UNIT V

ELECTROMAGNETIC WAVES

Weightage Marks : 03

TOPICS TO BE COVERED

Displacement current, electromagnetic waves and their characteristics (qualitative ideas only).

Transverse nature of electromagnetic waves. Electromagnetic spectrum (radio-waves, micro-waves, infrared, visible, ultraviolet, X-rays, gamma rays) including elementary facts about their uses.

KEY POINTS

- EM waves are produced by accelerated (only by the change in speed) charged particles.
- $\vec{E}$ and $\vec{B}$ vectors oscillate with the frequency of oscillating charged particles.
- Properties of em waves :
  - (i) Transverse nature
  - (ii) Can travel though vacuum.
  - (iii) $E_0/B_0 = E/B = v$ $\quad v \rightarrow$ Speed of EM waves.
  - (iv) Speed $= 3 \times 10^8$ m/s in vacuum.
  - (v) In any medium $v = \dfrac{1}{\sqrt{\mu \in}}$

Where $\mu = \mu_r \mu_0$, $\varepsilon = \varepsilon_r \varepsilon_0$

n = refractive index of medium $\sqrt{\epsilon_r} = n$

Also $v = c/n$

(vi) Wave intensity equals average of Poynting vector $I = |\vec{S}|_{av} = \frac{B_0 E_0}{2\mu_0}$

(vii) Average electric and average magnetic energy densities are equal.

- In an em spectrum, different waves have different frequency and wavelengths.
- Penetration powerof em waves depends on frequency. Higher the frequency larger the penetration power.
- Wavelength λ and frequency ν are related with each other $v = \lambda\nu$. Here v is the wave velocity.
- A wave travelling along +x axis is represented by

$$E_y = E_{oy} \cos(\omega t - kx)$$

$$B_z = B_{oz} \cos(\omega t - kx)$$

$$\omega = \frac{2\pi}{T} = 2\pi\nu \qquad \frac{\omega}{k} = \lambda\nu = v \text{ wave speed}$$

$$k = \frac{2\pi}{\lambda} = 2\pi\bar{\nu}$$

$\nu \rightarrow$ frequency

$$\bar{\nu} = \frac{1}{\lambda} \text{ wave number .}$$

QUESTIONS

VERY SHORT ANSWER QUESTIONS (I Mark)

1. Every *EM* wave has certain frequency. Name two parameters of an em wave that oscillate with this frequency.

2. What is the phase difference between electric and magnetic field vectors in an em wave?

3. Name em radiations used for detecting fake currency notes.

4. Give any two uses of microwaves.

5. Name the phenomenon which justifies the transverse nature of em waves.

6. Arrange the following em waves in descending order of wavelengths : γ ray, microwaves UV radiations.

7. Which component $\vec{E}$ or $\vec{B}$ of an em wave is responsible for visible effect?

8. Write expression for speed of em waves in a medium of electrical permittivity ϵ and magnetic permeability μ.

9. Which of the following has longest penetration power?

   UV radiation, X-ray, Microwaves.

10. Which of the following has least frequency?

    IR radiations, visible radiation, radio waves.

11. Which physical quantity is the same for microwaves of wavelength 1 mm and UV radiations of 1600 A° in vacuum?

12. Name two physical quantities which are imparted by an em wave to a surface on which it falls.

13. Name the physical quantity with unit same as that of

    $\left[I_d = \epsilon_0 \frac{d\phi_e}{dt}\right]$ where $\phi_e \rightarrow$ electric flux.

14. What is the source of energy associated with propagating em waves?

15. What is the wavelength range of em waves that were produced and observed by J.C. Bose?

16. Name the device used for producing microwaves.

17. Name the em radiations which are detected using Gieger tube.

18. Relative electric permittivity of a medium is 8 and relative permeability is close to unity. What is the speed of em waves in the medium.

19. Identify the part of the electromagnetic spectrum to which the following wavelengths belong :

    (i) 10^{-1} m (ii) 10^{-12} m

20. Name the part of the electromagnetic spectrum of wavelength 10^{-2} m and mention its one application.

21. Which of the following, if any, can act as a source of electromagnetic waves?

    (i) A charge moving with a constant velocity.

    (ii) A charge moving in a circular orbit.

    (iii) A charge at rest.

22. Mention the pair of space and time varying E and B fields which would generate a plane em wave trevelling in Z-direction.

23. The charging current for a capacitor is 0.2A. What is the displacement Current?

24. Give the ratio of Velocities of light waves of wavelengths 4000A° and 8000A° in Vaccum.

25. Which physical quantity, If any has the same value for waves belonging to the different parts of the electromagnetic spectrum?

SHORT ANSWER QUESTIONS (2 Marks)

1. Give one use of each of the following (i) UV ray (ii) γ-ray

2. Represent *EM* waves propagating along the *x*-axis. In which electric and magnetic fields are along *y*-axis and *z*-axis respectively.

3. State the principles of production of *EM* waves. An *EM* wave of wavelength λ goes from vacuum to a medium of refractive index n. What will be the frequency of wave in the medium?

4. An *EM* wave has amplitude of electric field E_0 and amplitude of magnetic field is B_0 the electric field at some instant become $\frac{3}{4}E_0$. What will be magnetic field at this instant? (Wave is travelling in vacuum).

5. State two applications of infrared radiations.
6. State two applications of ultraviolet radiations.
7. State two applications of x-rays.
8. Show that the average energy density of the electric field $\vec{E}$ equals the average energy density of the magnetics fields $\vec{B}$?

SHORT ANSWER QUESTIONS (3 Marks)

1. Name *EM* radiations used (i) in the treatment of cancer.
   (ii) For detecting flaw in pipes carrying oil.
   (iii) In sterilizing surgical instruments.
2. How would you experimentally show that *EM* waves are transverse in nature?
3. List any three properties of *EM* waves.
4. Find the wavelength of electromagnetic waves of frequency 5×10^{19} Hz in free space. Give its two applications

NUMERICALS

1. The refractive index of medium is 1.5. A beam of light of wavelength 6000 A° enters in the medium from air. Find wavelength and frequency of light in the medium.
2. An *EM* wave is travelling in vaccum. Amplitude of the electric field vector is 5×10^4 V/m. Calculate amplitude of magnetic field vector.
3. Suppose the electric field amplitude of an em wave is $E_0 = 120\ NC^{-1}$ and that its frequency is $\nu = 50.0$ MHz.
   (a) Determine B_0, ω, κ and λ
   (b) Find expressions for E and B.
4. A radio can tune into any station of frequency band 7.5 MHz to 10 MHz. Find the corresponding wave length range.

5. The amplitude of the magnetic field vector of an electromagnetic wave travelling in vacuum is 2.4mT. Frequency of the wave is 16 MHz. Find :

   (i) Amplitude of electric field vector and

   (ii) Wavelength of the wave.

6. An *EM* wave travelling through a medium has electric field vector.

   $E_y = 4 \times 10^5 \cos (3.14 \times 10^8 \, t - 1.57 \, x)$ N/C. Here x is in m and t in s.

   Then find :

   (i) Wavelength

   (ii) Frequency

   (iii) Direction of propagation

   (iv) Speed of wave

   (v) Refractive index of medium

   (vi) Amplitude of magnetic field vector.