# CHAPTER 5: ELECTROMAGNETIC WAVES



## Single Correct Choice Type Questions

**1.** $Z = \sqrt{\frac{\mu_r}{\varepsilon_r}} \times \sqrt{\frac{\mu_0}{\varepsilon_0}}$

$\Rightarrow \quad Z = \sqrt{\frac{50}{2}} \times 376.6\ \Omega = 1883\ \Omega$

**Hence, the correct answer is (C).**

**2.** Since, $\frac{dE}{dz} = -\frac{dB}{dt}$

$\Rightarrow \quad \frac{dE}{dz} = -2E_0 k \sin kz \cos \omega t = -\frac{dB}{dt}$

$\Rightarrow \quad dB = +2E_0 k \sin kz \cos \omega t dt$

$\Rightarrow \quad B = +2E_0 k \sin kz \int \cos \omega t dt$

$\Rightarrow \quad B = +2E_0 \frac{k}{\omega} \sin kz \sin \omega t$

Also, $\frac{E_0}{B_0} = \frac{\omega}{k} = c$

$\Rightarrow \quad B = \frac{2E_0}{c} \sin kz \sin \omega t$

$\Rightarrow \quad \vec{B} = \frac{2E_0}{c} \sin kz \sin \omega t \hat{j}$

**Hence, the correct answer is (C).**

**3.** $v = \frac{c}{n} = \frac{c}{\sqrt{\mu_r \varepsilon_r}}$

$\Rightarrow \quad v = \frac{3 \times 10^8}{\sqrt{1.3 \times 2.14}} = 1.8 \times 10^8\ \text{ms}^{-1}$

**Hence, the correct answer is (D).**

**4.** $v = 1\ \text{BHz} = 10^9\ \text{Hz}$

$\lambda = \frac{c}{v} = \frac{3 \times 10^8}{10^9} = 0.3\ \text{m} = 30\ \text{cm}$ (radio waves)

**Hence, the correct answer is (B).**

**5.** The electric field $\vec{E}$ and the magnetic field $\vec{B}$ are mutually perpendicular to each other and are in phase i.e. they become zero and minimum at the same place and at the same time.
**Hence, the correct answer is (C).**

**6.** Frequency $v = \frac{1}{2\pi\sqrt{LC}}$

$\Rightarrow \quad v = \frac{1}{2 \times 3.14 \times \sqrt{100 \times 10^{-6} \times 400 \times 10^{-12}}}$

$\Rightarrow \quad v = \frac{1}{2 \times 3.14 \times 2 \times 10^{-7}}$

$\Rightarrow \quad \lambda = \frac{c}{v} = 3 \times 10^8 \times 2 \times 3.14 \times 2 \times 10^{-7} = 377\ \text{m}$

**Hence, the correct answer is (C).**

**7.** $u = \frac{1}{2}\varepsilon_0 E_{\text{rms}}^2 + \frac{1}{2\mu_0} B_{\text{rms}}^2$

$\Rightarrow \quad u = \frac{1}{2}\varepsilon_0 E_{\text{rms}}^2 + \frac{1}{2\mu_0}\left(\frac{E_{\text{rms}}^2}{c^2}\right) = \frac{1}{2}\varepsilon_0 E_{\text{rms}}^2 + \frac{1}{2\mu_0} E_{\text{rms}}^2 \varepsilon_0 \mu_0$

$\Rightarrow \quad u = \frac{1}{2}\varepsilon_0 E_{\text{rms}}^2 + \frac{1}{2}\varepsilon_0 E_{\text{rms}}^2 = \varepsilon_0 E_{\text{rms}}^2$

$\Rightarrow \quad u = (8.85 \times 10^{-12}) \times (720)^2 = 4.58 \times 10^{-6}\ \text{Jm}^{-3}$

**Hence, the correct answer is (B).**

**9.** $I_D = \varepsilon_0 \frac{d\phi_E}{dt} = \varepsilon_0 \frac{EA}{t} = \varepsilon_0 \left(\frac{V}{d}\right)\left(\frac{A}{t}\right)$

$I_D = \frac{(8.85 \times 10^{-12})(400)(60 \times 10^{-4})}{(10^{-3})(10^{-6})}$

$I_D = 1.602 \times 10^{-2}\ \text{A}$

**Hence, the correct answer is (B).**

**11.** $\vec{E} \times \vec{B}$ gives direction of wave propagation,

$\Rightarrow \quad (\hat{k} \times \vec{B}) \parallel \left(\frac{\hat{i} + \hat{j}}{\sqrt{2}}\right)$

Since, $\hat{k} \times \left(\frac{\hat{i} - \hat{j}}{\sqrt{2}}\right) = \frac{\hat{j} - (-\hat{i})}{\sqrt{2}} = \frac{\hat{i} + \hat{j}}{\sqrt{2}}$

Wave propagation vector should be along $\frac{\hat{i} + \hat{j}}{\sqrt{2}}$ and direction of magnetic field is along $\frac{\hat{i} - \hat{j}}{\sqrt{2}}$.

