CHAPTER

8 Electromagnetic Waves

- **Four Maxwell's Equations**

1. $\oint \vec{E}.\vec{ds} = \frac{q}{\varepsilon_0}$

2. $\oint \vec{B}.\vec{ds} = 0$

3. $\oint \vec{E}.\vec{dl} = -\frac{d}{dt}\phi_B = \frac{-d}{dt}\int \vec{B}.\vec{ds}$

4. $\oint \vec{B}.\vec{dl} = \mu_0(I_C + I_D) = \mu_0\left(I_C + \varepsilon_0 \frac{d\phi_E}{dt}\right)$

- Displacement current $I_D = \varepsilon_0 \frac{d}{dt}\phi_E = \varepsilon_0 \frac{d\oint \vec{E}.\vec{ds}}{dt} = C\frac{dV}{dt}$

- **The electric and magnetic fields wave equations for an EM wave.**

$$\frac{\partial^2 E}{\partial x^2} = \mu_0\varepsilon_0 \frac{\partial^2 E}{\partial t^2}; \frac{\partial^2 B}{\partial x^2} = \mu_0\varepsilon_0 \frac{\partial^2 B}{\partial t^2}$$

  - $E = E_0\sin(\omega t - kx)$ and $B = B_0\sin(\omega t - kx)$
  - $c_{vacuum} = \frac{1}{\sqrt{\mu_0\varepsilon_0}}; V_{medium} = \frac{1}{\sqrt{\mu_r\mu_0\varepsilon_r\varepsilon_0}}$
  - Refractive index of medium, $n = \sqrt{\mu_r.\varepsilon_r}$
  - $\frac{E_0}{B_0} = \frac{E_{RMS}}{B_{RMS}} = \frac{E}{B} = c$

- Intensity, $I = \frac{\text{power}(P)}{\text{Area}(A)}$

- Average intensity of wave I_{av} = (average energy density) × (speed of light), $I_{av} = U_{av}\, c = \frac{E_0B_0}{2\mu_0} = \frac{E_0^2}{2c\mu_0} = \frac{cB_0^2}{2\mu_0}$

- Instantaneous energy density, $u = u_E + u_B$

$$u = \frac{1}{2}\varepsilon_0E^2 + \frac{B^2}{2\mu_0} = \varepsilon_0E^2 = \frac{B^2}{\mu_0}$$

- Average energy density $u_{av} = \frac{1}{4}\varepsilon_0E_0^2 + \frac{B_0^2}{4\mu_0} = \frac{\varepsilon_0E_0^2}{2} = \frac{B_0^2}{2\mu_0}$

- Energy = (momentum). c or U = Pc

- Radiation pressure $= \frac{\text{Intensity}}{c}$

(when the wave is completely absorbed)

$= \frac{2(\text{Intensity})}{c}$ (when the wave is completely reflected)

- Intensity of wave from a source at a distance r from it is proportional to $\frac{1}{r^2}$ (for a point source)

$\frac{1}{r}$ (for a line source)

For a plane source intensity is constant & independent of r.