Electromagnetic Waves

1. An electromagnetic wave in vacuum has the electric and magnetic fields $\vec{E}$ and $\vec{B}$, which are always perpendicular to each other. The direction of polarization is given by $\vec{X}$ and that of wave propagation by $\vec{k}$. Then **[AIEEE-2012]**

(1) $\vec{X} || \vec{E}$ and $\vec{k} || \vec{E} \times \vec{B}$

(2) $\vec{X} || \vec{B}$ and $\vec{k} || \vec{E} \times \vec{B}$

(3) $\vec{X} || \vec{E}$ and $\vec{k} || \vec{B} \times \vec{E}$

(4) $\vec{X} || \vec{B}$ and $\vec{k} || \vec{B} \times \vec{E}$

2. A circular loop of radius 0.3 cm lies parallel to a much bigger circular loop of radius 20 cm. The centre of the small loop is on the axis of the bigger loop. The distance between their centres is 15 cm. If a current of 2.0 A flows through the smaller loop, then the flux linked with bigger loop is **[JEE (Main)-2013]**

(1) 9.1×10^{-11} weber (2) 6×10^{-11} weber

(3) 3.3×10^{-11} weber (4) 6.6×10^{-9} weber

3. The magnetic field in a travelling electromagnetic wave has a peak value of 20 nT. The peak value of electric field strength is : [JEE (Main)-2013]

(1) 3 V/m (2) 6 V/m

(3) 9 V/m (4) 12 V/m

4. During the propagation of electromagnetic waves in a medium **[JEE (Main)-2014]**

(1) Electric energy density is double of the magnetic energy density

(2) Electric energy density is half of the magnetic energy density

(3) Electric energy density is equal to the magnetic energy density

(4) Both electric and magnetic energy densities are zero

5. Match List-I (Electromagnetic wave type) with List - II (Its association/application) and select the correct option from the choices given below the lists:

List-I		List-II	
(a)	Infrared waves	(i)	To treat muscular strain
(b)	Radio waves	(ii)	For broadcasting
(c)	X-rays	(iii)	To detect fracture of bones
(d)	Ultraviolet rays	(iv)	Absorbed by the ozone layer of the atmosphere

[JEE (Main)-2014]

	(a)	(b)	(c)	(d)
(1)	(iv)	(iii)	(ii)	(i)
(2)	(i)	(ii)	(iv)	(iii)
(3)	(iii)	(ii)	(i)	(iv)
(4)	(i)	(ii)	(iii)	(iv)

6. A red LED emits light at 0.1 watt uniformly around it. The amplitude of the electric field of the light at a distance of 1 m from the diode is **[JEE (Main)-2015]**

(1) 1.73 V/m (2) 2.45 V/m

(3) 5.48 V/m (4) 7.75 V/m

7. Arrange the following electromagnetic radiations per quantum in the order of increasing energy: **[JEE (Main)-2016]**

A : Blue light

B : Yellow light

C : X-ray

D : Radiowave

(1) A, B, D, C

(2) C, A, B, D

(3) B, A, D, C

(4) D, B, A, C

8. An EM wave from air enters a medium. The electric fields are $\vec{E}_1 = E_{01}\hat{x}\cos\left[2\pi\nu\left(\frac{z}{c}-t\right)\right]$ in air and $\vec{E}_2 = E_{02}\hat{x}\cos[k(2z-ct)]$ in medium, where the wave number k and frequency ν refer to their values in air. The medium is non-magnetic. If ε_{r_1} and ε_{r_2} refer to relative permittivities of air and medium respectively, which of the following options is correct? **[JEE (Main)-2018]**

(1) $\frac{\varepsilon_{r_1}}{\varepsilon_{r_2}} = 4$ (2) $\frac{\varepsilon_{r_1}}{\varepsilon_{r_2}} = 2$

(3) $\frac{\varepsilon_{r_1}}{\varepsilon_{r_2}} = \frac{1}{4}$ (4) $\frac{\varepsilon_{r_1}}{\varepsilon_{r_2}} = \frac{1}{2}$

