EMW

1. The energy associated with electric field is (U_E) and with magnetic field is (U_B) for an electromagnetic wave in free space. Then :

(1) $U_E = \frac{U_B}{2}$ (2) $U_E < U_B$
(3) $U_E = U_B$ (4) $U_E > U_B$

2. A plane electromagnetic wave of frequency 50 MHz travels in free space along the positive x-direction. At a particular point in space and time, $\vec{E} = 6.3\hat{j}\,V/m$. The corresponding magnetic field $\vec{B}$, at that point will be:

(1) $18.9\times10^{-8}\hat{k}T$ (2) $6.3\times10^{-8}\hat{k}T$
(3) $2.1\times10^{-8}\hat{k}T$ (4) $18.9\times10^{8}\hat{k}T$

3. A conducting circular loop made of a thin wire, has area 3.5×10^{-3} m^2 and resistance 10Ω. It is placed perpendicular to a time dependent magnetic field $B(t) = (0.4T)\sin(50\pi t)$. The field is uniform in space. Then the net charge flowing through the loop during t = 0 s and t = 10 ms is close to :

(1) 14mC (2) 21 mC
(3) 6 mC (4) 7 mC

4. The electric field of a plane polarized electromagnetic wave in free space at time t= 0 is given by an expression

$\vec{E}(x,y) = 10\hat{j}$ cos [(6x + 8z)]

The magnetic field $\vec{B}$ (x, z, t) is given by : (c is the velocity of light)

(1) $\frac{1}{c}(6\hat{k}+8\hat{i})\cos[(6x-8z+10ct)]$

(2) $\frac{1}{c}(6\hat{k}-8\hat{i})\cos[(6x+8z-10ct)]$

(3) $\frac{1}{c}(6\hat{k}+8\hat{i})\cos[(6x+8z-10ct)]$

(4) $\frac{1}{c}(6\hat{k}-8\hat{i})\cos[(6x+8z+10ct)]$

5. If the magnetic field of a plane electromagnetic wave is given by (The speed of light = 3×10^8/m/s)

$B=100 \times 10^{-6} \sin\left[2\pi\times2\times10^{15}\left(t-\frac{x}{c}\right)\right]$ then the maximum electric field associated with it is :

(1) 4×10^4 N/C
(2) 4.5×10^4 N/C
(3) 6×10^4 N/C
(4) 3×10^4 N/C

6. A 27 mW laser beam has a cross-sectional area of 10 mm^2. The magnitude of the maximum electric field in this electromagnetic wave is given by [Given permittivity of space $\epsilon_0 = 9 \times 10^{-12}$ SI units, Speed of light $c = 3 \times 10^8$ m/s]:-

(1) 1 kV/m (2) 2 kV/m
(3) 1.4 kV/m (4) 0.7 kV/m

7. An electromagnetic wave of intensity 50 Wm^{-2} enters in a medium of refractive index 'n' without any loss. The ratio of the magnitudes of electrric fields, and the ratio of the magnitudes of magnetic fields of the wave before and after entering into the medium are respectively, given by :

(1) $\left(\frac{1}{\sqrt{n}},\frac{1}{\sqrt{n}}\right)$ (2) $\left(\sqrt{n},\frac{1}{\sqrt{n}}\right)$

(3) $\left(\sqrt{n},\sqrt{n}\right)$ (4) $\left(\frac{1}{\sqrt{n}},\sqrt{n}\right)$

8. The mean intensity of radiation on the surface of the Sun is about 10^8 W/m^2. The rms value of the corresponding magnetic field is closest to :

(1) 10^2T (2) 10^{-4}T (3) 1T (4) 10^{-2}T

9. The magnetic field of an electromagnetic wave is given by :-

$$\vec{B} = 1.6\times10^{-6}\cos\left(2\times10^{7}z + 6\times10^{15}t\right)\left(2\hat{i}+\hat{j}\right)\frac{Wb}{m^2}$$

The associated electric field will be :-

(1) $\vec{E} = 4.8\times10^{2}\cos\left(2\times10^{7}z + 6\times10^{15}t\right)\left(\hat{i}-2\hat{j}\right)\frac{V}{m}$

