UNIT -111

ELECTROMAGENTIC WAVES

INTRODUCTION

The greatest theoretical achievement of physics in the 19th century was the discovery of electromagnetic waves. The history of electromagnetic theory begins with ancient measures to understand atmospheric electricity, in particular lightning, but were unable to explain the phenomena. People then had little understanding of electricity except these facts. Electric forces in nature come in two kinds. First, there is the electric attraction between unlike (+) and ( ) charges or repulsion between like (+) and (+) or ( ) and ( ) electric charges. It is possible to use this to define a unit of electric charge, as the charge which repels a similar charge at a distance of, say, 1 meter, with a force of unit strength.

Then Faraday showed that a magnetic field which varied in time like the one produced by an alternating current(AC) could drive electric currents, if (say) copper wires were placed in it in the appropriate way. That was "magnetic induction," the phenomenon on which electric transformers are based. So, magnetic fields could produce electric currents, and we already know that electric currents produce magnetic fields. In the 19th century it had become clear that electricity and magnetism were related, and their theories were unified: wherever charges are in motion electric current results, and magnetism is due to electric current. The source for electric field is electric charge, whereas that for magnetic field is electric current (charges in motion).

In 1864 Maxwell theoretically proposed that electromagnetic disturbance travels in free space with the speed of light. Although the idea was remained hidden in his set of equations but virtually never said anything about the waves nor he said anything about the generation of such waves. Later on

Hertz in 1888 succeeded in producing and observing electromagnetic waves of wavelength of the order of 6m in the laboratory.

J. C. Bose in 1895 succeeded in producing and observing electromagnetic waves of much shorter wavelength 25 mm- 5 mm.

G. Marconi in the same year succeeded in transmitting electromagnetic waves over distances of many kilometers.

Basics & Terminologies

The Lorentz force law characterizes the observable effects of electric and magnetic fields on charges, Maxwells equations characterize the origins of those fields and their relationships to each other. The simplest representation of Maxwells equations is in differential form, which leads directly to waves. But before going to the Maxwell's equations let us refresh ourself with few terminologies which will have regular appearances in the equations. The four Maxwell

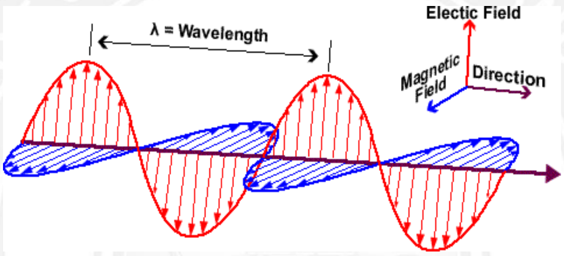
Field variables	Names	Unit
$\vec{E}$	Electric Field	volts/meter; Vm^{-1}
$\vec{H}$	Magnetic Intensity	amperes/meter; Am^{-1}
$\vec{B}$	Magnetic Flux Density	Tesla, T
$\vec{D}$	Electric Displacement	coulombs/m^2; Cm^{-2}
$\vec{J}$	Electric current density	amperes/m^2; Am^{-2}
ρ	Electric charge density	coulombs/m^3; Cm^{-3}

equations which will be derived in the next section invoke one scalar and five vector quantities comprising 16 variables. Some variables only characterize how matter alters field behavior. In vacuum we can eliminate three vectors (9variables) by noting $\vec{D} = \varrho_0 \vec{E}$, $\vec{B} = \mu_0 \vec{H}$ *and* $\vec{J} = \rho$ $\vec{v} = \sigma \vec{E}$. where $\varrho_0 = 8.8542 \times 10^{-12}$ [farads m^{-1}] is the absolute permittivity of vacuum, $\mu_0 = 4\pi$ 10^{-7} [henries m^{-1}] is the absolute permeability of vacuum, $\vec{v}$ is the drift velocity of the local net charge density ρ, and σ is the conductivity of a medium [Siemens m^{-1}]. If we regard the electrical sources ρ and $\vec{J}$ as given, then the equations can be solved for all remaining unknowns. Specifically, we can then find $\vec{E}$ and $\vec{B}$, and thus compute the forces on all charges present.

E -M Waves

Definition:

Electromagnetic waves or EM waves are oscillating magnetic and electric fields at right angles to each other, self-propagating in direction perpendicular to both the electric and magnetic fields.



Basic Definitions-

Electric field intensity (E) - It is defined as the ratio of electrostatic force to the electric charge. Electric Field = F/q. Unit of E is NC-1 or Vm-1.

Electric displacement vector (D) - It is defined as electric flux (Q) per unit area. It is also known as Electric flux density.

Electrical permittivity (ε): It is defined as the ratio of displacement current 9D) to the electric field intensity(E). It is given by

ε = D / E and i ts unit is Unit: $C2N{-}1m{-}2$

Dielectric constant (or) relative permittivity ($\varepsilon\mathbf{r}$): The dielectric constant of a substance is the ratio of the permittivity of the substance to the permittivity of the free space. It shows the extent to which a

material can hold electric flux within it. It is given by ϵr= ϵ0ϵ

here,

ϵr is the dielectric constant

ϵ is the permittivity of the substance ϵ0 is the permittivity of the free space

Magnetic flux density(→): It is defined as the number of magnetic lines of force (ϕm) passing normally through unit area of cross section.

Unit: ‘weber/m2’ or Tesla

Magnetic field intensity(→): It is defined as the force experienced by a unit north pole placed at the point in a magnetic field. It is given by H = F/M

Unit: Ampere / meter.

Magnetic permeability (μ): It is the ratio of magnetic flux density(→) to the magnetic field intensity (→). It is given by

μ = μ0 μr =B→

μ0 → permeability of free space

μr → relative permeability

Unit: $Ns2C{-}2$

Relative permeability (μr):

It is the ratio of absolute permeability (μ) of the medium to the permeability of free space(μ0).

It is a number. For air and non-magnetic

material, its value is ‘1’.

μr = μ / μ0

μ0 = 4π × 10−7$Ns2C{-}2$