8 Electromagnetic Waves

Multiple Choice Questions (MCQs)

DIRECTIONS : *This section contains multiple choice questions. Each question has four choices (a), (b), (c) and (d) out of which only one is correct.*

1. A plane electromagnetic wave is incident on a material surface. If the wave delivers momentum p and energy E, then
(a) $p = 0, E = 0$ (b) $p \neq 0, E \neq 0$
(c) $p \neq 0, E = 0$ (d) $p = 0, E \neq 0$

2. A new system of unit is evolved in which the values of μ_0 and ϵ_0 are 2 and 8 respectively. Then the speed of light in this system will be
(a) 0.25 (b) 0.5 (c) 0.75 (d) 1

3. The velocity of all radio waves in free space is 3×10^8 m/s. The frequency of a radio wave of wavelength 150 m is
(a) 20 kHz (b) 2 kHz
(c) 2 MHz (d) 1 MHz

4. If a source is transmitting electromagnetic wave of frequency 8.2×10^6 Hz, then wavelength of the electromagnetic waves transmitted from the source will be
(a) 36.6 m (b) 40.5 m (c) 42.3 m (d) 50.9 m

5. In an electromagnetic wave, the direction of the magnetic induction $\vec{B}$ is
(a) parallel to the electric field $\vec{E}$
(b) perpendicular to the electric field $\vec{E}$
(c) antiparallel to the Poynting vector $\vec{S}$
(d) random

6. A plane electromagnetic wave travels in free space along x-axis. At a particular point in space, the electric field along y-axis is 9.3V m^{-1}. The magnetic induction (B) along z-axis is
(a) 3.1×10^{-8} T (b) 3×10^{-5} T
(c) 3×10^{-6} T (d) 9.3×10^{-6} T

7. In an apparatus, the electric field was found to oscillate with an amplitude of 18 V/m. The magnitude of the oscillating magnetic field will be
(a) 4×10^{-6} T (b) 6×10^{-8} T
(c) 9×10^{-9} T (d) 11×10^{-11} T

8. An electromagnetic wave of frequency $f = 3$ MHz passes from vacuum into a dielectric medium with permittivity $\varepsilon = 4$. Then
(a) wavelength and frequency both become half.
(b) wavelength is doubled and frequency remains unchanged.
(c) wavelength and frequncy both remain unchanged.
(d) wavelength is halved and frequency remains unchanged.

9. The electromagnetic waves do not transport_____.
(a) energy (b) charge
(c) momentum (d) information

10. Which of the following is/are true/false for electromagnetic waves?
I. They transport energy.
II. They have momentum.
III. They travel with speed of light through vaccum.
(a) T,F,T (b) F,T,F
(c) T,T,T (d) T,T,F

11. Radio waves and visible light in vacuum have
(a) same velocity but different wavelength
(b) same frequency
(c) different velocity
(d) same wavelength

12. The waves which are electromagnetic in nature are
(a) sound waves and light waves
(b) water waves and radio waves
(c) light waves and X-rays
(d) sound waves and water waves

13. Select the true/false from the following statement(s)
I. Wavelength of microwaves is greater than that of ultraviolet rays.
II. The frequency of infrared rays is lesser than that of ultraviolet rays.
III. The frequency of microwaves is lesser than that of infrared rays.
IV. Gamma ray has largest frequency in the electromagnetic spectrum.
(a) T,T,F,F (b) F,T,T,F (c) F,F,T,T (d) T,T,T,T

14. Photons of an electromagnetic radiation has an energy 11 keV each. Then it belongs to _____region of electromagnetic spectrum.
(a) X-ray (b) Ultraviolet
(c) Infrared (d) Visible

15. One requires 11 eV of energy to dissociate a carbon monoxide molecule into carbon and oxygen atoms. The minimum frequency of the appropriate electromagnetic radiation to achieve the dissociation lies in
(a) visible region (b) infrared region
(c) ultraviolet region (d) microwave region

16. A linearly polarised electromagnetic wave given as $E = E_0\hat{i}\cos(kz - \omega t)$ is incident normally on a perfectly reflecting infinite wall at z = a. Assuming that the material of the wall is optically inactive, the reflected wave will be given as
(a) $E_r = E_0\hat{i}(kz - \omega t)$
(b) $E_r = E_0\hat{i}\cos(kz + \omega t)$
(c) $E_r = -E_0\hat{i}\cos(kz + \omega t)$
(d) $E_r = E_0\hat{i}\sin(kz - \omega t)$

17. Light with an energy flux of 20 W/cm^2 falls on a non-reflecting surface at normal incidence. If the surface has an area of 30 cm^2, the total momentum delivered (for complete absorption) during 30 min is
(a) 36×10^{-5} kg-m/s (b) 36×10^{-4} kg-m/s
(c) 108×10^{4} kg-m/s (d) 1.08×10^{7} kg-m/s

