Physics (Q. & Ans.)
Class XII

Chapter: 08
Electromagnetic Waves

1. **A plane electromagnetic wave travels in vacuum along Z-direction. What can you say about the direction of electric and magnetic field vectors?**

Ans.: The direction of electric and magnetic field vectors are along X and Y-directions respectively. Directions of electric field, magnetic field and propagation of wave are mutually perpendicular to one another.

2. **Write two uses of microwaves.**

Ans. Uses of Microwaves:
i. In RADAR communication.
ii. In analysis of molecular and atomic structure.

3. **Write two uses of infrared rays.**

Ans. Uses of Infrared Rays:
i. In knowing the molecular structure.
ii. In remote control of TV, VCR, etc.

4. **Arrange the following in descending order of wavelength.**
X-rays, radiowaves, blue light, infrared light.

Ans. Radio wave > Infrared > Blue light > X-ray is the descending order of wavelength.

5. **Why we use Microwave for water heating?**

Ans: Microwaves are used for water heating because its wavelength is of the size (order) of H_2O molecules & they have sufficient energy to vibrate H2O molecules as a result of that Water gets heated up. Radio waves has less energy so it cannot heat & light wave has more energy so they will pass through it with oscillating them.

6. **Why we use microwave for RADAR?**

Ans: for their Coherence property for a very large distances.

7. **Which part of electromagnetic spectrum has largest penetrating power?**

Ans. γ-rays have highest frequency range and hence highest penetrating power.

8. Name the constituent radiation of electromagnetic spectrum which is used for
i. Aircraft navigation
ii. Studying the crystal structure
Write the frequency range for each.

Ans. (i) Microwaves are used for aircraft navigation, their frequency range is 10^9 Hz to 10^{12} Hz.
(ii) X-rays are used to study crystal structure their frequency range is 10^{16} Hz to 10^{20} Hz.

9. How are X-rays produced? Write their two important uses.

Ans. X-rays can be produced by colliding fast moving electron beam on metal target,
Uses
(i) medical diagnosis.
(ii) Study of crystal structure.

10. Identify the following electromagnetic radiations as per the wavelengths given below. Write one application of each.
i. 10^{-3} nm
ii. 10^{-3} m
iii. 1 nm

Ans. (i) 10^{-3} nm X-rays, medical diagnosis.
(ii) 10^{-3} M Infrared, remote control of TV, VCR, etc.
(ii) 1 nm UV rays, in food preservation.

11. Why did Maxwell introduce displacement current in Ampere's circuital law?

Ans.
Ampere's Circuital law was found inconsistent when applied to the circuit for charging a capacitor.
Therefor Maxwell added displacement Current to usual Conduction current.
The displacement current is $I_d = \varepsilon_0 \frac{d\phi_E}{dt}$, $where\ \phi_E\ is\ electric\ flux$

12. What is the origin of displacement current?

Ans. Displacement current does not arise due to motion of charge carriers but it arises due to time variation of electric flux.

13. Which of the following 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.
Given reason.

Ans. Only an accelerated charge can radiate electromagnetic waves. As charge moving in a circular orbit is accelerated, so it can radiate electromagnetic waves.

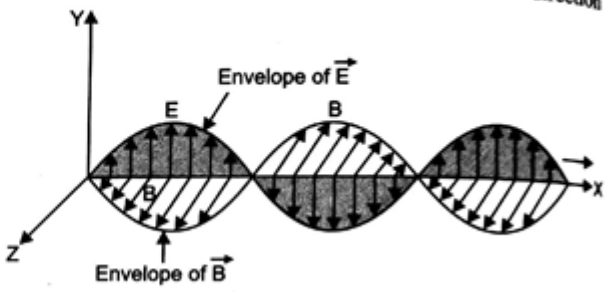
14. What is meant by the transverse nature of electromagnetic waves? Draw a diagram showing the propagation of an electromagnetic wave along X- direction, indicating clearly the directions of oscillating electric and magnetic Fields associated with it.

Ans.

Transverse Nature of Electromagnetic Waves :

In an electromagnetic wave, the electric and magnetic field vectors oscillate, perpendicular to the direction of propagation of wave. This is called transverse nature of electromagnetic wave.

