

FORMULA SHEET

Electromagnetic Waves

1. Displacement Current

$$I_d = \epsilon_0 \frac{d\phi_E}{dt} = \epsilon_0 \frac{d(EA)}{dt}$$

$\phi_E \rightarrow$ Electric flux ($\phi = EA \cos \theta$)

2. Modified Ampere's circuital Law

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 \left(I + \epsilon_0 \frac{d\phi_E}{dt} \right)$$

3. Maxwell's Equations

(i) $\oint \vec{E} \cdot d\vec{A} = \frac{q}{\epsilon_0}$ [Gauss law in electrostatics]

(ii) $\oint \vec{B} \cdot d\vec{A} = 0$ [Gauss law in magnetism]

(iii) $\oint \vec{E} \cdot d\vec{l} = - \frac{d\phi}{dt}$ [Faraday's law]

(iv) $\oint \vec{B} \cdot d\vec{l} = \mu_0 I_c + \mu_0 \epsilon_0 \frac{d\phi_E}{dt}$ [Ampere-Maxwell law]

4. Mathematical Expression for EM Waves

The oscillating electric and magnetic fields $\vec{E}$ and $\vec{B}$ are perpendicular to each other, and

to the direction of propagation of EM wave

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

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

} Dirⁿ of propagation
of EM wave is along x axis

Where $k = \frac{2\pi}{\lambda}$, $\omega = 2\pi\nu$
 $\lambda \rightarrow$ wavelength $\nu \rightarrow$ frequency

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Here E and B are oscillating along y and z axis respectively.

5. Velocity of EM Waves

$$v = c = \frac{1}{\sqrt{\mu_0 \epsilon_0}} = 3 \times 10^8 \text{ m/s}$$

6. Propagation of EM Waves

$$\frac{E_0}{B_0} = c \quad \text{or} \quad \frac{E}{B} = c$$

7. Average Energy Density

$$u_E = \frac{B^2}{2\mu_0} = u_B$$

8. Momentum carried by EM Wave

$$p = \frac{U}{c}$$

$U \rightarrow$ energy

9. Intensity of EM Wave

$$I = \frac{1}{2} c \epsilon_0 E^2 = \frac{B^2 c}{2\mu_0}$$

10. Poynting Vector ($\vec{S}$)

$$\vec{S} = \frac{1}{\mu_0} (\vec{E} \times \vec{B})$$

Poynting vector represents the directional energy flux (the energy transfer per unit area per unit time)

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