18. The electric field intensity produced by the radiations coming from 100 W bulb at a 3 m distance is E. The electric field intensity produced by the radiations coming from 50 W bulb at the same distance is
(a) $\frac{E}{2}$ (b) 2E (c) $\frac{E}{\sqrt{2}}$ (d) $\sqrt{2}E$

19. If E and B represent electric and magnetic field vectors of the electromagnetic wave, the direction of propagation of electromagnetic wave is along
(a) E (b) B (c) B × E (d) E × B

20. The ratio of contributions made by the electric field and magnetic field components to the intensity of an EM wave is
(a) c : 1 (b) c^2 : 1 (c) 1 : 1 (d) $\sqrt{c}$: 1

21. An EM wave radiates outwards from a dipole antenna, with E_0 as the amplitude of its electric field vector. The electric field E_0 which transports significant energy from the source falls off as
(a) $\frac{1}{r^3}$ (b) $\frac{1}{r^2}$
(c) $\frac{1}{r}$ (d) remains constant

22. An electromagnetic wave travels in vacuum along z-direction $E = (E_1\hat{i} + E_2\hat{j})\cos(kz - \omega t)$. Choose the correct options from the following
(a) The associated magnetic field is given as
$B = \frac{1}{c}(E_1\hat{i} - E_2\hat{j})\cos(kz - \omega t)$
(b) The associated magnetic field is given as
$B = \frac{1}{c}(E_1\hat{i} - E_2\hat{j})\cos(kz - \omega t)$
(c) The given electromagnetic field is circularly polarised
(d) The given electromagnetic wave is plane polarised

23. An electromagnetic wave going through vacuum is described by $E = E_0\sin(kx - \omega t)$; $B = B_0 \sin(kx - \omega t)$. Which of the following equations is true?
(a) $E_0k = B_0\omega$ (b) $E_0\omega = B_0k$
(c) $E_0B_0 = \omega k$ (d) None of these

24. The ozone layer in the atmosphere absorbs
(a) only the radiowaves
(b) only the visible light
(c) only the γ-rays
(d) X-rays and ultraviolet rays

25. The electric and magnetic field of an electro-magnetic wave are
(a) in opposite phase and perpendicular to each other
(b) in opposite phase and parallel to each other
(c) in phase and perpendicular to each other
(d) in phase and parallel to each other.

26. When electromagnetic waves enter the ionised layer, then the relative permittivity i.e. dielectric constant of the layer.
(a) does not change
(b) appears to increase
(c) appears to decrease
(d) sometimes appears to increase and sometimes to decrease

27. The electromagnetic waves travel with a velocity
(a) equal to velocity of sound
(b) equal to velocity of light
(c) less than velocity of light
(d) None of these

28. The speed of electromagnetic wave in vacuum depends upon the source of radiation. It
(a) increases as we move from γ-rays to radio waves
(b) decreases as we move from γ-rays to radio waves
(c) is same for all of them
(d) None of these

29. The wavelength of the matter waves is independent of
(a) charge (b) momentum
(c) velocity (d) mass

30. An electromagnetic wave is propagating along Y-axis. Then
(a) oscillating electric field is along X-axis and oscillating magnetic field is along Y-axis
(b) oscillating electric field is along Z-axis and oscillating magnetic field is along X-axis
(c) both oscillating electric and magnetic fields are along Y-axis, but phase difference between them is 90°
(d) both oscillating electric and magnetic fields are mutually perpendicular in arbitrary direction

31. When an electromagnetic wave with poynting vector is $\vec{s}$ is incident an a perfectly absorbing surface, then radiation pressure on surface is

(a) $P = \frac{\vec{S}}{C}$ (b) $P = \frac{\vec{S}}{SC}$ (c) $\frac{2\vec{S}}{3C}$ (d) $\vec{S}C$

32. An electromagnetic wave passes through space and its equation is given by $E = E_0 \sin(\omega t - kx)$ where E is electric field. Energy density of electromagnetic wave in space is

(a) $\frac{1}{2}\varepsilon_0 E_0^2$ (b) $\frac{1}{4}\varepsilon_0 E_0^2$ (c) $\varepsilon_0 E_0^2$ (d) $2\varepsilon_0 E_0^2$

33. A plane electromagnetic wave is incident on a plane surface of area A, normally and is perfectly reflected. If energy E strikes the surface in time t then force exerted on the surface is (c = speed of light)

(a) $\frac{2E}{Atc}$ (b) $\frac{E}{2c}$ (c) $\frac{2E}{ct}$ (d) zero

34. Which of the following type of radiations are radiated by an oscillating electric charge?

(a) Electric (b) Magnetic
(c) Thermoelectric (d) Electromagnetic

35. The wave impendance of free space is

(a) zero (b) 376.6 Ω
(c) 33.66 Ω (d) 3.76 Ω

36. The pressure exerted by an electromagnetic wave of intensity I (watts/m^2) on a nonreflecting surface is [c is the velocity of light]