(2) $\vec{E} = 4.8\times10^{2}\cos\left(2\times10^{7}z - 6\times10^{15}t\right)\left(2\hat{i}+\hat{j}\right)\frac{V}{m}$

(3) $\vec{E} = 4.8\times10^{2}\cos\left(2\times10^{7}z - 6\times10^{15}t\right)\left(-2\hat{j}+\hat{i}\right)\frac{V}{m}$

(4) $\vec{E} = 4.8\times10^{2}\cos\left(2\times10^{7}z + 6\times10^{15}t\right)\left(-\hat{i}+2\hat{j}\right)\frac{V}{m}$

10. A plane electromagnetic wave travels in free space along the x-direction. The electric field component of the wave at a particular point of space and time is $E = 6\ V\ m^{-1}$ along y-direction. Its corresponding magnetic field component, B would be :

(1) 6×10^{-8} T along z-direction

(2) 6×10^{-8} T along x-direction

(3) 2×10^{-8} T along z-direction

(4) 2×10^{-8} T along y-direction

11. The magnetic field of a plane electromagnetic wave is given by :

$\vec{B} = B_0\hat{i}\left[\cos(kz-\omega t)\right] + B_1\hat{j}\cos(kz+\omega t)$ where $B_0 = 3 \times 10^{-5}$ T and $B_1 = 2 \times 10^{-6}$ T. The rms value of the force experienced by a stationary charge $Q = 10^{-4}$ C at z = 0 is closest to :

(1) 0.9 N (2) 0.1 N

(3) 3×10^{-2} N (4) 0.6 N

12. The electric field of a plane electromagnetic wave is given by

$\vec{E} = E_0\hat{i}\cos(kz)\cos(\omega t)$

The corresponding magnetic field $\vec{B}$ is then given by :

(1) $\vec{B} = \frac{E_0}{C}\hat{j}\sin(kz)\cos(\omega t)$

(2) $\vec{B} = \frac{E_0}{C}\hat{j}\sin(kz)\sin(\omega t)$

(3) $\vec{B} = \frac{E_0}{C}\hat{k}\sin(kz)\cos(\omega t)$

(4) $\vec{B} = \frac{E_0}{C}\hat{j}\cos(kz)\sin(\omega t)$

13. A plane electromagnetic wave having a frequency $\nu = 23.9$ GHz propagates along the positive z-direction in free space. The peak value of the electric field is 60 V/m. Which among the following is the acceptable magnetic field component in the electromagnetic wave ?

(1) $\vec{B} = 2\times10^{7}\sin(0.5\times10^{3}z + 1.5\times10^{11}t)\hat{i}$

(2) $\vec{B} = 2\times10^{-7}\sin(1.5\times10^{2}x + 0.5\times10^{11}t)\hat{j}$

(3) $\vec{B} = 2\times10^{-7}\sin(0.5\times10^{3}z - 1.5\times10^{11}t)\hat{i}$

(4) $\vec{B} = 60\sin(0.5\times10^{3}x + 1.5\times10^{11}t)\hat{k}$

14. An electromagnetic wave is represented by the electric field

$\vec{E} = E_0\hat{n}\sin[\omega t + (6y-8z)]$. Taking unit vectors in x, y and z directions to be $\hat{i}, \hat{j}, \hat{k}$, the direction of propogation $\hat{s}$, is :

(1) $\hat{s} = \frac{4\hat{j}-3\hat{k}}{5}$ (2) $\hat{s} = \frac{3\hat{i}-4\hat{j}}{5}$

(3) $\hat{s} = \left(\frac{-3\hat{j}+4\hat{k}}{5}\right)$ (4) $\hat{s} = \frac{-4\hat{k}+3\hat{j}}{5}$

SOLUTION

1. Ans. (3)

Average energy density of magnetic field,

$u_B = \dfrac{B_0^2}{2\mu_0}$, B_0 is maximum value of magnetic field.

