



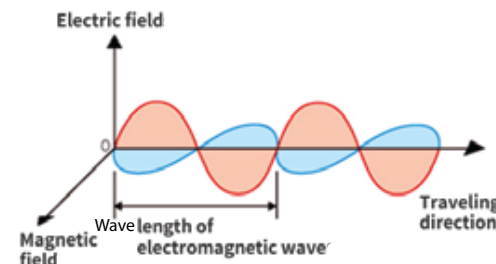
ELECTRO MAGNETIC WAVES

Time varying electric and magnetic fields that propagate in space

Oscillating electric and magnetic fields are mutually perpendicular to each other and both are perpendicular to direction of propagation

Speed of wave = Speed of light = 3×10^8 m/s

TRANSVERSE NATURE OF EM WAVES



$$E_y = E_0 \sin(\omega t - kx)$$

$$B_z = B_0 \sin(\omega t - kx)$$

$$E_0 = c B_0$$

INTENSITY OF WAVE

Energy crossing per unit time area perpendicular to the direction of wave propagation

$$\text{Intensity} = \frac{\text{Energy}}{\text{time} \times \text{area}} = \frac{\text{Power}}{\text{area}}$$

FORMULAE TO REMEMBER

$$I = \frac{1}{2} \epsilon_0 E^2 \times c$$

$$I = \frac{B^2}{2\mu_0} \times c$$

ENERGY DENSITY

1. U_E (Electric field) = $\frac{1}{2} \epsilon_0 E^2$

2. U_B (Magnetic field) = $\frac{1}{2} \frac{B^2}{\mu_0}$

3. Average energy density $\bar{U}_E = \frac{1}{4} \epsilon_0 E^2$, $\bar{U}_B = \frac{1}{4} \frac{B^2}{\mu_0}$

4. $\bar{U}_E = \bar{U}_B$

5 Total average energy density

$$u = u_E + u_B = \frac{1}{2} \epsilon_0 E^2 = \frac{1}{2} \frac{B^2}{\mu_0} \quad [u_E = u_B]$$

SPEED OF EM WAVE (VACUUM) $c = \frac{1}{\sqrt{\mu_0 \epsilon_0}} = 3 \times 10^8$ m/s

SPEED OF EM WAVE (MEDIUM) $v_{\text{med}} = \frac{1}{\sqrt{\mu_0 \mu_r \epsilon_0 \epsilon_r}} = \frac{1}{\sqrt{\mu_r \epsilon_r}}$

REFRACTIVE INDEX $\mu_{\text{med}} = \frac{c}{v_{\text{med}}} = \sqrt{\mu_r \epsilon_r}$

REMARKS

$$c = \frac{E_0}{B_0}, \quad c = \frac{\omega}{k}$$

Maximum electric force $F_{E(\text{max})} = qE_0$

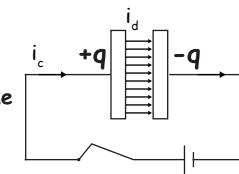
Maximum magnetic force $F_{B(\text{max})} = qvB_0$

DISPLACEMENT CURRENT

Displacement current - Current in vacuum or dielectric when electric field is changing with time

$$I_d = \epsilon_0 \frac{d\phi_E}{dt}$$

Displacement current = Conduction current



POYNTING VECTOR

$$S = \frac{\text{Energy}}{\text{time} \times \text{area}} = \frac{\text{Power}}{\text{area}} \quad \vec{S} = \frac{\vec{E} \times \vec{B}}{\mu_0}$$

POYNTING VECTOR

Magnitude represents power per unit area
Direction is along the direction of wave propagation
SI unit :- $\frac{\text{Joule}}{\text{sec m}^2}$ or $\frac{\text{Watt}}{\text{m}^2}$

MOMENTUM OF EM WAVES

1) $P = \frac{U}{c}$ (If wave is completely absorbed)

2) $P = \frac{2U}{c}$ (If wave is completely reflected)

MAXWELL'S EQUATIONS

$$\oint \vec{E} \cdot d\vec{A} = \frac{Q}{\epsilon_0} \quad [\text{Gauss's Law of Electrostatics}]$$

$$\oint \vec{B} \cdot d\vec{A} = 0 \quad [\text{Gauss's Law of Magnetism}]$$

$$\oint \vec{E} \cdot d\vec{l} = -\frac{d\phi_E}{dt} \quad [\text{Faraday's Law of Electromagnetic Induction}]$$

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 (i_c + i_d) = \mu_0 i_c + \mu_0 \epsilon_0 \frac{d\phi_E}{dt} \quad [\text{Ampere-Maxwell's Law}]$$

EM WAVES

ELECTROMAGNETIC SPECTRUM

RadioWaves

Produced by : Accelerated motion of charges in conducting wires

Frequency : 500 kHz - 1000MHz

Application : Cellular phones

Microwaves

Produced by : Special vacuum tubes - Klystrons, magnetrons, Gunn diodes

Detection by : Point contact diodes

Application : Radar systems, microwave oven in domestic purposes

Infrared waves

Produced by : Vibration of atoms and molecules

Detection by : Thermopiles, Bolometer, Infrared photographic film

Application : Used in remote switches for TV set, maintains average temperature through green house effect, Infrared lamps, Infrared detectors

Visible light

Wavelength : 400nm to 700nm

Frequency : 4×10^{14} Hz to 7×10^{14} Hz

Ultraviolet rays

Wavelength : 4×10^{-7} m to 6×10^{-10} m

Produced by : Very hot bodies

Important source : Sun

Application : LASIK Surgery,

UV lamps - Kills germs in purifiers

Detection by : Photocells, photographic film

X-RAYS

Produced by : High energy electrons striking metal targets

Wavelength range : 10nm to 10^{-4} nm

Application : Diagnostic tool, treatment of cancer

Detection : Photographic film, Geiger tubes, Ionisation chamber

GAMMA rays

Produced in : Nuclear reactions, Radioactive decay of nucleus

Wavelength range : 10nm to 10^{-14} nm

Application : In medicine to Kill cancer cells.

Decreasing order of wavelength \longrightarrow

R M I V U X G

\longrightarrow Increasing order of frequency