(a) Ic (b) Ic^2 (c) I/c (d) I/c^2

37. Intensity of electromagnetic wave will be

(a) $I = c\mu_0 B_0^2 / 2$ (b) $I = c\varepsilon_0 B_0^2 / 2$

(c) $I = B_0^2 / c\mu_0$ (d) $I = E_0^2 / 2c\varepsilon_0$

38. The electric field of an electromagnetic wave travelling through vaccum is given by the equation $E = E_0 \sin(kx - \omega t)$. The quantity that is independent of wavelength is

(a) $k\omega$ (b) $\frac{k}{\omega}$ (c) $k^2\omega$ (d) ω

39. Electromagnetic radiation of highest frequency is

(a) infrared radiations (b) visible radiation
(c) radio waves (d) γ-rays

40. Which of the following electromagnetic waves has minimum frequency ?

(a) Microwaves (b) Audible waves
(c) Ultrasonic wave (d) Radiowaves

41. Which of the following shows green house effect ?

(a) Ultraviolet rays (b) Infrared rays
(c) X-rays (d) None of these

42. Which of the following waves have the maximum wavelength

(a) X-rays (b) I.R. rays
(c) UV rays (d) Radio waves

43. Which rays are not the portion of electromagnetic spectrum ?

(a) X-rays (b) Microwaves
(c) α-rays (d) Radio waves

44. Which radiation in sunlight, causes heating effect ?

(a) Ultraviolet (b) Infrared
(c) Visible light (d) All of these

45. Microwave oven acts on the principle of :

(a) giving rotational energy to water molecules
(b) giving translational energy to water molecules
(c) giving vibrational energy to water molecules
(d) transferring electrons from lower to higher energy levels in water molecule

46. If v_s, v_x and v_m are the speed of soft gamma rays, X-rays and microwaves respectively in vacuum, then

(a) $v_s > v_x > v_m$ (b) $v_s < v_x < v_m$
(c) $v_s > v_x < v_m$ (d) $v_s = v_x = v_m$

47 We consider the radiation emitted by the human body. Which of the following statements is true?

(a) the radiation emitted lies in the ultraviolet region and hence is not visible.
(b) the radiation emitted is in the infra-red region.
(c) the radiation is emitted only during the day.
(d) the radiation is emitted during the summers and absorbed during the winters.

48. In which one of the following regions of the electromagnetic spectrum will the vibrational motion of molecules give rise to absorption ?

(a) Ultraviolet (b) Microwaves
(c) Infrared (d) Radio waves

49. The range of wavelength of the visible light is

(a) 10 Å to 100 Å (b) 4,000 Å to 8,000 Å
(c) 8,000 Å to 10,000Å (d) 10,000 Å to 15,000 Å

50. If microwaves, X rays, infrared, gamma rays, ultra-violet, radio waves and visible parts of the electromagnetic spectrum are denoted by M, X, I, G, U, R and V then which of the following is the arrangement in ascending order of wavelength ?

(a) R, M, I, V, U, X and G
(b) M, R, V, X, U, G and I
(c) G, X, U, V, I, M and R
(d) I, M, R, U, V, X and G

51. Which of the following is the infrared ray wavelength?

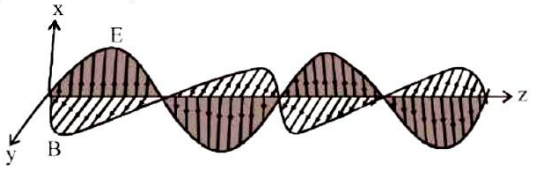
(a) 10^{-4} cm (b) 10^{-5} cm
(c) 10^{-6} cm (d) 10^{-7} cm

Case/Passage Based Questions

DIRECTIONS : *Study the given Case/Passage and answer the following questions.*

Case/Passage-I

Electromagnetic waves are constituted by varying or oscillating electric and magnetic fields. The electric and magnetic fields are perpendicular to each other and are also perpendicular to the direction of propagation of the wave. Hence **electromagnetic waves are transverse in nature**. E is the envelope of electric intensity vector and B is the envelope of magnetic intensity vector.



52. In an electromagnetic wave, the direction of the magnetic induction $\vec{B}$ is
(a) parallel to the electric field $\vec{E}$
(b) perpendicular to the electric field $\vec{E}$
(c) antiparallel to the Poynting vector $\vec{S}$
(d) random

53. The polarisation of electromagnetic wave is in
(a) the directions of electric and magnetic field
(b) the directions of electric field
(c) the direction of magnetic field
(d) can not be polarized

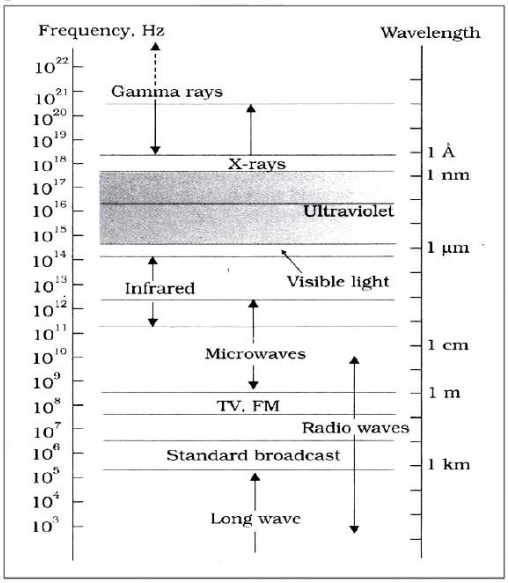
54. In an electromagnetic wave
(a) power is transmitted along the magnetic field
(b) power is transmitted along the electric field
(c) power is equally transferred along the electric and magnetic fields
(d) power is transmitted in a direction perpendicular to both the fields