9. A plane electromagnetic wave of frequency 50 MHz travels in free space along the positive x-direction. At a particular point in space and time, $\vec{E} = 6.3\hat{j}$ V/m. The corresponding magnetic field $\vec{B}$, at that point will be **[JEE (Main)-2019]**

(1) $18.9\times10^{-8}\hat{k}$ T (2) $2.1\times10^{-8}\hat{k}$ T

(3) $6.3\times10^{-8}\hat{k}$ T (4) $18.9\times10^{8}\hat{k}$ T

10. The energy associated with electric field is (U_E) and with magnetic field is (U_B) for an electromagnetic wave in free space, Then **[JEE (Main)-2019]**

(1) $U_E < U_B$ (2) $U_E = \frac{U_B}{2}$

(3) $U_E = U_B$ (4) $U_E > U_B$

11. The magnetic field associated with a light wave is given, at the origin, by $B = B_0$ [sin(3.14 × 10^7)ct + sin(6.28 × 10^7)ct]. If this light falls on a silver plate having a work function of 4.7 eV, what will be the maximum kinetic energy of the photo electrons? **[JEE (Main)-2019]**

(c = 3 × 10^8 ms^{-1}, h = 6.6 × 10^{-34} J-s)

(1) 8.52 eV (2) 7.72 eV

(3) 12.5 eV (4) 6.82 eV

12. If the magnetic field of a plane electromagnetic wave is given by (The speed of light = 3 × 10^8 m/s) $B = 100\times10^{-6}\sin\left[2\pi\times2\times10^{15}\left(t-\frac{x}{c}\right)\right]$, then the maximum electric field associated with it is **[JEE (Main)-2019]**

(1) 6 × 10^4 N/C (2) 3 × 10^4 N/C

(3) 4.5 × 10^4 N/C (4) 4 × 10^4 N/C

13. The electric field of a plane polarized electromagnetic wave in free space at time t = 0 is given by an expression **[JEE (Main)-2019]**

$\vec{E}(x,y) = 10\hat{j}\cos[(6x+8z)]$

The magnetic field $\vec{B}$ (x, z, t) is given by

(c is the velocity of light)

(1) $\frac{1}{c}\left(6\hat{k}+8\hat{i}\right)\cos[(6x+8z-10ct)]$

(2) $\frac{1}{c}\left(6\hat{k}-8\hat{i}\right)\cos[(6x+8z+10ct)]$

(3) $\frac{1}{c}\left(6\hat{k}+8\hat{i}\right)\cos[(6x-8z+10ct)]$

(4) $\frac{1}{c}\left(6\hat{k}-8\hat{i}\right)\cos[(6x+8z-10ct)]$

14. An electromagnetic wave of intensity 50 Wm^{-2} enters in a medium of refractive index 'n' without any loss. The ratio of the magnitudes of electric fields, and the ratio of the magnitudes of magnetic fields of the wave before and after entering into the medium are respectively, given by **[JEE (Main)-2019]**

(1) $\left(\frac{1}{\sqrt{n}}, \sqrt{n}\right)$ (2) $\left(\sqrt{n}, \frac{1}{\sqrt{n}}\right)$

(3) $\left(\frac{1}{\sqrt{n}}, \frac{1}{\sqrt{n}}\right)$ (4) $\left(\sqrt{n}, \sqrt{n}\right)$

15. A 27 mW laser beam has a cross-sectional area of 10 mm^2. The magnitude of the maximum electric field in this electromagnetic wave is given by

[Given permittivity of space ϵ_0 = 9 × 10^{-12} SI units, Speed of light c = 3 × 10^8 m/s] **[JEE (Main)-2019]**

(1) 1.4 kV/m (2) 1 kV/m

(3) 2 kV/m (4) 0.7 kV/m

16. A light wave is incident normally on a glass slab of refractive index 1.5. If 4% of light gets reflected and the amplitude of the electric field of the incident light is 30 V/m, then the amplitude of the electric field for the wave propogating in the glass medium will be **[JEE (Main)-2019]**

(1) 6 V/m (2) 10 V/m

(3) 24 V/m (4) 30 V/m

17. The mean intensity of radiation on the surface of the Sun is about 10^8 W/m^2. The rms value of the corresponding magnetic field is closet to **[JEE (Main)-2019]**

