CHAPTER

8

Electromagnetic Waves

A Quick Recapitulation of the Chapter

1. **Displacement Current** The current which comes into play in the region in which the electric field and the electric flux is changing with time. It is given by

$$i_D = \varepsilon_0 \frac{d\phi_E}{dt}$$

2. **Maxwell's equations** of electromagnetic waves are the basic laws of electricity and magnetism. There are four maxwell's equations which gives complete description of all electromagnetic interactions.

   (i) Gauss' law in electrostatics, $\oint \mathbf{E} \cdot d\mathbf{S} = \frac{q}{\varepsilon_0}$

   (ii) Gauss' law in magnetism, $\oint \mathbf{B} \cdot d\mathbf{S} = 0$

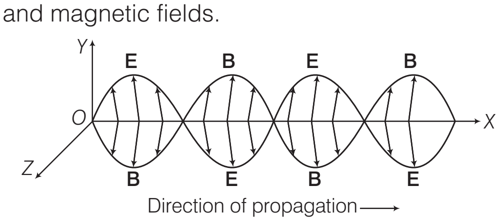
   (iii) Faraday's law of electromagnetic induction,
   $$\oint \mathbf{E} \cdot d\mathbf{l} = -\frac{d\phi_B}{dt}$$

   (iv) Modified Ampere's circuital law,
   $$\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 (i_C + i_D)$$

   where, i_C is conduction current and i_D is displacement current.

3. An **electromagnetic wave** is a wave radiated by an accelerated or oscillatory charge in which varying magnetic field is the source of electric field and varying electric field is the source of magnetic field. Thus, two fields becomes source of each other and the wave propagates in a direction perpendicular to both the fields.

4. **Electromagnetic waves** are transverse in nature. *i.e.*, electric and magnetic fields are perpendicular to each other and to the direction of wave propagation. Electromagnetic waves are not deflected by electric and magnetic fields.



5. **E** (electric field) and **B** (magnetic field) in electromagnetic waves are in same phase.

6. For a wave of frequency ν, wavelength λ, propagating along z-direction, we have

$$E = E_x(t) = E_0 \sin(kz - \omega t) = E_0 \sin\left[2\pi\left(\frac{z}{\lambda} - \frac{t}{T}\right)\right]$$

$$B = B_y(t) = B_0 \sin(kz - \omega t)$$
$$= B_0 \sin[2\pi(z/\lambda - t/T)] \text{ in vacuum}$$

7. Speed of electromagnetic wave

$$c = \frac{E_0}{B_0} = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = 3 \times 10^8 \text{ ms}^{-1}$$

8. In a general medium, the speed of EM wave

$$v = \frac{1}{\sqrt{\mu\varepsilon}}$$

   where, μ is permeability and ε is permittivity of the medium.

9. The energy in electromagnetic wave is divided equally between electric and magnetic fields.

10. Average energy density associated with an electromagnetic wave is

$$U = \frac{1}{2}\varepsilon_0 E^2 + \frac{B^2}{2\mu_0}$$

11. Linear momentum delivered to a surface by an electromagnetic wave, $p = \frac{U}{c}$

where, U = total energy transmitted by the electromagnetic wave and c = speed of electromagnetic wave.

12. The systematic distribution of electromagnetic waves in ascending or descending order of frequency or wavelength is known as **electromagnetic spectrum.** The range varies from 10^{-12} m to 10^4 m *i.e.,* from γ-rays to radio waves.

Different Types of Electromagnetic Waves

Type	Wavelength range	Frequency range (Hz)	Production	Detection
Radio wave	> 0.1 m	3×10^3 to 3×10^8	Rapid acceleration and deceleration of electrons in aerials.	Receiver's aerials
Microwave	0.1 m to 1 nm	3×10^8 to 3×10^{11}	Klystron valve or magnetron valve	Point contact diodes
Infrared wave	1 mm to 700 nm	3×10^{11} to 4×10^{14}	Vibration of atoms and molecules	Thermopile, Bolometer, infrared photographic film
Light	700 nm to 400 nm	4×10^{14} to 8×10^{14}	Electrons in atoms emit light when they move from one energy level to a lower energy level.	The eye, photocells, photographic film
Ultraviolet rays	400 nm to 1 nm	8×10^{14} to 8×10^{16}	Inner shell electrons in atoms moving from one energy level to a lower level.	Photocells, photographic film
X-rays	1 nm to 10^{-3} nm	1×10^{16} to 3×10^{21}	X-ray tubes or inner shell electrons.	Photographic film Geiger tubes
γ-rays	< 10^{-3} nm	5×10^{18} to 5×10^{22}	Radioactive decay of the nucleus.	Photographic film ionisation chamber