55. Which of the following has/have zero average value in a plane electromagnetic wave?
(a) Both magnetic and electric field
(b) Electric field only
(c) Magnetic energy
(d) Electric energy

56. 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

Case/Passage-II

The electromagnetic waves have continuous wavelength starting from short gamma rays to long radio waves. The orderly distribution of wavelength of e.m. waves is called electromagnetic spectrum. The waves according to their increasing order of wavelength or decreasing order of frequency are arranged as follows:



57 Which one of the following has the maximum energy?
(a) Radio waves (b) Infrared rays
(c) Ultraviolet rays (d) Micro waves

58. The velocity of all radio waves in free space is 3×10^8 m/s. The frequency of a radio wave of wavelength 150m is
(a) 20kHz (b) 2kHz (c) 2MHz (d) 1MHz

59. Ozone layer above earth's atmosphere will not
(a) prevent infrared radiations from sun reaching earth.
(b) prevent infra red radiations originated from earth from escaping earth's atmosphere.
(c) prevent ultraviolet rays from sun.
(d) reflect back radio waves.

60. If $\lambda = 10\,\text{Å}$ then it corresponds to
(a) infrared (b) microwaves
(c) ultraviolet (d) X-rays

61. The electromagnetic radiation used in food processing sterilizing agent is
(a) microwaves (b) UV rays
(c) gamma rays (d) radio waves

Case/Passage-III

The electric and magnetic field of a sinusoidal plane electromagnetic wave propagating in the positive x-direction can also be written as

$E = E_m \sin(kx - \omega t)$; $B = B_m \sin(kx - \omega t)$

where **ω is the angular frequency of the wave** and **k is wave number** which are given by $\omega = 2\pi f$ and $k = \dfrac{2\pi}{\lambda}$

62. For plane electromagnetic waves propagating in the z-direction, which one of the following combination gives the correct possible direction for $\vec{E}$ and $\vec{B}$ field respectively?
(a) $(2\hat{i}+3\hat{j})$ and $(\hat{i}+2\hat{j})$
(b) $(-2\hat{i}-3\hat{j})$ and $(3\hat{i}-2\hat{j})$
(c) $(3\hat{i}+4\hat{j})$ and $(4\hat{i}-3\hat{j})$
(d) $(\hat{i}+2\hat{j})$ and $(2\hat{i}-\hat{j})$

63. A plane electromagnetic wave propagating in the X-direction has wavelength of 6.0 mm. The electric field is in the Y-direction and its maximum magnitude is 33 Vm^{-1}. The equation for the electric field as a function of x and t is
(a) $11\sin\pi\left(t-\dfrac{x}{c}\right)$ (b) $33\sin\left[\pi\times10^{11}\left(t-\dfrac{x}{c}\right)\right]$
(c) $33\sin\pi\left(t-\dfrac{x}{c}\right)$ (d) $11\sin\left[\pi\times10^{11}\left(t-\dfrac{x}{c}\right)\right]$

64. The magnetic field in the plane electromagnetic field is given by: $B_y = 2\times10^{-7}\sin(0.5\times10^3 z + 1.5\times10^{11} t)$ T
The expression for the electric field may be given by
(a) $E_y = 2\times10^{-7}\sin(0.5\times10^3 z + 1.5\times10^{11} t)$ V/m
(b) $E_x = 2\times10^{-7}\sin(0.5\times10^3 z + 1.5\times10^{11} t)$ V/m
(c) $E_y = 60\sin(0.5\times10^3 z + 1.5\times10^{11} t)$ V/m
(d) $E_x = 60\sin(0.5\times10^3 z + 1.5\times10^{11} t)$ V/m

65. Suppose that the electric field amplitude of an em wave is $E_o = 120$ N/C and that its frequency is $\upsilon = 50$ Hz, then

(a) $B_o = 200$ T (b) $\omega = r \times 10^8$ rad/s

(c) $k = \left(\pi/4\right)$ rad/m (d) $\lambda = 92$m

66. The amplitude of the electric field if the intensity of a plane electromagnetic wave is given as 2.0 Wm^{-2} is

(a) 38.8 NC^{-1} (b) 48.3 NC^{-1}

(c) 50.2 NC^{-1} (d) 68.8 NC^{-1}

Assertion & Reason

DIRECTIONS : *Each of these questions contains an assertion followed by reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*

(a) If both **Assertion** and **Reason** are **correct** and the Reason is the **correct explanation** of the Assertion.

