq}{r^2} \hat{\mathbf{r}}$ $\mathbf{E} = k \int \frac{dq}{r^2} \hat{\mathbf{r}}$ $\mathbf{E} = \frac{2k\lambda}{r}$ $E = \frac{2k\lambda}{r}$ $E = \frac{\sigma}{2\varepsilon_o}$ $E = \frac{\sigma}{\varepsilon_o}$ $E = \sigma$	$\mathbf{F}_{12} = \frac{kq_1q_2}{r^2}\hat{\mathbf{r}}_{12}$	Coulomb's Law
$\mathbf{E} = k \frac{q}{r^2} \hat{\mathbf{r}}$ $\mathbf{E} = k \int \frac{dq}{r^2} \hat{\mathbf{r}}$ $\mathbf{E} = k \int \frac{dq}{r^2} \hat{\mathbf{r}}$ $E = \frac{2k\lambda}{r}$ $E = \frac{2k\lambda}{r}$ $E = \frac{\sigma}{2\varepsilon_o}$ $E = \frac{\sigma}{\varepsilon_o}$		Electric Field
$\mathbf{E} = k \int \frac{dq}{r^2} \hat{\mathbf{r}}$ $E = \frac{2k\lambda}{r}$ $E = \frac{2k\lambda}{r}$ $E = \frac{\sigma}{2\varepsilon_o}$ $E = \frac{\sigma}{\varepsilon_o}$ $E = \frac{\sigma}{\varepsilon_o}$ $E = \int \mathbf{E} \cdot \mathbf{d} \mathbf{A}$ $\Phi_E = \int \mathbf{E} \cdot \mathbf{d} \mathbf{A}$ $\Phi_E = \mathbf{E} \cdot \mathbf{e} \cdot \mathbf{d}$ $\Phi_E = \mathbf{E} \cdot \mathbf{e} $	$\mathbf{E} = k  \frac{q}{r^2}  \hat{\mathbf{r}}$	
$E = \frac{\sigma}{\varepsilon_o}$ $\Phi_E = \int \mathbf{E} \bullet d\mathbf{A}$ $\Phi_E = \oint \mathbf{E} \bullet d\mathbf{A} = \frac{q_{enc}}{\varepsilon_o}$ $p = qd$ $\mathbf{E}$ $\mathbf{E} = \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} = \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} = \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet $	$\mathbf{E} = k \int \frac{dq}{r^2} \hat{\mathbf{r}}$	
$E = \frac{\sigma}{\varepsilon_o}$ $\Phi_E = \int \mathbf{E} \bullet d\mathbf{A}$ $\Phi_E = \oint \mathbf{E} \bullet d\mathbf{A} = \frac{q_{enc}}{\varepsilon_o}$ $p = qd$ $\mathbf{E}$ $\mathbf{E} = \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} = \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} = \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E} \bullet \mathbf{E}$ $\mathbf{E} \bullet \mathbf{E} \bullet $	$E = \frac{2k\lambda}{r}$	
$\Phi_{E} = \oint \mathbf{E} \bullet \mathbf{dA} = \frac{q_{enc}}{\varepsilon_{o}}$ $p = qd$ $\mathbf{T} = \mathbf{p} \times \mathbf{E}$ $U = -\mathbf{p} \bullet \mathbf{E}$ $\Delta V = \frac{\Delta U}{q} = V_{B} - V_{A} = -\int_{A}^{B} \mathbf{E} \bullet d\mathbf{s}$ $U = qV$ $U = \frac{kq_{1}q_{2}}{r}$ $V = \frac{kq}{r}$ $V = k \int \frac{dq}{r}$ $Electric Potential Energy Electric Potential Energy Electric Potential Ue to a point charge Electric Potential due to an extended body of charge Electric Potential due to an extended body of charge Electric Potential due to an extended body of charge Electric Potential due to an extended body of charge Electric Potential due to an extended body of charge Electric Potential due to an extended body of charge Electric Potential due to an extended body of charge Electric Potential due to an extended body of charge Electric Potential due to an extended body of charge Electric Potential due to an extended body of charge Electric Potential Energy Capacitance For Potential due to an extended body of charge Electric Potential Energy Electric Potential$	$E = \frac{\sigma}{2\varepsilon_o}$	
$\Phi_{E} = \oint \mathbf{E} \bullet \mathbf{dA} = \frac{q_{enc}}{\varepsilon_{o}}$ $p = qd$ $\mathbf{T} = \mathbf{p} \times \mathbf{E}$ $U = -\mathbf{p} \bullet \mathbf{E}$ $\Delta V = \frac{\Delta U}{q} = V_{B} - V_{A} = -\int_{A}^{B} \mathbf{E} \bullet d\mathbf{s}$ $U = qV$ $U = \frac{kq_{1}q_{2}}{r}$ $V = \frac{kq}{r}$ $V = k \int \frac{dq}{r}$ $Electric Potential Energy Electric Potential Energy Electric Potential Ue to a point charge Electric Potential due to an extended body of charge Electric Potential due to an extended body of charge Electric Potential due to an extended body of charge Electric Potential due to an extended body of charge Electric Potential due to an extended body of charge Electric Potential due to an extended body of charge Electric Potential due to an extended body of charge Electric Potential due to an extended body of charge Electric Potential due to an extended body of charge Electric Potential due to an extended body of charge Electric Potential Energy Capacitance For Potential due to an extended body of charge Electric Potential Energy Electric Potential$	$E = \frac{\sigma}{\varepsilon_o}$	-
$\Phi_{E} = \oint \mathbf{E} \bullet \mathbf{dA} = \frac{q_{enc}}{\varepsilon_{o}}$ $p = qd$ $\mathbf{T} = \mathbf{p} \times \mathbf{E}$ $U = -\mathbf{p} \bullet \mathbf{E}$ $\Delta V = \frac{\Delta U}{q} = V_{B} - V_{A} = -\int_{A}^{B} \mathbf{E} \bullet d\mathbf{s}$ $U = qV$ $U = \frac{kq_{1}q_{2}}{r}$ $V = \frac{kq}{r}$ $V = k \int \frac{dq}{r}$ $Electric Potential Energy Electric Potential Energy Electric Potential Ue to a point charge Electric Potential due to an extended body of charge Electric Potential due to an extended body of charge Electric Potential due to an extended body of charge Electric Potential due to an extended body of charge Electric Potential due to an extended body of charge Electric Potential due to an extended body of charge Electric Potential due to an extended body of charge Electric Potential due to an extended body of charge Electric Potential due to an extended body of charge Electric Potential due to an extended body of charge Electric Potential Energy Capacitance For Potential due to an extended body of charge Electric Potential Energy Electric Potential$	$\Phi_E = \int \mathbf{E} \bullet \mathbf{dA}$	Electric Flux
