PHYSICS

CLASS NOTES FOR CBSE

Chapter 24. Electromagnetic Waves

01. Introduction

Basic Equations of Electricity and Magnetism

The whole concept of electricity and magnetism can be explained by the four basic equations we have deal so far.

(i) $\int E \times ds = \frac{Q}{\epsilon_0}$ (Gauss law for electrostatic)

(ii) $\int B \times ds = 0$ (Gauss law for magnetism)

(iii) $\int B \times d\ell = \mu_0 i$ (Ampere's law for Magnetism)

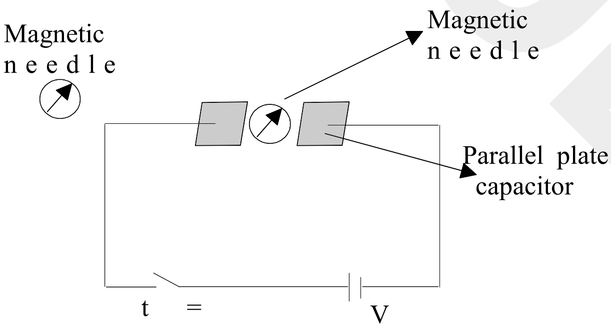
(iv) $\int E \times d\ell = 0$ (Ampere's law for electrostatic)

The above stated equation are true for non-time varying fields

02. Concept of Displacement Current (Modified Amper's Law)

Maxwell tried to generalis the concept of faradays law that if changing magnetic field can produce changing electric field then the reverse should also be true i.e. changing electric field must produce magnetic field.

To understand the concept of displacement current let us try to understand this experiment when the switch was closed at t = 0 both the needles deflected.



Deflection of needle (1) is under stood as M.F. is produced due to current flowing in the wire.

But why did needle 2 deflect? It is lying in between the two plates of capacitor where there is no current. This magnetic field between the plates is due to the changing electric field between the plates (During charging of capacitor).

Hence maxwell conducted that changing electric field produces a magnetic field
For Needle (1) Amper's law

$$\int B \times d\ell = \mu_0 i_c \quad \text{........ (1)}$$

For needle (2) Amper's law

$$\int B \times d\ell = \mu_0 \in_0 \frac{d\phi_E}{dt} \quad \text{........ (2)}$$

Hence there are two methods of producing M.F.

(a) Due to flow of electron which is known as conduction current

(b) Due to changing electric field combining eq. (1) and eq. (2)

$$\int B \times d\ell = \mu_0 \left[i_C + \left(\varepsilon_0 \frac{d\phi_E}{dt} \right) \right]$$

Modifield ampere's law

NOTE ☞ $\varepsilon_0 \frac{d\phi_E}{dt}$ is known as displacement current

03. Final Form of Maxwell's Equation

(a) $\int E \times ds = \frac{q}{\in_0}$

(b) $\int B \times ds = 0$

(c) $\int E \times dl = -\frac{d\phi_B}{dt}$

(d) $\int B \times dl = \mu_0 \left[I + \in_0 \frac{d\phi_E}{dt} \right]$

The above equation is known as Maxwell's equation for time varying form.
Howover for free space there are no charges and no conduction current the equations that are significant.

$$\int E \times d\ell = -\frac{d\phi_B}{dt}$$

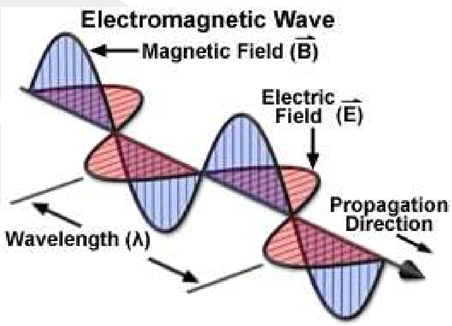
$$\int B \times d\ell = \mu_0 \in_0 \frac{d\phi_E}{dt}$$

04. Transverse Nature of Electro Magnetic Wave and its Properties

Electromagnetic waves

The idea of electromagnetic waves was given by Maxwell and experimental verification was provided by Hertz and other scientists. A brief history of electromagnetic waves is as follows: On the basis of experimental study of electromagnetic induction, Faraday concluded that a magnetic field changing with time at a point produces a time varying electric field at that point. Maxwell in 1864 pointed out an electric field changing with time at a point also produces a time varying magnetic field. The two fields are mutually perpendicular to each other. This idea led Maxwell to conclude that the mutually perpendicular time varying electric and magnetic fields produce electromagnetic disturbances in space. These disturbances have the properties of wave which are called as electromagnetic waves.

According to Maxwell, **the electromagnetic waves are those waves in which there are sinusoidal variation of electric and magnetic field vectors at right angle to each other as well as right angles to the direction of wave propagation.** An electromagnetic wave is shown in figure.



The velocity of electromagnetic wave in free space is given by

$$c = \frac{1}{\sqrt{(\mu_0 \in_0)}}$$

05. Poynting Vector

Poynting vector is a vector that describes the magnitude and direction of energy flow rate.

$$\boxed{\vec{S} = \frac{\vec{E} \times \vec{B}}{\mu_0}}$$

$\vec{S} \rightarrow$ Poynting vector

The magnitude of poynting vector represents the rate at which energy flows through a unit surface area perpendicular to the direction of wave propogation SI unit J/sm^2 or w/m^2