ELECTROMAGNETIC WAVES

DISPLACEMENT CURRENT-

Current that flows due to change in electric field is known as displacement current.

$$I = \frac{dq}{dt}$$

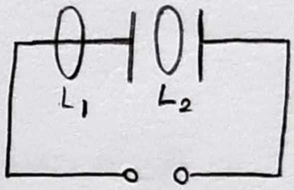
$$\phi_e = \frac{q}{\varepsilon_0} \qquad q = \phi_e \varepsilon_0$$

$$I = \frac{d}{dt} \phi_e \varepsilon_0$$

$$\boxed{I_D = \varepsilon_0 \frac{d\phi_e}{dt}}$$

- The magnitude of I_D = magnitude of conduction current

MAXWELL'S MODIFICATION OF ACL



$$\oint \vec{B} \cdot \vec{dl} = \mu_0 (i_c + i_D)$$

$$\oint_{L_1} \vec{B} \cdot \vec{dl} = \mu_0 i_c \; [\text{outside capacitor}, i_D = 0]$$

$$\oint_{L_2} \vec{B} \cdot \vec{dl} = \mu_0 \cdot \varepsilon_0 \frac{d\phi}{dt} \; [\text{inside capacitor}, i_c = 0]$$

FOUR EQUATIONS OF ELECTROMAGNETISM

① Gauss theorem for electrostats

→ To find flux and EF

$$\oint \vec{E} \cdot \vec{dA} = \frac{Q_{en}}{\varepsilon_0}$$

② Gauss theorem for magnetism

→ To find flux and MF

$$\oint \vec{B} \cdot \vec{dA} = 0$$

3. Maxwell's Ampere Circuital Law

$$\oint \vec{B} \cdot \vec{dl} = \mu_0 \left(i_c + \varepsilon_0 \frac{d\phi_e}{dt} \right)$$

→ This proves changing electric flux creates MF.

4. Faraday's law of electromagnetic induction

→ $$\oint E \cdot dl = -\frac{d\phi_B}{dt}$$

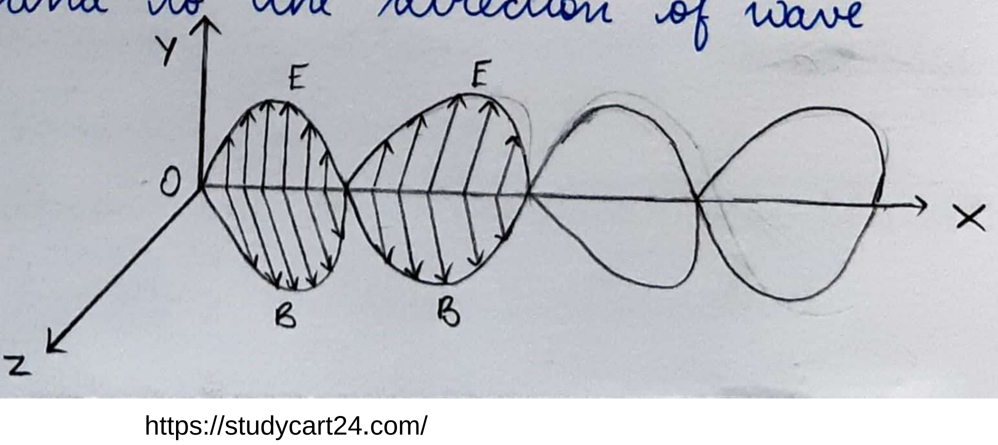
changing magnetic flux creates electric flux.

ELECTROMAGNETIC WAVES

A wave radiated by an accelerated or oscillatory charge in which varying magnetic field is the source of electric field and varying electric field is the source of magnetic field.

CHARACTERISTICS OF EM WAVES

1. The energy in EMW is divided on average equally between electric and magnetic fields.
2. The waves are transverse in nature.
3. EMW carry energy and exert force and pressure
4. EMW are not deflected by electric & magnetic field
5. EMW are transverse in nature i.e. electric field and magnetic fields are perpendicular to each other and to the direction of wave propagation.



ELECTROMAGNETIC SPECTRUM

The systematic sequential distribution of EMW in ascending or descending order of frequency or wavelength is known as electromagnetic spectrum.