(1) 10^2 T (2) 10^{-4} T

(3) 1 T (4) 10^{-2} T

18. In SI units, the dimensions of $\sqrt{\dfrac{\varepsilon_0}{\mu_0}}$ is **[JEE (Main)-2019]**

(1) $AT^2M^{-1}L^{-1}$ (2) $AT^{-3}ML^{3/2}$

(3) $A^{-1}TML^3$ (4) $A^2T^3M^{-1}L^{-2}$

19. A plane electromagnetic wave travels in free space along the *x*-direction. The electric field component of the wave at a particular point of space and time is $E = 6$ Vm^{-1} along *y*-direction. Its corresponding magnetic field component, *B* would be **[JEE (Main)-2019]**

(1) 2×10^{-8} T along *y*-direction

(2) 6×10^{-8} T along *z*-direction

(3) 2×10^{-8} T along *z*-direction

(4) 6×10^{-8} T along *x*-direction

20. The magnetic field of an electromagnetic wave is given by: **[JEE (Main)-2019]**

$$\vec{B} = 1.6\times10^{-6}\cos(2\times10^7 z + 6\times10^{15}t)(2\hat{i}+\hat{j})\frac{\text{Wb}}{\text{m}^2}$$

The associated electric field will be:

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

(2) $\vec{E} = 4.8\times10^2\cos\left(2\times10^7 z - 6\times10^{15}t\right)(2\hat{i}+\hat{j})\frac{\text{V}}{\text{m}}$

(3) $\vec{E} = 4.8\times10^2\cos\left(2\times10^7 z - 6\times10^{15}t\right)(-2\hat{j}+\hat{i})\frac{\text{V}}{\text{m}}$

(4) $\vec{E} = 4.8\times10^2\cos\left(2\times10^7 z + 6\times10^{15}t\right)(\hat{i}-2\hat{j})\frac{\text{V}}{\text{m}}$

21. The magnetic field of a plane electromagnetic wave is given by

$\vec{B} = \vec{B}_0\hat{i}\,[\cos(kz - \omega t) + B_1\hat{j}\cos(kz + \omega t)$

where $B_0 = 3 \times 10^{-5}$ T and $B_1 = 2 \times 10^{-6}$ T

The rms value of the force experienced by a stationary charge $Q = 10^{-4}$ C at $z = 0$ is closest to **[JEE (Main)-2019]**

(1) 0.6 N (2) 0.9 N

(3) 3×10^{-2} N (4) 0.1 N

22. The electric field of a plane electromagnetic wave is given by

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

The corresponding magnetic field $\vec{B}$ is then given by : **[JEE (Main)-2019]**

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

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

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

(4) $\vec{B} = \dfrac{E_0}{C}\hat{k}\ \sin(kz)\cos(\omega t)$

23. An electromagnetic wave is represented by the electric field

$\vec{E} = E_0\hat{n}\sin[\omega t + (6y - 8z)]$. Taking unit vectors in *x*, *y* and *z* directions to be $\hat{i}$, $\hat{j}$, $\hat{k}$, the direction of propogation $\hat{s}$, is : **[JEE (Main)-2019]**

(1) $\hat{s} = \left(\dfrac{-3\hat{j}+4\hat{k}}{5}\right)$ (2) $\hat{s} = \left(\dfrac{3\hat{i}-4\hat{j}}{5}\right)$

(3) $\hat{s} = \left(\dfrac{-4\hat{k}+3\hat{j}}{5}\right)$ (4) $\hat{s} = \left(\dfrac{4\hat{j}-3\hat{k}}{5}\right)$

24. Which of the following combinations has the dimension of electrical resistance (ε_0 is the permittivity of vacuum and μ_0 is the permeability of vacuum)? **[JEE (Main)-2019]**

