

**Formulas:**

$$\sin 30^\circ = \cos 60^\circ = 1/2, \quad \cos 30^\circ = \sin 60^\circ = \sqrt{3}/2, \quad \sin 45^\circ = \cos 45^\circ = \sqrt{2}/2$$

$$F = k \frac{q_1 q_2}{r^2} \quad \text{Coulomb's law} ; k = 9 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2 ; \vec{F}_{12} = \frac{k q_1 q_2}{|\vec{r}_2 - \vec{r}_1|^3} (\vec{r}_2 - \vec{r}_1)$$

$$\text{Electric field due to charge } q \text{ at distance } r : \vec{E} = \frac{kq}{r^2} \hat{r} ; \text{ Force on charge } Q: \vec{F} = Q\vec{E}$$

$$\text{Electric field of dipole: along dipole axis / perpendicular: } E = \frac{2kp}{x^3} / \quad E = \frac{kp}{y^3} (p=qd)$$

$$\text{Energy of and torque on dipole in E-field: } U = -\vec{p} \cdot \vec{E} , \quad \vec{\tau} = \vec{p} \times \vec{E}$$

$$\text{Linear, surface, volume charge density: } dq = \lambda ds , \quad dq = \sigma dA , \quad dq = \rho dV$$

$$\text{Electric field of infinite: line of charge: } E = \frac{2k\lambda}{r} ; \quad \text{sheet of charge: } E = 2\pi k\sigma = \sigma / (2\epsilon_0)$$

$$\text{Gauss law: } \Phi = \oint \vec{E} \cdot d\vec{A} = \frac{q_{enc}}{\epsilon_0} ; \quad \Phi = \text{electric flux} ; k = \frac{1}{4\pi\epsilon_0} ; \epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2 / \text{Nm}^2$$

$$U_B - U_A = \Delta U_{AB} = -W_{AB} = -\int_A^B \vec{F} \cdot d\vec{l} = -\int_A^B q\vec{E} \cdot d\vec{l} = q\Delta V_{AB} = q(V_B - V_A) \quad V = N/C$$

$$V = \frac{kq}{r} ; V = \int \frac{k dq}{r} ; V = \frac{kp \cos \theta}{r^2} \text{ (dipole)} ; E_l = -\frac{\partial V}{\partial l} ; \vec{E} = -\nabla V$$

$$\text{Electrostatic energy: } U = k \frac{q_1 q_2}{r} ; \text{ Capacitors: } Q = CV ; \text{ with dielectric: } C = \kappa C_0 ; \epsilon_0 = 8.85 \text{ pF/m}$$

$$C = \frac{\epsilon_0 A}{d} \text{ parallel plates} ; C = \frac{2\pi\epsilon_0 L}{\ln(b/a)} \text{ cylindrical} ; C = 4\pi\epsilon_0 \frac{ab}{b-a} \text{ spherical}$$

$$\text{Energy stored in capacitor: } U = \frac{Q^2}{2C} = \frac{1}{2} QV = \frac{1}{2} CV^2 ; U = \int dv u_E ; u_E = \frac{1}{2} \epsilon_0 E^2$$

$$\text{Capacitors in parallel: } C = C_1 + C_2 ; \text{ in series: } C = C_1 C_2 / (C_1 + C_2)$$

$$\text{Elementary charge: } e = 1.6 \times 10^{-19} \text{ C}$$

$$I = \frac{dq}{dt} = \int \vec{J} \cdot d\vec{A} ; \vec{J} = ne\vec{v}_d ; v_d = \frac{eE\tau}{m} ; \rho = \frac{m}{ne^2\tau} ; R = \rho \frac{\ell}{A} ; \vec{E} = \rho \vec{J}, \vec{J} = \sigma \vec{E}$$

$$V = IR ; P = VI = I^2 R = V^2 / R ; P_{emf} = \mathcal{E}I ; R_{eq} = R_1 + R_2 \text{ (series)} ; R_{eq}^{-1} = R_1^{-1} + R_2^{-1} \text{ (parallel)}$$

$$\text{Charging capacitor: } Q(t) = C\mathcal{E}(1 - e^{-t/RC}) ; \text{ Discharging capacitor: } Q(t) = Q_0 e^{-t/RC}$$

$$\text{Force on moving charge: } \vec{F} = q(\vec{E} + \vec{v} \times \vec{B}) ; \text{ force on wire: } d\vec{F} = Id\vec{\ell} \times \vec{B}$$

$$\text{Circular motion: } a = \frac{v^2}{r} ; \text{ radius } r = \frac{mv}{qB} ; \text{ period } T = \frac{2\pi m}{qB}$$

$$\text{Magnetic dipole: } \vec{\mu} = I\vec{A} ; \text{ torque: } \vec{\tau} = \vec{\mu} \times \vec{B} ; \text{ energy: } U = -\vec{\mu} \cdot \vec{B}$$

$$\text{Biot - Savart law: } d\vec{B} = \frac{\mu_0}{4\pi} \frac{Id\vec{\ell} \times \hat{r}}{r^2} ; \mu_0 = 4\pi \times 10^{-7} \frac{\text{N}}{\text{A}^2} ; \text{ Ampere's law: } \oint \vec{B} \cdot d\vec{\ell} = \mu_0 I_{enc}$$

$$\text{Long wire: } B = \frac{\mu_0 I}{2\pi r} ; \text{ loop, along axis: } B = \frac{\mu_0 I a^2}{2(a^2 + z^2)^{3/2}} ; \text{ dipole: } \vec{B} = \frac{\mu_0 \vec{\mu}}{2\pi x^3}$$

$$\text{solenoid: } B = \mu_0 I n ; \text{ toroid: } B = \frac{\mu_0 N I}{2\pi r} ; \text{ Gauss law for magnetism: } \oint \vec{B} \cdot d\vec{A} = 0$$