ENGINEERING PHYSICS

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Week #1

- Review of Electric and magnetic fields

- EM Wave equation

- *Energy transported by EM Waves*

- Max Planck's Black Body Radiation equation

Class #3

- *Energy in an electric field*

- *Energy in a magnetic field*

- *Energy transported by Electric and Magnetic waves*

- *Total Energy of the EM wave*

- *Poynting Vector and average energy transported*

- *Polarization of EM waves*

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Unit I : Review of concepts leading to Quantum Mechanics

➢ *Suggested Reading*

1. *Fundamentals of Physics, Halliday, Resnik, Chapter 34*

2. *NCERT Physics Book I grade 12 – Chapter 8*

➢ *Reference Videos*

1. *https://nptel.ac.in/courses/108/106/108106073/*

2. *UE20PH101_week1_class2*

The energy of a capacitor charged to a potential V

$$Energy = \frac{1}{2}CV^2 = \frac{1}{2}\frac{\varepsilon_o A}{d}V^2 = \frac{1}{2}\varepsilon_o Ad \cdot E^2$$

The energy stored per unit volume of the capacitor

$$Energy\ per\ unit\ volume = \frac{1}{2}\varepsilon_o E^2$$

The energy per unit volume in an electric field is dependent

only on the strength of the field !

Energy in a magnetic field

*The energy of an inductor **L** with current **I** flowing*

$$Energy \quad = \frac{1}{2}LI^2$$

$$= \frac{1}{2}\frac{N^2\mu_o A}{l} \cdot \frac{B^2 l^2}{\mu_o{}^2 N^2} = \frac{1}{2}\frac{B^2 A.l}{\mu_o}$$

The energy stored per unit volume of the inductor

$$Energy \ per \ unit \ volume = \frac{1}{2}\frac{B^2}{\mu_o}$$

The energy per unit volume in a magnetic field !

Energy in an electromagnetic field

- **Energy content in a EM field =>**

- $\frac{1}{2}\varepsilon_o E_x{}^2 + \frac{1}{2}\frac{B_y{}^2}{\mu_o}$

$$= \frac{1}{2}\varepsilon_o E_x{}^2 + \frac{1}{2}\frac{E_x{}^2}{c^2\mu_o}$$

$$= \varepsilon_o E_x{}^2$$

- **Energy transported in the z direction**

Energy in an electromagnetic field

- *Energy transported per unit volume per unit time - Poynting Vector*

- $s \equiv \dfrac{1}{\mu_o} E \times B = c\varepsilon_o E \times B$

A beam of electromagnetic waves with unit area of cross section travelling in free space

$c\varepsilon_o E_x{}^2$

Energy in an electromagnetic field
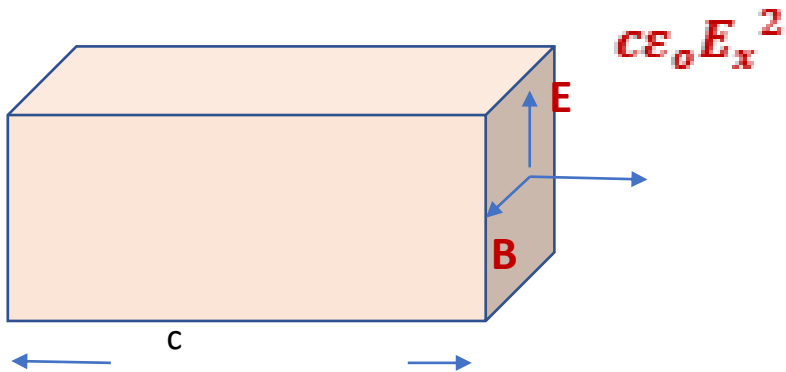
- **Average energy transported by an electromagnetic wave – energy transported in one cycle**

- $\langle Energy \rangle \quad = \frac{c\varepsilon_o}{T} \int_0^T E_x^2 \, dt$

$$= \frac{c\varepsilon_o}{T} \int_0^T E_{ox}^2 \sin^2(\omega t + kz) \, dt$$

$$= \frac{1}{2} \varepsilon_o c E_{ox}^2$$

$$= \frac{1}{2} c \frac{B_{oy}^2}{\mu_o}$$

$$= \frac{1}{2} \frac{E_{ox} B_{oy}}{\mu_o}$$

## Energy in an electromagnetic field

- **Energy transported is dependent on the amplitude of the electric and magnetic waves**

- **Energy is independent of the wavelength or frequency of the waves!!**

Polarisation of electromagnetic waves

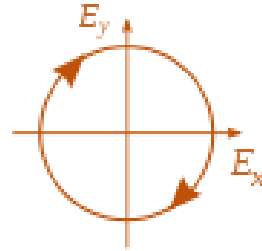- **Polarization of radiation / electromagnetic waves**

- **Polarization of the electric wave**

Plane polarized EM wave -
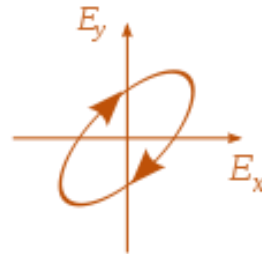**two waves in phase**

Polarization of electromagnetic waves
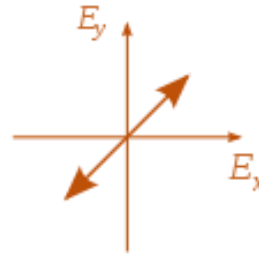
Circularly polarized EM wave –

two waves of equal amplitudes and out of phase by 90º

Elliptically polarized EM wave –

two waves of unequal amplitudes and out of phase <> 90º

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The concepts which apply to electromagnetic waves….

1. Electric waves in free space are longitudinal

2. Magnetic waves in free space are transverse

3. The curl of a magnetic field is uniformly zero

4. The divergence of a magnetic field can be non zero

5. The curl of an electric field is always linked to a time varying magnetic field

6. The divergence of a vector field is a scalar

7. Two waves out of phase by 90° and unequal amplitude form a circularly polarized wave

THANK YOU

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