(1) $\sqrt{\dfrac{\varepsilon_0}{\mu_0}}$ (2) $\dfrac{\varepsilon_0}{\mu_0}$

(3) $\sqrt{\dfrac{\mu_0}{\varepsilon_0}}$ (4) $\dfrac{\mu_0}{\varepsilon_0}$

25. A plane electromagnetic wave having a frequency ν = 23.9 GHz propagates along the positive *z*-direction in free space. The peak value of the electric field is 60 V/m. Which among the following is the acceptable magnetic field component in the electromagnetic wave? **[JEE (Main)-2019]**

(1) $\vec{B} = 60\sin(0.5\times10^3 x + 1.5\times10^{11} t)\hat{k}$

(2) $\vec{B} = 2\times10^7 \sin(0.5\times10^3 z + 1.5\times10^{11} t)\hat{i}$

(3) $\vec{B} = 2\times10^{-7} \sin(0.5\times10^3 z - 1.5\times10^{11} t)\hat{i}$

(4) $\vec{B} = 2\times10^{-7} \sin(1.5\times10^2 x + 0.5\times10^{11} t)\hat{j}$

26. If the magnetic field in a plane electromagnetic wave is given by

$\vec{B} = 3\times10^{-8} \sin(1.6\times10^3 x + 48\times10^{10} t)\hat{j}$ T,

then what will be expression for electric field? **[JEE (Main)-2020]**

(1) $\vec{E} = \left(60\sin(1.6\times10^3 x + 48\times10^{10} t)\hat{k}\text{ V/m}\right)$

(2) $\vec{E} = \left(3\times10^{-8}\sin(1.6\times10^3 x + 48\times10^{10} t)\hat{i}\text{ V/m}\right)$

(3) $\vec{E} = \left(9\sin(1.6\times10^3 x + 48\times10^{10} t)\hat{k}\text{ V/m}\right)$

(4) $\vec{E} = \left(3\times10^{-8}\sin(1.6\times10^3 x + 48\times10^{10} t)\hat{j}\text{ V/m}\right)$

27. The electric field of a plane electromagnetic wave is given by

$$\vec{E} = E_0 \frac{\hat{i}+\hat{j}}{\sqrt{2}}\cos(kz+\omega t)$$

At t = 0, a positively charged particle is at the point (x, y, z) = $\left(0, 0, \frac{\pi}{k}\right)$. If its instantaneous velocity at (t = 0) is $v_0\hat{k}$, the force acting on it due to the wave is **[JEE (Main)-2020]**

(1) Antiparallel to $\frac{\hat{i}+\hat{j}}{\sqrt{2}}$

(2) Zero

(3) Parallel to $\frac{\hat{i}+\hat{j}}{\sqrt{2}}$

(4) Parallel to $\hat{k}$

28. A plane electromagnetic wave of frequency 25 GHz is propagating in vacuum along the z-direction. At a particular point in space and time, the magnetic field is given by $\vec{B} = 5\times10^{-8}\hat{j}$ T. The corresponding electric field $\vec{E}$ is (speed of light c = 3 × 10^8 ms^{-1}) **[JEE (Main)-2020]**

(1) $-1.66\times10^{-16}\hat{i}$ V/m

(2) $1.66\times10^{-16}\hat{i}$ V/m

(3) $-15\,\hat{i}$ V/m

(4) $15\,\hat{i}$ V/m

29. The electric fields of two plane electromagnetic plane waves in vacuum are given by

$\vec{E}_1 = E_0\,\hat{j}\cos(\omega t - kx)$ and

$\vec{E}_2 = E_0\hat{k}\cos(\omega t - ky)$

At t = 0, a particle of chcarge q is at origin with a velocity $\vec{v} = 0.8\,c\hat{j}$ (c is the speed of light in vaccum). The instantaneous force experienced by the particle is **[JEE (Main)-2020]**

(1) $E_0 q(0.4\hat{i} - 3\hat{j} + 0.8\hat{k})$

(2) $E_0 q(-0.8\hat{i} + \hat{j} + \hat{k})$

(3) $E_0 q(0.8\hat{i} + \hat{j} + 0.2\hat{k})$

(4) $E_0 q(0.8\hat{i} - \hat{j} + 0.4\hat{k})$

30. A plane electromagnetic wave is propagating along the direction $\frac{\hat{i}+\hat{j}}{\sqrt{2}}$, with its polarization along the direction $\hat{k}$. The correct form of the magnetic field of the wave would be (here B_0 is an appropriate constant) **[JEE (Main)-2020]**

