EM WAVE

1. If the magnetic field in a plane electromagnetic wave is given by $\vec{B} = 3\times10^{-8}\sin\left(1.6\times10^{3}x + 48\times10^{10}t\right)\hat{j}T$, then what will be expression for electric field?

(1) $\vec{E} = \left(9\sin\left(1.6\times10^{3}x + 48\times10^{10}t\right)\hat{k}\ V/m\right)$

(2) $\vec{E} = \left(3\times10^{-8}\sin\left(1.6\times10^{3}x + 48\times10^{10}t\right)\hat{i}\ V/m\right)$

(3) $\vec{E} = \left(60\sin\left(1.6\times10^{3}x + 48\times10^{10}t\right)\hat{k}\ V/m\right)$

(4) $\vec{E} = \left(3\times10^{-8}\sin\left(1.6\times10^{3}x + 48\times10^{10}t\right)\hat{j}\ V/m\right)$

2. The electric field of a plane electromagnetic wave is given by $\vec{E} = E_0\dfrac{\hat{i}+\hat{j}}{\sqrt{2}}$ cos (kz + ωt)

At t = 0, a positively charged particle is at the point (x, y, z) = $\left(0, 0, \dfrac{\pi}{k}\right)$. If its instantaneous velocity at (t = 0) is $\upsilon_0\ \hat{k}$, the force acting on it due to the wave is :

(1) zero

(2) parallel to $\dfrac{\hat{i}+\hat{j}}{\sqrt{2}}$

(3) antiparallel to $\dfrac{\hat{i}+\hat{j}}{\sqrt{2}}$

(4) parallel to $\hat{k}$

3. A plane electromagnetic wave of frequency 25 GHz is propagating in vacuum along the z-direction. At a particular point in space and time, the magnetic field is given by $\vec{B} = 5\times10^{-8}\hat{j}T$. The corresponding electric field $\vec{E}$ is (speed of light c = 3 × 10^8 ms^{-1})

(1) $1.66\times10^{-16}\ \hat{i}\,V/m$

(2) $15\ \hat{i}\ V/m$

(3) $-1.66\times10^{-16}\ \hat{i}\ V/m$

(4) $-15\ \hat{i}\ V/m$

4. The electric fields of two plane electromagnetic plane waves in vacuum are given by

$\vec{E}_1 = E_0\hat{j}\cos(\omega t - kx)$ and

$\vec{E}_2 = E_0\hat{k}\cos(\omega t - ky)$

At t = 0, a particle of charge q is at origin with a velocity $\vec{v} = 0.8c\hat{j}$ (c is the speed of light in vacuum). The instantaneous force experienced by the particle is :

5. A plane electromagnetic wave, has frequency of 2.0 × 10^{10} Hz and its energy density is 1.02 × 10^{-8} J/ m^3 in vacuum. The amplitude of the magnetic field of the wave is close to ($\dfrac{1}{4\pi\varepsilon_0} = 9\times10^9\dfrac{Nm^2}{C^2}$ and speed of light = 3 × 10^8 ms^{-1}) :

(1) 180 nT

(2) 160 nT

(3) 150 nT

(4) 190 nT

6. In a plane electromagnetic wave, the directions of electric field and magnetic field are represented by $\hat{k}$ and $2\hat{i}-2\hat{j}$, respectively. What is the unit vector along direction of propagation of the wave.

(1) $\dfrac{1}{\sqrt{2}}\left(\hat{i}+\hat{j}\right)$

(2) $\dfrac{1}{\sqrt{5}}\left(\hat{i}+2\hat{j}\right)$

(3) $\dfrac{1}{\sqrt{5}}\left(2\hat{i}+\hat{j}\right)$

(4) $\dfrac{1}{\sqrt{2}}\left(\hat{j}+\hat{k}\right)$

7. The magnetic field of a plane electromagnetic wave is

$\vec{B} = 3\times10^{-8}\sin[200\pi(y+ct)]\hat{i}\ T$

Where c = 3 × 10^8 ms^{-1} is the speed of light.
The corresponding electric field is :

(1) $\vec{E} = -10^{-6}\sin[200\pi(y+ct)]\hat{k}\ \ V/m$

(2) $\vec{E} = -9\sin[200\pi(y+ct)]\hat{k}\ \ V/m$

(3) $\vec{E} = 9\sin[200\pi(y+ct)]\hat{k}\ \ V/m$

(4) $\vec{E} = 3\times10^{-8}\sin[200\pi(y+ct)]\hat{k}\ \ V/m$

8. The electric field of a plane electromagnetic wave propagating along the x direction in vacuum is $\vec{E} = E_0\hat{j}\cos(\omega t - kx)$. The magnetic field $\vec{B}$, at the moment t = 0 is :

