PHY2054 Exam 2 Formula Sheet

Vectors

$\vec{a} = a_x\hat{x} + a_y\hat{y} + a_z\hat{z}$ $\vec{b} = b_x\hat{x} + b_y\hat{y} + b_z\hat{z}$ **Cross Product Magbitude:** $\left|\vec{a}\times\vec{b}\right| = \left|\vec{a}\right|\left|\vec{b}\right|\sin\theta_{ab}$

Cross Product Vector: $\vec{c} = \vec{a}\times\vec{b} = (a_y b_z - a_z b_y)\hat{x} - (a_x b_z - a_z b_x)\hat{y} + (a_x b_y - a_y b_x)\hat{z}$

Electromagnetic Force

Electrmagnetic Force (vector): $\vec{F}_{EM} = \vec{F}_E + \vec{F}_B = q\vec{E} + q\vec{v}\times\vec{B}$ $\vec{F}_E = q\vec{E}$ $\vec{F}_B = q\vec{v}\times\vec{B}$

(r = distance between charge Q and charge q, v = velocity of charge q, V = velocity of charge Q)

$\vec{F}_E = k\dfrac{Qq}{r^2}\hat{r}$ (units = N) $\vec{F}_B = k\dfrac{Qq}{c^2r^2}\vec{v}\times\vec{V}\times\hat{r}$ (units = N)

$k = 1/(4\pi\varepsilon_0) \approx 8.99\text{x}10^9$ N·m^2/C^2 $\varepsilon_0 \approx 8.85\text{x}10^{-12}$ C^2/(N·m^2)

$k_B = k/c^2 = \mu_0/(4\pi) \approx 10^{-7}$ Tm/A $\mu_0 \approx 4\pi \times 10^{-7}$ Tm/A $c \approx 3 \times 10^8$ m/s (speed of light)

Electric Field (due to Q): $\vec{E} = k\dfrac{Q}{r^2}\hat{r}$ (units = N/C = V/m)

Magnetic Field (due to Q): $\vec{B} = k_B\dfrac{Q}{r^2}\vec{V}\times\hat{r}$ (units = N/(C·m/s) = T)

Magnetic Field (due to current I): $\vec{B} = k_B\dfrac{I}{r^2}\vec{l}\times\hat{r}$ (units = N/(C·m/s) = T)

Energy Density (Electric & Magnetic Field): $u_E = \frac{1}{2}\varepsilon_0 E^2$ $u_B = \frac{1}{2\mu_0}B^2$ (units = J/m^3)

Magnetic Force (on a long straight wire carrying current I): $\vec{F}_B = I\vec{L}\times\vec{B}$ (units = N)

Magnetic Dipole Moment (N loops, current I, area A): $\vec{\mu}_B = NI\vec{A}$ (units = A·m^2) $\vec{A} = A\hat{n}$

Magnetic Torque on a Magnetic Dipole: $\vec{\tau} = \vec{\mu}_B \times \vec{B}$ (units = N·m)

Ampere's Law: $\oint_C \vec{B}\cdot d\vec{l} = \sum_C B_{\parallel}\Delta l = \mu_0 I_{enclosed}$ (around a closed loop)

Magnetic Field (Examples)

Infinite Straight Wire Carrying Current I: $\left|\vec{B}\right| = 2k_B I / r_{perp}$ (units = T)

Center of a Circular Loop Carrying Current I: $\left|\vec{B}\right| = 2\pi k_B I / R$ (units = T)

Infinite Solenoid (current I, n loops per unit length): $\left|\vec{B}\right| = \mu_0 n I$ (units = T)

Electromagnetic Induction, RL Circuits, and LC Circuits

Magnetic Flux (uniform B, surface A)**:** $\Phi_B = \vec{B}\cdot\vec{A} = BA\cos\theta = B_{perp}A$ units = Tm^2 = Wb

Faraday's Law of Induction: $\varepsilon = -\dfrac{\Delta\Phi_B}{\Delta t}$ (ε = induced EMF, units = V)

Inductor (inductance L units = H)**:** $\Delta V_L = -L\dfrac{\Delta I}{\Delta t}$ (potential difference) $U_L = \frac{1}{2}LI^2$ (stored energy)

RL Circuits (time constant)**:** $\tau_L = L/R$ (units = H/Ω = s)

RL Circuits (EMF ε, Resistor R, Inductor L, swirch closed at t = 0)**:** $I(t) = \varepsilon(1 - e^{-t/\tau_L})/R$

Oscillating LC Circuit (no resistance)**:** $U_{tot} = \frac{1}{2}Q^2/C + \frac{1}{2}LI^2$ (stored energy) $\omega = 1/\sqrt{LC}$

Oscillating LC Circuit (no resistance)**:** $Q(t) = Q_0\sin(\omega t + \varphi)$ $I(t) = I_0\cos(\omega t + \varphi)$

Oscillating LC Circuit (no resistance)**: f = ω/2π** (frequency of oscillations in Hz)