(1) $B_0\frac{\hat{i}-\hat{j}}{\sqrt{2}}\cos\left(\omega t - k\frac{\hat{i}+\hat{j}}{\sqrt{2}}\right)$

(2) $B_0\hat{k}\cos\left(\omega t - k\frac{\hat{i}+\hat{j}}{\sqrt{2}}\right)$

(3) $B_0\frac{\hat{i}+\hat{j}}{\sqrt{2}}\cos\left(\omega t - k\frac{\hat{i}+\hat{j}}{\sqrt{2}}\right)$

(4) $B_0\frac{\hat{j}-\hat{i}}{\sqrt{2}}\cos\left(\omega t + k\frac{\hat{i}+\hat{j}}{\sqrt{2}}\right)$

31. A plane electromagnetic wave, has frequency of 2.0 × 10^{10} Hz and its energy density is 1.02 × 10^{-8} J/m^3 in vacuum. The amplitude of the magnetic field of the wave is close to ($\frac{1}{4\pi\varepsilon_0} = 9\times10^9\frac{Nm^2}{C^2}$ and speed of light = 3 × 10^8 ms^{-1}) **[JEE (Main)-2020]**

(1) 190 nT (2) 160 nT

(3) 150 nT (4) 180 nT

32. In a plane electromagnetic wave, the directions of electric field and magnetic field are represented by $\hat{k}$ and $2\hat{i}-2\hat{j}$, respectively. What is the unit vector along direction of propagation of the wave? **[JEE (Main)-2020]**

(1) $\frac{1}{\sqrt{5}}(\hat{i}+2\hat{j})$ (2) $\frac{1}{\sqrt{2}}(\hat{j}+\hat{k})$

(3) $\frac{1}{\sqrt{2}}(\hat{i}+\hat{j})$ (4) $\frac{1}{\sqrt{5}}(2\hat{i}+\hat{j})$

33. The electric field of a plane electromagnetic wave propagating along the x direction in vacuum is $\vec{E} = E_0\hat{j}\cos(\omega t - kx)$. The magnetic field $\vec{B}$, at the moment t = 0 is **[JEE (Main)-2020]**

(1) $\vec{B} = E_0\sqrt{\mu_0\varepsilon_0}\cos(kx)\hat{j}$

(2) $\vec{B} = E_0\sqrt{\mu_0\varepsilon_0}\cos(kx)\hat{k}$

(3) $\vec{B} = \frac{E_0}{\sqrt{\mu_0\varepsilon_0}}\cos(kx)\hat{k}$

(4) $\vec{B} = \frac{E_0}{\sqrt{\mu_0\varepsilon_0}}\cos(kx)\hat{j}$

34. Choose the correct option relating wavelengths of different parts of electromagnetic wave spectrum **[JEE (Main)-2020]**

(1) $\lambda_{\text{x-rays}} < \lambda_{\text{micro waves}} < \lambda_{\text{radio waves}} < \lambda_{\text{visible}}$

(2) $\lambda_{\text{visible}} > \lambda_{\text{x-rays}} > \lambda_{\text{radio waves}} > \lambda_{\text{micro waves}}$

(3) $\lambda_{\text{radio waves}} > \lambda_{\text{micro waves}} > \lambda_{\text{visible}} > \lambda_{\text{x-rays}}$

(4) $\lambda_{\text{visible}} < \lambda_{\text{micro waves}} < \lambda_{\text{radio waves}} < \lambda_{\text{x-rays}}$