(1) $\vec{B} = E_0\sqrt{\mu_0 \in_0}\cos(kx)\hat{j}$

(2) $\vec{B} = \frac{E_0}{\sqrt{\mu_0 \in_0}}\cos(kx)\hat{k}$

(3) $\vec{B} = E_0\sqrt{\mu_0 \in_0}\cos(kx)\hat{k}$

(4) $\vec{B} = \frac{E_0}{\sqrt{\mu_0 \in_0}}\cos(kx)\hat{j}$

9. Choose the correct option relating wavelengths of differnet parts of electromagnetic wave spectrum :

(1) $\lambda_{\text{x-rays}} < \lambda_{\text{micro waves}} < \lambda_{\text{radio waves}} < \lambda_{\text{visible}}$

(2) $\lambda_{\text{visible}} > \lambda_{\text{x-rays}} > \lambda_{\text{radio waves}} > \lambda_{\text{micro waves}}$

(3) $\lambda_{\text{radio waves}} > \lambda_{\text{micro waves}} > \lambda_{\text{visible}} > \lambda_{\text{x-rays}}$

(4) $\lambda_{\text{visible}} < \lambda_{\text{micro waves}} < \lambda_{\text{radio waves}} < \lambda_{\text{x-rays}}$

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

$\vec{E} = E_0(\hat{x} + \hat{y})\sin(kz - \omega t)$

Its magnetic field will be given by :

(1) $\frac{E_0}{c}(\hat{x} - \hat{y})\cos(kz - \omega t)$

(2) $\frac{E_0}{c}(-\hat{x} + \hat{y})\sin(kz - \omega t)$

(3) $\frac{E_0}{c}(\hat{x} - \hat{y})\sin(kz - \omega t)$

(4) $\frac{E_0}{c}(\hat{x} + \hat{y})\sin(kz - \omega t)$

11. An electron is constrained to move along the y-axis with a speed of 0.1 c (c is the speed of light) in the presence of electromagnetic wave, whose electric field is

$\vec{E} = 30\hat{j}\ \sin(1.5\times10^{7}t - 5\times10^{-2}x)V/m$.

The maximum magnetic force experienced by the electron will be :

(given c = 3×10^8 ms^{-1} and electron charge = 1.6×10^{-19} C)

(1) 1.6×10^{-19} N (2) 4.8×10^{-19} N

(3) 3.2×10^{-18} N (4) 2.4×10^{-18} N

12. The correct match between the entries in column I and column II are :

I **Radiation**	II **Wavelength**
(a) Microwave	(i) 100m
(b) Gamma rays	(ii) 10^{-15} m
(c) A.M. radio waves	(iii) 10^{-10} m
(d) X-rays	(iv) 10^{-3} m

(1) (a)-(ii), (b)-(i), (c)-(iv), (d)-(iii)

(2) (a)-(i), (b)-(iii), (c)-(iv), (d)-(ii)

(3) (a)-(iii), (b)-(ii), (c)-(i), (d)-(iv)

(4) (a)-(iv), (b)-(ii), (c)-(i), (d)-(iii)

13. Suppose that intensity of a laser is $\left(\frac{315}{\pi}\right)W/m^2$. The rms electric field, in units of V/m associated with this source is close to the nearest integer is

($\in_0 = 8.86 \times 10^{-12}$ C^2 Nm^{-2}; c = 3×10^8 ms^{-1})

14. For a plane electromagnetic wave, the magnetic field at a point x and time t is

$\vec{B}(x,t) = \left[1.2\times10^{-7}\sin(0.5\times10^{3}x + 1.5\times10^{11}t)\hat{k}\right]T$

The instantaneous electric field $\vec{E}$ corresponding to $\vec{B}$ is : (speed of light c = 3×10^8 ms^{-1})

(1) $\vec{E}(x,t) = \left[36\sin(0.5\times10^{3}x + 1.5\times10^{11}t)\hat{k}\right]\frac{V}{m}$

(2) $\vec{E}(x,t) = \left[-36\sin(0.5\times10^{3}x + 1.5\times10^{11}t)\hat{j}\right]\frac{V}{m}$

