

EM WAVES & PRINCIPLES OF COMMUNICATION

1. A plane electromagnetic wave propagating in x-direction is described by

$$E_y = (200 \text{ Vm}^{-1}) \sin[1.5 \times 10^7 t - 0.05 x];$$

The intensity of the wave is :

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

- (1) 35.4 Wm^{-2} (2) 53.1 Wm^{-2}
 (3) 26.6 Wm^{-2} (4) 106.2 Wm^{-2}

2. Match List I with List II.

List-I		List-II	
A.	$\oint \vec{B} \cdot d\vec{l} = \mu_0 i_c + \mu_0 \epsilon_0 \frac{d\phi_E}{dt}$	I.	Gauss' law for electricity
B.	$\oint \vec{E} \cdot d\vec{l} = \frac{d\phi_B}{dt}$	II.	Gauss' law for magnetism
C.	$\oint \vec{E} \cdot d\vec{A} = \frac{Q}{\epsilon_0}$	III.	Faraday law
D.	$\oint \vec{B} \cdot d\vec{A} = 0$	IV.	Ampere – Maxwell law

Chose the correct answer from the options given below:

- (1) A-IV, B-I, C-III, D-II
 (2) A-II, B-III, C-I, D-IV
 (3) A-IV, B-III, C-I, D-II
 (4) A-I, B-II, C-III, D-IV

3. A plane electromagnetic wave of frequency 35 MHz travels in free space along the X-direction.

At a particular point (in space and time)

$$\vec{E} = 9.6 \hat{j} \text{ V/m. The value of magnetic field at this point is :}$$

this point is :

- (1) $3.2 \cdot 10^{-8} \hat{k} \text{ T}$ (2) $3.2 \cdot 10^{-8} \hat{i} \text{ T}$
 (3) $9.6 \hat{j} \text{ T}$ (4) $9.6 \cdot 10^{-8} \hat{k} \text{ T}$

4. The electric field of an electromagnetic wave in free space is represented as $\vec{E} = E_0 \cos(\omega t - kz) \hat{j}$. The corresponding magnetic induction vector will be :

(1) $\vec{B} = E_0 C \cos(\omega t - kz) \hat{j}$

(2) $\vec{B} = \frac{E_0}{C} \cos(\omega t - kz) \hat{j}$

(3) $\vec{B} = E_0 C \cos(\omega t + kz) \hat{j}$

(4) $\vec{B} = \frac{E_0}{C} \cos(\omega t + kz) \hat{j}$

5. In a plane EM wave, the electric field oscillates sinusoidally at a frequency of $5 \times 10^{10} \text{ Hz}$ and an amplitude of 50 Vm^{-1} . The total average energy density of the electromagnetic field of the wave is : [Use $\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2 / \text{Nm}^2$]

(1) $1.106 \times 10^{-8} \text{ Jm}^{-3}$

(2) $4.425 \times 10^{-8} \text{ Jm}^{-3}$

(3) $2.212 \times 10^{-8} \text{ Jm}^{-3}$

(4) $2.212 \times 10^{-10} \text{ Jm}^{-3}$

6. Given below are two statements:

Statement I: Electromagnetic waves carry energy as they travel through space and this energy is equally shared by the electric and magnetic fields.

Statement II: When electromagnetic waves strike a surface, a pressure is exerted on the surface.

In the light of the above statements, choose the most appropriate answer from the options given below:

(1) Statement I is incorrect but Statement II is correct

(2) Both Statement I and Statement II are correct.

(3) Both Statement I and Statement II are incorrect.

(4) Statement I is correct but Statement II is incorrect.

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7. If frequency of electromagnetic wave is 60 MHz and it travels in air along z direction then the corresponding electric and magnetic field vectors will be mutually perpendicular to each other and the wavelength of the wave (in m) is :
- (1) 2.5 (2) 10
(3) 5 (4) 2
8. The electric field in an electromagnetic wave is given by $\vec{E} = \hat{i}40 \cos\omega\left(t - \frac{z}{c}\right) \text{NC}^{-1}$.
- The magnetic field induction of this wave is (in SI unit):
- (1) $\vec{B} = \hat{i} \frac{40}{c} \cos\omega\left(t - \frac{z}{c}\right)$
(2) $\vec{B} = \hat{j}40 \cos\omega\left(t - \frac{z}{c}\right)$
(3) $\vec{B} = \hat{k} \frac{40}{c} \cos\omega\left(t - \frac{z}{c}\right)$
(4) $\vec{B} = \hat{j} \frac{40}{c} \cos\omega\left(t - \frac{z}{c}\right)$
9. Arrange the following in the ascending order of wavelength :
- (A) Gamma rays (λ_1) (B) x-ray (λ_2)
(C) Infrared waves (λ_3) (D) Microwaves (λ_4)
- Choose the most appropriate answer from the options given below :
- (1) $\lambda_4 < \lambda_3 < \lambda_1 < \lambda_2$
(2) $\lambda_4 < \lambda_3 < \lambda_2 < \lambda_1$
(3) $\lambda_1 < \lambda_2 < \lambda_3 < \lambda_4$
(4) $\lambda_2 < \lambda_1 < \lambda_4 < \lambda_3$
10. An alternating voltage of amplitude 40 V and frequency 4 kHz is applied directly across the capacitor of 12 μF . The maximum displacement current between the plates of the capacitor is nearly:
- (1) 13 A (2) 8 A
(3) 10 A (4) 12 A

