Electromagnetic Waves

Displacement current

- It is the current that exists in the region where the electric field and the electric flux is changing with time.
- The displacement current is given by $I_D = \varepsilon_0 \frac{d\Phi_E}{dt}$
  - where,ε_0 = absolute permittivity of free space,
  - $\frac{d\Phi_E}{dt}$= time rate of change of the flux.

Ampere-Maxwell's Law

- According to this law the line integral of the magnetic field($\vec{B}$) over a closed path is equal to μ_0 times the sum of the conduction current$I$ and the displacement curent (I_D)
- $\oint \vec{B}.d\vec{l} = \mu_0\left(I + \varepsilon_0 \frac{d\Phi_E}{dt}\right)$

Electromagnetic waves

- These are the waves in which the electric and the magnetic field vary sinusoidally at right angle to each other as well as to the direction of propagation.
- The speed of electromagnetic waves in free space is given by

  $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = 3 \times 10^8\, ms^{-1}$.

- For an electromagnetic wave travelling along positive Z-axis, electric field oscillates along X-axis and is given by $E_x = E_0 \sin(kz - \omega t)$ and magnetic field oscillates along Y-axis and is given by $B_y = B_0 \sin(kz - \omega t)$.
- The relation between the amplitudes of magnetic and electric fields is $B_0 = \frac{E_0}{c}$.

  The intensity of electromagnetic wave is given by $\frac{1}{2}\varepsilon_0{}^2 E_0{}^2 c$.
- The velocity of light in a material medium is given by

  $v = \frac{1}{\sqrt{\mu \in}}$

  Here,
  $\in$ = permittivity of material medium
  μ = permeability of material medium
- Electromagnetic waves carry energy and momentum and they also exert pressure, called

radiation pressure.

- When the total energy (U) is transferred to a surface in time t, the magnitude of the total momentum delivered to the surface is given by

  $p = \frac{U}{c}$, where c = speed of light

- Hertz set up an experiment in order to produce and detect electromagnetic waves. In this experiment, a high voltage source causes spark to oscillate and, thus, electromagnetic waves are produced by the oscillating spark.

- Different electromagnetic waves:

•	Type	Wavelength range
a	Radio waves	>0.1 m
b	Microwave	0.1 m to 1 mm
c	Infra-red	1 mm to 700 nm
d	Visible light	700 nm to 400 nm
e	Ultra-violet	400 nm to 1 nm
f	X-rays	1 nm to 10^{-3} nm
g	Gamma rays	$<10^{-3}$ nm

- Uses of electromagnetic radiations:

Electromagnetic radiations	Uses
Infrared	to identify molecular structure of compounds, ion long distance photography, diagnosing tumors, in TV remote and solar energy operated devices.
UV	Used as sterilizer, in fluorescent lamps, treatment of diseases skin and bone, in radiography, to study of crystal structure.
X-rays	in treatment of cancer and skin diseases, locate fractured bones, in radiography, to study of crystal structure.
γ-rays	in treatment of cancer, used as catalyst in manufacturing of some chemicals, to produce photoelectric effect, and in radiography.
Microwave	In RADAR, satellite communication and ovens.
Radio wave	In communication, TV and Radio broadcasting.