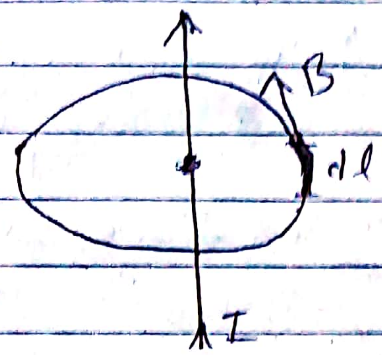
SEMESTER VI Paper (13) Physics Core

BASED ON Maxwell's Equation (Short answer type)

Que: What is Ampere circuital Law?

Ans: Ampere Circuital Law states the relation between the current and magnetic field created by it. This states that the line integral of magnetic field density B along an imaginary closed path is equal to the product of current enclosed by the path and permeability of the medium.

$$\boxed{\oint \vec{B}\cdot\vec{dl} = \mu_0 I}$$



Que2. What do you mean by Displacement current and how Ampere Circuital Law is modified by Maxwell.

Ans: Displacement current is a quantity appearing in Maxwell's Equation. It is defined in terms of the rate of change of electric displacement field. $\frac{\partial D}{\partial t}$.

We know from Ampere Circuital Law

The line Integral of magnetic field intensity

$$\oint \vec{B}\cdot dl = \mu_0 I.$$

or, $\oint \frac{\vec{B}}{\mu_0} \cdot dl = I$, $\oint \nabla \cdot \vec{H} = I = \int_S J\, ds$ (1)

where $I = \int_S J \cdot ds$ is the current enclosed by the path

$\oint$ represents the integral over closed path S

J - Current density

By Stoke's theorem

$$\oint_C H \cdot dl = \int_S \text{curl}\, H \cdot ds$$

So, Equation (I) can be written as

$$\int_S \text{curl}\, H \cdot ds = \int_S J \cdot ds$$

or, $\int_S (\text{curl}\, H - J) \cdot ds = 0$

As the surface is arbitrary, $(\text{curl}\, H - J)\, ds = 0$

So, $\boxed{\text{curl}\, H = J}$ —— (II)

Taking div. on both side

$$\text{div curl}\, H = \text{div}\, J = 0 \quad \Big| \because \text{div curl}\, \vec{A} = 0$$

But this doesn't obey continuity equation or conservation of charge, $\text{div}\, J = \nabla J = -\frac{\partial \rho}{\partial t}$ (III)

Thus we conclude that Ampere law is valid for steady state condition only for which $\text{div} \cdot J = 0$ and it is insufficient for time varying fields. Here Maxwell modified Ampere's law and include time varying field by adding another current density J_d to J.

So, $\text{curl}\, H = J + J_d$

so, $\text{div curl}\, H = \text{div}(J + J_d) = 0$

So, $\text{div}\, J + \text{div}\, J_d = 0$

$$\text{div}.\, J_d = -\text{div}\, J = \frac{\partial \rho}{\partial t} \quad \Big| \text{ where } \rho - \text{charge density}$$

$$\therefore \text{div}\, J_d = \frac{\partial \rho}{\partial t}$$

But $\text{div}\, D = \rho$ (From differential form of Gauss's law)

$$\therefore \text{div} \cdot J_d = \frac{\partial}{\partial t}(\text{div}.\, D) = \text{div} \frac{\partial D}{\partial t}$$

$$\therefore J_d = \frac{\partial D}{\partial t}$$

So modified form of Ampere's law is

$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

Here $\frac{\partial D}{\partial t}$ is called displacement current

Que: What are the boundary Conditions satisfied by the electromagnetic field vectors E, D, B and H on the plane interface between two media?

Ans: Following are the boundary Conditions which are satisfied by the electromagnetic wave on the plane interface between two media

1. The normal Component of electric displacement (D) is discontinuous across the interface by an amount equal to free space charge density of charge at the interface i.e. $D_{1n} - D_{2n} = \sigma$
2. The normal Component of magnetic induction B is Continuous across the interface, i.e. $B_{1n} = B_{2n}$
3. The tangential Component of electric field Intensity E is Continuous across the interface. i.e. $E_{1t} = E_{2t}$
4. (a) if either the two media has infinite Conductivity, the tangential Component of magnetic field Intensity is discontinuous at the interface by an equal amount to Surface Current density at the interface

$$H_{1t} - H_{2t} = J_{sL}$$

(b) If both media have finite Conductivity, the tangential Component of magnetic field intensity is Continuous across at the interface

$$H_{1t} = H_{2t}$$

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Que: What is poynting theorem? Explain poynting vector?

Ans: The statement of poynting theorem is as follows:
The time rate of change of electromagnetic energy with a certain volume plus time rate of the energy flowing out through the boundary surface is equal to the power transferred into the electromagnetic field.

$$-J \cdot E = \frac{\partial u}{\partial t} + \nabla S$$

where S is poynting vector $= (E \times H)$

This statement of conservation of energy in electromagnetism is known as poynting theorem.

Poynting vector

In poynting theorem term $\boxed{S = E \times H}$ is known as poynting vector and it is interpreted as power flux i.e. amount of energy crossing unit area placed perpendicular to the vector per unit time.