2) <u>Maxwell equation</u>

$$\nabla\cdot\vec{B}=0$$
$$\vec{B}=\nabla\times\vec{A}$$
$$\mu\vec{H}=\nabla\times\vec{A}$$
$$H=\frac{1}{\mu}(\nabla\times\vec{A})$$
$$\nabla\times\vec{E}=-\frac{d\vec{B}}{dt}=-\dot{\vec{B}}=-(\nabla\times\vec{A})^{\cdot}=-\nabla\times\dot{\vec{A}}\quad\left[-\dot{\nabla}\times\vec{A}=-\nabla\times\dot{\vec{A}}\right]$$
$$\nabla\times(\vec{E}+\dot{\vec{A}})=0$$
$$\vec{E}+\dot{\vec{A}}=-\nabla V$$

In electrostatic case the electric field (-) times the gradient of the scaler electric potential. So that this relation is consistent when time derivatives are set to "0" if put $\partial/\partial t=0$, we will get

$$E=-\nabla V$$
$$\nabla\times H=\vec{J}+\frac{\partial D}{\partial t}=J+\dot{D}$$
$$D=\epsilon E$$
$$\nabla\times H=\vec{J}+\epsilon\dot{\vec{E}}$$
$$\nabla\times\left\{\frac{1}{\mu}\nabla\times\vec{A}\right\}=J+\epsilon\dot{\vec{E}}$$
$$\nabla\times\nabla\times\vec{A}=\mu J+\mu\epsilon\dot{\vec{E}}$$
$$\nabla(\nabla\cdot\vec{A})-\nabla^2\vec{A}=\mu J+\mu\epsilon\dot{\vec{E}}$$
$$\nabla^2\vec{A}-\mu\epsilon\ddot{\vec{A}}=-\mu J+\mu\epsilon\nabla\dot{V}+\nabla(\nabla\cdot\vec{A})$$

The time derivatives of the time variation for all the electric and magnetic fields vector potential all these quantities is harmonic.

5) Greens functions:-

$\nabla^2 G + \beta^2 G = \delta$ $\quad$ G - Greenfunction replaced the $\vec{A}$.

Expand this in spherical coordinates.

we get,

$$\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial G}{\partial r}\right)+\frac{1}{r^2\sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial G}{\partial\theta}\right)+\frac{1}{r^2\sin^2\theta}\frac{\partial^2 G}{\partial\phi^2}+\beta^2 G=\delta$$

Now since these are impulse and these are scalar quantity now was in this equation now (G) we are putting a scalar quantity because the vector nature is with the vector potential and currents. This is putting a point on the origin. We are ~~tak~~ talking about for which the source is located at the origin of the coordinate system. ~~and therefore~~ the ~~no matter~~ This equation now is spherically symmetric.

It does not depend on θ and ϕ.

So identically $\theta = 0$ and $\phi = 0$

$$\partial/\partial\theta = 0 \text{ and } \partial/\partial\phi = 0$$

$$\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial G}{\partial r}\right)+\beta^2 G=\delta(r)$$

$$\psi = rG \quad G = \psi/r$$

$$\frac{d^2\psi}{dr^2}+\beta^2\psi=\delta(r)$$

5) a) Antenna Directivity

Directivity is the measure of the concentration of an antenna's radiation ~~pattern~~ pattern in a particular direction. Directivity is expressed in dB. The higher the directivity, the more concentrated or focussed in the beam radiated by an antenna. A higher directivity also means that the beam will travel further.

Antenna Gain = Directivity x Antenna Efficiency

b) Antenna Beamwidth

Beam width is the aperture angle from where most of the power is radiated. The two main considerations of this beam width are Half Power Beam width (HPBW) and First-Null Beam width (FNBW)

~~HPBW:~~ HPBW is an angle between the half power points of the main lobe as measured at -3dB. This is considered to be the part of the antenna output that has maximum consistency and utility and is closed related to the gain of the antenna

FNBW is the degree of angular separation from the main beam. It is found between the null points of the main lobe of the antenna's radiation pattern.

