Chapter 8

FORMULA SHEET

Electromagnetic Waves

1. Displacement Current

$$I_d = \epsilon_0 \frac{d\phi_E}{dt} = \epsilon_0 \frac{d}{dt}(EA)$$

$\phi_E \rightarrow$ Electric flux $(\phi = EA\cos\theta)$

2. Modified Ampere's circuital Law

$$\int \vec{B}\cdot d\vec{l} = \mu_0 \left(I + \epsilon_0 \frac{d\phi_E}{dt} \right)$$

3. Maxwell's Equations

(i) $\oint \vec{E}\cdot d\vec{A} = \frac{q}{\epsilon_0}$ [Gauss law in electrostatics]

(ii) $\oint \vec{B}\cdot d\vec{A} = 0$ [Gauss law in magnetism]

(iii) $\oint \vec{E}\cdot d\vec{l} = -\frac{d\phi}{dt}$ [Faraday's law]

(iv) $\oint \vec{B}\cdot d\vec{l} = \mu_0 I_c + \mu_0 \epsilon_0 \frac{d\phi_E}{dt}$ [Ampere-Maxwell law]

4. Mathematical Expression for EM Waves

The oscillating electric and magnetic fields $\vec{E}$ and $\vec{B}$ are perpendicular to each other, and to the direction of propagation of EM wave

$$E_y = E_0 \sin(kx - \omega t)$$

and $$B_z = B_0 \sin(kx - \omega t)$$

} Dirⁿ of propagation of EMW is along x axis

Where $k = \frac{2\pi}{\lambda}$, $\omega = 2\pi\nu$

$\lambda \rightarrow$ wavelength, $\nu \rightarrow$ frequency

Here E and B are oscillating along y and z axis respectively.

5. Velocity of EM Waves

$$v = c = \frac{1}{\sqrt{\mu_0 \epsilon_0}} = 3 \times 10^8 \ m/s$$

6. Propagation of EM Waves

$$\frac{E_0}{B_0} = c \quad \text{or} \quad \frac{E}{B} = c$$

7. Average Energy Density

$$u_E = \frac{B^2}{2\mu_0} = u_B$$

8. Momentum carried by EM Wave

$$p = \frac{U}{c}$$

$U \rightarrow$ energy

9. Intensity of EM Wave

$$I = \frac{1}{2} c \epsilon_0 E = \frac{Bc}{2\mu_0}$$

10. Poynting Vector ($\vec{S}$)

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

Pointing vector represents the directional energy flux (the energy transfer per unit area per unit time)