35. The electric field of a plane electromagnetic wave is given by **[JEE (Main)-2020]**

$\vec{E} = E_0(\hat{x}+\hat{y})\sin(kz-\omega t)$

Its magnetic field will be given by

(1) $\frac{E_0}{c}(\hat{x}-\hat{y})\cos(kz-\omega t)$

(2) $\frac{E_0}{c}(\hat{x}-\hat{y})\sin(kz-\omega t)$

(3) $\frac{E_0}{c}(-\hat{x}+\hat{y})\sin(kz-\omega t)$

(4) $\frac{E_0}{c}(\hat{x}-\hat{y})\sin(kz-\omega t)$

36. The quantities $x = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$, $y = \frac{E}{B}$ and $z = \frac{l}{CR}$ are defined where C-capacitance, R-Resistance, l-length, E-Electric field, B-magnetic field and ε_0, μ_0, - free space permittivity and permeability respectively. Then **[JEE (Main)-2020]**

(1) Only x and y have the same dimension

(2) Only x and z have the same dimension

(3) x, y and z have the same dimension

(4) Only y and z have the same dimension

37. The correct match between the entries in column I and column II are **[JEE (Main)-2020]**

I		II	
	Radiation		**Wavelength**
(a)	Microwave	(i)	100 m
(b)	Gamma rays	(ii)	10^{-15} m
(c)	A.M. radio waves	(iii)	10^{-10} m
(d)	X = rays	(iv)	10^{-3} m

(1) (a)-(ii), (b)-(i), (c)-(iv), (d)-(iii)

(2) (a)-(iv), (b)-(ii), (c)-(i), (d)-(iii)

(3) (a)-(iii), (b)-(ii), (c)-(i), (d)-(iv)

(4) (a)-(i), (b)-(iii), (c)-(iv), (d)-(ii)

38. The magnetic field of a plane electromagnetic wave is **[JEE (Main)-2020]**

$\vec{B} = 3\times10^{-8}\sin[200\pi(y+ct)]\hat{i}\,T$

where $c = 3 \times 10^8$ ms^{-1} is the speed of light.

The corresponding electric field is

(1) $\vec{E} = -9\sin[200\pi(y+ct)]\hat{k}$ V/m

(2) $\vec{E} = 9\sin[200\pi(y+ct)]\hat{k}$ V/m

(3) $\vec{E} = -10^{-6}\sin[200\pi(y+ct)]\hat{k}$ V/m

(4) $\vec{E} = 3\times10^{-8}\sin[200\pi(y+ct)]\hat{k}$ V/m

39. For a plane electromagnetic wave, the magnetic field at a point x and time t is **[JEE (Main)-2020]**

$\vec{B}(x,t) = [1.2\times10^{-7}\sin(0.5\times10^3x+1.5\times10^{11}t)\hat{k}]$T.

The instantaneous electric field $\vec{E}$ corresponding to $\vec{B}$ is

(speed of light $c = 3 \times 10^8$ ms^{-1})

(1) $\vec{E}(x,t) = \left[36\sin(1\times10^3 x + 1.5\times10^{11}t)\hat{i}\right]\frac{\text{V}}{\text{m}}$

(2) $\vec{E}(x,t) = \left[36\sin(0.5\times10^3 x + 1.5\times10^{11}t)\hat{k}\right]\frac{\text{V}}{\text{m}}$

(3) $\vec{E}(x,t) = \left[-36\sin(0.5\times10^3 x + 1.5\times10^{11}t)\hat{j}\right]\frac{\text{V}}{\text{m}}$

(4) $\vec{E}(x,t) = \left[36\sin(1\times10^3 x + 0.5\times10^{11}t)\hat{j}\right]\frac{\text{V}}{\text{m}}$

40. A beam of electromagnetic radiation of intensity 6.4×10^{-5} W/cm^2 is comprised of wavelength, $\lambda = 310$ nm. It falls normally on a metal (work function $\varphi = 2$ eV) of surface area of 1 cm^2. If one in 10^3 photons ejects an electron, total number of electrons ejected in 1 s is 10^x. ($hc = 1240$ eVnm, 1 eV = 1.6×10^{-19} J), then x is _______.

[JEE (Main)-2020]

41. Suppose that intensity of a laser is $\left(\frac{315}{\pi}\right)$ W/m^2. The rms electric field, in units of V/m associated with this source is close to the nearest integer is ______. **[JEE (Main)-2020]**

($\varepsilon_0 = 8.86 \times 10^{-12}$ C^{2}Nm^{-2}; $c = 3 \times 10^8$ ms^{-1})

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