Q1) If the time varying electric and magnetic fields existed. In what from they would exist and we concluded that they exist in the form of electromagnetic waves

A device which generates electromagnetic radiation is called antenna. We will talk about the practical devices which can generate electromagnetic waves from currents and voltages and which can convert the electro magnetic energy and the electromagnetic waves to currents and voltages when these waves impinge on the structure, that is called antenna. It is essentially is the transducer which converts the electrical quantity, like current and voltage, into electromagnetic quantities like electric and magnetic fields and vice-versa. So, when we use this device like a transmitting device, we ~~exi~~ excite this with voltage and current, and antenna can generate electromagnetic wave, the same structure capable of receiving electromagnetic waves that means when the electro-magnetic wave is incident on the structure, you get currents and voltage at the terminals of the structure called antenna. Now the basic for radiation is accelarated charges. ~~It~~ In electrostatic case, we had a charge and then charge essentially produced that is called electric field the effect of charge could be felt by electric field. If the charges are kept in motion, uniform motion, then they can constitute current and we know that there is a ~~cont~~ constant uniform current, gives you magnetic field.

4) Since the radiation is investigated in the spherical coordinate system then we have to convert A in (r, θ, ϕ) components

$$A_r = A_z \cos\theta$$
$$A_\theta = -A_z \sin\theta$$
$$A_\phi = 0$$

$$H = \frac{1}{\mu} \nabla \times A$$

$$= \frac{1}{\mu} \frac{1}{r^2 \sin\theta} \begin{vmatrix} \hat{r} & r\hat{\theta} & r\sin\theta\hat{\phi} \\ \frac{\partial}{\partial r} & \frac{\partial}{\partial \theta} & \frac{\partial}{\partial \phi} \\ A_r & rA_\theta & r\sin\theta A_\phi \end{vmatrix}$$

$$H = \frac{1}{\mu r^2 \sin\theta} \begin{vmatrix} \hat{r} & r\hat{\theta} & r\sin\theta\hat{\phi} \\ \frac{\partial}{\partial r} & \frac{\partial}{\partial \theta} & 0 \\ A_z\cos\theta & -rA_z\sin\theta & 0 \end{vmatrix}$$

$$H_r = 0$$

$$H_\theta = 0$$

$$H_\phi = \frac{1}{\mu} \frac{1}{r} \left\{ \frac{\partial}{\partial r}(-rA_z \sin\theta) - \frac{\partial}{\partial \theta}(A_z \cos\theta) \right\}$$

$$H_\phi = \frac{I_0 dl e^{j\omega t}}{4\pi r} \left\{ \frac{\partial}{\partial r}\left(e^{-j\beta r} \sin\theta\right) + \frac{\partial}{\partial \theta}\left(\frac{e^{-j\beta r}\cos\theta}{r}\right) \right.$$

$$H = \frac{I_0 dl\, e^{j\omega t}}{4\pi r}\left\{ j\beta e^{-j\beta r}\sin\theta + \frac{e^{-j\beta r}}{r}\sin\theta \right\}$$

$$H_\phi = \frac{I_0 dl\, e^{j\omega t}\sin\theta}{4\pi r} e^{-j\beta r}\left\{ j\beta + \frac{1}{r} \right\}$$

$$E = \frac{1}{j\omega\epsilon} \nabla \times H$$

$$= \frac{1}{j\omega\epsilon r^2 \sin\theta}\begin{vmatrix} a_r & r a_\theta & r\sin\theta\, a_\phi \\ \frac{\partial}{\partial r} & \frac{\partial}{\partial \theta} & 0 \\ 0 & 0 & H_\phi r \sin\theta \end{vmatrix}$$

$$E_r = \frac{1}{j\omega\epsilon r\sin\theta}\frac{\partial (H_\phi r \sin\theta)}{\partial\theta}$$

$$= \frac{1}{j\omega\epsilon}\frac{2 I_0 dl\, e^{j\omega t}\cos\theta\, e^{-j\beta r}}{4\pi r^2}\left\{ j\beta + \frac{1}{r} \right\}$$