In an electromagnetic wave, the three vectors $\vec{E}, \vec{B}$ and $\vec{K}$ form a right handed system. Accordingly if a wave is propagating along X-axis, the electric field vector oscillates along Y-axis and magnetic field vector oscillates along Z-axis. Diagram is shown in figure.



15. Name the parts of the electromagnetic spectrum which is
(i) suitable for radar system used in aircraft navigation.
(ii) Used to treat muscular strain.
(iii) Used as a diagnostic tool in medicine .
Write in brief, how these waves can be produced.

Ans.
(i) Microwave
(ii) Infrared
(iii) X-Rays
Microwaves are produced by special vacuum tubes, like magnetrons.
Infrared are produced by the vibrating molecules & atoms in the hot bodies.
X-rays are produced by the bombardment of high energy electrons on a metal target of high atomic weight like tungsten.

16. Name the constituent radiation of electromagnetic spectrum which
(a) is used in satellite communication spectrum which
(b) is used for studying crystal structure.
(c) Is similar to the radiations emitted during the decay of radioactive nuclei?
(d) Has its wavelength range between 390 nm and 700 nm.
(e) Is absorbed from sunlight by ozone layer.
(f) Produces intense heating effect.

Ans
(a) Short radiowaves $\lambda < 10\ m\ or\ \nu > 30 Mhz$ are used in satellite Communications
(b) X-rays are used for studying crystal Structure.
(c) $\gamma - radiations$ is similar to the radiation emitted during decay of radioactive nuclei.
(d) Visible radiations
(e) Ultraviolet rays
(f) Infrared Radiations

17. A radio can tune into any station in the 7.5 MHz to 12 MHz band. What is the corresponding wavelength band?

Ans

Speed of wave $c = 3 \times 10^8$ ms^{-1},

When frequency $\nu_1 = 7.5$ MHz $= 7.5 \times 10^6$ Hz, Wavelength $\lambda_1 = \frac{C}{\nu_1} = \frac{3 \times 10^8}{7.5 \times 10^6} = 40$ m

When frequency $\nu_2 = 12$ MHz, wavelength $\lambda_2 = \frac{C}{\nu_2} = \frac{3 \times 10^8}{12 \times 10^6} = 25$ m

Wavelength band is from 25 m to 40 m.

18. Suppose the electric field amplitude of an electromagnetic wav is $E_0 = 120N/C$ and that its frequency v=50.0MHz.(a) Determine B_0, ω, k and λ (b) Find expression for $\vec{E}$ and $\vec{B}$.

Ans.

We have $\frac{E_0}{B_0} = c \Rightarrow B_0 = \frac{E_0}{c} = \frac{120}{3 \times 10^8} = 4 \times 10^{-7}$ T

$\omega = 2\pi\nu = 2 \times 3.14 \times 50 \times 10^6 = 3.14 \times 10^8$ rad s^{-1}

$k = \frac{\omega}{c} = \frac{3.14 \times 10^8}{3 \times 10^8} = 1.05$ rad m^{-1}

Wavelength, $\lambda = \frac{c}{\nu} = \frac{3 \times 10^8}{50.0 \times 10^6} = 6.00$ m.

If wave is propagating along X-axis, electric field will be along Y-axis and magnetic field along Z-axis.

$\vec{E} = E_0 \sin(kx - \omega t)\,\hat{j}$, where x is in m and t in s

$\Rightarrow \quad \vec{E} = 120 \sin(1.05\,x - 3.14 \times 10^8\,t)\,\hat{j}$ N/C

$\vec{B} = B_0 \sin(kx - \omega t)\,\hat{k}$

$= (4 \times 10^{-7}) \sin(1.05\,x - 3.14 \times 10^8\,t)\,\hat{k}$ tesla.