**Hence, the correct answer is (B).**

**13.** Polarization proves the transverse nature of electromagnetic waves.
**Hence, the correct answer is (A).**

**14.** $\lambda_m T = \text{constant}$

$\Rightarrow \quad \lambda_m \times (2.7\text{ K}) = 2.888 \times 10^{-3}\text{ Km}$

$\Rightarrow \quad \lambda_m = \dfrac{0.2888}{2.7}\text{ cm}$

$\Rightarrow \quad \lambda_m = 0.10\text{ cm} = 1\text{ mm}$ (For microwave)

**Hence, the correct answer is (B).**

**15.** $I_d = \varepsilon_0 A \dfrac{dE}{dt} = \varepsilon_0 \dfrac{A}{d}\dfrac{dV}{dt} \qquad \left\{\because E = \dfrac{V}{d}\right\}$

$\Rightarrow \quad I_d = \dfrac{8.86 \times 10^{-12} \times 3.14 \times (2 \times 10^{-2})^2}{0.1 \times 10^{-3}} \times 5 \times 10^{13}$

$\Rightarrow \quad I_d = 5.56 \times 10^3\text{ A}$

**Hence, the correct answer is (C).**

**16.** $I = \left(\dfrac{1}{2}\varepsilon_0 E_0^2\right)c$

$\Rightarrow \quad E_0 = \sqrt{\dfrac{2I}{\varepsilon_0 c}} = \sqrt{\dfrac{2 \times 5 \times 10^{-16}}{8.85}} = 0.61 \times 10^{-6}\text{ Vm}^{-1}$

Since, $E_0 = \dfrac{V_0}{d}$

$\Rightarrow \quad V_0 = E_0 d = (0.61 \times 10^{-6})(2) = 1.23\ \mu\text{V}$

**Hence, the correct answer is (A).**

**17.** $d = \sqrt{2hR} \Rightarrow d \propto \sqrt{h}$

**Hence, the correct answer is (B).**

**18.** Given that $E_0 = 100\text{ Vm}^{-1}$ and $B_0 = 0.265\text{ Am}^{-1}$

Maximum rate of energy flow is

$S = E_0 \times B_0$

$S = 100 \times 0.265 = 26.5\text{ Wm}^{-2}$

**Hence, the correct answer is (A).**

**20.** $\dfrac{E_0}{B_0} = c = \dfrac{\omega}{k}$

$\Rightarrow \quad E_0 K = B_0 \omega$

**Hence, the correct answer is (A).**

**22.** $E = E_0 \sin(\omega t + 6y - 8z)$

$\Rightarrow \quad \hat{s} = \dfrac{8\hat{k} - 6\hat{j}}{10} = \left(\dfrac{4\hat{k} - 3\hat{j}}{5}\right)$

**Hence, the correct answer is (A).**

**24.** The intensity of the wave is

$I_{av} = \left(\dfrac{1}{2}\varepsilon_0 E_0^2\right)c = \dfrac{P}{4\pi R^2}$

$\Rightarrow \quad E_0 = \sqrt{\dfrac{P}{2\pi R^2 \varepsilon_0 c}}$

$\Rightarrow \quad E_0 = \sqrt{\dfrac{3}{2 \times 3.14 \times 100 \times 8.85 \times 10^{-12} \times 3 \times 10^8}}$