Average energy density of electric field,

$u_E = \dfrac{\varepsilon_0 \in_0^2}{2}$

now, $\in_0 = CB_0$, $C^2 = \dfrac{1}{\mu_0 \in_0}$

$u_E = \dfrac{\in_0}{2} \times C^2 B_0^2$

$= \dfrac{\in_0}{2} \times \dfrac{1}{\mu_0 \in_0} \times B_0^2 = \dfrac{B_0^2}{2\mu_0} = u_B$

$u_E = u_B$

since energy density of electric & magnetic field is same, energy associated with equal volume will be equal.

$u_E = u_B$

2. Ans. (3)

$|B| = \dfrac{|E|}{C} = \dfrac{6.3}{3\times10^8} = 2.1\times10^{-8}\,T$

and $\hat{E}\times\hat{B} = \hat{C}$

$\hat{j}\times\hat{B} = \hat{i}$

$\hat{B} = \hat{k}$

$\vec{B} = |B|\hat{B}$ = $2.1\times10^8\,\hat{k}T$

3. Ans. (1)

$Q = \dfrac{\Delta\phi}{R} = \dfrac{1}{10}A\left(B_f - B_i\right) = \dfrac{1}{10}\times3.5\times10^{-3}\left(0.4\sin\dfrac{\pi}{2} - 0\right)$

$= \dfrac{1}{10}\left(3.5\times10^{-3}\right)\left(0.4-0\right)$

$= 1.4 \times 10^{-4} = 0.14$ mC

No answer matching but NTA answer is 14 mC

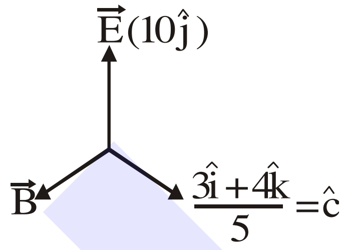
4. Ans. (2)

$\vec{E} = 10\hat{j}\cos\left[\left(6\hat{i}+8\hat{k}\right)\cdot\left(x\hat{i}+z\hat{k}\right)\right]$

$= 10\,\hat{j}\cos[\vec{K}\cdot\vec{r}]$

$\therefore$ $\vec{K} = 6\hat{i}+8\hat{k}$; direction of waves travel.

i.e. direction of 'c'.



$\therefore$ Direction of $\hat{B}$ will be along

$\hat{C}\times\hat{E} = \dfrac{-4\hat{i}+3\hat{k}}{5}$

Mag. of $\vec{B}$ will be along $\hat{C}\times\hat{E} = \dfrac{-4\hat{i}+3\hat{k}}{5}$

Mag. of $\vec{B}$ = $\dfrac{E}{C} = \dfrac{10}{C}$

$\therefore$ $\vec{B} = \dfrac{10}{C}\left(\dfrac{-4\hat{i}+3\hat{k}}{5}\right) = \dfrac{\left(-8\hat{i}+6\hat{k}\right)}{C}$

5. Ans. (4)

$E_0 = B_0 \times C$

$= 100 \times 10^{-6} \times 3 \times 10^8$

$= 3 \times 10^4$ N/C

$\therefore$ correct answer is 3×10^4 N/C

6. Ans. (3)

Intensity of EM wave is given by

$I = \dfrac{\text{Power}}{\text{Area}} = \dfrac{1}{2}\varepsilon_0 E_0^2 C$

$= \dfrac{27\times10^{-3}}{10\times10^{-6}} = \dfrac{1}{2}\times 9\times10^{-12}\times E^2\times3\times10^8$

$E = \sqrt{2}\times10^3$ kv/m

= 1.4 kv/m

7. Ans. (2)

$$C=\frac{1}{\sqrt{\mu_0 \in_0}}$$

$$V=\frac{1}{\sqrt{k \in_0 \mu_0}}$$ [For transparent medium $\mu_r \approx \mu_0$]

$$\therefore \frac{C}{V}=\sqrt{k}=n$$

$$\frac{1}{2}\in_0 E_0^2 C = \text{intensity} = \frac{1}{2}\in_0 kE^2 v$$

$$\therefore E_0^2 C = kE^2 v$$

$$\Rightarrow \frac{E_0^2}{E^2}=\frac{kV}{C}=\frac{n^2}{n} \Rightarrow \frac{E_0}{E}=\sqrt{n}$$

similarly

$$\frac{B_0^2 C}{2\mu_0}=\frac{B^2 v}{2\mu_0} \Rightarrow \frac{B_0}{B}=\frac{1}{\sqrt{n}}$$