(b) If both **Assertion** and **Reason** are correct but Reason is **not the correct explanation** of the Assertion.

(c) If the **Assertion** is **correct** but **Reason** is **incorrect**.

(d) If the **Assertion** is **incorrect** but the **Reason** is **correct**.

67. **Assertion :** Electromagnetic waves do not require medium for their propagation.

Reason : They can't travel in vacuum

68. **Assertion :** Electromagnetic waves exert radiation pressure.

Reason : Electromagnetic waves have momentum.

69. **Assertion :** The basic difference between various types of electromagnetic waves lies in their wavelength or frequencies.

Reason : Electromagnetic waves travel through vacuum with the same speed.

70. **Assertion :** Infrared radiation plays an important role in maintaining the average temperature of earth.

Reason : Infrared radiations are sometimes referred to as heat waves.

71. **Assertion :** Ultraviolet radiations of higher frequency waves are dangerous to human being.

Reason : Ultraviolet radiation are absorbed by the ozone layer in atmosphere

Match the Following

DIRECTIONS : *Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in column-I have to be matched with statements (1, 2, 3, 4) in column-II.*

72. Match the following according to their uses from Column I and Column II.

	Column I		**Column II**
(A)	Ultraviolet rays	(1)	in satellite signals
(B)	Infrared rays	(2)	night vison and security cameras
(C)	Microwave	(3)	television and cellular phones
(D)	Radio wave	(4)	detecting forged bank notes

(a) (A) → (4) ; (B) → (2) ; (C) → (1) ; (D) → (3)

(b) (A) → (2) ; (B) → (2) ; (C) → (4) ; (D) → (3)

(c) (A) → (4) ; (B) → (3) ; (C) → (2) ; (D) → (1)

(d) (A) → (2) ; (B) → (1) ; (C) → (4) ; (D) → (3)

73. Various electromagnetic waves are given in column I and various frequency ranges in column II. Match the two columns.

	Column I		**Column II**
(A)	Radio waves	(1)	3×10^{16} Hz – 3×10^{19} Hz
(B)	γ–rays	(2)	300 MHz – 300 GHz
(C)	Microwaves	(3)	$> 10^{19}$ Hz
(D)	X-rays	(4)	300 GHz – 3KHz

(a) (A) → (2) ; (B) → (5) ; (C) → (3) ; (D) → (4)

(b) (A) → (2) ; (B) → (2) ; (C) → (4) ; (D) → (3)

(c) (A) → (4) ; (B) → (3) ; (C) → (2) ; (D) → (1)

(d) (A) → (2) ; (B) → (1) ; (C) → (4) ; (D) → (3)

Fill in the Blanks

DIRECTIONS : *Complete the following statements with an appropriate word / term to be filled in the blank space(s).*

74. The average electric field of electromagnetic waves in certain region of free space is 9×10^{-4} NC^{-1}. Then the average magnetic field in the same region is of the order of_____ T.

75. All components of the electromagnetic spectrum in vacuum have the same_____.

76. The wavelength of X-ray is of the order of_____.

77. In radar and satellite communication E.M. waves used of frequency range_____to_____ .

True / False

DIRECTIONS : *Read the following statements and write your answer as true or false.*

78. The velocity of electromagnetic waves depends on electric and magnetic properties of the medium.

79. Velocity of electromagnetic waves in free space is constant.

80. The basic difference between various types of electromagnetic waves lies in their wavelength or frequencies.

81. Electromagnetic waves travel through vacuum with different speed.

ANSWER KEY & SOLUTIONS

1. **(b)** An electromagnetic wave has both energy and momentum.

2. **(a)** The speed of light $c = \frac{1}{\sqrt{\mu_0\varepsilon_0}} = \frac{1}{\sqrt{2\times 8}} = \frac{1}{4} = 0.25$

3. **(c)** Velocity of electromagnetic waves in free space and wavelength are,

$v = 3\times10^8$ m/s and $\lambda = 150$ m

The frequency of radio waves is given by

$$f = \frac{v}{\lambda} = \frac{3\times10^8}{150} = 2\times10^6 \text{ Hz} = 2 \text{ MHz}$$

4. **(a)** Here, $\lambda = \frac{c}{f} = \frac{3\times10^8}{8.2\times10^6} = 36.6$ m

5. **(b)** In an electromagnetic wave the directions of magnetic induction is perpendicular to electric field.