11. Match List-I with List-II :

	List-I EM-Wave		List-II Wavelength Range
(A)	Infra-red	(I)	$< 10^{-3} \text{ nm}$
(B)	Ultraviolet	(II)	400 nm to 1 nm
(C)	X-rays	(III)	1 mm to 700 nm
(D)	Gamma rays	(IV)	1 nm to 10^{-3} nm

Choose the correct answer from the options given below :

- (1) (A)-(II), (B)-(I), (C)-(IV), (D)-(III)
(2) (A)-(III), (B)-(II), (C)-(IV), (D)-(I)
(3) (A)-(IV), (B)-(III), (C)-(II), (D)-(I)
(4) (A)-(I), (B)-(III), (C)-(II), (D)-(IV)
12. Electromagnetic waves travel in a medium with speed of $1.5 \times 10^8 \text{ ms}^{-1}$. The relative permeability of the medium is 2.0. The relative permittivity will be :
- (1) 5 (2) 1 (3) 4 (4) 2
13. In the given electromagnetic wave $E_y = 600 \sin(\omega t - kx) \text{Vm}^{-1}$, intensity of the associated light beam is (in W/m^2); (Given $\epsilon_0 = 9 \times 10^{-12} \text{C}^2\text{N}^{-1}\text{m}^{-2}$)
- (1) 486 (2) 243
(3) 729 (4) 972
14. A plane EM wave is propagating along x direction. It has a wavelength of 4 mm. If electric field is in y direction with the maximum magnitude of 60 Vm^{-1} , the equation for magnetic field is:
- (1) $B_z = 60 \sin\left[\frac{\pi}{2}(x - 3 \cdot 10^8 t)\right] \hat{k}\text{T}$
(2) $B_z = 2 \cdot 10^{-7} \sin\left[\frac{\pi}{2} \cdot 10^3(x - 3 \cdot 10^8 t)\right] \hat{k}\text{T}$
(3) $B_x = 60 \sin\left[\frac{\pi}{2}(x - 3 \cdot 10^8 t)\right] \hat{i}\text{T}$
(4) $B_z = 2 \cdot 10^{-7} \sin\left[\frac{\pi}{2}(x - 3 \cdot 10^8 t)\right] \hat{k}\text{T}$
15. The magnetic field in a plane electromagnetic wave is $B_y = (3.5 \times 10^{-7}) \sin(1.5 \times 10^3 x + 0.5 \times 10^{11} t)\text{T}$. The corresponding electric field will be
- (1) $E_y = 1.17 \sin(1.5 \times 10^3 x + 0.5 \times 10^{11} t)\text{Vm}^{-1}$
(2) $E_z = 105 \sin(1.5 \times 10^3 x + 0.5 \times 10^{11} t)\text{Vm}^{-1}$
(3) $E_z = 1.17 \sin(1.5 \times 10^3 x + 0.5 \times 10^{11} t)\text{Vm}^{-1}$
(4) $E_y = 10.5 \sin(1.5 \times 10^3 x + 0.5 \times 10^{11} t)\text{Vm}^{-1}$

SOLUTIONS
1. Ans. (2)