Objective Questions Based on NCERT Text

Topic 1
Displacement Current

1. The conduction current is the same as displacement current when source is
(a) only AC
(b) only DC
(c) Both (a) and (b)
(d) Neither (a) nor (b)

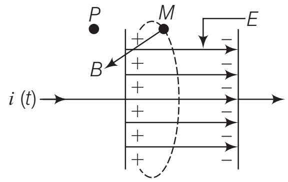
2. An oscillating charge is an example of
(a) displacement current (b) conduction current
(c) accelerating charge (d) accelerating current

3. The current $\varepsilon_0 \frac{d\phi_E}{dt} = i$ is a new term and is due to changing electric field, therefore called
(a) conduction current
(b) induced current
(c) Both (a) and (b)
(d) Maxwell's displacement current

4. There may be a large regions of space, where there is no conduction current, but there is only
(a) displacement current due to time varying electric fields
(b) induced current due to time varying electric fields
(c) Both (a) and (b)
(d) Neither (a) nor (b)

5. Which statement represents the symmetrical counterpart of Faraday's law and a consequence of the displacement current being a source of a magnetic field?
(a) An electric field changing with time gives rise to a magnetic field
(b) A magnetic field changing with time gives rise to an electric field
(c) An emf changing with time gives rise to an electric field
(d) An displacement current, changing with time gives rise to an electric field

6. In the given figure, a magnetic field (say at point M) between the plates of the capacitor to be the same as that just



(a) outside at P
(b) between the plates
(c) above the plates
(d) down the plates

7. The charge on a parallel-plate capacitor varies as $q = q_0 \cos 2\pi\nu t$. The plates are very large and close together (area = A, separation = d). Neglecting the edge effects, find the displacement current through the capacitor?

(a) $-\sin 2\pi\nu t\ (2\pi\nu)$
(b) $q_0 \cos 2\pi\nu t$
(c) $2\pi\ q_0\ \nu \sin\ (2\pi\nu t)$
(d) $-\ 2\pi\ q_0 \nu \sin\ (2\pi\nu t)$

8. What is an instantaneous take of change of voltage for displacement current of 10A current in the space between the parallel plate of 1 μF capacitor?

(a) $10^5\,\text{Vs}^{-1}$
(b) $10^6\,\text{Vs}^{-1}$
(c) $10^{-6}\ \text{Vs}^{-1}$
(d) $10^7\ \text{Vs}^{-1}$

9. The charge of a parallel plate capacitor is varying as $q = q_0 \sin 2\pi ft$. The plates are very large and close together (Area = A, separation = d). Neglecting edge effects, the displacement current through the capacitor is

(a) $\dfrac{d}{A\varepsilon_0}$
(b) $\dfrac{d}{\varepsilon_0} \sin\ 2\pi ft$
(c) $2\pi fq_0 \cos\ 2\pi ft$
(d) $\dfrac{2\pi fq_0}{\varepsilon_0} \cos\ 2\pi ft$

10. A parallel-plate capacitor consists of two circular plates with radius $R = 10$ cm separated by distance $d = 0.5$ mm. The capacitor is being changed at a uniform rate by applying a changing potential difference between the two plates. Calculate the displacement current for the capacitor. Assume that the electric field is due to the displacement current only and rate at which the electric field between the plates changes is $5\times 10^{13}\ \text{Vms}^{-1}$.

(a) 13.8 A (b) 12.6 A (c) 13.9 A (d) 10.5 A

11. A sinusoide voltage is applied directly across an 8 μF capacitor. The frequency of the source is 3.00 kHz and the voltage amplitude is 30.0 V. Find the displacement current and amplitude between the plates of the capacitor.

(a) 42.5 A (b) 4.25 μA (c) 4.52 A (d) 4.52 μA

12. You are given a parallel plate capacitor having capacitance of 2μF. How would you establish an instantaneous displacement current of 1 mA in the space between its plates?