6. **(a)** Velocity of light

$$c = \frac{E}{B} \Rightarrow B = \frac{E}{c} = \frac{9.3}{3\times10^8} = 3.1\times10^{-8}\text{ T}$$

7. **(b)** Here, $E_0 = 18$ V/m; $B_0 = ?$

$$B_0 = \frac{E_0}{c} = \frac{18}{3\times10^8} = 6\times10^{-8}\text{ T}$$

8. **(d)** The frequency of electromagnetic wave remains unchanged but the wavelength of electromagnetic wave changes when it passes from one medium to another.

$$c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$$

$$\therefore \quad c \propto \frac{1}{\sqrt{\varepsilon_0}} \text{ and } v \propto \frac{1}{\sqrt{\varepsilon}}$$

$$\therefore \quad \frac{c}{v} = \sqrt{\frac{\varepsilon}{\varepsilon_0}} = \sqrt{\frac{4}{1}} = 2$$

$$\frac{c}{v} = \frac{f\lambda}{f\lambda'} = \frac{\lambda}{\lambda'} = 2 \text{ or } \lambda' = \frac{\lambda}{2}$$

9. **(b)** The electromagnetic waves do not transport charge.

10. **(c)** The energy in EM waves is divided equally between the electric and magnetic fields.

EM waves also carry momentum. If a portion of EM wave of energy u propagating with speed C_1 then linear

$$\text{momentum} = \frac{\text{Energy (a)}}{\text{speed (c)}}$$

In free space, its speed

$$C = \frac{1}{\sqrt{\mu_0\varepsilon_0}} = \frac{E_0}{B_0} = 3\times10^8 \text{ m/sec}$$

11. **(a)** In vacuum velocity of all EM waves are same but their wavelengths are different.

12. **(c)** Light waves and X-rays are electromagnetic waves.

13. **(d)** $\lambda_{micro} > \lambda_{infrared} > \lambda_{ultraviolet} > \lambda_{gamma}$

14. **(a)** $E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E} = \frac{6.6\times10^{-34}\times3\times10^8}{11\times1000\times1.6\times10^{-19}} = 12.4$ Å

15. **(c)** As we know that,

$E = h\nu$

As given that $h = 6.62\times10^{-34}$ J-s

$E = 11$ eV $= 11\times1.6\times10^{-19}$

$\nu = ?$

11 eV $= h\nu$

So, $\nu = \frac{11\times1.6\times10^{-19}}{h}\text{J} = \frac{11\times1.6\times10^{-19}}{6.62\times10^{-34}}\text{J}$

$= 2.65\times10^{15}$ Hz

So, that frequency radiation belongs to ultraviolet region.

16. **(b)** The type of wave doesn't change when a wave is reflected from denser medium but only its phase changes by 180°. As E is along positive x-axis so reflected ray will be along negative x-axis and its component will also be opposite to earlier in (–z) direction and phase will change.

For the reflected wave $\hat{z} = -\hat{z}$, $\hat{i} = -\hat{i}$ and additional phase of π in the incident wave.

As given that the incident electromagnetic wave is,

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

So, the reflected electromagnetic wave is

$$E_r = E_0(-\hat{i})\cos(k(-z) - \omega t + \pi)$$

$$= -E_0\hat{i}\cos\left(-(kz + \omega t) + \pi\right)$$

$$= -E_0\hat{i}\cos\left(\pi - (kz + \omega t)\right)$$

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

17. **(b)** As we know that

the momentum of incident light

$$= \frac{U(\text{total energy})}{c}$$

As given that the energy flux $\phi = 20$W/cm^2

Surface are $A = 30$ cm^2

Time for total momentum delivered

$t = 30$ min $= 30\times60$ sec

So, total energy falling in time t sec is

$U = \phi At = 20\times30\times(30\times60)$ J

Momentum of the incident light

$$= \frac{U}{c} \qquad (\because c = 3\times10^8)$$

Momentum of incident light $= \frac{20 \times 30 \times (30 \times 60)}{3 \times 10^8}$

$= 36 \times 10^{-4}$ kg-ms^{-1}

As no reflection from the surface and for comidete absorption.

Momentum of the reflected light = 0

Hence, momentum delivered to the surface

= Charge in momentum. $= (p_f - f_i)$

$= 36 \times 10^{-4} - 0 = \quad 36 \times 10^{-4}$ kg-ms^{-1}

18. **(c)** As we know that the electric field intensity on a surface due to incident radiation is,

$$I_{av} \propto E_0^2$$

$$\frac{P_{av}}{A} \propto E_0^2 \quad \text{(A is constant)}$$

Here, $P_{av} \propto E_0^2$

So, $E_0 \propto \sqrt{P_{av}}$

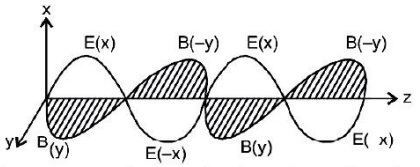
$$\therefore \quad \frac{(E_0)_1}{(E_0)_2} = \sqrt{\frac{(P_{av})_1}{(P_{av})_2}}$$

$$\frac{(E_0)_1}{(E_0)_2} = \sqrt{\frac{100}{50}} = \begin{bmatrix} \sqrt{2} \\ 1 \end{bmatrix}$$

$$(E_0)_2 = (E_0)_1 \sqrt{2}$$

19. **(d)** The direction of propagation of electromagnetic wave is perpendicular to both electric field E and magnetic field B, i.e., in the direction of E × B by right thumb rule.

