Physics 102 - Formula Sheet

Coulomb's law: $F_{12} = k\,\dfrac{|Q_1 Q_2|}{r^2} = \dfrac{1}{4\pi\varepsilon_0}\,\dfrac{|Q_1 Q_2|}{r^2}$

Force on a charge q due to electric field: $\vec{\boldsymbol{F}} = q\vec{\boldsymbol{E}}$

Electric field due to a charge distribution: $\vec{\boldsymbol{E}} = k\int_Q \dfrac{dq}{r^2}\,\hat{\boldsymbol{r}} = \dfrac{1}{4\pi\varepsilon_0}\int_Q \dfrac{dq}{r^2}\,\hat{\boldsymbol{r}}$

Gauss' law: $\Phi_E = \oint_S \vec{\boldsymbol{E}}\cdot d\vec{\boldsymbol{A}} = \dfrac{Q_{enc}}{\varepsilon_0}$

Electric field calculations:

Charge distribution	Electric field $\vec{\boldsymbol{E}}$
Point charge	$\vec{\boldsymbol{E}} = \dfrac{kQ}{r^2}\,\hat{\boldsymbol{r}}$
Charged ring of radius a (along its axis, which is taken to be the X-axis)	$\vec{\boldsymbol{E}} = \dfrac{kQ\,x}{(x^2+a^2)^{3/2}}\,\hat{\boldsymbol{i}}$
Charged disc of radius a (along its axis, which is taken to be the X-axis)	$E = \dfrac{\lvert\sigma\rvert}{2\varepsilon_0}\left[1 - \dfrac{\lvert x\rvert}{\sqrt{x^2+a^2}}\right]$ (magnitude)
Infinite non-conducting charged sheet perpendicular to the X-axis	$E = \dfrac{\lvert\sigma\rvert}{2\varepsilon_0}$ (magnitude)
Infinite line with uniform charge distribution	$\vec{\boldsymbol{E}} = \dfrac{\lambda}{2\pi\varepsilon_0 r}\,\hat{\boldsymbol{r}} = \dfrac{2k\lambda}{r}\,\hat{\boldsymbol{r}}$
Sphere of radius a with uniform charge distribution	$\vec{\boldsymbol{E}} = \dfrac{kQ}{r^2}\,\hat{\boldsymbol{r}}\quad r \geq a$ $\vec{\boldsymbol{E}} = \dfrac{kQ\,r}{a^3}\,\hat{\boldsymbol{r}}\quad r \leq a$

Electric potential: $V = k\int_Q \dfrac{dq}{r} = \dfrac{1}{4\pi\varepsilon_0}\int_Q \dfrac{dq}{r}$ relative to $V = 0$ at $r \to \infty$

Relationship between $\vec{\boldsymbol{E}}$ and V: $V_a - V_b = \int_a^b \vec{\boldsymbol{E}}\cdot d\vec{\boldsymbol{l}}$ $\qquad E_i = -\dfrac{\partial V}{\partial x_i}$

Work done by the field in moving a charge q from a to b : $W_{ab} = U_a - U_b = q\,(V_a - V_b)$

Potential energy of a system of point charges: $U = \sum_{i<j} \dfrac{kQ_iQ_j}{r_{ij}}$

Electric potential calculations (Relative to $V = 0$ at ∞):

Charge distribution	Electric potential V
Point charge	$\dfrac{kQ}{r}$
Charged ring of radius a (along its axis, which is taken to be the X-axis)	$\dfrac{kQ}{\sqrt{x^2+a^2}}$
Charged disc of radius a (along its axis, which is taken to be the X-axis)	$\dfrac{\sigma}{2\varepsilon_0}\left[\sqrt{x^2+a^2}-\lvert x\rvert\right]$
Sphere of radius a with uniform charge distribution	$\dfrac{kQ}{r}$ $\quad r \geq a$ $\dfrac{kQ}{2a}\left[3-\dfrac{r^2}{a^2}\right]$ $\quad r \leq a$

Capacitors: $C = \dfrac{Q}{V}$

Capacitance of different capacitors (for air or vacuum, $K = 1$):