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

$$I = \frac{1}{2} \cdot 8.85 \cdot 10^{-12} \cdot 4 \cdot 10^4 \cdot 3 \cdot 10^8$$

$$I = 53.1 \text{ W/m}^2$$

2. Ans. (3)
Sol. Ampere – Maxwell law

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 i_c + \mu_0 \epsilon_0 \frac{d\phi_E}{dt}$$

$$\text{Faraday law} \rightarrow \oint \vec{E} \cdot d\vec{l} = -\frac{d\phi_B}{dt}$$

$$\text{Gauss' law for electricity} \rightarrow \oint \vec{E} \cdot d\vec{A} = \frac{Q}{\epsilon_0}$$

$$\text{Gauss' law for magnetism} \rightarrow \oint \vec{B} \cdot d\vec{A} = 0$$

3. Ans. (1)

Sol. $\frac{E}{B} = C$

$$\frac{E}{B} = 3 \cdot 10^8$$

$$B = \frac{E}{3 \cdot 10^8} = \frac{9.6}{3 \cdot 10^8}$$

$$B = 3.2 \times 10^{-8} \text{ T}$$

$$\hat{B} = \hat{v} \cdot \hat{E}$$

$$= \hat{i} \cdot \hat{j} = \hat{k}$$

$$\text{So, } B = 3.2 \cdot 10^{-8} \hat{k} \text{ T}$$

4. Ans. (2)

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

$$\vec{B} = \frac{E_0}{C} \cos(\omega t - kz) \hat{j}$$

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

5. Ans. (1)

Sol. $U_E = \frac{1}{2} \epsilon_0 E^2$

$$U_E = \frac{1}{2} \cdot 8.85 \cdot 10^{-12} \cdot (50)^2$$

$$= 1.106 \times 10^{-8} \text{ J/m}^3$$

6. Ans. (2)

Sol. $\frac{1}{2} \epsilon_0 E^2 = \frac{B^2}{2\mu_0}$

$$\therefore E = CB \text{ and } C = \frac{1}{\mu_0 \epsilon_0}$$

7. Ans. (3)

Sol. $\lambda = \frac{c}{f} = \frac{3 \cdot 10^8}{60 \cdot 10^6} = 5 \text{ m}$

8. Ans. (4)

Sol. $\vec{E} = \hat{i} 40 \cos \omega \left(t - \frac{z}{c} \right)$

 \vec{E} is along +x direction
 \vec{v} is along +z direction

 So direction of \vec{B} will be along +y and
 magnitude of \vec{B} will be $\frac{E}{c}$

So answer is $\frac{40}{c} \cos \omega \left(t - \frac{z}{c} \right) \hat{j}$

9. Ans. (3)

Sol. $\lambda_1 < \lambda_2 < \lambda_3 < \lambda_4$

10. Ans. (4)
Sol. Displacement current is same as conduction current in capacitor.

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$$

$$= \frac{1}{2\pi \cdot 4 \cdot 10^3 \cdot 12 \cdot 10^{-6}} = 3.317 \Omega$$

$$I = \frac{V}{X_C} = \frac{40}{3.317} = 12 \text{ A}$$

11. Ans. (2)
Sol. Infrared is the least energetic thus having biggest wavelength (λ) & gamma rays are most energetic thus having smallest wavelength (λ).

12. Ans. (4)

Sol. $\frac{\epsilon_m \cdot \omega_m}{\epsilon_0 \cdot \omega_0} = \frac{1}{c^2}$

$$\epsilon_r \cdot \omega^2 = \frac{c^2}{v^2};$$

$$\epsilon_r \cdot 2 = \frac{(3 \cdot 10^8)^2}{(1.5 \cdot 10^8)^2}$$

$$\epsilon_r \cdot 2 = 4$$

$$\epsilon_r = 2$$

13. Ans. (1)

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

$$= \frac{1}{2} \times 9 \times 10^{-12} \times (600)^2 \times 3 \times 10^8$$

$$= \frac{9}{2} \times 36 \times 3 = 486 \text{ w/m}^2$$

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14. Ans. (2)

Sol. $E = BC \Rightarrow 60 = B \times 3 \times 10^8$

$$\Rightarrow B = 2 \times 10^{-7}$$

Also $C = f\lambda$

$$\Rightarrow 3 \times 10^8 = f \times 4 \times 10^{-3}$$

$$\Rightarrow f = \frac{3}{4} \cdot 10^{11}$$

$$\Rightarrow \omega = 2\pi f = \frac{3}{2} \cdot \pi \cdot 10^{11}$$

$$\Rightarrow \omega = \frac{\pi}{2} \cdot 10^3 \text{C}$$

 \Rightarrow Electric field \Rightarrow y direction

 Propagation \Rightarrow x direction

 Magnetic field \Rightarrow z-direction

15. Ans. (2)

Sol. $E_0 = B_0 C$

$$E_0 = 3 \times 10^8 (3.5 \times 10^{-7} \sin(1.5 \times 10^3 x + 0.5 \times 10^{11} t))$$

$$E_0 = 105 \sin(1.5 \times 10^3 x + 0.5 \times 10^{11} t) \text{Vm}^{-1}$$

Data inconsistent while calculating speed of wave. You can challenge for data.