Important Concepts & Formulae of EMWs

- Light is a 'transverse' Electromagnetic Wave
- EMWs can be produced by accelerated charges
- Electric current (stable / non-varrying / constant) only produces Magnetic field.
- Two current carrying wire exerts a magnetic force on each other.
- Changing Magnetic field produces electricfield & changing electric field produces magnetic field.

- speed of EMWs in Vacuum $= 2.99792458 \times 10^8 \, m/s \approx 3 \times 10^8 \, m/s$

- $C = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$

  where c = speed of light in Vacuum
  μ_0 = magnetic permeability of free space.
  ϵ_0 = electrical permitivity of free space.

- $\boxed{v = \frac{1}{\sqrt{\mu \epsilon}}}$

  where v = speed of light in medium
  μ = electrical permeability of medium
  ϵ = electrical permitivity of medium

  $v = \frac{1}{\sqrt{\mu_0 \mu_r \epsilon_0 K}}$

  $v = \frac{1}{\sqrt{\mu_0 \epsilon_0}} \times \frac{1}{\sqrt{\mu_r K}}$

  $\boxed{v = \frac{c}{\sqrt{\mu_r K}}}$

  μ_r = relative permeability of medium
  K = dielectric constant of medium or ϵ_r = relative permitivity $= K$

- **MAXWELL'S EQUATIONS IN VACUUM**

  1. $\oint \mathbf{E} \cdot d\mathbf{A} = Q/\varepsilon_0$ (Gauss's Law for electricity)
  2. $\oint \mathbf{B} \cdot d\mathbf{A} = 0$ (Gauss's Law for magnetism)
  3. $\oint \mathbf{E} \cdot d\mathbf{l} = \frac{-d\Phi_B}{dt}$ (Faraday's Law)
  4. $\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 i_c + \mu_0 \varepsilon_0 \frac{d\Phi_E}{dt}$ (Ampere – Maxwell Law)

- $i_d = \epsilon_0 \frac{d\phi_E}{dt}$ where i_d = displacement current

- "Electric and magnetic fields oscillate sinusoidally in space and time in an electromagnetic wave." The oscillating electric and magnetic fields, **E** and **B** are perpendicular to each other, and to the direction of propagation of the electromagnetic wave. For a wave of frequency ν, wavelength λ, propagating along z-direction, we have

- $E = E_x(t) = E_0 \sin (kz - \omega t)$

- $= E_0 \sin \left[2\pi\left(\frac{z}{\lambda} - \nu t\right)\right] = E_0 \sin\left[2\pi\left(\frac{z}{\lambda} - \frac{t}{T}\right)\right]$

where $k = \frac{2\pi}{\lambda}$

- $B = B_y(t) = B_0 \sin (kz - \omega t)$

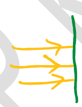
$= B_0 \sin\left[2\pi\left(\frac{z}{\lambda} - \nu t\right)\right] = B_0 \sin\left[2\pi\left(\frac{z}{\lambda} - \frac{t}{T}\right)\right]$

They are related by $\boxed{E_0/B_0 = c}$ $\longrightarrow$ $\boxed{\frac{E_0}{B_0} = c}$

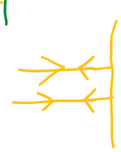
- Electromagnetic waves carry energy as they travel through space and this energy is shared equally by the electric and magnetic fields. Electromagnetic waves 'transport momentum' as well. When these waves strike a surface, a pressure is exerted on the surface. If 'total energy transferred to a surface in time t is U', 'total momentum' delivered to this surface is $\boxed{p = U/c}$.

Remember there are two case (i) when energy falling on surface is fully absorbed

(ii) when energy falling on surface is fully reflected



In first case $p = \frac{U}{c}$



second case $p = \frac{2(U)}{c}$

- Wave number $= \bar{\nu} = \frac{1}{\lambda}$

- If we have $\vec{E}$ & $\vec{k}$ $\longrightarrow$ $\boxed{\vec{B} = \frac{\vec{k} \times \vec{E}}{\omega}}$

- If we have $\vec{k}$ & $\vec{B}$ $\longrightarrow$ $\boxed{\vec{E} = \frac{-c^2}{\omega}(\vec{k} \times \vec{B})}$

- $\vec{k} \cdot \vec{B} = kB\cos 90 = kB(0) = 0$ $\quad \boxed{\vec{k} \cdot \vec{B} = 0}$ $\quad \because$ $\vec{k}$ & $\vec{B}$ are always perpendicular to eachother.

- $\vec{k} \cdot \vec{E} = 0$ $\longrightarrow$ $\vec{k}$ & $\vec{E}$ " " "

- $\vec{B}$, $\vec{E}$ & $\vec{k}$ are always perpendicular to each other in a EMWs

- Poynting Vector ($\vec{S}$) : Gives the direction of flow of energy

$$\boxed{\vec{S} = \vec{E} \times \vec{H} = \frac{\vec{E} \times \vec{B}}{\mu_0}}$$

$\left\{ \because \vec{H} = \frac{\vec{B}}{\mu_0} \right\}$

- Time average value of Poynting Vector

$$\boxed{\langle \vec{S} \rangle = \langle U_e \rangle c = \frac{1}{2} \epsilon_0 E^2 c}$$

$\left\{ \text{when } U_e = \frac{1}{2} \epsilon_0 E^2 \rightarrow \right.$ Electric energy Component (electric energy density) $\left. \right\}$

- $\boxed{U_m = \frac{B^2}{2\mu_0}}$ Magnetic energy Component

- If a charged particle 'q' is "placed" in EMW then initially

$\boxed{\vec{F}_E = q\vec{E}}$ but $\boxed{\vec{F}_B = q\vec{v} \times \vec{B} = 0}$

$\left\{ \begin{array}{l} \because \text{initially particle is placed (rest) } \vec{v} = 0 \\ \therefore \vec{F}_B = q(0) \times \vec{B} = 0 \end{array} \right.$

as it starts moving due to Electric force it gain some velocity let us say $\vec{v}$ then $\boxed{\vec{F}_E = q\vec{E}}$ & $\boxed{\vec{F}_B = q\vec{v} \times \vec{B}}$