EM WAVES

1. An electromagnetic wave of frequency 5 GHz, is travelling in a medium whose relative electric permittivity and relative magnetic permeability both are 2. Its velocity in this medium is ________ $\times 10^7$ m/s.

2. Match List - I with List - II.

List - I	List - II
(a) Source of microwave frequency	(i) Radioactive decay on nucleus
(b) Source of infrared frequency	(ii) Magnetron
(c) Source of Gamma Rays	(iii) Inner shell electrons
(d) Source of X-rays	(iv) Vibration of atoms and molecules
	(v) LASER
	(vi) RC circuit

Choose the correct answer from the options given below :

(1) (a)-(vi), (b)-(iv), (c)-(i), (d)-(v)
(2) (a)-(vi), (b)-(v), (c)-(i), (d)-(iv)
(3) (a)-(ii), (b)-(iv), (c)-(vi), (d)-(iii)
(4) (a)-(ii), (b)-(iv), (c)-(i), (d)-(iii)

3. An electromagnetic wave of frequency 3 GHz enters a dielectric medium of relative electric permittivity 2.25 from vacuum. The wavelength of this wave in that medium will be ____ $\times 10^{-2}$ cm.

4. The peak electric field produced by the radiation coming from the 8 W bulb at a distance of 10 m is $\frac{x}{10}\sqrt{\frac{\mu_0 c}{\pi}}\frac{V}{m}$. The efficiency of the bulb is 10% and it is a point source. The value of x is____________.

5. A radiation is emitted by 1000 W bulb and it generates an electric field and magnetic field at P, placed at a distance of 2 m. The efficiency of the bulb is 1.25%. The value of peak electric field at P is x × 10^{-1} V/m. Value of x is_. (Rounded-off to the nearest integer)
[Take $\varepsilon_0 = 8.85 \times 10^{-12}\ C^2N^{-1}\ m^{-2}$, $c = 3 \times 10^8\ ms^{-1}$]

6. A plane electromagnetic wave of frequency 500 MHz is travelling in vacuum along y-direction. At a particular point in space and time, $\vec{B} = 8.0 \times 10^{-8}\ \hat{z}T$. The value of electric field at this point is : (speed of light = 3 × 10^8 ms^{-1}) $\hat{x}, \hat{y}, \hat{z}$ are unit vectors along x, y and z direction.

(1) $-24\hat{x}$ V/m
(2) $2.6\hat{x}$ V/m
(3) $24\hat{x}$ V/m
(4) $-2.6\hat{y}$ V/m

7. For an electromagnetic wave travelling in free space, the relation between average energy densities due to electric (U_e) and magnetic (U_m) fields is :

(1) $U_e = U_m$
(2) $U_e > U_m$
(3) $U_e < U_m$
(4) $U_e \neq U_m$

8. The electric field intensity produced by the radiation coming from a 100 W bulb at a distance of 3m is E. The electric field intensity produced by the radiation coming from 60 W at the same distance is $\sqrt{\frac{x}{5}}E$. Where the value of x =_________.

9. A plane electromagnetic wave of frequency 100 MHz is travelling in vacuum along the x direction. At a particular point in space and time, $\vec{B} = 2.0 \times 10^{-8}\hat{k}T$. (where, $\hat{k}$ is unit vector along z-direction) What is $\vec{E}$ at this point ?

(1) $0.6\hat{j}$ V/m
(2) $6.0\hat{k}$ V/m
(3) $6.0\hat{j}$ V/m
(4) $0.6\hat{k}$ V/m

10. A plane electromagnetic wave propagating along y-direction can have the following pair of electric field $(\vec{E})$ and magnetic field $(\vec{B})$ components.