$p = qd$ Electric Dipole Moment $\tau = \mathbf{p} \times \mathbf{E}$ Torque on Electric Dipole $U = -\mathbf{p} \bullet \mathbf{E}$ PE of electric dipole $\Delta V = \frac{\Delta U}{q} = V_B - V_A = -\int_A^B \mathbf{E} \bullet d\mathbf{s}$ Electric Potential Difference $U = qV$ Electric Potential Energy $U = \frac{kq_1q_2}{r}$ Electric Potential due to a point charge $V = \frac{kq}{r}$ Electric Potential due to an extended body of charge $\vec{E} = -\vec{\nabla}V$ Relation between V and E $C = \frac{Q}{V}$ Capacitance $C = \frac{\varepsilon_o A}{d}$ Capacitance for Parallel-Plate Capacitor $C_{ac} = C_1 + C_2$ Capacitors in Parallel	$\Phi_E = \oint \mathbf{E} \bullet \mathbf{dA} = \frac{q_{enc}}{\varepsilon_o}$	Gauss's Law
$U = -\mathbf{p} \bullet \mathbf{E}$ $\Delta V = \frac{\Delta U}{q} = V_B - V_A = -\int_A^B \mathbf{E} \bullet d\mathbf{s}$ $U = qV$ $U = \frac{kq_1q_2}{r}$ $V = \frac{kq}{r}$ $V = k \int \frac{dq}{r}$ $Electric Potential Energy$ $Electric Potential Energy$ $Electric Potential due to a point charge$ $Electric Potential due to a point charge$ $Electric Potential due to a point charge$ $Electric Potential due to an extended body of charge$ $Electric Potential due to an extended body of charge$ $Electric Potential due to an extended body of charge$ $Capacitance$ $Capacitance$ $Capacitance$ $Capacitance for Parallel-Plate Capacitor Capacitors in Parallel$		Electric Dipole Moment
$\Delta V = \frac{\Delta U}{q} = V_B - V_A = -\int_A^B \mathbf{E} \cdot d\mathbf{s}$ $U = qV$ $U = \frac{kq_1q_2}{r}$ $V = \frac{kq}{r}$ $V = k \int \frac{dq}{r}$ $\vec{E} = -\vec{\nabla}V$ $C = \frac{Q}{V}$ $Electric Potential Energy Electric Potential due to a point charge Electric Potential due to a point charge Capacitance \vec{E} = -\vec{\nabla}V Capacitance Capacitance for Parallel-Plate Capacitor Capacitors in Parallel$	$\tau = \mathbf{p} \times \mathbf{E}$	Torque on Electric Dipole
$\Delta V = \frac{\Delta C}{q} = V_B - V_A = -\int_A \mathbf{E} \cdot d\mathbf{s}$ $U = qV$ Electric Potential Energy $U = \frac{kq_1q_2}{r}$ Electric Potential Ue to a point charge $V = k\frac{dq}{r}$ Electric Potential due to a point charge $V = k\int_{-r}^{r} \frac{dq}{r}$ Electric Potential due to an extended body of charge $\vec{E} = -\vec{\nabla}V$ Relation between V and E $C = \frac{Q}{V}$ $C = \frac{\varepsilon_o A}{d}$ $Capacitance$ Capacitance for Parallel-Plate Capacitor $C_{aa} = C_1 + C_2$ Capacitors in Parallel	$U = -\mathbf{p} \bullet \mathbf{E}$	PE of electric dipole
$U = \frac{kq_1q_2}{r}$ Electric Potential Energy $V = \frac{kq}{r}$ Electric Potential due to a point charge $V = k \int \frac{dq}{r}$ Electric Potential due to an extended body of charge $\vec{E} = -\vec{\nabla}V$ Relation between V and E $C = \frac{Q}{V}$ Capacitance $C = \frac{\varepsilon_o A}{d}$ Capacitance for Parallel-Plate Capacitor $C_{aa} = C_1 + C_2$ Capacitors in Parallel	$\Delta V = \frac{\Delta U}{q} = V_B - V_A = -\int_A^B \mathbf{E} \bullet d\mathbf{s}$	Electric Potential Difference
$U = \frac{kq}{r}$ $V = \frac{kq}{r}$ Electric Potential due to a point charge $V = k \int \frac{dq}{r}$ Electric Potential due to an extended body of charge $\vec{E} = -\vec{\nabla}V$ Relation between V and E $C = \frac{Q}{V}$ $C = \frac{e_o A}{d}$ $Capacitance$ Capacitance for Parallel-Plate Capacitor $C_{aa} = C_1 + C_2$ Capacitors in Parallel	U = qV	Electric Potential Energy
$r$ $V = k \int \frac{dq}{r}$ Electric Potential due to an extended body of charge $\vec{E} = -\vec{\nabla}V$ Relation between V and E $C = \frac{Q}{V}$ Capacitance $C = \frac{\varepsilon_o A}{d}$ Capacitance for Parallel-Plate Capacitor $C_{aa} = C_1 + C_2$ Capacitors in Parallel	$U = \frac{kq_1q_2}{r}$	Electric Potential Energy
$C = \frac{Q}{V}$ Capacitance $C = \frac{\varepsilon_o A}{d}$ Capacitance for Parallel-Plate Capacitor $C_{aa} = C_1 + C_2$ Capacitors in Parallel	r	
$C = \frac{Q}{V}$ Capacitance $C = \frac{\varepsilon_o A}{d}$ Capacitance for Parallel-Plate Capacitor $C_{aa} = C_1 + C_2$ Capacitors in Parallel	$V = k \int \frac{dq}{r}$	
$C = \frac{Q}{V}$ Capacitance $C = \frac{\varepsilon_o A}{d}$ Capacitance for Parallel-Plate Capacitor $C_{aa} = C_1 + C_2$ Capacitors in Parallel	$\vec{E} = -\vec{\nabla}V$	Relation between V and E
$C = \frac{\varepsilon_o A}{d}$ Capacitance for Parallel-Plate Capacitor $C_{eq} = C_1 + C_2$ Capacitors in Parallel  1 1 1 Capacitors in Series	$C = \frac{Q}{V}$	Capacitance
$C_{eq} = C_1 + C_2$ Capacitors in Parallel  1 1 1 Capacitors in Series	V	
1 1 1 Capacitors in Series	$C = \frac{\varepsilon_o A}{d}$	
$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$ Capacitors in Series	$C = \frac{\varepsilon_o A}{d}$ $C_{eq} = C_1 + C_2$	Plate Capacitor

