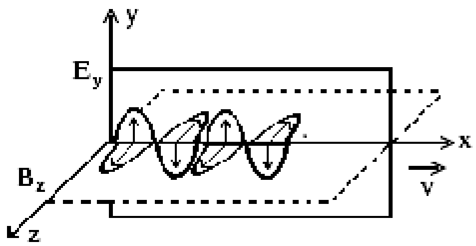
ELECTROMAGNETIC WAVES

1) According to Max well an accelerated charge produces a sinusoidally varying magnetic field which in turn produces sinusoidal time varying electric field. These two fields are mutually perpendicular to each other.



The electric and magnetic fields shown in the above figure are mathematically represented by

i) $\bar{E} = E_y = E_0 \sin[kx - wt] \quad = E_0 \sin 2\pi\left(\frac{x}{\lambda} - vt\right)$

$E_x = E_z = 0$

ii) $\bar{B} = B_z = B_0 \sin[kx - wt] = B_0 \sin 2\pi\left(\frac{x}{\lambda} - vt\right)$

$B_x = B_y = 0$

iii) E_0 and B_0 are the amplitudes of the electric fields.

iv) $\bar{E}$ and $\bar{B}$ are the instantaneous values.

2) The mutually perpendicular electric & magnetic field constitutes electromagnetic waves which can propagate through empty space. The velocity of the electromagnetic wave in vacuum is given by $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$

3) In any isotropic medium the velocity is given by $v = \frac{1}{\sqrt{\mu\varepsilon}}$

4) **Displacement current:**
The current following due to the varying electric field but not due to the actual flow of charges is called displacement current.

i) $i_d = \varepsilon_0 \frac{dq_e}{dt}$

ii) $i_d = \in_0 A\frac{dE}{dt}$ Where $\frac{dE}{dt}$ is variable electrical field

5) Maxwell's Displacement Current:

i) The rate of change of electrical flux produces a current called displacement current "i_d".

ii) The displacement current is also called "induced magnetic field".

iii) Maxwell made the laws of electricity and magnetism symmetrical with the help of displacement current.

iv) Unlike conduction current displacement current exists where there is rate of change of electrical flux.

v) The displacement current is found between the plates of a condenser during its charging or discharging.

vi) It is also found between the plates of a condenser when AC is applied.

vii)It is called current because it produces a magnetic field.

6) Displacement current in the gap between the condenser plates:

i) When a charging current "i" which is constant is given, "i_d" the displacement current = charging current "i".

ii) When a variable electrical field is applied to the gap $i_d = A\in_0 \frac{dE}{dt}$.

iii) When a variable potential difference is applied to the plates of a condenser of capacity C

$$i_d = C\frac{dv}{dt} .$$

vi) **Ampere - Maxwell's law or Amperes Law is modified by Maxwell.**

v) $\int \vec{B}.\vec{dl} = \mu_0 (i_c + i_d)$ and $\int \vec{B}.\vec{dl} = \mu_0 \left(i_c + \epsilon_0 \frac{d\phi_E}{dt} \right)$

i_c = The conduction current found in a conductor carrying current

i_d = Displacement current which is found between the plates of a condenser which is discontinuous.

7) Maxwell's Equations:

i) $\int \vec{E}.d\vec{A} = q_{net}/\varepsilon_0$ [Gauss law in magnetism]

ii) $\oint B.ds = 0$ [Gauss law in magnetism]

iii) $\int \vec{E}.d\vec{l}. = -\frac{d\phi_B}{dt}$ [Faraday's law]

vi) $\int \vec{B}.d\vec{l}. = \mu_0 i_c + \mu_0 \varepsilon_0 \frac{d\phi_E}{dt} = \mu_0 (i_c + i_d)$ [Ampere-Maxwell law]

8) Pointing vector:

The rate of flow of energy in an electro magnetic wave is described by a vector called pointing vector and it is given by the expression $\vec{S} = \frac{1}{\mu_0}\left[\vec{\in} \times \vec{B}\right]$.Its unit is Wm^{-2}

9) Energy density in electric field:

$$E_d = \frac{1}{2}\in_0 \in^2$$

10) Energy density in magnetic field:

$$E_d = \frac{B^2}{2\mu_0}$$

11) Total energy density:

$$(E_d)_T = \frac{1}{2}\left[\in_0 \in^2 + \frac{B^2}{\mu_0}\right]$$

12) Radiation pressure:

i) When electromagnetic waves incident on any surface the pressure exerted on the surface is called radiation pressure.

ii) If a portion of electromagnetic wave is propagating with speed c, then the linear momentum of electromagnetic wave is $P = \frac{U}{c}$

Where U is the total energy transferred to the surface in a time t

iii) When the radiation incident on a surface is entirely reflected back along its original path, the magnitude of the momentum delivered to the surface is $P = \frac{2U}{c}$