(1) E_y, B_y or E_z, B_z
(2) E_y, B_x or E_x, B_y
(3) E_x, B_z or E_z, B_x
(4) E_x, B_y or E_y, B_x

11. In an electromagnetic wave the electric field vector and magnetic field vector are given as $\vec{E} = E_0\ \hat{i}$ and $\vec{B} = B_0\hat{k}$ respectively. The direction of propagation of electromagnetic wave is along :

(1) $(\hat{k})$
(2) $\hat{J}$
(3) $(-\hat{k})$
(4) $(-\hat{j})$

12. Intensity of sunlight is observed as 0.092 Wm^{-2} at a point in free space. What will be the peak value of magnetic field at that point ?
($\varepsilon_0 = 8.85 \times 10^{-12}C^2N^{-1}m^{-2}$)

(1) 2.77×10^{-8} T
(2) 1.96×10^{-8} T
(3) 8.31 T
(4) 5.88 T

13. A linearly polarized electromagnetic wave in vacuum is

$E = 3.1\cos\left[(1.8)z - (5.4\times10^6)t\right]\hat{i}\ N/C$

is incident normally on a perfectly reflecting wall at z = a. Choose the correct option

(1) The wavelength is 5.4 m

(2) The frequency of electromagnetic wave is 54×10^4 Hz.

(3) The transmitted wave will be $3.1\cos\left[(1.8)z - (5.4\times10^6)t\right]\hat{i}\ N/C$

(4) The reflected wave will be $3.1\cos\left[(1.8)z + (5.4\times10^6)t\right]\hat{i}\ N/C$

14. A light beam is described by E = 800 sinω $\left(t - \frac{x}{c}\right)$. An electron is allowed to move normal to the propagation of light beam with a speed of 3×10^7 ms^{-1}. What is the maximum magnetic force exerted on the electron ?

(1) 1.28×10^{-18} N
(2) 1.28×10^{-21} N
(3) 12.8×10^{-17} N
(4) 12.8×10^{-18} N

15. The magnetic field vector of an electromagnetic wave is given by $B = B_o \frac{\hat{i}+\hat{j}}{\sqrt{2}}\cos(kz - \omega t)$; where $\hat{i}, \hat{j}$ represents unit vector along x and y-axis respectively. At t = 0 s, two electric charges q_1 of 4π coulomb and q_2 of 2π coulomb located at $\left(0,0,\frac{\pi}{k}\right)$ and $\left(0,0,\frac{3\pi}{k}\right)$, respectively, have the same velocity of $0.5\,c\,\hat{i}$, (where c is the velocity of light). The ratio of the force acting on charge q_1 to q_2 is :-

(1) $2\sqrt{2} : 1$
(2) $1 : \sqrt{2}$
(3) 2 : 1
(4) $\sqrt{2} : 1$

16. Electric field in a plane electromagnetic wave is given by $E = 50\sin(500x - 10 \times 10^{10}t)$ V/m

The velocity of electromagnetic wave in this medium is :

(Given C = speed of light in vacuum)

(1) $\frac{3}{2}C$ (2) C (3) $\frac{2}{3}C$ (4) $\frac{C}{2}$

17. A plane electromagnetic wave with frequency of 30 MHz travels in free space. At particular point in space and time, electric field is 6 V/m. The magnetic field at this point will be x × 10^{-8} T. The value of x is _____.

18. The electric field in an electromagnetic wave is given by E = (50 NC^{-1}) sinω (t–x/c)

The energy contained in a cylinder of volume V is 5.5×10^{-12} J. The value of V is ________ cm

$\left(\text{given } \epsilon_0 = 8.8\times10^{-12}\,C^2N^{-1}m^{-2}\right)$

19. Electric field of plane electromagnetic wave propagating through a non–magnetic medium is given by $E = 20\cos(2 \times 10^{10} t - 200x)$ V/m. The dielectric constant of the medium is equal to : (Take $\mu_r = 1$)

(1) 9 (2) 2 (3) $\frac{1}{3}$ (4) 3

20. The electric field in a plane electromagnetic wave is given by

$$\vec{E} = 200\cos\left[\left(\frac{0.5\times10^3}{m}\right)x - \left(1.5\times10^{11}\frac{rad}{s}\times t\right)\right]\frac{V}{m}\hat{j}$$

If this wave falls normally on a perfectly reflecting surface having an area of 100 cm^2. If the radiation pressure exerted by the E.M. wave on the surface during a 10 minute exposure is $\frac{x}{10^9}\frac{N}{m^2}$. Find the value of x.