Capacitor	Capacitance
Parallel-plate capacitor with plate-area A and thickness d	$K\varepsilon_0 \, \dfrac{A}{d}$
Spherical capacitor of radii a and b	$K\varepsilon_0 \, \dfrac{4\pi ab}{b-a}$
Isolated sphere of radius a	$K\varepsilon_0 \, 4\pi a$
Cylindrical capacitor of radii a and b, and length L	$K\varepsilon_0 \, \dfrac{2\pi L}{\ln(b/a)}$

Capacitor combinations:

Series connection: $\dfrac{1}{C_{eq}} = \sum_{i=1}^{N} \dfrac{1}{C_i}$

Parallel connection: $C_{eq} = \sum_{i=1}^{N} C_i$

Energy stored: $U = \dfrac{1}{2}QV = \dfrac{1}{2}CV^2 = \dfrac{Q^2}{2C}$

Energy density: $u = \dfrac{1}{2}K\varepsilon_0 E^2$

Electric current and resistance: $I = \frac{dQ}{dt} = \int \vec{\boldsymbol{J}} \cdot d\vec{\boldsymbol{A}}$ $\quad \vec{\boldsymbol{J}} = nq\vec{\boldsymbol{v}}_d$ $\quad Q = \int I\, dt$

$V = IR$ $\quad R = \rho \frac{L}{A}$ $\quad \rho_T = \rho_0 \left[1 + \alpha (T - T_0)\right]$ $\quad P = IV = I^2 R = \frac{V^2}{R}$

Resistor combinations:

Series connection: $R_{eq} = \sum_{i=1}^{N} R_i$ $\quad$ Parallel connection: $\frac{1}{R_{eq}} = \sum_{i=1}^{N} \frac{1}{R_i}$

RC circuits: (Time Constant, $\tau = RC$)

Charging: $Q(t) = C\mathcal{E}\left(1 - e^{-t/\tau}\right)$ $\quad$ Discharging: $Q(t) = Q_0 e^{-t/\tau}$

Charged particle in a uniform magnetic field: $\vec{\boldsymbol{F}} = q\vec{\boldsymbol{v}} \times \vec{\boldsymbol{B}}$ $\quad R = \frac{mv_\perp}{Bq}$ $\quad T = \frac{2\pi m}{Bq}$

Force on a current carrying conductor in a uniform magnetic field: $\vec{\boldsymbol{F}} = I\vec{\boldsymbol{L}} \times \vec{\boldsymbol{B}}$

Magnetic field of a moving point charge: $\vec{\boldsymbol{B}} = \frac{\mu_0}{4\pi} \frac{q\vec{\boldsymbol{v}} \times \hat{\boldsymbol{r}}}{r^2}$

Biot and Savart law: $d\vec{\boldsymbol{B}} = \frac{\mu_0}{4\pi} \frac{I\, d\vec{\boldsymbol{l}} \times \hat{\boldsymbol{r}}}{r^2}$

Amperes's law: $\oint \vec{\boldsymbol{B}} \cdot d\vec{\boldsymbol{l}} = \mu_0 I_{enc}$

Magnetic field calculations:

Shape of the conductor carrying current	Magnetic field B (magnitude)
Long straight wire	$B = \frac{\mu_0 I}{2\pi r}$
Circular loop of radius a (along its axis, which is taken to be the X-axis)	$B = \frac{\mu_0 I a^2}{2\left(x^2 + a^2\right)^{3/2}}$
Long solenoid	$B = \mu_0 n I$

Force between two long parallel straight wires carrying current: $\frac{F}{L} = \frac{\mu_0 I_1 I_2}{2\pi d}$

Faraday's law of induction: $\mathcal{E} = -N\frac{d\Phi_B}{dt}$ $\quad \Phi_B = \int \vec{\boldsymbol{B}} \cdot d\vec{\boldsymbol{A}}$

Motional emf: $\mathcal{E} = BLv$ $\quad F = \frac{B^2 L^2 v}{R}$ $\quad$ Induced electric field: $\oint \vec{\boldsymbol{E}} \cdot d\vec{\boldsymbol{l}} = -\frac{d\Phi_B}{dt}$