NARAYANA EDUCATIONAL INSTITUTIONS

TOPIC: ELECTRO MAGNETIC WAVES

1. In an electric circuit, a capacitor of resistance 50Ω is connected across the source of 220v. Find the displacement current
   a. 2.4A b. 3.4A c. 4.4A d. 5.2A
2. A plane electromagnetic wave $E_z = 100\cos\left(6\times10^8 t + 4x\right) v/m$ propagates in a medium of dielectric constant
   a. 1.5 b. 2.0 c. 2.4 d. 4.0
3. A plane electromagnetic wave propagating in the x-direction has wave length of 6mm. The electric field is in the y-direction and its maximum magnitude is 33 v/m. The equation for the electric field as function of x and t is
   a. $11\sin\pi\left(t-\frac{x}{c}\right)$ b. $33\sin\pi\times10^{11}\left(t-\frac{x}{c}\right)$
   c. $33\sin\pi\left(t-\frac{x}{c}\right)$ d. $11\sin\pi\times10^{11}\left(t-\frac{x}{c}\right)$
4. A plane electromagnetic wave travels in free space along x-direction. If the value of $\vec{B}(\text{in tesla})$ at a particular point in space and time is $1.2\times10^{-8}\hat{K}$, the value of $\vec{E}\left(in\, vm^{-1}\right)$ at that point is
   a. $1.2\hat{J}$ b. $3.6\hat{K}$ c. $1.2\hat{K}$ d. $3.6\hat{J}$
5. The electric field part of an electromagnetic wave in vacuum is $E = 3.1\frac{N}{C}\cos\left[\left(1.8\frac{rad}{m}\right)y + \left(5.4\times10^8\frac{rad}{s}\right)t\right]\hat{l}$ The wave length of this part of electromagnetic wave is
   a. 1.5m b. 2m c. 2.5m d. 3.5m
6. The electric field part of an electromagnetic wave in a medium is represented by $E_x = 0, E_y = 2.5\frac{N}{C}\cos\left[\left(2\pi\times10^6\frac{rad}{m}\right)t - \left(\pi\times10^{-2}\frac{rad}{s}\right)x\right], E_z = 0.$ The wave is
   a. Moving along x direction with frequency 10^6 HZ and wave length 100m
   b. Moving along X direction with frequency 10^6 HZ and wave length 200m
   c. Moving along –X direction with frequency 10^6 HZ and wave length 200m
   d. Moving along Y direction with frequency $2\pi\times10^6$ HZ and wave length 200m
7. The electric field associated with an electromagnetic wave in vacuum is given by $\vec{E} = 40\cos\left(KZ - 6\times10^8 t\right)\hat{I}$, where E,Z and t are in volt per meter, meter and second respectively. The value of wave vector K is
   a. $2m^{-1}$ b. $0.5m^{-1}$ c. $6m^{-1}$ d. $3m^{-1}$
8. A plane electromagnetic wave travels in vacuum along z direction. If the frequency of the wave is $40MHZ$ then its wavelength is
   a. 5m b. 7.5m c. 8.5m d. 10m
9. If $\in_0$ *and* μ_0 represent the permittivity and permeability of vacuum and $\in$ and μ represent the permittivity and permeability of medium, the refractive index of the medium is given by

a. $\sqrt{\frac{\in_0 \mu_0}{\in \mu}}$ b. $\sqrt{\frac{\in \mu}{\in_0 \mu_0}}$ c. $\sqrt{\frac{\in}{\mu_0 \in_0}}$ d. $\sqrt{\frac{\mu_0 \in_0}{\in}}$

10. In a plane electromagnetic wave, the electric field oscillates sinsoidally at a frequency of $2.5\times10^{10}\,HZ$ and amplitude 480 v/m. The amplitude of the oscillating magnetic field will be
a. $1.52\times10^{-8}\,wb/m^2$ b. $1.52\times10^{-7}\,wb/m^2$
c. $1.6\times10^{-6}\,wb/m^2$ d. $1.6\times10^{-7}\,wb/m^2$

11. A radiowave has a maximum electric field intensity of $10^{-4}\,v/m$ on arrival at a receiving antenna. The maximum magnetic flux density of such a wave is
a. Zero b. $3\times10^{-4}\,T$ c. $5.8\times10^{-9}\,T$ d. $3.3\times10^{-13}\,T$

12. The transmitting antenna of a radio- station is mounted vertically. At a point 10km due north of the transmitter the peak electric field is $10^{-3}\,v/m$. The amplitude of the radiated magnetic field is
a. $3.33\times10^{-10}\,T$ b. $3.33\times10^{-12}\,T$ c. $10^{-3}\,T$ d. $3\times10^{5}\,T$