SOLUTION

1. Official Ans. by NTA (15)

Sol. Given : Frequency of wave f = 5 GHz
$= 5 \times 10^9$ Hz
Relative permittivity, $\in_r = 2$
and Relative permeability, $\mu_r = 2$
Since speed of light in a medium is given by,

$$v = \frac{1}{\sqrt{\mu \in}} = \frac{1}{\sqrt{\mu_r \mu_0 \cdot \in_r \in_0}}$$

$$v = \frac{1}{\sqrt{\mu_r \in_r}} \frac{1}{\sqrt{\mu_0 \in_0}} = \frac{C}{\sqrt{\mu_r \in_r}}$$

Where C is speed of light is vaccum.

$$\therefore\ v = \frac{3\times10^8}{\sqrt{4}} = \frac{30\times10^7}{2} \text{ m/s}$$

$= 15 \times 10^7$ m/s $\qquad \therefore$ Ans. is 15

2. Official Ans. by NTA (4)

Sol. (a) Source of microwave frequency is magnetron.
(b) Source of infrared frequency is vibration of atoms and molecules.
(c) Source of Gamma rays is radioactive decay of nucleus
(d) Source of X-rays inner shell electron transition.
Option (4) is correct.

3. Official Ans. by NTA (667)

Sol. λ in vacuum $= \frac{c}{f} = \frac{3\times10^8}{3\times10^9} = 0.1\text{m}$

$\therefore\ \lambda$ in medium $= \frac{0.1}{\mu}$

Where refractive index
$\mu = \sqrt{\mu_r \varepsilon_r}$
Assuming non-magnetic material $\mu_r = 1$
$\therefore\ \mu = \sqrt{2.25} = 1.5$

$$\lambda_m = \frac{0.1}{1.5} = \frac{1}{15}\text{m} = 6.67\text{cm}$$

$= 667 \times 10^{-2}$ cm $\qquad$ Ans. 667

4. Official Ans. by NTA (2)

Sol. $I = \frac{1}{2} c \in_0 E_0^2$

$$\frac{8}{4\pi\times10^2}\times\frac{1}{2} = \frac{1}{4}\times c\times\frac{1}{\mu_0 c^2}\times E_0^2$$

$$E_0 = \frac{2}{10} \times \sqrt{\frac{\mu_0 c}{\pi}} \Rightarrow x = 2$$

5. Official Ans. by NTA (137)

Sol. $I_{avg} = \frac{1}{2}\varepsilon_0 E_0^2 C$

$$\frac{1.25}{100}\times\frac{1000}{4\pi(2)^2} = \frac{1}{2} \times 8.85 \times 10^{-12} \times 3 \times 10^8 \times$$

$E_0^2 \qquad E_0^2 = 187.4$

$\therefore\ E_0 = 13.689$ V/m
$= 136.89 \times 10^{-1}$ V/m
$\therefore\ x = 136.89$
Rounding off to nearest integer
x = 137

6. Official Ans. by NTA (1)

Sol. $f = 5 \times 10^8$ Hz
EM wave is travelling towards $+\hat{j}$

$\vec{B} = 8.0\times10^{-8}\hat{z}\text{T}$

$\vec{E} = \vec{B}\times\vec{C} = (8 \times 10^{-8}\hat{z}) \times (3 \times 10^8\ \hat{y})$

$= -24\,\hat{x}$ V / m

7. Official Ans. by NTA (1)

Sol. In EMW, Average energy density due to electric (U_e) and magnetic (U_m) fields is same.

8. Official Ans. by NTA (3)

Sol. $c \in_0 E^2 = \frac{100}{4\pi\times3^2}$

$$c \in_0 \left(\sqrt{\frac{x}{5}}E\right)^2 = \frac{60}{4\pi\times3^2}$$

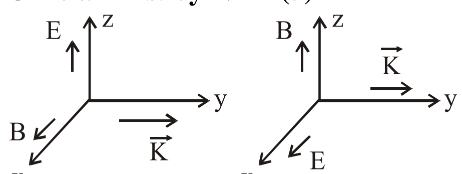
$$\Rightarrow \frac{x}{5} = \frac{3}{5} \Rightarrow x = 3$$

9. Official Ans. by NTA (3)

Sol. E = BC = 6
(Dir. of wave) $\parallel (\vec{E}\times\vec{B})$
$\hat{i} = \hat{j}\times\hat{k} \qquad \vec{E} = 6\hat{j}$ V / m

10. Official Ans. by NTA (3)

Sol.



