Formula Sheet: Electricity and Magnetism

Coulomb's law

$$F = k\frac{qQ}{r^2}$$

Electric Field

$$\vec{E} = \frac{\vec{F}}{q}$$

Field of a point charge

$$E = k\frac{Q}{r^2}$$

Electric field inside a capacitor

$$E = \frac{\eta}{\varepsilon_0}$$

Principle of superposition

$$\vec{E}_{net} = \sum_{i=1}^{N} \vec{E}_i$$

Electric flux

$$\Phi_E = \int \vec{E} \cdot d\vec{A}$$

Gauss's law

$$\Phi = \oint \vec{E} \cdot d\vec{A} = \frac{Q_{in}}{\varepsilon_0}$$

Electric potential

$$V = \frac{U}{q}$$

$$\Delta V = V_f - V_i = -\int_i^f \vec{E} \cdot d\vec{s}$$

For a point charge $V(r) = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$

For a paralle-plate capacitor

$$V = Es$$

Potential Energy

$$U = qV$$

Two point charges

$$U = k\frac{qQ}{r}$$

Capacitors

$$C = \frac{Q}{\Delta V}$$

Parallel-plate $C = \varepsilon_0 \frac{A}{d}$

Capacitors connected in parallel

$$C_{eq} = C_1 + C_2 + \cdots$$

Capacitors connected in series

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots$$

Energy stored in a capacitor $U = \frac{Q^2}{2C}$

Ohm's law

$$V = IR$$

$$I = \frac{dQ}{dt}$$

$$R = \rho\frac{l}{A}$$

$$\sum I_{in} = \sum I_{out}$$

$$\sum \Delta V_i = 0$$

Power

$$P = IV$$

Resistors connected in series

$$R_{eq} = R_1 + R_2 + R_3 + \cdots$$

Resistors connected in parallel

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$$

The potential difference across a charging capacitor in RC circuit

$$V(t) = \varepsilon(1 - e^{-t/RC})$$

A magnetic field exerts a force

$$\overrightarrow{dF} = I\overrightarrow{dl} \times \vec{B}$$

$$\vec{F} = I\vec{l} \times \vec{B}$$

$$\vec{F} = q\vec{v} \times \vec{B}$$

The Biot-Savart Law

$$\vec{B} = \frac{\mu_0 q\vec{v} \times \hat{r}}{4\pi r^2}$$

$$d\vec{B} = \frac{\mu_0 I d\vec{s} \times \hat{r}}{4\pi r^2}$$

The magnetic field of:

A straight line wire

$$B = \frac{\mu_0 I}{2\pi r}$$

A solenoid

$$B = \mu_0 n I$$

Magnetic flux

$$\Phi_B = \int \vec{B} \cdot d\vec{A}$$

Inductance

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

$$L = \frac{\mu_0 N^2 A}{l}$$

$$\varepsilon = -L\frac{dI}{dt}$$

Energy stored in an inductor

$$U = L\frac{I^2}{2}$$

"Discharged" LR circuit

$$I = I_0 e^{-t/\tau};\ \tau = L/R$$

Maxwell's equations

$$\oint \vec{E} \cdot \overrightarrow{dA} = \frac{Q}{\varepsilon_0}$$

$$\oint \vec{B} \cdot \overrightarrow{dA} = 0$$

$$\mathcal{E} = \oint \vec{E} \cdot \overrightarrow{ds} = -\frac{d\Phi_B}{dt}$$

$$\oint \vec{B} \cdot \overrightarrow{ds} = \mu_0 I + \mu_0 \varepsilon_0 \frac{d\Phi_E}{dt}$$

$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$$

The Poynting vector

$$\vec{S} = \frac{1}{\mu_0}(\vec{E} \times \vec{B})$$

Malus's Law

$$I = I cos^2\theta$$

Traveling Wave

$$y(x,t) = Asin(kx - \omega t + \varphi_0)$$

$$k = \frac{2\pi}{\lambda};\ \omega = \frac{2\pi}{T};\ v = \lambda f$$

Interference

$$\Delta\varphi = 2\pi\frac{\Delta r}{\lambda} + \Delta\varphi_0 = m2\pi\ (constr)$$

$$\Delta\varphi = 2\pi\frac{\Delta r}{\lambda} + \Delta\varphi_0 = (m + \frac{1}{2})2\pi\ (destr)$$

$$A = \left|2\text{acos}(\frac{\Delta\varphi}{2})\right|$$

Standing Waves

$$A(x)=2a\,Sin(kx)$$

$$\lambda_m = \frac{2L}{m};\ \ f_m = m\frac{v}{2L}$$

Double Slit

$$y_m = \frac{m\lambda L}{d}$$

Diffraction grating

$$d\sin\theta_m = m\lambda$$

$$y_m = L\tan\theta_m$$

Thin-lens equation:

$$\frac{1}{f} = \frac{1}{s} + \frac{1}{s'}$$

$$m = -\frac{s'}{s};\quad |m| = \frac{h'}{h}$$

Snell's Law:

$$n_1\sin\theta_1 = n_2\sin\theta_2$$

$$\text{TIR:}\quad \sin\theta_c = \frac{n_2}{n_1}$$

Constants

Charge on electron

$e = 1.60 \cdot 10^{-19}\ C$

Electron mass $m = 9.11 \cdot 10^{-31}\ kg$

Proton mass $m = 1.67 \cdot 10^{-27}\ kg$

Permittivity of free space

$$\varepsilon_0 = 8.85 \cdot 10^{-12}\ C^2/Nm^2$$

Permeability of free space

$$\mu_0 = 4\pi \cdot 10^{-7}\ Tm/A$$

$$k = \frac{1}{4\pi\varepsilon_0} = 8.99 \cdot 10^9\ Nm^2/C^2$$

$$c = \frac{1}{\sqrt{\varepsilon_0\mu_0}} = 3.0 \cdot 10^8 m/s$$

Kinematic eq-ns with const. Acc.:

$v(t) = v_{0x} + at$

$x(t) = x_0 + v_{0x}t + (1/2)\,at^2$

$v^2 = v_{0x}^2 + 2a(x - x_0)$

Centripetal acceleration $a_R = v^2/r$

$L = 2\pi R$

$A = \pi R^2$

$V = (4/3)\pi R^3$