Electromagnetic wave

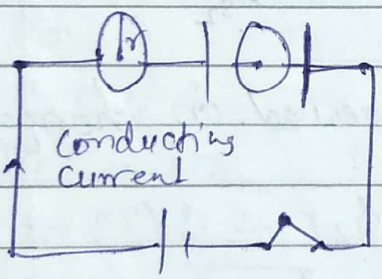
E.M wave:

Oested: Current - carrying wire can produce m.f

faraday: Time varrying M.f can Produce E.f

Clarke Maxwell:

Since time varring M.f can produce electric field hence by sammetrise of nature time varring electric field should also produce magnetic field should also produce magnetic field collectively these are called electromagnetic field.



at P

$\int \vec{B}_1 \cdot d\vec{l} = \mu_0 I_{in}$

$B_1 2\pi r = \mu_0 I$

$B_1 = \frac{\mu_0 I}{2\pi r}$

at P_2 $\int B_2 \, dl = \mu_0 I_{inc}$

$B_2 2\pi r = 0$

$B_2 = 0$

By Amperes law of magnetic field inside the plate is zero but actually it is not zero. Hence there must be some current present b/w the plate known as displacement current

$$\int \vec{B_2} \cdot d\vec{l} = \mu_0 I_D$$

$$B_2 = \frac{\mu_0 I_D}{2\pi r}$$

Let charge on plate i.e q at any time

electric field b/w the plate

$$E = \frac{\sigma}{\varepsilon_0} , \quad E = \frac{q}{A\varepsilon}$$

$$EA = \frac{q}{\varepsilon_0}$$

$$\phi_E = EA = \frac{q}{\varepsilon_0}$$

$$\frac{d\phi_E}{dt} = \frac{A\,dE}{dt} = \frac{1}{\varepsilon_0}\frac{dq}{dt}$$

$$\frac{dq}{dt} = \varepsilon_0 \frac{d\phi_E}{dt}$$

$$I_D = \varepsilon_0 \frac{d\phi_E}{dt}$$

modified Ampear law

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 (I_C + I_D)$$

an Conductor $I_c \neq 0$ $I_D = 0$
Insulator $I_c = 0$ $I_D \neq 0$

Current produce in isulasting medium due to time varying electric flux is called displacem current.

<u>Maxwells eqn of E.M wave!</u>

(i) $\oint \vec{E}.d\vec{s} = \frac{q_{in}}{\varepsilon_0}$ → Gauss law

(ii) $\int \vec{B}.d\vec{s} = 0$ for a closed surface Gauss law of m.f
↳ magnetic monopole never exist

(iii) $\int \vec{E}.d\vec{r} = -\frac{d\phi_B}{dt}$ → Faraday law of E.M.I

(iv) $\int \vec{B}.d\vec{l} = \mu_0 (I_c + I_D)$
$= \mu_0 (I_c + \varepsilon_0 \frac{d\phi_E}{dt})$

(v) $\vec{f} = q\bar{E} + q(\bar{v} \times \bar{B})$ → Lorentz force

* <u>Properties of E.M.W</u>

(1) These are Produce accelerating charge particle

(2) The travell in space with the speed of light

③ In a medium there speed depends electric & magnetic Property of medium.

$$\text{Vaccume} = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} \qquad c = \frac{E_0}{B_0} = \frac{E_{max}}{E_{min}}$$

$$C_m = \frac{1}{\sqrt{\mu_0 \mu_r \varepsilon_0 \varepsilon_r}} \qquad c = \frac{E_{rms}}{B_{rms}}$$

④ These are Transverse in nature.

⑤ Electric magnetic field changes sinusodally with Position & time and have max & min value at some place & same time.