(a) $550\ \text{Vs}^{-1}$
(b) $500\ \text{Vs}^{-1}$
(c) $525\ \text{Vs}^{-1}$
(d) $475\ \text{Vs}^{-1}$

13. A parallel plate capacitor is charged to 100×10^{-6} C. Due to radiations falling, from a radiating source the plate loses charge at the rate of $2\times 10^{-7}\ \text{Cs}^{-1}$. The magnitude of displacement current is

(a) 10^{-6} A
(b) 10^{-4} A
(c) 2×10^{-7} A
(d) $2\times 10^{-7}\ \text{mCs}^{-1}$

Topic 2
Maxwell's Equation

14. Which is the most important prediction to emerge from Maxwell's equations?

(a) Existence of magnetic waves
(b) Existence of electrical waves
(c) Existence of radio waves
(d) Existence of electromagnetic waves

15. The total current passing through any surface, of which the closed loop is the perimeter, is

(a) sum of conduction current and displacement current
(b) difference of conduction current and displacement current
(c) product of conduction current and displacement current
(d) fraction of conduction current and displacement current

16. We have a contradiction, calculated one way, there is a magnetic field at a point P, calculated another way, the magnetic field at P is zero. Since, the contradiction arises from our use of

(a) Ampere's circuital law
(b) Lorentz's force law
(c) Fleming's right hand rule
(d) Fleming left hand rule

17. 'Time-dependent electric and magnetic fields give rise to each other'. Which laws give a quantitative expression of this statement?

(a) Faraday's law of electromagnetic induction
(b) Ampere-Maxwell law
(c) Faraday's left hand rule of electromagnetic induction
(d) Both (a) and (b)

18. If we generalise Ampere's circuital law by adding to the total current carried by conductors through the surface, another term which is ε_0 times the rate of change of electric flux through the same surface, the total value of current for all surfaces will be

(a) same (b) different
(c) may be same (d) None of these

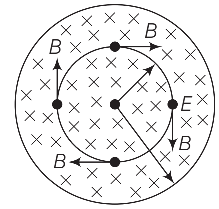
19. Find magnetic field on circular loop of radius r, placed between circular plates of capacitor of radius R having displacement current i_d, $r < R$.

(a) $\frac{\mu_0 i_d r}{2\pi R^2}$ (b) $\frac{\mu_0 i_d}{2\pi R}$ (c) $\frac{\mu_0 i_d}{2\pi r}$ (d) zero

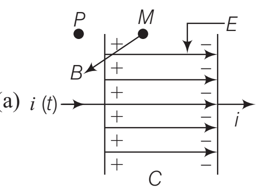
20. An expression for the magnetic field strength B at the point between the capacitor plates in terms of the rate of change of the electric field strength *i.e.*, dE/dt between the plates is

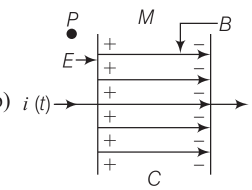
(a) $\frac{\mu_0 i}{2\pi r}$ (b) $\frac{\varepsilon_0 \mu_0 r}{2} \frac{dE}{dt}$
(c) zero (d) $\frac{\mu_0 i}{2r}$

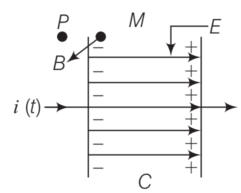
21. Consider cross-sectional view of the given figure.

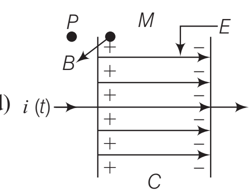


Now choose the correct option.

(a) 

(b) 

(c) 

(d) 

Topic 3
Sources and Nature of EM Waves

22. Which scientist's experiment marks the beginning of the field of communication using electromagnetic waves?

(a) Maxwell (b) JC Bose
(c) Hertz (d) Marconi

23. Electromagnetic waves can be deflected by

(a) only electric field (b) only magnetic field
(c) Both (a) and (b) (d) None of these

24. Which waves propagate in a solid, which is rigid and that resists shear?

(a) Electromagnetic waves
(b) Sound waves
(c) Transverse waves of water
(d) Transverse elastic sound waves

25. Name of famous scientists who demolished the conclusively the hypothesis of ether?

(a) Maxwell and Hertz in 1890
(b) JC Bose and Hertz in 1886
(c) Marconi and Maxwell in 1887
(d) Michelson and Morley in 1887

