CHAPTER - A

ELECTROMAGNETIC WAVES

Date Planned : __ / __ / __	Daily Tutorial Sheet - 1	Expected Duration : 90 Min
Actual Date of Attempt : __ / __ / __	Level - 1	Exact Duration :________

1. The magnetic field of an EM wave is given by: $\vec{B} = 60\sin(\pi \times 10^3 x + 3\pi \times 10^{11} t)\,\hat{k}$ (all quantities are in SI units). The wavelength of the wave is:

(A) 2 km **(B)** 2 m
(C) 2 mm **(D)** 2 μm

2. The transverse nature of electromagnetic waves is evident from:

(A) polarization **(B)** interference **(C)** reflection **(D)** diffraction

3. The relative permitivity and relative permeability of a medium are ε_r and μ_r respectively. The refractive index of the medium is:

(A) $\frac{1}{\sqrt{\mu_r \varepsilon_r}}$ **(B)** $\sqrt{\mu_r \varepsilon_r}$ **(C)** $\sqrt{\frac{\varepsilon_r}{\mu_r}}$ **(D)** $\mu_r \varepsilon_r$

4. The refractive index and dielectric constant of a medium are 1.5 and 1.8 respectively. The relative permeability of the medium is:

(A) 3 **(B)** 2.7
(C) 1.67 **(D)** 1.25

5. The electric field of an electromagnetic wave is given by: $\vec{E} = E_0 \sin(\omega t - kz)\,\hat{i}$. The magnetic field of the same wave is:

(A) $\vec{B} = E_0\left(\frac{k}{\omega}\right)\sin(\omega t - kz)\,\hat{i}$ **(B)** $\vec{B} = E_0\left(\frac{k}{\omega}\right)\sin(\omega t - kz)\,\hat{j}$
(C) $\vec{B} = E_0\left(\frac{\omega}{k}\right)\sin(\omega t - kz)\,\hat{i}$ **(D)** $\vec{B} = E_0\left(\frac{\omega}{k}\right)\sin(\omega t - kz)\,\hat{j}$

6. An electromagnetic wave is travelling towards the +X direction. At a particular point, the magnetic field of the wave points in the –Y direction. Then, at the same point, the electric field of the wave points in:

(A) the +X direction **(B)** the –X direction
(C) the +Z direction **(D)** the –Z direction

7. An electromagnetic wave is generated due to oscillation of a charged particle with a frequecny 10^9 *Hz.* The wavelength of this electromagnetic wave in vaccum is:

(A) 3 m **(B)** 30 cm
(C) 3 cm **(D)** 3 mm

8. The rms value of the intensity of the magnetic field of an EM wave propagating in a medium of relative electric permittivity 1.44 and relative magnetic permeability 1 is $1\,\mu T$. The intensity of the EM wave (in W/m^2) is:

(Permeability of vacuum, $\mu_0 = 4\pi \times 10^{-7} m\ kg\ s^{-2} A^{-2}$)

(A) $\frac{250}{\pi}$ **(B)** $\frac{625}{\pi}$

(C) $\frac{2500}{\pi}$ **(D)** $\frac{5000}{\pi}$

9. The intensity I of an EM wave propagating in vacuum is given in terms of the rms value of the electric field and the rms value of the magnetic field as:

(A) $I = \sqrt{\frac{\varepsilon_0}{\mu_0}} E_{rms}^2$ **(B)** $I = \sqrt{\frac{\mu_0}{\varepsilon_0}} B_{rms}^2$

(C) Both (A) and (B) **(D)** Neither (A) nor (B)

10. A plane electromagnetic wave,

$E_z = 100\cos(6\times 10^8 t + 4x) V/m$

Propagates in a medium of refractive index :

(A) 1.5 **(B)** 2.0 **(C)** 2.4 **(D)** 4.0

11. An electromagnetic wave is propagating along the +Z direction. Then, the respective directions along which the electric field and magnetic field of this wave oscillate CANNOT be along the unit vectors:

(A) $(-\hat{i})$ and $(-\hat{j})$ **(B)** $\left(\frac{-\hat{i}-\hat{j}}{\sqrt{2}}\right)$ and $\left(\frac{\hat{i}-\hat{j}}{\sqrt{2}}\right)$

(C) $(-\hat{j})$ and $\hat{i}$ **(D)** $\left(\frac{-\hat{i}+\hat{j}}{\sqrt{2}}\right)$ and $\left(\frac{\hat{i}+\hat{j}}{\sqrt{2}}\right)$