8. Ans. (2)

$I = \varepsilon_0 C E_{rms}^2$

$\& E_{rms} = cB_{rms}$

$I = \varepsilon_0 C^3 B_{rms}^2$

$$B_{rms} = \sqrt{\frac{I}{\in_0 C^3}}$$

$B_{rms} \approx 10^{-4}$

9. Ans. (4)

Sol. If we use that direction of light propagation will be along $\vec{E}\times\vec{B}$. Then (4) option is correct.

Detailed solution is as following.

magnitude of E = CB

$E = 3 \times 10^8 \times 1.6 \times 10^{-6} \times \sqrt{5}$

$E = 4.8 \times 10^2 \sqrt{5}$

$\vec{E}$ and $\vec{B}$ are perpendicular to each other

$\Rightarrow \vec{E}.\vec{B} = 0$

$\Rightarrow$ either direction of $\vec{E}$ is $\hat{i}-2\hat{j}$ or $-\hat{i}+2\hat{j}$ from given option

Also wave propagation direction is parallel to $\vec{E}\times\vec{B}$ which is $-\hat{k}$

$\Rightarrow \vec{E}$ is along $\left(-\hat{i}+2\hat{j}\right)$

10. Ans. (3)

Sol. The direction of propogation of an EM wave is direction of $\vec{E}\times\vec{B}$.

$\hat{i}=\hat{j}\times\hat{B}$

$\Rightarrow \hat{B}=\hat{k}$

$$C=\frac{E}{B} \Rightarrow B=\frac{E}{C}=\frac{6}{3\times10^8}$$

$B = 2 \times 10^{-8}$ T along z direction.

11. Ans. (4)

Sol. Maximum Electric field E = (B) (c)

$\vec{E}_0 = (3 \times 10^{-5})c \left(-\hat{j}\right)$

$\vec{E}_1 = (2 \times 10^{-6})c \left(-\hat{i}\right)$

Maximum force

$\vec{F}_{net} = q\vec{E} = qc\left(-3\times10^{-5}\hat{j}-2\times10^{-6}\hat{i}\right)$

$\vec{F}_{0max} = 10^{-4} \times 3 \times 10^8 \sqrt{(3\times10^{-5})^2+(2\times10^{-6})^2}$

= 0.9N

$F_{rms} = \frac{F_0}{\sqrt{2}} = 0.6$ N (approx)

Option (4)

12. Ans. (2)

Sol. $\because \vec{E}\times\vec{B} \parallel \vec{v}$

Given that wave is propagating along positive z-axis and $\vec{E}$ along positive x-axis. Hence $\vec{B}$ along y-axis.

From Maxwell equation

$$\vec{\nabla}\times\vec{E}=-\frac{\partial B}{\partial t}$$

i.e. $\frac{\partial E}{\partial Z}=-\frac{\partial B}{dt}$ and $B_0=\frac{E_0}{C}$

13. Ans. (3)

Sol. Magnetic field when electromagnetic wave propagates in +z direction

$B = B_0 \sin(kz - \omega t)$

where

$B_0 = \frac{60}{3\times10^8} = 2 \times 10^{-7}$

$k = \frac{2\pi}{\lambda} = 0.5\times10^3$

$\omega = 2\pi f = 1.5 \times 10^{11}$

14. Ans. (3)

Sol. $\vec{E} = E_0\hat{n}\sin(\omega t + (6y - 8z))$

$= E_0\hat{n}\sin(\omega t + \vec{k}.\vec{r})$

where $\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$

and $\vec{k}.\vec{r} = 6y - 8z$

$\Rightarrow \vec{k} = 6\hat{j} - 8\hat{k}$

direction of propagation

$\hat{s} = -\hat{k}$

$= \left(\frac{-3\hat{j} + 4\hat{k}}{5}\right)$