26. In which medium, electric and magnetic fields, oscillating in space and time, can sustain each other?

(a) Air (b) Vacuum
(c) Free space (d) Water

27. The velocity of light depends on

(a) electric properties of the medium
(b) magnetic properties of the medium
(c) Both (a) and (b)
(d) Neither (a) nor (b)

28. In a material medium of permittivity ε and magnetic permeability μ, the velocity of light becomes

(a) $v = \frac{1}{\mu\varepsilon}$ (b) $v = \frac{1}{\sqrt{\mu\varepsilon}}$ (c) $v = \sqrt{\mu/\varepsilon}$ (d) $v = \sqrt{\frac{\varepsilon}{\mu}}$

29. Electromagnetic waves of different wavelengths with the same velocity (independent of wavelength) within a few metres per second and the value of speed of light is

(a) 3×10^8 ms^{-1} (b) 3×10^{11} ms^{-1}
(c) 3×10^{12} ms^{-1} (d) 3×10^9 ms^{-1}

30. The constancy of the velocity of electromagnetic waves in vacuum is used to define a standard of

(a) breadth (b) thickness
(c) length (d) Both (a) and (b)

31. The distance travelled by light in vacuum in a time $(1/c)$ seconds $= (2.99792458 \times 10^8)^{-1}$ second is known as

(a) centimetre (b) metre
(c) decimetre (d) millimetre

32. The direction of k describes
(a) direction of propagation of the wave
(b) opposite direction of propagation of the wave
(c) direction of propagation of the wave (ω/k)
(d) opposite direction of propagation of the wave (ω/k)

33. The signal will be greatly diminished, when the antenna is turned
(a) horizontal (b) vertical
(c) at the angle of 45° (d) at angle of 60°

34. What will be the magnetic energy density, in the magnetic field B?
(a) $B^2/2\mu_0$ (b) $B/2\mu_0$
(c) $2B/\mu_0$ (d) $2B^2\mu_0$

35. The average value of electric energy density in an electromagnetic wave is (E_0 is peak value)
(a) $\frac{1}{2}\varepsilon_0 E_0^2$ (b) $\frac{E_0^2}{2\varepsilon_0}$ (c) $\varepsilon_0 E_0^2$ (d) $\frac{1}{4}\varepsilon_0 E_0^2$

36. During the propagation or electromagnetic waves in a medium. **[JEE Main 2014]**
(a) Electric energy density is double of the magnetic energy density
(b) Electric energy density is half of the magnetic energy density
(c) Electric energy density is equal to the magnetic energy density
(d) Both electric and magnetic energy densities are zero

37. Out of the following options which one can be used to produce a propagating electromagnetic wave? **[NEET 2016]**
(a) A stationary charge
(b) A charge less particle
(c) An accelerating charge
(d) A charge moving at constant velocity

38. If the total energy transferred to a surface in time t is U, then the magnitude of the total momentum delivered to this surface (for complete absorption) is
(a) $p = \frac{U}{c}$ (b) $p = \frac{c}{U}$
(c) $p = cU$ (d) $p = \frac{2c}{U}$

39. Solar radiation is
(a) transverse electromagnetic wave
(b) longitudinal electromagnetic wave
(c) stationary wave
(d) None of the above

40. A plane electromagnetic wave of frequency 25 MHz travels in free space along the x-direction. At a particular point in space and time, $E = 6.3$ JV/m. What is B at this point?
(a) $2.1\times 10^{-8}\,\hat{\mathbf{k}}$ T (b) $2.1\times 10^{8}\,\hat{\mathbf{k}}$ T
(c) $3.5\times 10^{6}\,\hat{\mathbf{k}}$ T (d) $3.0\times 10^{5}\,\hat{\mathbf{k}}$ T

41. Light with an energy flux of $18\ \text{Wcm}^{-2}$ falls on a non-reflecting surface at normal incidence. If the surface has an area of $20\ \text{cm}^2$, find the average force executed on the surface during a 30 min time span.
(a) 12×10^{-6} N (b) 1.2×10^{-7} N
(c) 1.2×10^{-6} N (d) 12×10^{7} N

42. By measuring the heating of a material as it absorbs light from the sun, one finds that the intensity of sunlight at the surface of the earth is $1300\ \text{Wm}^{-2}$. What will be magnetic field of sunlight?
(a) 990 T (b) 3×10^{-6} T
(c) 3.3×10^{-6} T (d) 9.9×10^{-6} T