$\Rightarrow \quad E_0 = 1.34\text{ Vm}^{-1}$

**Hence, the correct answer is (A).**

**25.** $B_0 = \dfrac{E_0}{c} = \dfrac{10^{-3}}{3 \times 10^8} = 3.33 \times 10^{-12}\text{ T}$

**Hence, the correct answer is (B).**

**26.** $E = \dfrac{hc}{\lambda} = \dfrac{6.6 \times 10^{-34} \times 3 \times 10^8}{21 \times 10^{-2}}$

$\Rightarrow \quad E = 0.94 \times 10^{-24} \approx 10^{-24}\text{ J}$

**Hence, the correct answer is (D).**

**28.** $|\vec{E}_1| = cB_1$ and $|\vec{E}_2| = cB_2$

Since $\vec{E}_1 \perp E_2$

$\Rightarrow \quad F_{net} = \dfrac{Q}{\sqrt{2}}\sqrt{E_1^2 + E_2^2}$

$\Rightarrow \quad F_{net} = \dfrac{10^{-4}}{\sqrt{2}} \times 3 \times 10^8 \times 30 \times 10^{-6}$

$\Rightarrow \quad F_{net} = \dfrac{90 \times 10^8 \times 10^{-10}}{\sqrt{2}}$

$\Rightarrow \quad F_{net} \approx 0.6\text{ N}$

**Hence, the correct answer is (A).**

**30.** Infrared radiation produces thermal effect and is detected by pyrometer.

**Hence, the correct answer is (B).**

**31.** Electric energy density

$u_e = \dfrac{1}{2}\varepsilon_0 E_{rms}^2$

Since, $E_{rms} = \dfrac{E_0}{\sqrt{2}}$

$\Rightarrow \quad u_e = \dfrac{1}{4}\varepsilon_0 E_0^2$

**Hence, the correct answer is (D).**

**32.** Momentum transferred to the mirror in one second is

$F = \dfrac{\Delta p}{\Delta t} = \left(\dfrac{2I}{c}\right)A$

$\Rightarrow \quad F = \dfrac{2S_{av}A}{c} = \dfrac{2 \times 6 \times 40 \times 10^{-4}}{3 \times 10^8}$

$\Rightarrow \quad F = \dfrac{\Delta p}{\Delta t} = 1.6 \times 10^{-10}\ \text{kgms}^{-2}$

**Hence, the correct answer is (D).**

**34.** Amplitude of electric field, $E_0 = B_0 c$

$\Rightarrow \quad E_0 = 1.6 \times 10^{-6} \times \sqrt{5} \times 3 \times 10^8$

$\Rightarrow \quad E_0 = 4.8 \times 10^2 \sqrt{5}\ \text{Vm}^{-1}$

Also $\vec{E} \times \vec{B}$ is along $-\hat{k}$ which is the direction of propagation.

$\vec{E} = 4.8 \times 10^2 \cos\left(2 \times 10^7 z + 6 \times 10^{15} t\right)\left(-\hat{i} + 2\hat{j}\right)\ \text{Vm}^{-1}$

**Hence, the correct answer is (A).**

**37.** $\beta$-rays are not electromagnetic waves.
**Hence, the correct answer is (C).**

**39.** Speed of light of vacuum is

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$$

Speed of light in any medium is

$$v = \frac{1}{\sqrt{\mu \varepsilon}}$$

$$\Rightarrow \quad \frac{c}{v} = \sqrt{\frac{\mu \varepsilon}{\mu_0 \varepsilon_0}} = \sqrt{\mu_r K}$$

$$\Rightarrow \quad v = \frac{c}{\sqrt{\mu_r K}}$$

**Hence, the correct answer is (C).**

**41.** During propagation of a wave from one medium to another, frequency remains constant and wavelength changes

$$\mu = \sqrt{\frac{\varepsilon}{\varepsilon_0}} = \sqrt{4} = 2$$

Since $\mu \propto \dfrac{1}{\lambda}$

$\Rightarrow$ Wavelength is halved.
**Hence, the correct answer is (C).**

**42.** $\vec{E}$, $\vec{B}$ and $\vec{k}$ form a right handed system $\vec{k}$ is along $z$-axis

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

$\Rightarrow \quad E_x \hat{i} \times B_y \hat{j} = c\hat{k}$

i.e. $E$ is along $x$-axis and $B$ is along $y$-axis.