12. The electric field part of an electromagnetic wave in a medium is represented by $E_x = 0$,

$E_y = 2.5\frac{N}{C}\cos\left[\left(2\pi\times 10^6 \frac{rad}{s}\right)t - \left(\pi\times 10^{-2}\frac{rad}{m}\right)x\right]$; $E_z = 0$. The wave is:

(A) Moving along X-direction with frequency $10^6 Hz$ and wave length 100 m

(B) Moving along X-direction with frequency $10^6 Hz$ and wavelength 200 m

(C) Moving along – X-direction with frequency $10^6 Hz$ and wavelength 200 m

(D) Moving along Y-direction with frequency $2\pi\times 10^6$ and wavelength 200 m

13. An electromagnetic wave passes from vacuum into a non-magnetic medium of relative permittivity $\varepsilon_r = 4$.

Which of these options is correct?

(A) wavelength is doubled and the frequency remains unchanged

(B) wavelength is doubled and frequency becomes half

(C) wavelength is halved and frequency remains unchanged

(D) wavelength and frequency both remains unchanged

14. A radiation of energy E falls normally on a perfectly reflecting surface. The momentum transferred to the surface is:

(A) $\frac{E}{c}$ **(B)** $\frac{2E}{c}$ **(C)** Ec **(D)** $\frac{E}{c^2}$

15. Which of the following radiations has the least wavelength?

(A) γ-rays **(B)** Ultraviolet **(C)** Microwaves **(D)** X-rays

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1. An electromagnetic wave of frequency $\upsilon = 3.0\ MHz$ passes from vacuum into a dielectric medium with permittivity $\varepsilon = 4.0$. Then **[2004]**

(A) wavelength is doubled and the frequency remains unchanged
(B) wavelength is doubled and frequency becomes half
(C) wavelength is halved and frequency remains unchanged
(D) wavelength and frequency both remain unchanged

2. 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: **[2006]**

(A) $3.3 \times 10^{-3}\ J/m^3$ **(B)** $4.58 \times 10^{-6}\ J/m^3$ **(C)** $6.37 \times 10^{-9}\ J/m^3$ **(D)** $81.35 \times 10^{-12}\ J/m^3$

3. This question has Statement-1 and Statement-2. Of the four choice given after the statements, choose the one that best describes the two statements. **[2013]**

Statements -1: Out of the radio waves and microwaves, the radio waves undergo more diffraction.
Statements - 2: Radio waves have greater frequency compared to microwaves.

(A) Statement 1 is true, Statement 2 is true, Statement 2 is the correct explanation of Statement-1
(B) Statement 1 is false, Statements 2 is true
(C) Statement 1 is true, Statement 2 is false
(D) Statement 1 is true, Statement 2 is true, Statement 2 is not the correct explanation of Statement-1

4. Which of the following modulated signal has best noise-tolerance? **[2013]**

(A) long-wave **(B)** short wave **(C)** medium-wave **(D)** amplitude-modulated

5. A plane electromagnetic wave in a non magnetic dielectric medium is given by $\vec{E} = \vec{E}_0(4 \times 10^{-7} \times -50t)$ with distance being in meter and time in seconds. The dielectric constant of the medium is: **[2013]**

(A) 2.4 **(B)** 5.8 **(C)** 8.2 **(D)** 4.8

6. Select the correct statement from the following: **[2013]**

(A) Electromagnetic waves cannot travel in vacuum
(B) Electromagnetic waves are longitudinal waves
(C) Electromagnetic waves are produced by charges moving with uniform velocity
(D) Electromagnetic waves carry both energy and momentum as they propagate through space

7. The magnetic field in a travelling electromagnetic wave has a peak value of 20 nT. The peak value of electric field strength is: **[2013]**

(A) 6 V/m **(B)** 9 V/m **(C)** 12 V/m **(D)** 3 V/m

8. A red LED emits light of 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: **[2014]**

(A) 2.45 V/m **(B)** 5.48 V/m **(C)** 7.75 V/m **(D)** 1.73 V/m

9. During the propagation of electromagnetic waves in a medium : **[2014]**

(A) Electric energy density is equal to the magnetic energy density
(B) Both electric and magnetic energy densities are zero
(C) Electric energy density is double of the magnetic energy density
(D) Electric energy density is half of the magnetic energy density

10. Match the List-I (Phenomenon associated with electromagnetic radiation) with List-II (part of electromagnetic spectrum) and select the correct code from the choices given below the lists: **[2014]**

	List – I		List - II
I.	Doublet of sodium	A	Visible radiation
II.	Wavelength corresponding to temperature associated with the isotropic radiation filling all space	B	Microwave
III.	Wavelength emitted by atomic hydrogen in interstellar space	C	Short radio wave
IV.	Wavelength of radiation arising from two close levels in energy of hydrogen spectra	D	X-rays