43. An electromagnetic wave propagating in the y-direction has wavelength of 5.0 mm. The electric field is in the x-direction and its maximum magnitude of $66\ \text{Vm}^{-1}$. The equation for the electric field as function of x and t is
(a) $11\sin(t - y/c)$ (b) $66\sin 1.2\pi\times 10^{11}(t - y/c)$
(c) $66\sin 1.2\pi(t - x/c)$ (d) $11\sin \pi\times 10^{11}(t - x/c)$

44. Suppose that the electric field amplitude of an electromagnetic wave is $E_0 = 120\ \text{NC}^{-1}$ and its frequency is $\nu = 50.0$ MHz. The expressions for E will be (if wave travels along X)
(a) $[(120\ \text{NC}^{-1})\sin\{(1.05\ \text{radm}^{-1})x - (3.14\times 10^8\ \text{rads}^{-1})t\}]\,\hat{\mathbf{i}}$
(b) $[(120\ \text{NC}^{-1})\sin\{(1.05\ \text{radm}^{-1})x - (3.14\times 10^8\ \text{rads}^{-1})t\}]\,\hat{\mathbf{k}}$
(c) $[(120\ \text{NC}^{-1}\sin\{(1.05\ \text{radm}^{-1})x - (3.14\times 10^8\ \text{rads}^{-1})t\}]\,\hat{\mathbf{j}}$
(d) $[(120\ \text{NC}^{-1})\cos\{(1.05\ \text{radm}^{-1})x - (3.14\times 10^8\ \text{rads}^{-1})t\}]\,\hat{\mathbf{j}}$

45. The magnetic field of an electromagnetic wave is given by $B_y = 3\times 10^{-7}\sin(10^3 x + 6.28\times 10^{12}\,t)$.

The wavelength of the electromagnetic wave is
(a) 6.28 cm (b) 3.14 cm (c) 0.63 cm (d) 0.32 cm

46. Light having an energy flux of $40\ \text{Wcm}^{-2}$ falls on non-reflecting surface at normal incidence. If the surface has an area of $20\ \text{cm}^2$, the total momentum delivered (for complete absorption) during 10 min is
(a) $24\times 10^{-5}\ \text{kg ms}^{-1}$ (b) $24\times 10^{-4}\ \text{kg ms}^{-1}$
(c) $102\times 10^{4}\ \text{kg ms}^{-1}$ (d) $1.03\times 10^{7}\ \text{kg ms}^{-1}$

47. A plane electromagnetic wave of frequency 30 MHz travels in free space along x-direction. The electric field component of the wave at a particular point of space and time $E = 6\ \text{Vm}^{-1}$ along y-direction. Its magnetic field component B at this point would be
(a) 2×10^{-8} T along z-direction
(b) 6×10^{-8} T along x-direction
(c) 2×10^{-8} T along y-direction
(d) 6×10^{-8} T along z-direction

48. The refractive index and the permeability of a medium are respectively 1.5 and 5×10^{-7} Hm^{-1}. The relative permittivity of the medium is nearly

(a) 25 (b) 15 (c) 81 (d) 6

49. If ε_0 and μ_0 are the electric permittivity and magnetic permeability of free space and ε and μ are the corresponding quantities in the medium, the index of refraction of the medium in terms of above parameter is

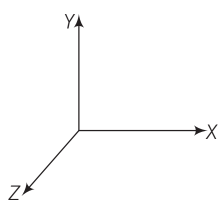
(a) $\frac{\varepsilon\mu}{\varepsilon_0\mu_0}$ (b) $\left(\frac{\varepsilon\mu}{\varepsilon_0\mu_0}\right)^{1/2}$ (c) $\left(\frac{\varepsilon_0\mu_0}{\varepsilon\mu}\right)$ (d) $\left(\frac{\varepsilon_0\mu_0}{\varepsilon\mu}\right)^{1/2}$

50. 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) $\frac{E}{c^2}$

51. Light wave is travelling along y-direction. If the corresponding E vector at any time is along the X-axis, the direction of B vector at that time is along



(a) Y-axis (b) X-axis
(c) + Z-axis (d)– Z-axis

52. The electric field associated with an electro magnetic wave in vacuum is given by $E = i\,40\cos(kz - 6\times10^8\,t)$, where E, z and t are in V m^{-1}, meter and second respectively. The value of wave vector k is **[CBSE AIPMT 2012]**