13. The magnetic field in the plane electromagnetic wave is given by $B_z = 2\times10^{-7}\sin\left(0.5\times10^{3}x+1.5\times10^{11}t\right)telsa$ The expression for electric field will be
a. $E_z = 30\sqrt{2}\sin\left(0.5\times10^{3}x+1.5\times10^{11}t\right)v/m$
b. $E_z = 60\sin\left(0.5\times10^{3}x+1.5\times10^{11}t\right)v/m$
c. $E_y = 30\sqrt{2}\sin\left(0.5\times10^{11}x+0.5\times10^{3}t\right)v/m$
d. $E_y = 60\sin\left(0.5\times10^{3}x+1.5\times10^{11}t\right)v/m$

14. The refractive index and permeability of a medium are 1.5 and $5\times10^{-7}\,H/m$. The relative permittivity of the medium is nearly
a. 25 b. 15 c. 10 d. 6

15. An electromagnetic wave propagating along north has its electric field vector upwards. Its magnetic field vector point towards
a. North b. east c. west d. downwards

16. The rms value of the electric field of the light coming from the sun is 720 N/C.The average total energy density of the electromagnetic wave is
a. $3.3\times10^{-3}\,Jm^{-3}$ b. $4.58\times10^{-6}\,Jm^{-3}$
c. $6.37\times10^{-9}\,Jm^{-3}$ d. $81.35\times10^{-12}\,Jm^{-3}$

17. Which of the following rays is not an electromagnetic wave
a. X- rays b. r- rays c. β-rays d. Heat rays

18. Radio waves diffract around buildings, although light waves do not. The reason is that radio waves
a. Travel with speed large that C
b. Have much larger wavelength than light
c. Are not electromagnetic waves
d. None of these

19. The ultra high frequency band of radiowaves in electromagnetic wave is used as in
a. Television waves b. cellular phone communication
c. commercial FM radio d. none

20. The part of the spectrum of the electromagnetic radiation used to cook food is
a. Ultraviolet rays b. cosmic rays c. x-rays d. microwaves

21. The electric field of a plane electromagnetic wave varies with time of amplitude 2 v/m propagating along z-axis . The average energy density of the magnetic field $\left(in\,Jm^{-3}\right)$ is ________ $\times10^{-12}$

22. The magnetic field of a beam emerging from a filter facing a flood light as given by $B = 12\times10^{-8}\sin\left(1.20\times10^{7}z-3.60\times10^{15}t\right)$ The average intensity of the beam is _________ $\left(Wm^{-2}\right)$.

23. The electric field $\left(in\, NC^{-1}\right)$ in an electromagnetic wave is given by $E=50\sin W\left(t-\frac{x}{c}\right)$. The energy stored in a cylinder of cross- section $10cm^2$ and length 100cm along the x-axis will be ________ $\times10^{-11}J$
24. In an electromagnetic wave, the amplitude of electric field is 1 v/m. The frequency of wave is $5\times10^{+14}HZ$. The wave is propagating along z-axis. The average energy density of electric field in J/m^3 will be ________ $\times10^{-12}J/m^{+3}$
25. Intensity of the electromagnetic wave is about, If $B_0=2\times10^{-7}T$ is _______ Wm^{-2}
26. If the magnetic field of a plane electromagnetic wave is given by $B=300\times10^{-6}\sin\left(2\pi\times2\times10^{15}\left(t-\frac{x}{c}\right)\right)$ Find the maximum electric field in _______ $\times10^4 N/C$ associated with it.
27. A 27mW beam of cross – sectional area of $10mm^2$. Find the magnitude of the maximum electric field $\left(in\, kv/m\right)$ in the electromagnetic wave is given by _______ $\left(E_0=9\times10^{-12}\,SI\,units; c=3\times10^8 m/s\right)$
28. About 5% of the power of a 100w light bulb is converted intensity $\left(in\, Wm^{-2}\right)$ of visible radiation at a distance of 1m from the bulb? _______ $\times10^{-1}W/m^2$
29. Light with an energy flux of $20W/cm^2$ falls on a non- reflecting surface at normal incidence. If the surface has an area of $30cm^2$, find the total momentum $\left(in\, k^2\times10^{-4}kg\, m/s\right)$ delivered (for complete absorption) during 30min, where k=_______
30. A plane em wave of wave intensity of 10 W / m^2 strikes a small mirror of area 20cm^2, held perpendicular to the approaching wave. The radiation force on the mirror will be ________ $\times10^{-10}N$

S.NO	1-c	2-b	3-b	4-d	5-d	6-b	7-a	8-b	9-b	10-c
Multiple choice type	11-d	12-b	13-d	14-d	15-b	16-b	17-c	18-b	19-b	20-d
Numerical type questions	Integer value 21 Ans-9	22 Ans-2	23 Ans-1	24 Ans-2	25 Ans-5	26 Ans-3	27 Ans-1	28 Ans-4	29 Ans-6	30 Ans-1