$\mu = \frac{1}{2}\varepsilon_o E^2$ $C = kC_o$	Energy Density in an E-field
$C = kC_o$	Capacitance with Dielectric
$E = \frac{E_o}{k}$	E-field with Dielectric
$E = \frac{b}{k}$ $U = \frac{1}{2}CV^{2}$ $I = \frac{dQ}{dt}$ $J = \frac{I}{A}$ $\mathbf{J} = \sigma \mathbf{E}$	Energy in a Capacitor
$I = \frac{dQ}{dt}$	Electric Current
$J = \frac{I}{A}$	Current Density
$J = \sigma E$	Ohm's Law
$R = \frac{\rho \ell}{A}$ $V = IR$	Resistance
V = IR	"Ohm's Law"
$\rho = \frac{1}{\sigma}$ $R_{eq} = R_1 + R_2$	Resistivity
$R_{eq} = R_1 + R_2$	Resistors in Series
$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$	Resistors in Parallel
$I(t) = \frac{V}{R}e^{-\frac{t}{\tau}}$	Current Charging Capacitor
$q(t) = CV(1 - e^{-\frac{t}{\tau}})$	Charge Charging Capacitor
$\tau = RC$	Time-Constant
$\mathbf{F} = q\mathbf{v} \times \mathbf{B}$	Magnetic Force on a Moving Charge
$\mathbf{F} = I \mathbf{L} \times \mathbf{B}$	Magnetic Force on a Current-Carrying Conductor
$\mathbf{F} = I \int_{a}^{b} d\mathbf{s} \times \mathbf{B}$	Magnetic Force on a Current-Carrying Conductor
$\tau = \mu \times \mathbf{B}$	Torque on Current Loop
$U = -\mu \bullet \mathbf{B}$	Magnetic Potential Energy
$\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$	Lorentz Force
$\Delta V_H = \frac{IB}{nqt}$	Hall Voltage