(3) $\vec{E}(x,t) = \left[36\sin(1\times10^{3}x + 0.5\times10^{11}t)\hat{j}\right]\frac{V}{m}$

(4) $\vec{E}(x,t) = \left[36\sin(1\times10^{3}x + 1.5\times10^{11}t)\hat{j}\right]\frac{V}{m}$

SOLUTION

1. NTA Ans. (1)

Sol. $\vec{E}\times\vec{B}=\vec{C}=-\hat{i}$

where $\vec{B}$ is along $\hat{j}$

$\frac{E}{B}=C$

$E = 3\times10^{-8}\times3\times10^{8} = 9$ V/m.

2. NTA Ans. (3)

Sol. $\vec{F}=q(\vec{E}+\vec{v}\times\vec{B})$

$\vec{E}=E_0\left(\frac{\hat{i}+\hat{j}}{\sqrt{2}}\right)\cos\pi$

$=-E_0\frac{\hat{i}+\hat{j}}{\sqrt{2}}$

as $\vec{E}\times\vec{B}=\vec{c}$

$+E_0\left(\frac{\hat{i}+\hat{j}}{\sqrt{2}}\right)\times\vec{B}=c\hat{k}$

$\Rightarrow \vec{B}=-\left(\frac{\hat{i}-\hat{j}}{\sqrt{2}}\right)\frac{E_0}{c}$

$\vec{F}=q\left(-E_0\frac{(\hat{i}+\hat{j})}{\sqrt{2}}-\frac{v_0\hat{k}}{c}\times(\hat{i}-\hat{j})E_0\right)$

since $\frac{v_0}{c}<<1$

$\Rightarrow$ F is antiparallel to $\frac{\hat{i}+\hat{j}}{\sqrt{2}}$

3. NTA Ans. (2)

Sol. $E=\vec{B}\times\vec{V}$

$=(5\times10^{-8}\hat{j})\times(3\times10^{8}\hat{k})$

$=15\,\hat{i}$ V/m

4. NTA Ans. (3)

Sol. $\vec{E}_1=E_0\hat{j}\cos(\omega t-kx)$

Its corresponding magnetic field will be

$\vec{B}_1=\frac{E_0}{c}\hat{k}\cos(\omega t-kx)$

$\vec{E}_2=E_0\hat{k}\cos(\omega t-ky)$

$\vec{B}_2=\frac{E_0}{c}\hat{i}\cos(\omega t-ky)$

Net force on charge particle

$=q\vec{E}_1+q\vec{E}_2+q\vec{v}\times B_1+q\vec{v}\times\vec{B}_2$

$=qE_0\hat{j}+qE_0\hat{k}+q(0.8c\hat{j})\times\left(\frac{E_0}{c}\hat{k}\right)+q(0.8c\hat{j})\times\left(\frac{E_0}{c}\hat{i}\right)$

$=qE_0\hat{j}+qE_0\hat{k}+0.8qE_0\hat{i}-0.8qE_0\hat{k}$

$\vec{F}=qE_0[0.8\hat{i}+1\hat{j}+0.2\hat{k}]$

5. Official Ans. by NTA (2)

Sol. Energy density $\frac{dU}{dV}=\frac{B_0^2}{2\mu_0}$

$1.02\times10^{-8}=\frac{B_0^2}{2\times4\pi\times10^{-7}}$

$B_0^2=(1.02\times10^{-8})\times(8\pi\times10^{-7})$

$B_0 = 16\times10^{-8}$ T = 160 nT

6. Official Ans. by NTA (1)

Sol. $\hat{E}=\hat{k}$

$\vec{B}=2\hat{i}-2\hat{j}\Rightarrow\hat{B}=\frac{\vec{B}}{|B|}=\frac{2\hat{i}-2\hat{j}}{2\sqrt{2}}$