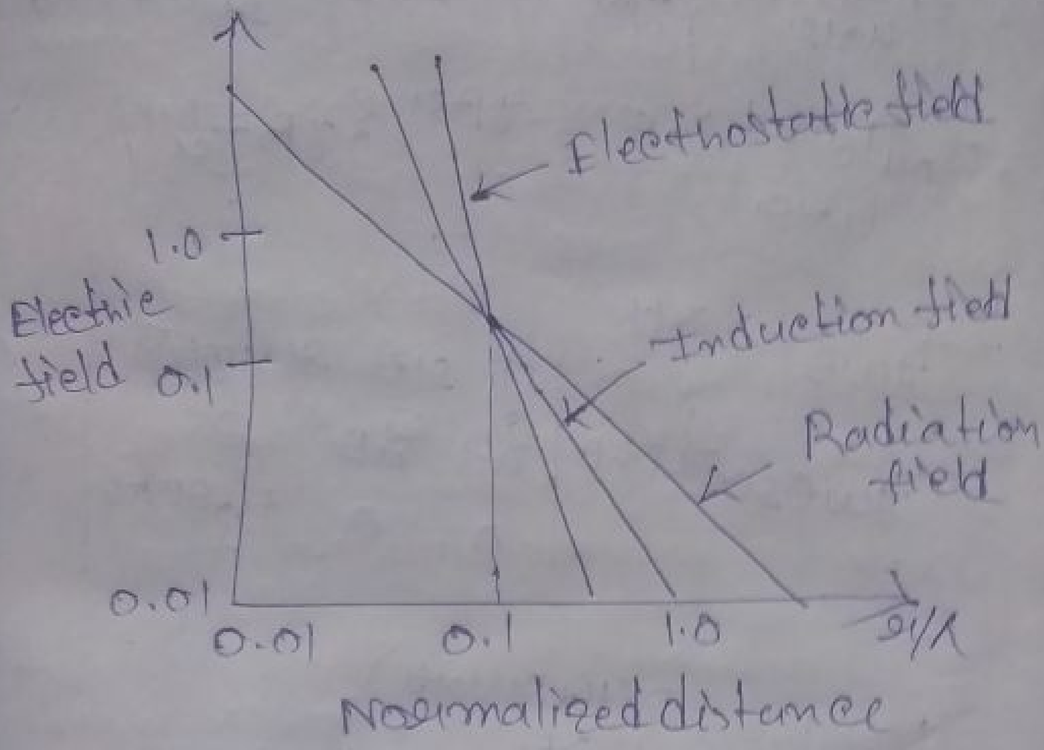
$$E_r = \frac{2 I_0 dl\, e^{j\omega t}\cos\theta\, e^{-j\beta r}}{4\pi\omega\epsilon}\left\{ \frac{\beta}{r^2} - \frac{j}{r^3} \right\}$$

$$E_\theta = -\frac{1}{j\omega\epsilon}\frac{1}{r\sin\theta}\frac{\partial}{\partial r}(r\sin\theta H_\phi)$$

$$= -\frac{1}{j\omega\epsilon}\frac{1}{r}\frac{\partial}{\partial r}(r H_\phi)$$

$$= \frac{I_0 dl \sin\theta\, e^{j\omega t} e^{-j\beta r}}{4\pi\epsilon}\left\{ \frac{j\beta^2}{\omega r} + \frac{\beta}{\omega r^2} - \frac{j}{\omega r^3} \right\}$$

We see the electric field (E) lies in the plane (r, θ) whereas the magnetic field H lies in the ϕ plane.



Electhostatic field
Induction field
Radiation field
Electric field
1.0
0.1
0.01
0.01
0.1
1.0
r/λ
Normalized distance