1. Radio Wave -

- Wavelength range - >0.1 m
- Frequency range - $10^4 - 10^9$ Hz
- Production - Rapid acceleration and decelaration of e^-.
- Detection - Receiver's aerials
- Uses - (i) In radio and TV communication
  (ii) In astronomical field

2. Microwaves

- Wavelength range - 0.1 m - 1 mm
- Frequency range - $10^9 - 10^{11}$
- Production - Klystron valve or magnetron valve
- Detection - Point contact diodes
- Uses - (i) In RADAR communication
  (ii) For cooking purpose

3. Infrared wave

- Wavelength range - 1 mm - 700 nm
- Frequency range - $3 \times 10^{11} - 4 \times 10^{14}$
- Production - Vibration of atoms and molecules
- Detection - Thermopile, Bolometer
- Uses - (i) In treatment of muscular complaints
  (ii) In knowing molecular structure

4. Visible rays

- Wavelength range - 700 nm to 400 nm
- Frequency range - $4 \times 10^{14} - 8 \times 10^{14}$ Hz
- Production - Electrons in atoms emit light when they move from one energy level to a lower energy level.
- Detection - The eye, photocells, photographic film
- Uses - (i) To see things
  (ii) In optical instruments.

5. Ultraviolet Rays

- Wavelength range - 400 nm - 1 ~~m~~ nm
- Frequency range - $8 \times 10^{14} - 8 \times 10^{16}$ Hz
- Production - Inner shell e^- in atoms moving from one energy level to a lower level.
- Detection - Photocells, photographic film
- Uses - (i) In burglar alarm
  (ii) To kill germs in minerals

6. X-Rays

- Wavelength range - 1 nm - 10^{-3} nm
- Frequency range - $1 \times 10^{16} - 3 \times 10^{21}$
- Production - X-ray tubes or inner shell e^-
- Detection - Photographic film, Geiger tubes
- Uses - (i) In medical diagnosis
  (ii) In detecting faults, cracks

7. Gamma Rays

- Wavelength range - $< 10^{-3}$ nm
- Frequency range - $5 \times 10^{18} - 5 \times 10^{22}$ Hz
- Production - Radioactive decay of the nucleus
- Detection - Photographic film, ionisation chamber
- Uses - (i) For food preservation by killing pathogenic microorganisms.
  (ii) In radiotherapy for treatment of tumour and cancer.

IMPORTANT QUESTIONS

1. A radio can tune into any station in the 7.5 MHz to 12 MHz band. What is the corresponding wavelength? NCERT

Sol. For 7.5 MHz band,

$$\text{Wavelength}, \lambda_1 = \frac{c}{\nu} = \frac{3\times10^8}{7.5\times10^6} = 40\ m$$

For 12 MHz band,

$$\text{Wavelength}, \lambda_2 = \frac{c}{\nu} = \frac{3\times10^8}{12\times10^6} = 25\ m$$

So, wavelength range is from 25 m – 40 m.

2. About 5% of the power of a 100 W light bulb is connected to visible radiation. What is the average intensity of visible radiation at
(i) distance of 1 m from the bulb
(ii) distance of 10 m?
Assume that the radiation is emitted isotropically and neglect reflection. NCERT

Sol. (i) Intensity, $I = \frac{\text{Power of visible light}}{\text{Area}}$

$$= \frac{100\times(5/100)}{4\pi(1)^2}$$

$$= 0.4\ W/m^2$$

(ii) $$I = \frac{100\times\left(\frac{5}{100}\right)}{4\pi(10)^2}$$

$$= 4\times10^{-3}\ W/m^2$$

3. The amplitude of the magnetic field part of a harmonic electromagnetic wave in vacuum is $B_0 = 510 \, nT$. What is the amplitude of the electric field part of the wave?

NCERT

Sol. $B_0 = 510 \, nT = 510 \times 10^{-9} \, T$

Speed of light in vacuum, $c = \frac{E_0}{B_0}$

where, E_0 is the ~~of~~ amplitude of electric field part of the wave.

$$3 \times 10^8 = \frac{E_0}{510 \times 10^{-9}}$$

$$E_0 = 153 \, N/C$$

Thus, the amplitude of the electric field part of wave is 153 N/C.