11. Official Ans. by NTA (4)

Sol. Direction of propagation = $\vec{E}\times\vec{B} = \hat{i}\times\hat{k} = -\hat{j}$

12. Official Ans. by NTA (1)

Sol. $I_{avg} = \frac{B_0^2 C}{2\mu_0}$ & $\frac{1}{\mu_0} = \epsilon_0 C^2$

$I = \frac{B_0^2}{2} \epsilon_0 C^3$

$B_0 = \sqrt{\frac{2I}{\epsilon_0 C^3}}$

$B_0 = 2.77 \times 10^{-8}$ T

13. Official Ans. by NTA (4)

Sol. Reflected wave will have direction opposite to incident wave.

14. Official Ans. by NTA (4)

Sol. $\frac{E_0}{C} = B_0$

$F_{max} = eB_0V$

$= 1.6 \times 10^{-19} \times \frac{800}{3 \times 10^8} \times 3 \times 10^7$

$= 12.8 \times 10^{-18}$N

Ans. 4

15. Official Ans. by NTA (3)

Sol. $\vec{F} = q(\vec{V} \times \vec{B})$

$\vec{F}_1 = 4\pi\left[0.5c\hat{i} \times B_0\left(\frac{\hat{i}+\hat{j}}{2}\right)\cos\left(K.\frac{\pi}{K} - 0\right)\right]$

$\vec{F}_2 = 2\pi\left[0.5c\hat{i} \times B_0\left(\frac{\hat{i}+\hat{j}}{2}\right)\cos\left(K.\frac{3\pi}{K} - 0\right)\right]$

$\cos\pi = -1, \quad \cos 3\pi = -1$

$\therefore \frac{F_1}{F_2} = 2$

16. Official Ans. by NTA (3)

Sol. $V = \frac{\omega}{K} = \frac{10 \times 10^{10}}{500} = 2 \times 10^8$

$\mathbf{V} = \frac{2C}{3}$.

17. Official Ans. by NTA (2)

Sol. $|B| = \frac{|E|}{C} = \frac{6}{3 \times 10^8}$

$= 2 \times 10^{-8}$ T

$\therefore x = 2$

18. Official Ans. by NTA (500)

Sol. $E = 50\sin\left(\omega t - \frac{\omega}{c}.x\right)$

Energy density $= \frac{1}{2}\epsilon_0 E_0^2$

Energy for volume V $= \frac{1}{2}\epsilon_0 E_0^2.V = 5.5 \times 10^{-12}$

$\frac{1}{2}8.8 \times 10^{-12} \times 2500V = 5.5 \times 10^{-12}$

$V = \frac{5.5 \times 2}{2500 \times 8.8} = .0005\text{m}^3$

$= .0005 \times 10^6$ (c.m)^3

$= 500$ (c.m)^3

19. Official Ans. by NTA (1)

Sol. Speed of wave $= \frac{2 \times 10^{10}}{200} = 10^8$ m/s

Refractive index $= \frac{3 \times 10^8}{10^8} = 3$

Now refractive index $= \sqrt{\varepsilon_r \mu_r}$

$3 = \sqrt{\varepsilon_r(1)} \Rightarrow \varepsilon_r = 9$

Option (1)

20. Official Ans. by NTA (354)

Sol. $E_0 = 200$

$I = \frac{1}{2}\varepsilon_0 E_0^2 \cdot C$

Radiation pressure

$P = \frac{2I}{C}$

$= \left(\frac{2}{C}\right)\left(\frac{1}{2}\varepsilon_0 E_0^2 C\right) = \varepsilon_0 E_0^2$

$= 8.85 \times 10^{-12} \times 200^2$

$= 8.85 \times 10^{-8} \times 4 = \frac{354}{10^9}$

Ans. 354.0