⑥ electric & magnetic field are ⊥ to each other and also ⊥ to the direction of propagation of E.M waves

$$\vec{E} = E_0 \sin(kx - \omega t)\hat{j}$$

$$\vec{B} = B_0 \sin(kx - \omega t)\vec{k}$$

⑦ optical properties of Emw are due to electric field vector. Hence it is also called light vector

⑧ They carry energy and momentum are applied force & pressure on a surface called radiation pressure

* Intensity of E.M.W

Energy density

electric energy density $= \frac{1}{2}\varepsilon_0 E^2$

may — $= \frac{B^2}{2\mu_0}$

E.M wave

$U_E = \frac{1}{2}\varepsilon_0 E_{rms}^2$

$U_B = \frac{1}{2}\frac{B_{rms}^2}{\mu_0}$

$U_E = U_B$

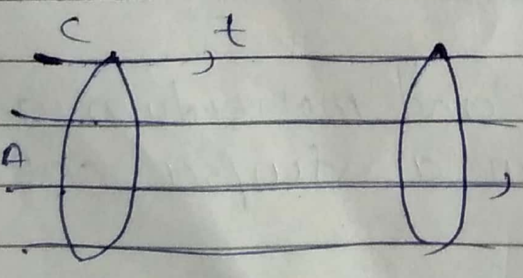
$U = \frac{1}{2}\varepsilon_0 E_{rms}^2 + \frac{B_{rms}^2}{2\mu_0}$

$U = \varepsilon_0 E_{rms}^2 \Rightarrow \frac{B_{rms}^2}{\mu_0}$

Total Energy density of E.M.

$= \varepsilon_0 E_{rms}^2 = \frac{1}{2}\varepsilon_0 E_0^2$

$E_{rms} = \frac{E_0}{\sqrt{2}}$



em wave

Vol. of cylinder = Act

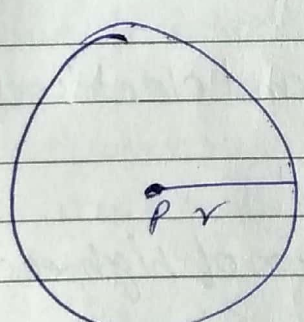
Total energy $= \frac{1}{2}\varepsilon_0 E_0^2 Act$

Intensity $= \frac{Energy}{tA}$

Intensity $= \frac{1}{2}\varepsilon_0 E_0^2 c$

Intensity $= \frac{B_0^2 c}{2\mu_0}$

Q. A small bulb of power emits E.M.W find intensity and maximum value of electric & magnetic field at distance from the source.



$I = \frac{P}{4\pi r^2} = \frac{1}{2}\varepsilon_0 E_0^2 c$

$c = \frac{E_0}{B_0}$

Q. A sinusoidal EMW travell through empty space along x-axis Electric field is along y-axis and its maximum value is 63 volt/m. frequency of wave = 1.5 G Hz. find it wave length maximum value of magnetic field and Ef and M.F as a function of position and time.

frequency = 1.5 G Hz = 1.5×10^9 Hz. max value = 63 V/m.

$c = f\lambda$ $\qquad$ $c = \frac{E_0}{B_0}$

$\frac{3 \times 10^8}{1.5 \times 10^9} = \lambda$

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

$\omega = 2\pi f$ $\qquad$ $\frac{3}{15} = \lambda$ = $\lambda = \frac{1}{5}$

$\vec{E} = E_0 \sin(kx - \omega t)\hat{j}$.

$\vec{B} = B_0 \sin(kx - \omega t)\hat{k}$

K.M

* Electromagnetic (wave) Spectrum:

① **Radiowave:** $\lambda \simeq (10^3 - 1\ m)$

Generated by L-C oscillations

② **Microwave:** $\lambda \simeq (1 - 10^{-4}\ m)$.
Generated by electronic devices.

③ **Infra red:** $\lambda \simeq (10^{-3}\ to\ 10^{-6})$
Produce by molecules at room temp.

④ **Visible Part: (Light wave):** $\lambda \simeq (4000\ A^\circ - 7000\ A^\circ)$
Produce by de exitation of Atoms and molecules)

⑤ **Ultraviolet:** $\lambda \simeq (10^{-6} - 10^{-9})$
Produced by excited atoms and electric discharge.

⑥ **X-Rays:** $\lambda \simeq (10^{-8}\ to\ 10^{-11})$
Produced by de acceleration of high energetic e^-s by a metal target.

⑦ **γ-Rays:** $\lambda \simeq (10^{-10}\ to\ 10^{-11})$ Produce in Radioactive nuclii and nuclear Reactions

RMI
VU
XY Ray