**Hence, the correct answer is (A).**

**43.** EM waves carry momentum and hence can exert pressure on surfaces. They also carry energy, so we have

$p \neq 0$ and $E \neq 0$

**Hence, the correct answer is (B).**

**45.** Electric field is given by

$$E = \frac{V}{l} = \frac{iR}{l}$$

where, $R$ is the resistance of wire
Magnetic field at the surface of wire or radius $a$ is

$$B = \frac{\mu_0 i}{2\pi a}$$

Hence Poynting vector, directed radially inward is given by

$$S = \frac{EB}{\mu_0} = \left(\frac{iR}{\mu_0 l}\right)\left(\frac{\mu_0 i}{2\pi a}\right) = \frac{i^2 R}{2\pi a l}$$

**Hence, the correct answer is (D).**

**47.** The angular wave number is given by

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

where $\lambda$ is the wave length.
The angular frequency is $\omega = 2\pi f$

The ratio $\dfrac{\omega}{k} = \dfrac{2\pi f}{2\pi/\lambda} = f\lambda = c$

$\Rightarrow \quad \dfrac{k}{\omega} = \text{constant}$

**Hence, the correct answer is (C).**

**49.** Average energy density of electric field is given by

$$u_e = \frac{1}{2}\varepsilon_0 E^2 = \frac{1}{2}\varepsilon_0 \left(\frac{E_0}{\sqrt{2}}\right)^2 = \frac{1}{4}\varepsilon_0 E_0^2$$

$$\Rightarrow \quad u_e = \frac{1}{4}(8.85 \times 10^{-12})(1)^2 = 2.2 \times 10^{-12}\ \text{Jm}^{-3}$$

**Hence, the correct answer is (B).**

**51.** The pressure due to radiation is

$$P = \frac{I}{c} = \frac{0.5}{3 \times 10^8} = 0.166 \times 10^{-8}\ \text{Nm}^{-2}$$

**Hence, the correct answer is (A).**

**53.** $c = \dfrac{E}{B}$

$\Rightarrow \quad B = \dfrac{E}{c} = \dfrac{18}{3 \times 10^8} = 6 \times 10^{-8}\ \text{T}$

**Hence, the correct answer is (B).**

**54.** $v = \dfrac{1}{2\pi\sqrt{LC}}$

$\lambda = \dfrac{c}{v} = 2\pi c\sqrt{LC}$

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$\Rightarrow \quad \lambda = 3\times10^8 \times 2\pi\sqrt{1\times10^{-6}\times0.01\times10^{-6}}$

$\Rightarrow \quad \lambda = 3\times10^8\times2\times3.14\times10^{-7} = 188.4 \text{ m}$

**Hence, the correct answer is (C).**

55. Area through which the energy of beam passes is

$$A = (6.328\times10^{-7})^2 = 4\times10^{-13} \text{ m}^2$$

$$\Rightarrow \quad I = \frac{P}{A} = \frac{10^{-3}}{4\times10^{-13}} = 2.5\times10^9 \text{ Wm}^{-2}$$

**Hence, the correct answer is (B).**

57. EM waves transport energy, momentum and information but not charge. EM waves do not possess any charge.
**Hence, the correct answer is (B).**

58. $B = \frac{E}{c} = \frac{10^{-4}}{3\times10^8} = 3.3\times10^{-13} \text{ T}$

**Hence, the correct answer is (D).**

59. $f = \frac{c}{\lambda}$

$$f_1 = \frac{3\times10^8}{1} = 300 \text{ MHz} \text{ and}$$

$$f_2 = \frac{3\times10^8}{10} \text{ Hz} = 30 \text{ MHz}$$

**Hence, the correct answer is (A).**

61. Intensity of EM wave is given by

$$I = \frac{P}{4\pi R^2} = \langle u\rangle c = \left(\frac{1}{2}\varepsilon_0 E_0^2\right)c$$

$$\Rightarrow \quad E_0 = \sqrt{\frac{P}{2\pi R^2\varepsilon_0 c}}$$

$$\Rightarrow \quad E_0 = \sqrt{\frac{800}{2\times3.14\times(4)^2\times8.85\times10^{-12}\times3\times10^8}}$$

$$\Rightarrow \quad E_0 = 54.77 \text{ Vm}^{-1}$$

**Hence, the correct answer is (D).**

63. $\lambda = \frac{c}{f} = \frac{3\times10^8}{8.2\times10^6} = 36.5 \text{ m}$

**Hence, the correct answer is (A).**

65. EM waves travels in the direction perpendicular to $\vec{E}$ as well as $\vec{B}$ and the direction of propagation of the EM wave is along the vector $\vec{E}\times\vec{B}$
**Hence, the correct answer is (C).**

67. $v = 1057$ MHz

$$\lambda = \frac{c}{v} = \frac{3\times10^8}{1057\times10^6} \text{ m}$$

$$\Rightarrow \quad \lambda = 0.28 \text{ m} = 28 \text{ cm} (\text{radiowaves})$$

