ELECTRO MAGNETIC WAVES

- Time varying electric and magnetic fields that propogate 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

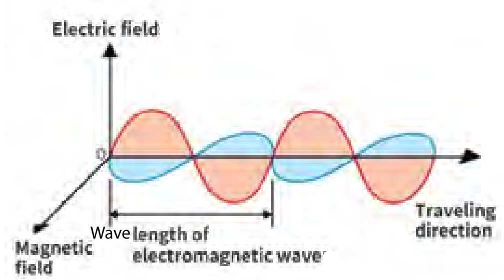
SOURCE OF ELECTROMAGNETIC WAVES IS ACCELERATING / OSCILLATING CHARGE

ENERGY DENSITY

1. U_E (Electric field) $= \frac{1}{2}\varepsilon_0 E^2$
2. U_B (Magnetic field) $= \frac{1}{2}\frac{B^2}{\mu_0}$
3. Average energy density $\bar{u}_E = \frac{1}{4}\varepsilon_0 E^2$, $\bar{u}_B = \frac{1}{4}\frac{B^2}{\mu_0}$
4. $\bar{u}_E = \bar{u}_B$
5. Total average energy density

$$u = u_E + u_B = \frac{1}{2}\varepsilon_0 E^2 = \frac{1}{2}\frac{B^2}{\mu_0} \quad [\bar{u}_E = \bar{u}_B]$$

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

$I = \frac{1}{2}\varepsilon_0 E^2 \times c$

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

SPEED OF EM WAVE (VACUUM) $C = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = 3 \times 10^8$ m/s

SPEED OF EM WAVE (MEDIUM) $V_{med} = \frac{1}{\sqrt{\mu_0 \mu_r \varepsilon_0 \varepsilon_r}} = \frac{1}{\sqrt{\mu_m \varepsilon_m}}$

REFRACTIVE INDEX $\mu_{med} = \frac{c}{V_{med}} = \sqrt{\mu_r \varepsilon_r}$

REMARKS

$C = \frac{E_0}{B_0}$, $C = \frac{\omega}{K}$

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

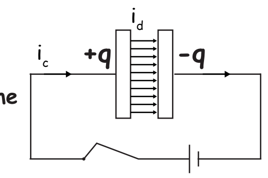
Maximum magnetic force $F_{B(max)} = qvB_0$

DISPLACEMENT CURRENT

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

$I_d = \varepsilon_0 \frac{d\phi_E}{dt}$

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 :- $\frac{\text{Joule}}{\text{sec m}^2}$, $\frac{\text{Watt}}{\text{m}^2}$

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

$\oint \vec{E}.d\vec{A} = \frac{Q}{\varepsilon_0}$ [Gauss's Law of Electrostatics]

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

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

$\oint \vec{B}.d\vec{l} = \mu_0 (i_c + i_d) = \mu_0 i_c + \mu_0 \varepsilon_0 \frac{d\phi_E}{dt}$ [Ampere-Maxwell's Law]

EM WAVES

ELECTROMAGNETIC SPECTRUM

Radio Waves

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}

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