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

$$\mathbf{B} = \frac{\mu_o}{4\pi} \frac{q\mathbf{v} \times \hat{\mathbf{r}}}{r^2}$$

$$\oint \mathbf{B} \bullet d\ell = \mu_o (I + I_d)$$

$$I_d = \varepsilon_o \frac{d\Phi_E}{dt}$$

$$B = \mu_o nI$$

$$\Phi_B = \int \mathbf{B} \bullet d\mathbf{A}$$

$$\varepsilon = -\frac{d\Phi_B}{dt}$$

$$\oint \mathbf{E} \bullet d\mathbf{s} = -\frac{d\Phi_B}{dt}$$

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

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

$$I = \frac{V}{R} (1 - e^{-\frac{t}{\tau}})$$

$$\tau = \frac{L}{R}$$

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

$$\mu_{B} = \frac{B^{2}}{2\mu_{o}}$$

$$M_{12} = \frac{N_{2}\Phi_{12}}{I_{1}}$$

$$I_{rms} = \frac{I_{p}}{\sqrt{2}}$$

$$V_{rms} = \frac{V_{p}}{\sqrt{2}}$$

$$X_{L} = \omega L$$

$$X_{x} = \frac{1}{\omega C}$$

$$V_{R} = I_{p}R\sin \omega t$$

$$V_{L} = I_{p}X_{L}\sin\left(\omega t + \frac{\pi}{2}\right)$$

$$V_{c} = I_{p}X_{c}\sin\left(\omega t - \frac{\pi}{2}\right)$$

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

$$V = I_{p}Z$$

$$Z = \sqrt{R^{2} + (X_{L} - X_{c})^{2}}$$

$$\phi = \tan^{-1}\left(\frac{X_{L} - X_{c}}{R}\right)$$

$$\omega_{o} = \frac{1}{\sqrt{LC}}$$