19. In a plane electromagnetic wave, the electric field oscillates sinusoidally at a frequency of 2.0 X10^{10} Hz and amplitude 48 Vm^{-1}
(a) what is the wavelength of a wave
(b) what is the amplitude of the oscillating magnetic field?
(c)Show that the average energy density of the electric field equals the average energy density of the B field. [c=3x10^8 m/s]

Ans

(*a*) Wavelength $\lambda = \frac{c}{\nu} = \frac{3 \times 10^8}{2 \times 10^{10}} = 1.5 \times 10^{-2}$ m

(*b*) $B_0 = \frac{E_0}{c} = \frac{48}{3 \times 10^8} = 1.6 \times 10^{-7}$ tesla

(*c*) Energy density of electric field

$$u_e = \frac{1}{2}\varepsilon_0 E^2 \qquad \ldots(i)$$

Energy density of magnetic field

$$u_B = \frac{1}{2\mu_0} B^2 \qquad \ldots(ii)$$

Now, $u_e = \frac{1}{2}\varepsilon_0 E^2 = \frac{1}{2}\varepsilon_0 (cB)^2 (\because E = cB)$

$= \frac{1}{2}\varepsilon_0 \left(\frac{1}{\sqrt{\mu_0 \varepsilon_0}}\right)^2 B^2 \qquad \left(\because c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}\right) \qquad = \frac{1}{2\mu_0} \times B^2$

$u_e = u_B$

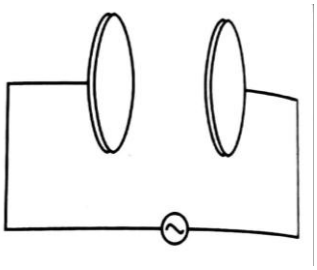
20.

A parallel plate capacitor (fig.) made of circular plates each of radius R = 6.0 cm has a capacitance C = 100 pF. The capacitor is connected to a 230 V ac supply with an angular frequency of 300 rad/s.

(*a*) What is the rms value of the conduction current?

(*b*) Is conduction current equal to the displacement current?

(*c*) Determine the amplitude of magnetic field induction B at a point 3.0 cm from the axis between the plates. [*NCERT*]



Ans

Ans. Given $R = 6.0$ cm, $C = 100$ pF $= 100 \times 10^{-12}$ F $= 10^{-10}$ F, $\omega = 300$ rad/s, $V_{rms} = 230$ V

(*a*) Impedance of circuit Z = capacitance reactance $X_C = \dfrac{1}{\omega C}$

Root mean square current, $I_{rms} = \dfrac{V_{rms}}{Z} = V_{rms} \times \omega C$

$$= 230 \times 300 \times 10^{-10} = 6.9 \times 10^{-6} \text{ A} = 6.9\ \mu\text{A}$$

(*b*) Yes, the conduction current is equal to the displacement current.

(*c*) The whole space between the plates occupies displacement current which is equal in magnitude to the conduction current.

Magnetic field $B = \dfrac{\mu_0 I r}{2\pi R^2}$

Here $r = 3$ cm $= 3 \times 10^{-2}$ m, $R = 6$ cm $= 6 \times 10^{-2}$ m

Amplitude of displacement current = Peak value of conduction current $= I_0 = I_{rms}\sqrt{2}$

$\therefore$ Amplitude of magnetic field

$$B = \frac{\mu_0 I_0 r}{2\pi R^2} = \frac{\mu_0 I_{rms}\sqrt{2} r}{2\pi R^2}$$

$$= \frac{4\pi \times 10^{-7} \times 6.9 \times 10^{-6} \times 1.41 \times (3 \times 10^{-2})}{2\pi \times (6 \times 10^{-2})^2} = 1.63 \times 10^{-11} \text{ T}$$

21.

Suppose that the electric field of an electromagnetic wave in vacuum is

$$\vec{E} = \{(3.1\ \text{N/C}) \cos (1.8\ \text{rad/m})\, y + (5.4 \times 10^6\ \text{rad/s})\, t\}\, \hat{i}$$

(*a*) What is the direction of propagation?

(*b*) What is the wavelength λ?

(*c*) What is the frequency ν?

(*d*) What is the amplitude of the magnetic field part of the wave?

(*e*) Write an expression for the magnetic field part of the wave.

Ans

(*a*) Wave is propagating along negative y-axis.

(*b*) Standard equation of wave is $\vec{E} = E_0 \cos (ky + \omega t)\, \hat{i}$

Comparing the given equation with standard equation, we have

$E_0 = 3.1$ N/C, $k = 1.8$ rad/m, $\omega = 5.4 \times 10^6$ rad/s.

