

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 $x \times 10^{-1}$ V/m. Value of x is_. (Rounded-off to the nearest integer)

[Take $\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2\text{N}^{-1}\text{m}^{-2}$, $c = 3 \times 10^8 \text{ ms}^{-1}$]

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

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

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, $\vec{B} = 2.0 \times 10^{-8} \hat{k} \text{ T}$. (where, \hat{k} is unit vector along z-direction) What is \vec{E} at this point ?

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

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 ?

($\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2\text{N}^{-1}\text{m}^{-2}$)

- (1) $2.77 \times 10^{-8} \text{ T}$ (2) $1.96 \times 10^{-8} \text{ T}$
 (3) 8.31 T (4) 5.88 T

13. A linearly polarized electromagnetic wave in vacuum is
 $E = 3.1 \cos[(1.8)z - (5.4 \times 10^6)t] \hat{i} \text{ N/C}$
 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 $54 \times 10^4 \text{ Hz}$.
 (3) The transmitted wave will be $3.1 \cos[(1.8)z - (5.4 \times 10^6)t] \hat{i} \text{ N/C}$
 (4) The reflected wave will be $3.1 \cos[(1.8)z + (5.4 \times 10^6)t] \hat{i} \text{ N/C}$
14. A light beam is described by $E = 800 \sin \omega \left(t - \frac{x}{c} \right)$. An electron is allowed to move normal to the propagation of light beam with a speed of $3 \times 10^7 \text{ ms}^{-1}$. What is the maximum magnetic force exerted on the electron?
 (1) $1.28 \times 10^{-18} \text{ N}$ (2) $1.28 \times 10^{-21} \text{ N}$
 (3) $12.8 \times 10^{-17} \text{ N}$ (4) $12.8 \times 10^{-18} \text{ N}$
15. The magnetic field vector of an electromagnetic wave is given by $B = B_0 \frac{\hat{i} + \hat{j}}{\sqrt{2}} \cos(kz - \omega t)$;
 where \hat{i}, \hat{j} represents unit vector along x and y-axis respectively. At $t = 0 \text{ s}$, two electric charges q_1 of $4\pi \text{ coulomb}$ and q_2 of $2\pi \text{ coulomb}$ 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 $E = 50 \sin(500x - 10 \times 10^{10}t) \text{ V/m}$
 The velocity of electromagnetic wave in this medium is :
 (Given $C = \text{speed of light in vacuum}$)
 (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 $x \times 10^{-8} \text{ T}$. The value of x is ____.
18. The electric field in an electromagnetic wave is given by $E = (50 \text{ NC}^{-1}) \sin \omega (t - x/c)$
 The energy contained in a cylinder of volume V is $5.5 \times 10^{-12} \text{ J}$. The value of V is _____ cm
 (given $\epsilon_0 = 8.8 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$)
19. Electric field of plane electromagnetic wave propagating through a non-magnetic medium is given by $E = 20 \cos(2 \times 10^{10} t - 200x) \text{ V/m}$. 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

$$\vec{E} = 200 \cos \left[\left(\frac{0.5 \times 10^3}{\text{m}} \right) x - \left(1.5 \times 10^{11} \frac{\text{rad}}{\text{s}} \times t \right) \right] \frac{\text{V}}{\text{m}} \hat{j}$$

 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 $\frac{x}{10^9} \frac{\text{N}}{\text{m}^2}$. Find the value of x .

SOLUTION

1. Official Ans. by NTA (15)

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

$$v = \frac{1}{\sqrt{\mu \epsilon}} = \frac{1}{\sqrt{\mu_r \mu_0 \cdot \epsilon_r \epsilon_0}}$$

$$v = \frac{1}{\sqrt{\mu_r \epsilon_r}} \cdot \frac{1}{\sqrt{\mu_0 \epsilon_0}} = \frac{C}{\sqrt{\mu_r \epsilon_r}}$$

Where C is speed of light in vacuum.

$$\therefore v = \frac{3 \times 10^8}{\sqrt{4}} = \frac{30 \times 10^7}{2} \text{ m/s}$$

$$= 15 \times 10^7 \text{ m/s} \quad \therefore \text{Ans. is } 15$$

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 $= \frac{c}{f} = \frac{3 \times 10^8}{3 \times 10^9} = 0.1 \text{ m}$

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

Where refractive index

$$\mu = \sqrt{\mu_r \epsilon_r}$$

Assuming non-magnetic material $\mu_r = 1$

$$\therefore \mu = \sqrt{2.25} = 1.5$$

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

$$= 667 \times 10^{-2} \text{ cm}$$

Ans. 667

4. Official Ans. by NTA (2)

Sol. $I = \frac{1}{2} c \epsilon_0 E_0^2$

$$\frac{8}{4\pi \times 10^2} \times \frac{1}{2} = \frac{1}{4} \times c \times \frac{1}{\mu_0 c^2} \times E_0^2$$

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

5. Official Ans. by NTA (137)

Sol. $I_{\text{avg}} = \frac{1}{2} \epsilon_0 E_0^2 C$

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

$$E_0^2 \quad E_0^2 = 187.4$$

$$\therefore E_0 = 13.689 \text{ V/m}$$

$$= 136.89 \times 10^{-1} \text{ V/m}$$

$$\therefore x = 136.89$$

Rounding off to nearest integer

$$x = 137$$

6. Official Ans. by NTA (1)

Sol. $f = 5 \times 10^8 \text{ Hz}$

EM wave is travelling towards $+\hat{j}$

$$\vec{B} = 8.0 \times 10^{-8} \hat{z} \text{ T}$$

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

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

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. $c \epsilon_0 E^2 = \frac{100}{4\pi \times 3^2}$

$$c \epsilon_0 \left(\sqrt{\frac{x}{5}} E \right)^2 = \frac{60}{4\pi \times 3^2}$$

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

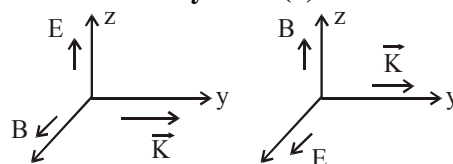
9. Official Ans. by NTA (3)

Sol. $E = BC = 6$

(Dir. of wave) $\parallel (\vec{E} \times \vec{B})$

$$\hat{i} = \hat{j} \times \hat{k} \quad \vec{E} = 6\hat{j} \text{ V/m}$$

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

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

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

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

13. Official Ans. by NTA (4)

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

14. Official Ans. by NTA (4)

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

$$F_{\text{max}} = eB_0 V$$

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

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

Ans. 4

15. Official Ans. by NTA (3)

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

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

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

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

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

16. Official Ans. by NTA (3)

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

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

17. Official Ans. by NTA (2)

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

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

$$\therefore x = 2$$

18. Official Ans. by NTA (500)

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

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

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

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

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

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

$$= 500 (\text{c.m})^3$$

19. Official Ans. by NTA (1)

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

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

$$\text{Now refractive index} = \sqrt{\epsilon_r \mu_r}$$

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

Option (1)

20. Official Ans. by NTA (354)

Sol. $E_0 = 200$

$$I = \frac{1}{2} \epsilon_0 E_0^2 \cdot C$$

Radiation pressure

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

$$= \left(\frac{2}{C} \right) \left(\frac{1}{2} \epsilon_0 E_0^2 C \right) = \epsilon_0 E_0^2$$

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

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

Ans. 354.0