The diagram given below



So, electromagnetic wave is along the z-direction which is give the cross product of E and B direction is perpendicular to E and B from $\vec{E}$ to $\vec{B}$. i.e., (E × B) in z-direction.

20. **(c)** Intensity in terms of electric field

$$U_{av} = \frac{1}{2}\varepsilon_0 E_0^2$$

Intensity in terms of magnetic field

$$U_{av} = \frac{1}{2}\frac{B_0^2}{\mu_0}$$

We also know that the relationship between E and B is $E_0 = cB_0$

So the average energy by electric field is

$$(U_{av}) = \frac{1}{2}\varepsilon_0 E_0^2 = \frac{1}{2}\varepsilon_0 E_0 (cB_0)^2$$

$$= \frac{1}{2}\varepsilon_0 \times c^2 B^2 \qquad \left(\because c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}\right)$$

$$\therefore \quad (U_{av})_{\text{Electric field}} = \frac{1}{2}\varepsilon_0 \times \frac{1}{\mu_0 \varepsilon_0} B_0^2$$

$$= \frac{1}{2}\frac{B_0^2}{\mu_0} = (U_{av})_{\text{Magnetic field}}$$

So, the energy in electromagnetic wave is divided equally between electric field vector and magnetic field vector.

Then, the ratio of contributions by the electric field and magnetic field components to the intensity of an electromagnetic wave is

$$\text{Ratio} = \frac{(U_{av})_{\text{electric field}}}{(U_{av})_{\text{Magnetic field}}} = 1 : 1$$

21. **(c)** As we know that, the electric field is inversly proportional to r, so $\left(E_0 \propto \frac{1}{r}\right)$

From a diode antenna, an electromagnetic waves are radiated outwards from dipole antenna with the amplitude of electric field vector (E_0) which transports significant energy from the source falls off intensity inversely as the distance (r) from the antenna, i.e.,

radiated energy $\left(E_0 \propto \frac{1}{r}\right)$

22. **(d)** In electromagnetic wave, the electric field vector is

$$E = \left(E_1 \hat{i} + E_2 \hat{j}\right)\cos(kz - \omega t)$$

and the associated magnetic field vector,

$$B = \frac{E}{c} = \frac{E_1 \hat{i} + E_2 \hat{j}}{c}\cos(kz - \omega t)$$

So, E and B are perpendicular to each other and the propagation of electromagnetic wave is perpendicular to E as well as B, so the electromagnetic wave plane polarised.

23. **(a)** $\frac{E_0}{B_0} = c$. also $k = \frac{2\pi}{\lambda}$ and $\omega = 2\pi\nu$

These relation gives $E_0 k = B_0 \omega$

24. **(d)**

25. **(c)** **26. (c)**

27. **(b)** Velocity of EM waves

$$= \frac{1}{\sqrt{\mu_0 \in_0}} = 3 \times 10^8 \text{ m/s} = \text{velocity of light}$$

28. **(c)** Speed of EM waves in vacuum $= \frac{1}{\sqrt{\mu_0 \in_0}} = \text{constant}$

29. **(a)** **30. (b)** **31. (a)**

32. **(a)** Energy density (EM waves)

$$= \varepsilon_0 E_{rms}^2 = \varepsilon_0 \left(\frac{E_0}{\sqrt{2}}\right)^2 = \frac{1}{2}\varepsilon_0 E_0^2$$

33. **(c)** Incident momentum, $p = \frac{E}{c}$

For perfectly reflecting surface with normal incidence

$$\Delta p = 2p = \frac{2E}{c}; \quad F = \frac{\Delta p}{\Delta t} = \frac{2E}{ct}; \quad P = \frac{F}{A} = \frac{2E}{ctA}$$

34. **(d)**

35. **(b)** Wave impedance $= Z = \sqrt{\frac{\mu_0}{\varepsilon_0}} = 376.6\ \Omega$

36. **(c)** **37.** **(b)**

38. **(b)** Here, $k = \frac{2\pi}{\lambda}$, $\omega = 2\pi\upsilon$

$\therefore \quad \frac{k}{\omega} = \frac{2\pi/\lambda}{2\pi\upsilon} = \frac{1}{\pi\upsilon} = \frac{1}{c} \qquad (\because\ c = \upsilon\,\lambda)$

where c is the speed of electromagnetic wave in vacuum. It is a constant whose value is $3 \times 10^6\ m\ s^{-1}$

39. **(c)** $\nu_{\gamma-\text{rays}} > \nu_{\text{visible radiation}} > \nu_{\text{infrared}} > \nu_{\text{Radio waves}}$

40. **(d)**

41. **(b)** Infrared radiations reflected by low lying clouds and keeps the earth warm.

42. **(d)** $\lambda_{\text{Radiowave}} > \lambda_{\text{IR rays}} > \lambda_{\text{UV rays}} > \lambda_{\text{x-rays}}$

43. **(c)**

44. **(b)** Infrared causes heating effect.

45. **(c)** Microwave oven acts on the principle of giving vibrational energy to water molecules.

