UNIT IV TIME VARYING FIELDS AND MAXWELL'S EQUATIONS

Faraday's Law of electromagnetic Induction:

Michael Faraday, in 1831 discovered experimentally that a current was induced in a conducting loop when the magnetic flux linking the loop changed. Faraday's Law describes the magnitude of the electromotive force (emf), or voltage, induced (generated) in a conductor due to electromagnetic induction (changing magnetic fields). It states that the induced emf in a conducting circuit is proportional to the rate of change of magnetic flux linkage Φ within the circuit. For a change of magnetic flux $\Delta\Phi$ in time Δt, the average emf E induced is

$$|\mathcal{E}| = N\left|\frac{\Delta\Phi}{\Delta t}\right|$$

where N is the number of turns in the conducting circuit if it is a coil. An emf is induced in a conductor whenever the magnetic flux linkage through the conductor changes. Faraday's Law states that the magnitude of the induced emf in a conductor is directly proportional to the rate of change of magnetic flux linkage. This form with $\Delta\Phi$ and Δt only applies when the rate of change of magnetic flux linkage is constant over the time period Δt, (or we are just calculating the average emf), otherwise calculus must be used. The direction of the induced emf can be determined using Lenz's Law.

Displacement Current:

Displacement current is the current that is produced by the rate of change of the electric displacement field. It differs from the normal current that is produced by the motion of the electric charge. Displacement current is the quantity explained in Maxwell's Equation. It is measured in Ampere. Displacement currents are produced by a time-varying electric field rather than moving charges.

What is Displacement Current?

Electricity and magnetism are related to each other. As the electric current travels through a wire, it creates magnetic field lines around the wire. This type of current is called conduction current, which is created by the movement of electrons through a conductor such as an electrical wire.

Whereas a displacement current is a type of current linked with Maxwell's Equation and is produced by a time-varying electric field.

Displacement Current Definition

A physical quantity related to Maxwell's equation that has the property of the electric current is called the Displacement Current. Displacement current is defined as the rate of change of the electric displacement field (D).

Maxwell's equation includes displacement current that proves the Ampere Circuit Law. It is measured in Ampere.

Current in Capacitor

A charging capacitor has no conduction of charge but the charge accumulation in the capacitor changes the electric field link with the capacitor that in turn produces the current called the Displacement Current.

$ID = JDS = S(\partial D/\partial t)$

where,

S is the area of the Capacitor Plate

ID is the Displacement Current

JD is the Displacement Current Density.

D is related to Electric Field E as,

$D = \varepsilon E$

ε is the Permittivity of material between plates

Displacement Current Equation

Maxwell's Equation defines the displacement current which has the same unit as the electric current, the Maxwell field equation is represented as,

$\nabla \times H = J + JD$

where,

H is related to magnetic field B as $B = \mu H$

μ is the permeability of the material between the plates

J is the Conducting Current Density.

JD is the Displacement Current Density.

We know that

$\nabla.(\nabla \times H) = 0$

$\nabla.J = -\partial \rho/\partial t$

$\nabla.J = -\nabla.\partial D/\partial t$

Using Gauss's Law

$\nabla.D = \rho$

Here, ρ is the electric charge density.

Thus the displacement current density equation is,

$JD = \partial D/\partial t$

Characteristics of Displacement Current

In an electric circuit, there are two types of current that are conduction current and the other is Displacement current. Various characteristics of displacement current are mentioned below:

- Displacement current does not appear from the actual movement of the electric charge as in the case of the conduction current but is produced by time changing electric field.
- Displacement current is a vector quantity.
- Electromagnetic waves propagate with the help of displacement current