1. Displacement current [id]= condition current [ic]

$$id = \frac{v}{X_c} = \frac{220}{50} = 4.4A$$

2. Comparing the given equation with equation of a plane EMW $E_z = E_0 \cos(wt + kx)$ we have

$w = 6\times10^8$ and $K = 4$

$V = \frac{W}{K}$ $V = \frac{W}{K} = \frac{6\times10^8}{4} = \frac{3}{2}\times10^8 m/s$

$\mu = \frac{c}{V} = \frac{3\times10^8}{\frac{3}{2}\times10^8} = 2$

3. $W = 2\pi f = \frac{2\pi c}{\lambda} = \frac{2\pi\times3\times10^8}{6\times10^{-3}}$

$W \approx \pi\times10^{11} rad/s$

The equation for the electric field along y-axis in the EMW is

$E_y = E_0 \sin w\left(t - \frac{x}{c}\right)$

$= 33\sin\pi\times10^{11}\left(t - \frac{x}{c}\right)$

4. Here $\vec{B} = 1.2\times10^{-8}\hat{k}T$

The magnitude of $\vec{E}$ is $E = BC$

$E = (1.2\times10^{-8})(3\times10^8) = 3.6v/m$

B is along Z direction and wave propagates along x-direction.

$\therefore \vec{E}$ is along y direction $\therefore \vec{E} = 3.6\hat{J}v/m$

5. $E = 3.1N/C\cos\left((1.8rad/m)y + (5.4\times10^8 rads^{-1})t\right)\hat{I}$

Comparing with $E = E_0\cos(Ky + wt)$

$K = 1.8radm^{-1}; E_0 = 3.1N/C; C = 3\times10^8 m/s$

$W = 5.4\times10^8 rad/s$

$\lambda = \frac{2\pi}{K} = \frac{2\times22}{1.8\times7} = 3.5m$

6. $E_y = 2.5N/C\times\cos\left(\left(2\pi\times10^6\frac{rad}{m}\right)t - \left(\pi\times10^{-2}\frac{rad}{s}\right)x\right)$

$E_z = 0; E_x = 0$

The wave is moving in the positive direction of x

This is in the form $E_y = E_0\cos(wt - kx)$

$w = 2\pi\times10^6; 2\pi f = 2\pi\times10^6$

$\Rightarrow f = 10^6 HZ$

$K = \frac{2\pi}{\lambda} \Rightarrow \frac{2\cancel{\pi}}{\lambda} = \cancel{\pi}\times10^{-2}$

$\Rightarrow \lambda = 200m$

7. Compare the given equation with

$E = E_0\cos(KZ - wt); W = 6\times10^8$

$K = \frac{W}{C} = \frac{6\times10^8}{3\times10^8} = 2m^{-1}$

8. $\lambda = \frac{c}{f} = \frac{3\times10^8}{40\times10^6} = 7.5m$

9. $\mu=\frac{c}{v}=\frac{1}{\sqrt{\mu_0 \in_0}}\sqrt{\frac{\mu \in}{\mu_0 \in_0}}=\sqrt{\frac{\in \mu}{\in_0 \mu_0}}$

10. $C=\frac{E_0}{B_0}\Rightarrow B_0=\frac{E_0}{C}=1.6\times10^{-6}Wb/m^2$

11. $B=\frac{E}{C}=\frac{10^{-4}}{3\times10^8}=3.3\times10^{-13}T$

12. $B_0=\frac{E_0}{C}=\frac{10^{-3}}{3\times10^8}=3.3\times10^{-12}T$

13. Wave is along +ve x-axis
B is directed along z-axis
E is along y-axis $E_0=B_0C\,; E_0=2\times10^{-7}\times3\times10^8=60v/m$
$\therefore E_y=60\sin\left(0.5\times10^3x+1.5\times10^{11}t\right)v/m$

14. $\mu=\frac{c}{v}=\frac{3\times10^8}{v}\Rightarrow v=\frac{3\times10^8}{\mu}=\frac{3\times10^8}{1.5}$
$\Rightarrow v=2\times10^8 m/s$
μ of the medium [given]= $5\times10^{-7}H/m$
$v=\frac{1}{\sqrt{\mu \in}}=\frac{1}{\sqrt{\mu \in_0 \in_r}}$
$\Rightarrow V^2=\frac{1}{\mu \in_0 \in_r}\Rightarrow E_r=\frac{1}{v^2\mu \in_0}$
$E_r=\frac{1}{\left(2\times10^8\right)^2\times5\times10^{-7}\times8.85\times10^{-12}}$
$\approx 5.65\approx 6$