**Hence, the correct answer is (A).**

68. Population covered is given by

$$\begin{pmatrix}\text{Population}\\ \text{Covered}\end{pmatrix} = (2\pi Rh)\begin{pmatrix}\text{Population}\\ \text{Density}\end{pmatrix}$$

**Hence, the correct answer is (C).**

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1. Amplitude of electric field, $E_0 = B_0 c$

$\Rightarrow \quad E_0 = 1.6\times10^{-6}\times\sqrt{5}\times3\times10^8$

$\Rightarrow \quad E_0 = 4.8\times10^2\sqrt{5} \text{ Vm}^{-1}$

Also $\vec{E}\times\vec{B}$ is along $-\hat{k}$ which is the direction of propagation.

$$\vec{E} = 4.8\times10^2\cos(2\times10^7 z + 6\times10^{15} t)(-\hat{i}+2\hat{j}) \text{ Vm}^{-1}$$

**Hence, the correct answer is (A).**

2. $B_0 = \frac{E_0}{c} = \frac{6}{3\times10^8} = 2\times10^{-8} \text{ T}$

Propagation direction is along $\hat{E}\times\hat{B}$

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

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

**Hence, the correct answer is (C).**

3. $|\vec{E}_1| = cB_1$

$|\vec{E}_2| = cB_2$

Since, $\vec{E}_1 \perp E_2$

$$\Rightarrow \quad F_{net} = \frac{Q}{\sqrt{2}}\sqrt{E_1^2+E_2^2}$$

$$\Rightarrow \quad F_{net} = \frac{10^{-4}}{\sqrt{2}}\times3\times10^8\times30\times10^{-6}$$

$$\Rightarrow \quad F_{net} = \frac{90\times 10^{8}\times 10^{-10}}{\sqrt{2}}$$

$$\Rightarrow \quad F_{net} \approx 0.6 \text{ N}$$

**Hence, the correct answer is (A).**

**4.** $\frac{E_0}{B_0} = c$

$$\Rightarrow \quad B_0 = \frac{E_0}{c}$$

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

$$\Rightarrow \quad \vec{E} = \frac{E_0}{2}\left[\cos(kz-\omega t)\hat{i} - \cos(kz+\omega t)\hat{i}\right]$$

The corresponding magnetic field is

$$\vec{B} = \frac{B_0}{2}\left[\cos(kz-\omega t)\hat{j} - \cos(kz+\omega t)\hat{j}\right]$$

$$\Rightarrow \quad \vec{B} = \frac{B_0}{2}\left[2\sin(kz)\sin(\omega t)\right]$$

$$\Rightarrow \quad \vec{B} = \frac{E_0}{c}\left[\sin(kz)\sin(\omega t)\right]\hat{j}$$

**Hence, the correct answer is (C).**

**5.** $E = E_0 \sin(\omega t + 6y - 8z)$

$$\Rightarrow \quad \hat{s} = \frac{8\hat{k}-6\hat{j}}{10} = \left(\frac{4\hat{k}-3\hat{j}}{5}\right)$$

**Hence, the correct answer is (A).**

**6.** $B_0 = \frac{E_0}{c} = \frac{60}{3\times 10^{8}} = 2\times 10^{-7}$ T

$\nu = 23.9\times 10^{9}$ Hz

$$\Rightarrow \quad \omega = 2\pi\nu = 2\times 3.142\times 23.9\times 10^{9}$$

$$\Rightarrow \quad \omega = 1.5\times 10^{11} \text{ s}^{-1}$$

Since, $c = \frac{\omega}{k}$

$$\Rightarrow \quad k = \frac{\omega}{c} = \frac{1.5\times 10^{11}}{3\times 10^{8}}$$

$$\Rightarrow \quad k = 0.5\times 10^{3}$$

$$\Rightarrow \quad \vec{B} = 2\times 10^{-7}\sin(0.5\times 10^{3}z - 1.5\times 10^{11}t)\hat{i}$$

**Hence, the correct answer is (C).**

**7.** In air, EM wave is

$$\vec{E}_1 = E_{01}\hat{x}\cos\left[2\pi\nu\left(\frac{z}{c} - t\right)\right]$$

$$\Rightarrow \quad \vec{E}_1 = E_{01}\hat{x}\cos\left[k(z-ct)\right] \qquad \left\{\because k = \frac{2\pi}{\lambda_0} = \frac{2\pi\nu}{c}\right\}$$