(A) (I) – (A), (II), - (B), (III) – (C), (IV) – (C) **(B)** (I) – (A), (II), - (B), (III) – (B), (IV) – (C)
(C) (I) – (B), (II), - (A), (III) – (D), (IV) – (A) **(D)** (I) – (D), (II), - (C), (III) – (A), (IV) – (B)

11. An electromagnetic wave of frequency 1×10^{14} hertz is propagating along z-axis. The amplitude of electric field is 4 V/m. If $\epsilon_0 = 8.8\times10^{-12} C^2 / N\text{-}m^2$, then average energy density of electric field will be: **[2014]**

(A) $35.2\times10^{-13}\ J/m^3$ **(B)** $35.2\times10^{-12}\ J/m^3$
(C) $35.2\times10^{-11}\ J/m^3$ **(D)** $35.2\times10^{-10}\ J/m^3$

12. An EM wave from air enters a medium. The electric fields are:

$\vec{E}_1 = E_{01}\hat{x}\cos\left[2\pi v\left(\frac{z}{c}-t\right)\right]$ in air and

$\vec{E}_2 = E_{02}\hat{x}\cos[k(2z-ct)]$ in medium, where the wave number k and frequency v refer to their values in air. The medium is non-magnetic. If ϵ_{r_1} *and* ϵ_{r_2} refer to relative permittivity's of air and medium respectively, which of the following options is correct? **[2018]**

(A) $\frac{\epsilon_{r_1}}{\epsilon_{r_2}} = \frac{1}{2}$ **(B)** $\frac{\epsilon_{r_1}}{\epsilon_{r_2}} = 4$ **(C)** $\frac{\epsilon_{r_1}}{\epsilon_{r_2}} = 2$ **(D)** $\frac{\epsilon_{r_1}}{\epsilon_{r_2}} = \frac{1}{4}$

13. The energy associated with electric field is (U_E) and with magnetic field is (U_B) for an electromagnetic wave in free space. Then: **[2019]**

(A) $U_E > U_B$ **(B)** $U_E = U_B$ **(C)** $U_E = \frac{U_B}{2}$ **(D)** $U_E < U_B$

14. 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: **[2019]**

(A) $6.3\times10^{-8}\hat{k}T$ **(B)** $18.9\times10^{-8}\hat{k}T$ **(C)** $2.1\times10^{-8}\hat{k}T$ **(D)** $18.9\times10^{8}\hat{k}T$

15. The electric field of plane polarized electromagnetic wave in free space at time t = 0 is given by an expression $\vec{E}(x,y) = 10\hat{j}\cos[(6x+8z)]$. The magnetic field $\vec{B}(x,z,t)$ is given by : (c is the velocity of light) **[2019]**

(A) $\frac{1}{c}(6\hat{k}+8\hat{i})\cos[(6x-8z+10ct)]$ **(B)** $\frac{1}{c}(6\hat{k}+8\hat{i})\cos[(6x+8z-10ct)]$
(C) $\frac{1}{c}(6\hat{k}-8\hat{i})\cos[(6x+8z-10ct)]$ **(D)** $\frac{1}{c}(6\hat{k}-8\hat{i})\cos[(6x+8z+10ct)]$

16. If the magnetic field of a plane electromagnetic wave is given by (The speed of light = $3\times10^8 m/s$)

$$B = 100\times10^{-6}\sin\left[2\pi\times2\times10^{15}\left(t-\frac{x}{c}\right)\right]$$

Then the maximum electric filed associated with it is: **[2019]**

(A) $3\times10^4 N/C$ **(B)** $6\times10^4 N/C$ **(C)** $4.5\times10^4 N/C$ **(D)** $4\times10^4 N/C$

17. A 27mW 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 $\epsilon_0 = 9\times10^{-12}$ SI unit, Speed of light $c = 3\times10^8 m/s$] **[2019]**

(A) $1kV/m$ **(B)** $0.7kV/m$ **(C)** $2kV/m$ **(D)** $1.4kV/m$

18. An electromagnetic wave of intensity $50Wm^{-2}$ 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: **[2019]**

(A) $\left(\sqrt{n},\sqrt{n}\right)$ **(B)** $\left(\sqrt{n},\frac{1}{\sqrt{n}}\right)$ **(C)** $\left(\frac{1}{\sqrt{n}},\frac{1}{\sqrt{n}}\right)$ **(D)** $\left(\frac{1}{\sqrt{n}},\sqrt{n}\right)$