15. East

16. Total average energy density of EMW is $U_{avg}=\frac{1}{2}to \in_0 E_{rms}^2+\frac{1}{2\mu_0}B_{rms}^2$

$B_{rms}=\frac{E_{rms}}{c};c=\frac{1}{\sqrt{\mu_0 E_0}}$
$=\frac{1}{2}\in_0 E_{rms}^2+\frac{1}{2\mu_0}\left(\frac{E_{rms}^2}{C^2}\right)$
$=\frac{1}{2}\in_0 E_{rms}^2+\frac{1}{2\cancel{\mu_0}}E_{rms}^2\cancel{\mu_0}\in_0$
$=\frac{1}{2}\in_0 E_{rms}^2+\frac{1}{2}\in_0 E_{rms}^2=\in_0 E_{rms}^2$
$=8.85\times10^{-12}\times\left(720\right)^2=4.58\times10^{-6}Jm^{-3}$

17. $\beta-rays$

18. The wave length of radio waves being much larger than light, has a size comparable to those of buildings, hence diffract from them.

19. Cellular phone

20. Microwaves are used to cook food microwave oven is a domestic application of these waves.

21. Amplitude of electric and magnetic field are related by $\frac{E_0}{B_r}=c$

Average energy density of the magnifield

$$U_B = \frac{1}{4}\frac{B_0{}^2}{\mu_0} = \frac{1}{4}\frac{E_0^2}{\mu_0 C^2}\left(C = \frac{1}{\sqrt{\mu_0 E_0}}\right)$$

$$= \frac{1}{4} \in_0 E_0^2$$

$$= \frac{1}{4} \times 8.854 \times 10^{-12} \times (2)^2 = 8.854 \times 10^{-12}$$

$$= 8.86 \times 10^{-12} Jm^{-3}$$

22. Here $B = 12 \times 10^{-8} \sin\left(1.20 \times 10^7 Z - 3.6 \times 10^{15} t\right)$

Comparing with $B = B_0 \sin(KZ - Wt)$

$B_0 = 12 \times 10^{-8} T$

$$I_{avg} = \frac{1}{2}\frac{B_0^2 c}{\mu_0} = \frac{1}{2}\frac{\left(12 \times 10^{-8}\right)^2 \times 3 \times 10^8}{4\pi \times 10^{-7}}$$

$$= 1.71 Wm^{-2}$$

23. Energy contained in a cylinder

U= average energy density $\times$volume

$$= \frac{1}{2} \in_0 E_0^2 \times AL$$

$$= \frac{1}{2} \times 8.85 \times 10^{-12} \times (50)^2 \times \left(10 \times 10^{-4}\right) \times 1$$

$$= 1.1 \times 10^{-11} J$$

24. The average density U_E is given by

$$U_E = \frac{1}{2} \in_0 E_{rms}^2 = \frac{1}{2} \in_0 \left(\frac{E_0}{\sqrt{2}}\right)^2$$

$$= \frac{1}{4} \in_0 E_0^2$$

$$= \frac{1}{4} \times \left(8.85 \times 10^{-12}\right) \times (1)^2$$

$$= 2.2 \times 10^{-12} Jm^{-3}$$

25. Intensity of EMW is

$$I = \frac{1}{2}\frac{B_0^2}{\mu_0} C = \frac{1}{2} \times \frac{\left(2 \times 10^{-7}\right)^2}{4\pi \times 10^{-7}} \times 3 \times 10^8$$

$$= 5 Wm^{-2}$$

26. $E_0 = B_0 \times C = 100 \times 10^{-6} \times 3 \times 10^8$

$$= 3 \times 10^4 N / C$$

27. $I = \frac{power}{area} \Rightarrow \frac{1}{2} E_0 E_0^2 C = \frac{27 \times 1\cancel{0}^{-3}}{1\cancel{0} \times 1\cancel{0}^{-6}}$

$$\Rightarrow \frac{1}{2} \times 9 \times 10^{-12} \times E^2 \times 3 \times 10^8 = 2700$$

$$\Rightarrow E = \sqrt{2} \times 10^3 \Rightarrow 1.4 kv / m$$

28. $I = \frac{power}{area} = \frac{100 \times 0.05}{4\pi(1)^2}$

$$= 0.4 W / m^2 = 4 \times 10^{-1} W / m^2$$

29. $\phi = 20 W / cm^2$ $\qquad A = 30 cm^2$

$t = 30 \min = 30 \times 60 s$

Total energy falling on the surface in time t is $U = \phi At$

$U = 20 \times 30 \times 30 \times 60 J$

Momentum delivered $= \frac{U}{C} = \frac{20 \times 30 \times 30 \times 60}{3 \times 10^8}$

$= 36 \times 10^{-4} kgms^{-1} = (6)^2 \times 10^{-4} kgms^{-1}$

Momentum of the reflected light= 0

30. Radiation force $= \frac{2I_{0w}A}{C}$

$= \frac{2 \times 10 \times 20 \times 10^{-4}}{3 \times 10^8}$

$= 1.33 \times 10^{-10} N$