46. **(d)**

47. **(b)** Depends on the magnitude of frequency

48. **(b)** Molecular spectra due to vibrational motion lie in the microwave region of EM-spectrum. Due to Kirchhoff's law in spectroscopy the same will be absorbed.

49. **(b)** Wavelength of visible spectrum is 3900Å – 7800 Å.

50. **(c)** Gamma rays < X-rays < Ultra violet < Visible rays < Infrared rays < Microwaves < Radio waves.

51. **(a)** The wavelength of infrared region is 8×10^{-5} cm to 3×10^{-3} cm. So maximum wavelength of infrared region $= 8 \times 10^{-5}$ cm $\approx 10^{-4}$ cm.

52. **(b)** In an electromagnetic wave the directions of magnetic induction is perpendicular to electric field.

53. **(b)** **54.** **(d)**

55. **(a)** Both magnetic and electric fields have zero average value in a plane e.m. wave.

56. **(b)** **57.** **(c)**

58. **(c)** Here : Velocity of electromagnetic waves in free space and wavelength

$v = 3 \times 10^8$ m/s and $\lambda = 150\ m$

The frequency of radio waves is given by

$$= \frac{v}{\lambda} = \frac{3\times10^8}{150} = 2\times10^6 \text{Hz} = 2\,\text{MHz}.$$

59. **(d)** Ozone layer will absorb ultraviolet rays; reflect the infrared radiation and does not reflect back radiowaves.

60. **(d)** **61.** **(b)**

62. **(b)** As we know, $\vec{E}\cdot\vec{B} = 0 \qquad \because [\vec{E} \perp \vec{B}]$

and $\vec{E}\times\vec{B}$ should be along Z direction

As $(-2\hat{i} - 3\hat{j})\times(3\hat{i} - 2\hat{j}) = 5\hat{k}$

Hence option (b) is the correct answer.

63. **(b)** $\omega = 2\pi\nu = \frac{2\pi c}{\lambda} = \frac{2\pi\times3\times10^8}{6\times10^{-3}}$

$= \pi \times 10^{11}$ rad/sec

The equation for the electric field, along y-axis in the electromagnetic wave is

$$Ey = E_0 \sin\omega\left(t - \frac{x}{c}\right) = 33\sin\left[\pi\times10^{11}\left(t - \frac{x}{c}\right)\right]$$

64. **(d)** $By = 2 \times 10^{-7} \sin(0.5 \times 10^3\ z + 1.5 \times 10^{11}\ t)$ T

The electric vector is perpendicular to B as well as direction of propagation of electromagnetic wave.

Therefore Ex has to be taken.

Further, $E_0 = B_0 \times c$

$= 2 \times 10^{-7} \times 3 \times 10^8$ V/m

$E_0 = 2 \times 10^{-7} \times 3 \times 10^8 = 60$ V/m

$\therefore$ The corresponding value of the electric field is

$Ex = 60 \sin(0.5 \times 10^3\ z + 1.5 \times 10^{11}\ t)$ V/m

65. **(b)**

66. **(a)** Intersity of a plane electromagnetic wave

$$= \frac{1}{2}\varepsilon_0 E_0^2 c$$

$$E = \sqrt{\frac{2I}{\varepsilon_0 c}} = 38.8\ \text{NC}^{-1}$$

67. **(c)**

68. **(a)** Electromagnetic waves have linear momentum as well as energy. This concludes that they can exert radiation pressure by falling beam of electromagnetic radiation on an object.

69. **(a)** The basic difference between various types of electromagnetic waves lies in their wavelengths or frequencies since all of them travel through vacuum with the same speed. Consequently, the waves differ considerably in their mode of interaction with matter.

70. **(b)** Infrared radiation help to maintain the earth warmth through the greenhouse effect. Incoming visible light which passes relatively easily through the atmosphere is absorbed by the earth's surface and re-radiated as infrared radiation. The radiation is trapped by greenhouse gases such as carbon dioxide and water vapour and they heat up and heat their surrondings.

71. **(b)** The wavelength of these wave ranges between 4000 Å to 100 Å that is smaller wavelength and higher frequency. They are absorbed by atmosphere and convert oxygen into ozone. They cause skin diseases and they are harmful to eye and cause permanent blindness.

72. **(a)** (A) → (4); (B) → (2); (C) → (1); (D) → (3)

73. **(c)** (A) → (4); (B) → (3); (C) → (2); (D) → (1)

74. (3×10^{-12}) For electromagnetic waves we know that,

$$\frac{E}{B} = c \quad \therefore \quad \frac{9\times10^{-4}}{B} = 3\times10^8\ \text{ms}^{-1}$$

$\Rightarrow \quad B = 3 \times 10^{-12}$ T.

75. (Velocity) All components of electromagnetic spectrum travel in vacuum with velocity 3×10^8 m/s.

76. (1 Angstrom)

77. [$(3 \times 10^3$ MHz) to 30×10^3 MHz)

78. (True) **79.** (True) **80.** (True) **81.** (False)