19. 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 closest to: **[2019]**

(A) $10^{-4}T$ **(B)** $10^{-2}T$ **(C)** $10^2 T$ **(D)** $1\ T$

20. 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 propagating in the glass medium will be: **[2019]**

(A) 10 V/m **(B)** 30 V/m **(C)** 24 V/m **(D)** 6 V/m

21. 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: **[2019]**

(A) $6\times10^{-8}T$ along *x*-direction **(B)** $2\times10^{-8}T$ along *y*-direction

(C) $2\times10^{-8}T$ along *z*-direction **(D)** $6\times10^{-8}T$ along *z*-direction

22. The magnetic field of an electromagnetic wave is given by:

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

The associated electric field will be: **[2019]**

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

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

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

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

23. The magnetic field of a plane electromagnetic wave is given by: $\vec{B} = B_0\,\hat{i}[\cos(kz - \omega t)] + B_1\hat{j}\cos(kz + \omega t)$ where $B_0 = 3\times10^{-5}T$ and $B_1 = 2\times10^{-6}T$. The rms value of the force experienced by a stationary charge $Q = 10^{-4}C$ at $z = 0$ is closed to: **[2019]**

(A) 0.1 N **(B)** $3\times10^{-2}N$ **(C)** 0.6 N **(D)** 0.9 N

24. 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: **[2019]**

(A) $\vec{B} = \frac{E_0}{C}\hat{j}\sin(kz)\sin(\omega t)$ **(B)** $\vec{B} = \frac{E_0}{C}\hat{k}\sin(kz)\cos(\omega t)$

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

25. A plane electromagnetic wave having a frequency $\upsilon = 23.9\,GHz$ 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? **[2019]**

(A) $\vec{B} = 60\sin(0.5\times10^3x + 1.5\times10^{11}t)\hat{k}$ **(B)** $\vec{B} = 2\times10^7\sin(0.5\times10^3z + 1.5\times10^{11}t)\hat{i}$

(C) $\vec{B} = 2\times10^{-7}\sin(1.5\times10^2x + 0.5\times10^{11}t)\hat{j}$ **(D)** $\vec{B} = 2\times10^{-7}\sin(0.5\times10^3z - 1.5\times10^{11}t)\hat{i}$

26. 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 propagation $\hat{s}$, is: **[2019]**

(A) $\hat{s} = \frac{3\hat{i} - 4\hat{j}}{5}$ **(B)** $\hat{s} = \frac{4\hat{j} - 3\hat{k}}{5}$ **(C)** $\hat{s} = \frac{-4\hat{k} + 3\hat{j}}{5}$ **(D)** $\hat{s} = \left(\frac{-3\hat{j} + 4\hat{k}}{5}\right)$

27. If the magnetic field in a plane electromagnetic wave is given by $\vec{B} = 3\times10^{-8}\sin(1.6\times10^3x + 48\times10^{10}t)\hat{j}T$, then what will be expression for electric field? **[2020]**

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

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

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

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

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 $c = 3\times10^8ms^{-1}$) **[2020]**

(A) $15\hat{i}V/m$ **(B)** $-15\hat{i}V/m$

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

29. 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 (there B_0 is an appropriate constant): **[2020]**

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

30. 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: **[2020]**

(A) zero
(B) antiparallel to $\frac{\hat{i}+\hat{j}}{\sqrt{2}}$
(C) parallel to $\hat{k}$
(D) parallel to $\frac{\hat{i}+\hat{j}}{\sqrt{2}}$

31. 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 $\vec{E}_2=\vec{E}_0\hat{k}\cos(\omega t-ky)$
At t = 0, a particle of charge q is at origin with a velocity $\vec{v}=0.8c\hat{j}$ (c is the speed of light in vacuum). The instantaneous force experienced by the particle is: **[2020]**

(A) $E_{0q}(-0.8\hat{i}-\hat{j}+0.4\hat{k})$
(B) $E_{0q}(0.8\hat{i}+\hat{j}+0.2\hat{k})$
(C) $E_{0q}(-0.8\hat{i}+\hat{j}+\hat{k})$
(D) $E_{0q}(0.4\hat{i}-3\hat{j}+0.8\hat{k})$

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? **[2020]**

(A) $\frac{1}{\sqrt{5}}\left(2\hat{i}+\hat{j}\right)$
(B) $\frac{1}{\sqrt{2}}\left(\hat{j}+\hat{k}\right)$
(C) $\frac{1}{\sqrt{2}}\left(\hat{i}+\hat{j}\right)$
(D) $\frac{1}{\sqrt{5}}\left(\hat{i}+2\hat{j}\right)$