In medium, EM wave is

$$\vec{E}_2 = E_{02}\hat{x}\cos\left[k(2z-ct)\right]$$

$$\Rightarrow \quad \vec{E}_2 = E_{02}\hat{x}\cos\left[2k\left(z - \frac{c}{2}t\right)\right]$$

During refraction, frequency remains unchanged, whereas wavelength changes

$$\Rightarrow \quad k' = 2k \qquad \text{\{from equations\}}$$

$$\Rightarrow \quad \frac{2\pi}{\lambda'} = 2\left(\frac{2\pi}{\lambda_0}\right)$$

$$\Rightarrow \quad \lambda' = \frac{\lambda_0}{2}$$

Since, $v = \frac{c}{2}$

$$\Rightarrow \quad \frac{1}{\sqrt{\mu_0\varepsilon_{r_2}}} = \frac{1}{2}\times\frac{1}{\sqrt{\mu_0\varepsilon_{r_1}}}$$

$$\Rightarrow \quad \frac{\varepsilon_{r_1}}{\varepsilon_{r_2}} = \frac{1}{4}$$

**Hence, the correct answer is (C).**

**8.** $\vec{E}\times\vec{B}$ gives direction of wave propagation,

$$\Rightarrow \quad (\hat{k}\times\vec{B}) \parallel \left(\frac{\hat{i}+\hat{j}}{\sqrt{2}}\right)$$

Since, $\hat{k}\times\left(\frac{\hat{i}-\hat{j}}{\sqrt{2}}\right) = \frac{\hat{j}-(-\hat{i})}{\sqrt{2}} = \frac{\hat{i}+\hat{j}}{\sqrt{2}}$

Wave propagation vector should be along $\frac{\hat{i}+\hat{j}}{\sqrt{2}}$ and direction of magnetic field is along $\frac{\hat{i}-\hat{j}}{\sqrt{2}}$.

**Hence, the correct answer is (B).**

**9.** Electric field in electromagnetic wave is given by

$$E = E_0\sin(\omega t_1 - kz_1)$$

Also, $E' = E_0\sin(\pi + \omega t_1 - kz_2)$

As per question, $E = E' = 0$

$$\Rightarrow \quad \omega t_1 - kz_1 = (\pi + \omega t_1 - kz_2)$$

$$\Rightarrow \quad \pi = k(z_2 - z_1) = \frac{2\pi}{\lambda}|z_2 - z_1|$$

$$\Rightarrow \quad \lambda = 2|z_2 - z_1|$$

$$\Rightarrow \quad \nu = \frac{c}{\lambda} = \frac{3\times 10^{8}}{2|z_2 - z_1|} = \frac{1.5\times 10^{8}}{|z_2 - z_1|}$$

**Hence, the correct answer is (D).**

**10.** If $E$ is magnitude of electric field, then

$$I=\left(\frac{1}{2}\varepsilon_0 E^2\right)c$$

$$\Rightarrow \quad E=\sqrt{\frac{2I}{c\varepsilon_0}}$$

Also, $B=\dfrac{E}{c}$

So, direction of $\vec{E}\times\vec{B}$ will be along $+\hat{j}$.

**Hence, the correct answer is (C).**

**11.** Given that $\vec{B}=B_0\sin(kx+\omega t)\hat{j}$ T

The relation between electric and magnetic field is,

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

$$\Rightarrow \quad E=cB$$

The electric field component is perpendicular to the direction of propagation and the direction of magnetic field. Therefore, the electric field component along $z$-axis is obtained as

$$E=cB_0\sin(kx+\omega t)\hat{k}$$

**Hence, the correct answer is (D).**

**12.** Since, $\dfrac{dE}{dz}=-\dfrac{dB}{dt}$

$$\Rightarrow \quad \frac{dE}{dz}=-2E_0k\sin kz\cos\omega t=-\frac{dB}{dt}$$

$$\Rightarrow \quad dB=+2E_0k\sin kz\cos\omega t dt$$

$$\Rightarrow \quad B=+2E_0k\sin kz\int\cos\omega t dt$$

$$\Rightarrow \quad B=+2E_0\frac{k}{\omega}\sin kz\sin\omega t$$

Also, $\dfrac{E_0}{B_0}=\dfrac{\omega}{k}=c$

$$\Rightarrow \quad B=\frac{2E_0}{c}\sin kz\sin\omega t$$

$$\Rightarrow \quad \vec{B}=\frac{2E_0}{c}\sin kz\sin\omega t\hat{j}$$

**Hence, the correct answer is (C).**

**13.** $\underset{A}{E_{\text{radiowave}}}<\underset{B}{E_{\text{yellow}}}<\underset{C}{E_{\text{blue}}}<\underset{D}{E_{x\text{-ray}}}$