Propagation constant $k = \dfrac{2\pi}{\lambda}$

$\therefore$ $\lambda = \dfrac{2\pi}{k} = \dfrac{2 \times 3.14}{1.8}$ m $= 3.49$ m

(*c*) We have $\omega = 5.4 \times 10^6$ rad / s

Frequency, $\nu = \dfrac{\omega}{2\pi} = \dfrac{5.4 \times 10^6}{2 \times 3.14}$ Hz $= 8.6 \times 10^5$ Hz

(*d*) Amplitude of magnetic field, $B_0 = \dfrac{E_0}{c} = \dfrac{3.1}{3 \times 10^8} = 1.03 \times 10^{-8}$ T

(*e*) The magnetic field is vibrating along Z-axis because $\vec{K}, \vec{E}, \vec{B}$ form a right handed system

$$-\hat{j} \times \hat{i} = \hat{k}$$

$\therefore$ Expression for magnetic field is

$$\vec{B} = B_0 \cos (ky + \omega t)\, \hat{k}$$

$$= [1.03 \times 10^{-8}\ T \cos \{(1.8\ \text{rad/m})\, y + (5.4 \times 10^6\ \text{rad/s})\, t\}]\, \hat{k}$$

22.

The oscillating electric field of an electromagnetic wave is given by

$$E_y = 30 \sin(2\times 10^{11}\, t + 300\pi x)\ \text{Vm}^{-1}$$

(*a*) Obtain the value of wavelength of the electromagnetic wave.

(*b*) Write down the expression for oscillating magnetic field.

Ans

(*a*) Given equation is

$$E_y = 30 \sin(2\times 10^{11}\, t + 300\,\pi x)\ \text{Vm}^{-1}$$

Comparing with standard equation

$$E_y = E_0 \sin(\omega t + kx)\ \text{Vm}^{-1}, \quad \text{we get}$$

$$E_0 = 30\ \text{Vm}^{-1},\ \omega = 2\times 10^{11}\ \text{rad s}^{-1}$$

$$k = \frac{2\pi}{\lambda} = 300\,\pi\ \text{m}^{-1}$$

$\therefore$ Wavelength,

$$\lambda = \frac{2\pi}{300\pi}\ \text{m} = \frac{1}{150}\ \text{m} = 6{\cdot}67\times 10^{-3}\ \text{m}$$

(*b*) The wave is propagating along *X*-axis, electric field is oscillating along *Y*-axis, so according to right hand system of $(\vec{E}, \vec{B}, \vec{K})$ the magnetic field must oscillate along *Z*-axis.

$\therefore$ $$B_0 = \frac{E_0}{C} = \frac{30}{3\times 10^8} = 10^{-7}\ \text{T}.$$

$\therefore$ Equation of oscillating magnetic field is

$$B_z = B_0 \sin(\omega t + kx)\, T$$

$\Rightarrow$ $$B_z = 10^{-7} \sin(2\times 10^{11}\, t + 300\,\pi x)\, T$$

23.

The oscillating magnetic field in a plane electromagnetic wave is given by

$$B_y = (8\times 10^{-6}) \sin[2\times 10^{11}\, t + 300\,\pi x]\, T$$

(*i*) Calculate the wavelength of the electromagnetic wave.

(*ii*) Write down the expression for the oscillating electric field.

Ans

(*i*) Standard equation of magnetic field is

$$B_y = B_0 \sin(\omega t + kx)\, T$$

Comparing this equation with the given equation, we get

$$B_0 = 8\times 10^{-6}\ \text{T},$$

$$\omega = 2\times 10^{11}\ \text{rad s}^{-1}$$

$$k = \frac{2\pi}{\lambda} = 300\pi m^{-1}$$

wavelength, $\lambda = \dfrac{2\pi}{300\pi} = \dfrac{1}{150}\ \text{m}$

(*ii*) $E_0 = B_0 c = 8\times 10^{-6}\times 3\times 10^8 = 2.4\times 10^3\ \text{Vm}^{-1}$.

According to right hand system of $\vec{E}, \vec{B}, \vec{K}$, the electric field oscillates along negative *Z*-axis, so equation is

$$E_z = -2.4\times 10^3 \sin(2\times 10^{11}\, t + 300\pi x)\ \text{V m}^{-1}$$