33. The magnetic field of a plane electromagnetic wave is
$\vec{B}=3\times10^{-8}\sin[200\ \pi(y+ct)]\hat{i}T$
Where $c=3\times10^{8}ms^{-1}$ is the speed of light. The corresponding electric field is: **[2020]**

(A) $\vec{E}=-9\sin[200\ \pi(y+ct)]\hat{k}\ V/m$
(B) $\vec{E}=3\times10^{-8}\sin[200\ \pi(y+ct)]\hat{k}\ V/m$
(C) $\vec{E}=-10^{-6}\sin[200\ \pi(y+ct)]\hat{k}\ V/m$
(D) $\vec{E}=9\sin[200\ \pi(y+ct)]\hat{k}\ V/m$

34. 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: **[2020]**

(A) $\vec{B} = E_0 \sqrt{\mu_0 \epsilon_0} \cos(kx)\hat{j}$ **(B)** $\vec{B} = \frac{E_0}{\sqrt{\mu_0 \epsilon_0}} \cos(kx)\hat{k}$

(C) $\vec{B} = E_0 \sqrt{\mu_0 \epsilon_0} \cos(kx)\hat{k}$ **(D)** $\vec{B} = \frac{E_0}{\sqrt{\mu_0 \epsilon_0}} \cos(kx)\hat{j}$

35. Choose the correct option relating wavelengths of different parts of electromagnetic wave spectrum: **[2020]**

(A) $\lambda_{visible} > \lambda_{x-ray} > \lambda_{radio\ waves} > \lambda_{micro\ waves}$

(B) $\lambda_{radio\ waves} > \lambda_{microwaves} > \lambda_{visible} > \lambda_{x\ rays}$

(C) $\lambda_{visible} < \lambda_{micro\ waves} < \lambda_{radio\ waves} < \lambda_{x\ rays}$

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

36. The electric field of a plane electromagnetic wave is given by $\vec{E} = E_0(\hat{x} + \hat{y})\sin(kz - \omega t)$. Its magnetic field will be given by: **[2020]**

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

(C) $\frac{E_0}{c}(\hat{x} - \hat{y})\cos(kz - \omega t)$ **(D)** $\frac{E_0}{c}(\hat{x} + \hat{y})\sin(kz - \omega t)$

37. An electron is constrained to move along the y-axis with a speed of 0.1 c (c is the speed of light) in the presence of electromagnetic wave, whose electric field is $\vec{E} = 30\hat{j}\sin\left(1.5 \times 10^7 t - 5 \times 10^{-2} x\right) V/m$. The maximum magnetic force experienced by the electron will be: **[2020]**
(given $c = 3 \times 10^8 ms^{-1}$ and electron charge = $1.6 \times 10^{-19} C$)

(A) $4.8 \times 10^{-19} N$ **(B)** $2.4 \times 10^{-18} N$

(C) $3.2 \times 10^{-18} N$ **(D)** $1.6 \times 10^{-19} N$

38. The correct match between the entries in column I and column II are : **[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

(A) (a)-(iii), (b)-(ii), (c)-(i), (d)-(iv) **(B)** (a)-(ii), (b)-(i), (c)-(iv), (d)-(iii)

(C) (a)-(iv), (b)-(ii), (c)-(i), (d)-(iii) **(D)** (a)-(i), (b)-(iii), (c)-(iv), (d)-(ii)

39. 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 ____________. **[2020]**

$\left(\varepsilon_0 = 8.86\times10^{-12}C^2Nm^{-2}; c = 3\times10^8 ms^{-1}\right)$

40. For a plane electromagnetic wave, the magnetic field at a point x and time t is $\vec{B}(x,t) = \left[1.2\times10^{-7}\ \sin\left(0.5\times10^3 x + 1.5\times10^{11}t\right)\hat{k}\right]T$. The instantaneous electric field $\vec{E}$ corresponding to $\vec{B}$ is : $\left(speed\ of\ light\ c = 3\times10^8\ ms^{-1}\right)$ **[2020]**

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

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

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

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

41. A plane electromagnetic wave, has frequency of $2.0\times10^{10}Hz$ and its energy density is $1.02\times10^{-8}J/m^3$ in vacuum. The amplitude of the magnetic field of the wave is close to $\left(\frac{1}{4\pi\epsilon_0} = 9\times10^9\frac{Nm^2}{C^2}\right.$ and speed of light $= 3\times10^8\ ms^{-1}$): **[2020]**

(A) 160 nT **(B)** 150 nT **(C)** 190 nT **(D)** 180 nT