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

$\vec{B}(x,t) = [1.2 \times 10^{-7} \sin(0.5 \times 10^3 x + 1.5 \times 10^{11} t)\hat{k}]\text{T}$

The instantaneous electric field $\vec{E}$ corresponding to $\vec{B}$ is: (speed of light $c = 3 \times 10^8 \text{ ms}^{-1}$) **[Sep. 06, 2020 (II)]**

(a) $\vec{E}(x,t) = [-36\sin(0.5 \times 10^3 x + 1.5 \times 10^{11} t)\hat{j}]\frac{\text{V}}{\text{m}}$

(b) $\vec{E}(x,t) = [36\sin(1 \times 10^3 x + 0.5 \times 10^{11} t)\hat{j}]\frac{\text{V}}{\text{m}}$

(c) $\vec{E}(x,t) = [36\sin(0.5 \times 10^3 x + 1.5 \times 10^{11} t)\hat{k}]\frac{\text{V}}{\text{m}}$

(d) $\vec{E}(x,t) = [36\sin(1 \times 10^3 x + 1.5 \times 10^{11} t)\hat{i}]\frac{\text{V}}{\text{m}}$

(a) Relation between electric field E_0 and magnetic field B_0 of an electromagnetic wave is given by

$$c = \frac{E_0}{B_0} \qquad \text{(Here, } c = \text{Speed of light)}$$

$$\Rightarrow E_0 = B_0 \times c = 1.2 \times 10^{-7} \times 3 \times 10^8 = 36$$

As the wave is propagating along x-direction, magnetic field is along z-direction

and $(\hat{E} \times \hat{B}) \parallel \hat{C}$

$\therefore \vec{E}$ should be along y-direction.

So, electric field $\vec{E} = E_0 \sin \vec{E} \cdot (x, t)$

$$= [-36\sin(0.5 \times 10^3 x + 1.5 \times 10^{11} t)\hat{j}]\frac{V}{m}$$

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. **[Sep. 02, 2020 (II)]**

(a) $\frac{1}{\sqrt{2}}(\hat{i}+\hat{j})$ (b) $\frac{1}{\sqrt{2}}(\hat{j}+\hat{k})$

(c) $\frac{1}{\sqrt{5}}(\hat{i}+2\hat{j})$ (d) $\frac{1}{\sqrt{5}}(2\hat{i}+\hat{j})$

(a) Electromagnetic wave will propagate perpendicular to the direction of Electric and Magnetic fields

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

Here unit vector $\hat{C}$ is perpendicular to both $\hat{E}$ and $\hat{B}$

Given, $\vec{E}=\hat{k}, \vec{B}=2\hat{i}-2\hat{j}$

$$\therefore\ \hat{C}=\hat{E}\times\hat{B}=\frac{1}{\sqrt{2}}\begin{vmatrix}\hat{i} & \hat{j} & \hat{k}\\ 0 & 0 & 1\\ 1 & -1 & 0\end{vmatrix}=\frac{\hat{i}+\hat{j}}{\sqrt{2}}$$

$$\Rightarrow \hat{C}=\frac{\hat{i}+\hat{j}}{\sqrt{2}}$$

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 $c = 3\times10^{8}$ ms^{-1} & electron charge $= 1.6\times10^{-19}$C)

[Sep. 05, 2020 (I)]

(a) 3.2×10^{-18} N (b) 2.4×10^{-18} N

(c) 4.8×10^{-19} N (d) 1.6×10^{-19} N

6

(c) In electromagnetic wave, $\frac{E_0}{B_0} = C$

$\therefore$ Maximum value of magnetic field, $B_0 = \frac{E_0}{C}$

$$F_{max} = qVB_{max}\sin 90^\circ = \frac{qV_0E_0}{C}$$

(Given $V_0 = 0.1$ C and $E_0 = 30$)

$$= \frac{1.6\times10^{-19}\times0.1\times3\times10^{8}\times30}{3\times10^{8}} = 4.8\times10^{-19}\text{N}$$

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 : **[Sep. 03, 2020 (II)]**

(a) $\vec{B} = \dfrac{E_0}{\sqrt{\mu_0\varepsilon_0}}\cos(kx)\hat{k}$

(b) $\vec{B} = E_0\sqrt{\mu_0\varepsilon_0}\cos(kx)\hat{j}$

(c) $\vec{B} = E_0\sqrt{\mu_0\varepsilon_0}\cos(kx)\hat{k}$

(d) $\vec{B} = \dfrac{E_0}{\sqrt{\mu_0\varepsilon_0}}\cos(kx)\hat{j}$

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

(c) Relation between electric field and magnetic field for an electromagnetic wave in vacuum is $B_0 = \dfrac{E_0}{c}$.

In free space, its speed $c = \dfrac{1}{\sqrt{\mu_0\varepsilon_0}}$

Here, μ_0 = absolute permeability, ε_0 = absolute permittivity

$$\therefore B_0 = \frac{E_0}{c} = \frac{E_0}{1/\sqrt{\mu_0\varepsilon_0}} = E_0\sqrt{\mu_0\varepsilon_0}$$

As the electromagnetic wave is propagating along x direction and electric field is along y direction.

$\therefore \hat{E}\times\hat{B} \parallel \hat{C}$ (Here, $\hat{C}$ = direction of propagation of wave)

$\therefore \vec{B}$ should be in $\hat{k}$ direction.

$\therefore$ B = $E_0\sqrt{\mu_0\varepsilon_0}\ \cos(\omega t - kx)\ \hat{k}$

At t = 0

B = $E_0\sqrt{\mu_0\varepsilon_0}\ \cos(kx)\ \hat{k}$