ELECTROMAGNETIC WAVE

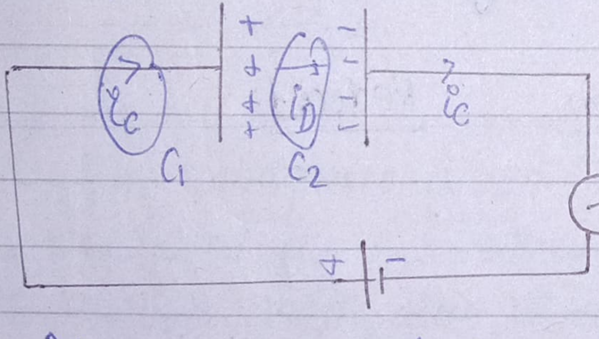
Concept of Displacement current →

(i) Current produces m. field (Oerested's Exp)
(ii) time varying m. field produces E field (Faraday law)

$$\mathcal{E} = -N\frac{d\phi}{dt} = -N\frac{d(BA)}{dt} = -NA\frac{dB}{dt} \quad (\text{if } A = \text{const.})$$

Does time varying E field produces m. field?
⇒ Yes, the answer is given by maxwell and he suggested that time varying E field produces current called displacement current, which produces m field

displacement current $i_D = \varepsilon_0 \frac{d\phi_E}{dt} = \varepsilon_0 \frac{d(EA)}{dt}$



$$\varepsilon_0 \frac{d}{dt}\left(\frac{q}{\varepsilon_0 A} A\right) = \frac{dq}{dt} = \text{Current}$$

Maxwell suggested that Ampere - Circuital law is inconsistent when a parallel plate capacitor charge through a cell

for loop C_1 $\oint \vec{B}\cdot\vec{dl} = \mu_0 i_c$
but in loop C_2 $\oint \vec{B}\cdot\vec{dl} = 0$

To remove this consistency, he suggested, that there will be displacement current in b/w plates of Capacitor then ampertal law is modified as – $\oint \vec{B}\cdot\vec{dl} = \mu_0 (i_c + i_D)$

Where, i_c = Conduction current, i_D = displacement current = $\varepsilon_0 \frac{d\phi_E}{dt}$

$$\oint B\cdot dl = \mu_0 \left(i_c + \varepsilon_0 \frac{d\phi_E}{dt}\right)$$

→ Modified form of Ampere circuital law or Ampere Maxwell law

here $i_c = i_D$

Note- Since time varying magnetic field produces Electric field and time varying electric field produces magnetic field thus change of either w.r.t time produces other. This change of Electric and magnetic field w.r.t time in space produces electromagnetic wave

Note- Neither stationary charge nor charge in uniform motion is a source of E.M wave
But Accelerated charge is a source of E.M wave

Maxwell's Equation Reduced

① Gauss law of electrostatics
$$\oint E\cdot dA = \frac{1}{\varepsilon_0}(q_{net})$$

② Gauss law in magnetism $\oint \vec{B}\cdot\vec{dA} = 0$ (monopoles do not exist)

③ Faraday law of E. magnetic Induction
$E = -\frac{d\phi_B}{dt}$ $$\oint \vec{E}\cdot\vec{dl} = -\frac{d\phi_B}{dt}$$

④ Modified form of Ampere Circuital law
$$\oint \vec{B}\cdot\vec{dl} = \mu_0 \left(i_c + \varepsilon_0 \frac{d\phi_E}{dt}\right)$$

Ques The voltage b/w the plates of a parallel plate capacitor, of capacitance 1 μF is changing at the rate of 5 V/s. What is the displacement current in the capacitor.

Soln $I_D = \frac{\epsilon_0 d\phi_E}{dt} = \epsilon_0 \frac{d}{dt}(EA) = \epsilon_0 A \frac{d}{dt}(V/d)$

$= \frac{\epsilon_0 A}{d} \frac{dV}{dt} = \frac{C\, dV}{dt} = 10^{-6} \times 5 = 5\times 10^{-6}$ amp

Ques A parallel plate capacitor has a circular plates each of radius 5 cm. It is being charged so that electric field in the gap b/w the plates rises steadily at the rate of 10^{+12} V/ms. What is the displacement current?

Soln $I_D = \frac{\epsilon_0 d\phi_E}{dt} = \epsilon_0 \frac{d}{dt}(EA) = \frac{\epsilon_0 A\, dE}{dt} = \epsilon_0 \pi r^2 \frac{dE}{dt}$

$= 8.86 \times 10^{-12} \times 3.14 \times 25 \times 10^{-4} \times 10^{12}$

$8.86 \times 10^{-4} \times 3.14 \times 25$

$= 0.069$

$= 0.07$ A

Electromagnetic wave - An electromagnetic wave is radiated by (accelerating charge or LC oscillations) which propagates through space in which electric and magnetic vectors oscillating ⊥ to each other and also ⊥ to direction of propagation of wave