UNIT 5

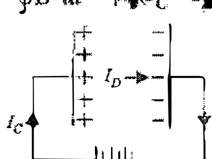
NEED FOR DISPLACEMENT CURRENT

- During the process of charging of capacitor, current flows through the connecting wires, known as **conduction current** I_C. As the charge accumulates on the plates of capacitor, a changing electric field is produced across the gap between its two plates, which produces magnetic field. Maxwell assumed that a current also flows in the gap between the two plates of capacitor, during the process of charging, known as **displacement current** I_D. This displacement current originates due to time varying electric field between the plates of capacitor and is given by

$$I_D = \varepsilon_0 \frac{d\phi_\varepsilon}{dt}$$

- where ϕ_ε gives the electric flux linked with the space between the two plates of the capacitor.
- Thus, displacement current I_D is the electric current which flows in the gap between the plates of capacitor during its charging, which originates due to time varying electric field in the space between the two plates of capacitor.
- So, using the concept of displacement current I_D, Ampere's circuital law can be modified as

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



- which is also called **Ampere-Maxwell's circuital law**.
- The displacement current I_D is precisely equal to the conduction current I_C, when the two are present in different part of the circuit. These currents are individually discontinuous, but the two currents together posses the property of continuity through any closed circuit. For example, during charging of capacitor, in connection wires, conduction current I_C is continuous whereas displacement current I_D is discontinuous. So, by Ampere-Maxwells circuital law

$$\oint \vec{B}\cdot d\vec{l} = \mu_0 I_C$$

- where as, in the space between the two plates of charging capacitor, conduction current I_C is discontinuous, but displacement current I_D is continuous. So by Ampere-Maxwell's circuital law

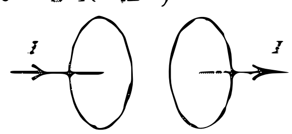
$$\oint \vec{B}\cdot d\vec{l} = \mu_0 I_D$$

- As I_C and I_D are numerically equal, so together they are continuous they are continuous in the circuit during the charging of capacitor.

Illustration 1

Figure shows a capacitor made of two circular plates each of radius 12 cm and separated by 5 mm. The capacitor is being charged by an external source. The charging current is constant and equal to 0.15 A.

(a) Calculate the capacitance and the rate of change of potential difference across the plates.
(b) Obtain the displacement current across the plates.
(c) Is Kirchhoff's junction rule valid at each plate of the capacitor?
($\varepsilon_0 = 8.85 \times 10^{-12}\ C^2N^{-1}m^{-2}$)



Sol.: (a) $C = \frac{\varepsilon_0 A}{d} = \frac{\varepsilon_0(\pi r^2)}{d}$

$$= \frac{(8.85 \times 10^{-12})(3.14 \times (12 \times 10^{-2})^2}{(5 \times 10^{-3})}$$

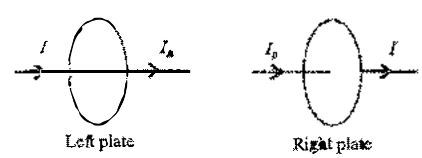
$$= 80.1 \times 10^{-12}\ F$$

Also, $I = \frac{dq}{dt} = \frac{d}{dt}CV = \frac{CdV}{dt} \Rightarrow \frac{dV}{dt} = \frac{I}{C}$

$$= \frac{0.15}{80.1 \times 10^{-12}} = 1.87 \times 10^9\ V\ s^{-1}.$$

(b) $I_D = I = 0.15$ A

(c)



Junction rule is valid at each plate as incoming current equals outgoing current.

ELECTROMAGNETIC WAVES

- These are those waves in which there is a sinusoidal variation of electric and magnetic field at right angles to each other as well as at right angles to the direction of wave propagation. For a plane progressive electromagnetic wave propagating along the +z direction, the electric and magnetic fields can be written as