So, D < B < A < C

**Hence, the correct answer is (A).**

**15.** An electromagnetic wave propagating in $+x$ direction means electric field and magnetic field should be function of $x$ and $t$.

Also, $\vec{E}\perp\vec{B}$ or $\hat{E}\perp\hat{B}$

$$\Rightarrow \quad (\hat{y}-\hat{z})\cdot(\hat{y}+\hat{z})=\hat{y}\cdot\hat{y}-\hat{z}\cdot\hat{z}=0$$

**Hence, the correct answer is (D).**

**16.** Intensity of light, $I=u_{\text{av}}c$

Also, $I=\dfrac{P}{4\pi r^2}$ and $u_{\text{av}}=\dfrac{1}{2}\varepsilon_0E_0^2$

$$\Rightarrow \quad \frac{P}{4\pi r^2}=\frac{1}{2}\varepsilon_0E_0^2c \text{ or } E_0=\sqrt{\frac{2P}{4\pi\varepsilon_0 r^2c}}$$

Here, $P=0.1$ W, $r=1$ m, $c=3\times10^8$ ms$^{-1}$

$$\frac{1}{4\pi\varepsilon_0}=9\times10^9 \text{ NC}^{-2}\text{m}^2$$

$$\Rightarrow \quad E_0=\sqrt{\frac{2\times0.1\times9\times10^9}{1^2\times3\times10^8}}=\sqrt{6}=2.45\text{ Vm}^{-1}$$

**Hence, the correct answer is (D).**

**17.** $f=2\times10^{14}$ Hz

$E_0=27$ Vm$^{-1}$

Since, $\dfrac{E_0}{B_0}=c$

$$\Rightarrow \quad B_0=\frac{27}{3\times10^8}=9\times10^{-8}\text{ T}$$

Also, $\lambda=\dfrac{c}{f}=\dfrac{3\times10^8}{2\times10^{14}}=1.5\times10^{-6}$ m

$$\Rightarrow \quad B=B_0\sin2\pi\left(\frac{x}{\lambda}-ft\right)$$

$$\Rightarrow \quad B=(9\times10^{-8}\text{ T})\sin2\pi\left(\frac{x}{1.5\times10^{-6}}-2\times10^{14}t\right)$$

Oscillation of $B$ can be along either $\hat{j}$ or $\hat{k}$ direction.

*No given option is correct

**18.** For electromagnetic wave, direction of propagation, $\vec{E}$ and $\vec{B}$ are transverse in nature.

According to question, $\vec{E}\times\vec{B}$ gives the direction of propagation which is along $+z$ direction. Only OPTION (B) satisfies both conditions

(i) $\vec{E}\cdot\vec{B}=0$ (ii) $(\vec{E}\times\vec{B})$ directed along the $z$-axis.

**Hence, the correct answer is (B).**

19. Infrared waves are used to treat muscular strain. Radio waves are used for broadcasting.
$X$-rays are used to detect fracture of bones. Ultraviolet rays are absorbed by the ozone layer of the atmosphere.
**Hence, the correct answer is (A).**

20. In an EM wave, energy is equally divided between the electric and the magnetic fields.
**Hence, the correct answer is (D).**

21. In EM wave, the peak value of electric field ($E_0$) and peak value of magnetic field ($B_0$) are related by

$$E_0 = B_0 c$$

$$\Rightarrow \quad E_0 = (20 \times 10^{-9} \text{ T})(3 \times 10^8 \text{ ms}^{-1}) = 6 \text{ Vm}^{-1}$$

**Hence, the correct answer is (C).**

22. The direction of polarization is parallel to electric field

$$\Rightarrow \quad \vec{X} \parallel \vec{E}$$

The direction of wave propagation is parallel to $\vec{E} \times \vec{B}$.

$$\Rightarrow \quad \vec{k} \parallel \vec{E} \times \vec{B}$$

**Hence, the correct answer is (A).**