$\Rightarrow\hat{B}=\frac{1}{\sqrt{2}}(\hat{i}-\hat{j})$

Direction of wave propagation $=\hat{C}=\hat{E}\times\hat{B}$

$\hat{C}=\hat{k}\times\left[\frac{1}{\sqrt{2}}(\hat{i}-\hat{j})\right]$

$\hat{C}=\frac{1}{\sqrt{2}}(\hat{k}\times\hat{i}-\hat{k}\times\hat{j})$

$\hat{C}=\frac{1}{\sqrt{2}}(\hat{i}+\hat{j})$

7. Official Ans. by NTA (2)

Sol. $\vec{B} = 3\times10^{-8}\sin[200\pi(y+ct)]\hat{i}\ T$

$E_0 = CB_0 \Rightarrow E_0 = 3\times10^{8}\times3\times10^{-8}$

$= 9\ V/m$

and direction of wave propagation is given as

$\left(\vec{E}\times\vec{B}\right) \parallel \vec{C}$

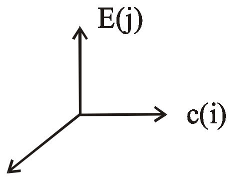
$\hat{B} = \hat{i}$ & $\hat{C} = -\hat{j}$

so $\hat{E} = -\hat{k}$

$\therefore \vec{E} = E_0\sin[200\pi(y+ct)](-\hat{k})\ V/m$

8. Official Ans. by NTA (3)

Sol.



$\therefore \vec{B}(\hat{k})$

$\Rightarrow \vec{B} = B_0\cos(wt-kx)\hat{k}$

Now put t = 0.

9. Official Ans. by NTA (3)

Sol. Information based

$\lambda_{radiowaves} > \lambda_{microwaves} > \lambda_{visible} > \lambda_{x\text{-}rays}$

10. Official Ans. by NTA (2)

Sol. $\vec{E} = E_0(\hat{x}+\hat{y})\sin(kz-\omega t)$

direction of propagation = $+\hat{k}$

$\hat{E} = \dfrac{\hat{i}+\hat{j}}{\sqrt{2}}$

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

$\hat{k} = \left(\dfrac{\hat{i}+\hat{j}}{\sqrt{2}}\right)\times\hat{B}$ $\Rightarrow \hat{B} = \dfrac{-\hat{i}+\hat{j}}{\sqrt{2}}$

$\therefore \vec{B} = \dfrac{E_0}{C}(-\hat{x}+\hat{y})\sin(kz-\omega t)$

11. Official Ans. by NTA (2)

Sol. $\Rightarrow E = \vec{E} = 30\hat{j}\sin(1.5\times10^{7}t - 5\times10^{-2}x)V/m$

$\Rightarrow B \Rightarrow E/V \Rightarrow \dfrac{30}{1.5\times10^{7}}\times5\times10^{-2}$

$\Rightarrow 10^{-7}$ Tesla

$\Rightarrow F_{mag} = q\left(\vec{V}\times\vec{B}\right) = |qVB|$

$= 1.6\times10^{-19}\times0.1\times 3\times10^{8}\times10^{-7}$

$= 4.8\times10^{-19}$ N

12. Official Ans. by NTA (4)

Sol. Energes of given Radiation can have The following relation

$E_{\gamma\text{-Rays}} > E_{X\text{-Rays}} > E_{microwave} > E_{AM\ Radiowaves}$

$\therefore \lambda_{\gamma\text{-Rays}} < \lambda_{X\text{-Rays}} < \lambda_{microwave} < \lambda_{AM\ Radiowaves}$

According To tres.

(a) Microwave $\rightarrow 10^{-3}$m (iv)

(b) Gamma Rays $\rightarrow 10^{-15}$m (ii)

(c) AM Radio wave $\rightarrow$ 100 m (i)

(d) X-Rays $\rightarrow 10^{-10}$m (iii)

13. Official Ans. by NTA (275.00)

Allen Ans. (194.00)

Sol. $I = \epsilon_0 E_{rms}^2 C$

$E_{rms}^2 = \dfrac{I}{\epsilon_0 C}$

$= \dfrac{315}{\pi\epsilon_0}\times\dfrac{1}{C}$

$= \dfrac{4\times315}{4\pi\epsilon_0}\times\dfrac{1}{3\times10^{8}}$

$= \dfrac{4\times315\times9\times10^{9}}{3\times10^{8}}$

$E_{rms}^2 = 4\times315\times30$

$E_{rms} = 2\sqrt{315\times30}$

$= 194.42$

Ans. 194.00

14. Official Ans. by NTA (2)

Sol. $\vec{E}$ and $\vec{B}$ are perpendicular for EM wave

$E_0 = CB_0$

$= 3\times10^{8}\times1.2\times10^{-7}$

$= 36$

Having same phase

Propagation is along –x-axis, $\vec{B}$ is along z-axis hence $\vec{E}$ must be along y-axis.

So, option (2) is correct