(a) 2 m^{-1} (b) 0.5 m^{-1} (c) 6 m^{-1} (d) 3 m^{-1}

53. Radiations of intensity 0.5 Wm^{-2} are striking a metal plate. The pressure on the plate is

(a) 0.66×10^{-8} Nm^{-2} (b) 0.332×10^{-8} Nm^{-2}

(b) 0.111×10^{-8} Nm^{-2} (c) 0.083×10^{-8} Nm^{-2}

54. 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]**

(a) 3 Vm^{-1} (b) 6 Vm^{-1}

(c) 9 Vm^{-1} (d) 12 Vm^{-1}

55. A charged particle with charge q enters a region of constant, uniform and mutually orthogonal fields **E** and **B** with a velocity **v** perpendicular to both **E** and **B**, and comes out without any change in magnitude or direction of **v**. Then,

(a) $\mathbf{v} = \mathbf{B}\times\mathbf{E}/B^2$ (b) $\mathbf{v} = \mathbf{B}\times\mathbf{E}/B^2$

(c) $\mathbf{v} = \mathbf{E}\times\mathbf{B}/E^2$ (d) $\mathbf{v} = \mathbf{B}\times\mathbf{E}/E^2$

56. The magnetic field component of intensity of electromagnetic wave is $4I_0$. What is the electric field component of intensity?

(a) $2I_0$ (b) $4I_0$ (c) I_0 (d) $\frac{I_0}{4}$

Topic 4
Electromagnetic Spectrum

57. At the time Maxwell predicted the existence of electromagnetic waves, which was the more familiar electromagnetic waves at that time?

(a) X-rays
(b) γ-rays
(c) Visible light waves
(d) Radiowaves

58. Which of the following are electromagnetic waves?

(a) Visible light waves and X-rays
(b) Gamma rays and radio waves
(c) Microwaves and ultraviolet rays
(d) All of the above

59. The classification of electromagnetic waves according to frequency is called

(a) electromagnetic beam
(b) electromagnetic spectrum
(c) Both (a) and (b)
(d) Neither (a) nor (b)

60. Infrared waves are produced by

(a) hot bodies and molecules (b) cold bodies and molecules
(c) Neither hot nor cold (d) Both (a) and (b)

61. Infrared radiations is trapped by

(a) ozone layer (b) water vapour
(c) CO_2 (d) Both (b) and (c)

62. Visible rays in the spectrum runs from about

(a) 4×10^{14}Hz to 4×10^{11} Hz
(b) 4×10^{14} Hz to 7×10^{14} Hz
(c) 4×10^{12} Hz to 7×10^{14} Hz
(d) 4×10^{11} Hz to 7×10^{14} Hz

63. In the electromagnetic spectrum, X-ray region lies

(a) beyond the microwave region
(b) above the ultraviolet region
(c) beyond the UV region
(d) above the infrared ray region

64. Arrange the following electromagnetic radiations in the order of increasing energy. **[JEE Main 2016]**

I. Blue light II. Yellow light
III. X-ray IV. Radio wave

(a) IV, II, I, III
(b) I, II, IV, III
(c) III, I, II, IV
(d) II, I, IV, III

65. UV radiation is absorbed by
(a) ordinary glass (b) prism
(c) black glass (d) Both (b) and (c)

66. The energy of the EM waves is of the order of 15 keV. To which part of the spectrum does it belong? **[CBSE AIPMT 2015]**
(a) X-ray (b) Infrared rays
(c) Ultraviolet rays (d) γ-rays

67. Wavelength of gamma rays are
(a) 10^{-10} nm to less than 10^{-14} m
(b) 10^{-14} m to less than 10^{-10} m
(c) 10^{-11} m to less than 10^{-14} m
(d) 10^{-14} nm to less than 10^{-10} nm

68. Gamma rays are used in medicine to destroy
(a) PB cells (b) cancer cells
(c) Both (a) and (b) (d) Neither (a) nor (b)

69. One common way to generate X-rays is that
(a) bombard a metal target by high energy electrons
(b) bombard a metal target by low energy neutrons
(c) bombard a metal target by low energy protons
(d) bombard a metal target by high energy neutrons

70. All components of the electromagnetic spectrum in vacuum have the same
(a) energy (b) velocity
(c) wavelength (d) frequency

71. The condition under which a microwave oven heats up a food item containing water molecules most efficiently is **[NEET 2013]**
(a) the frequency of the microwave must match the resonant frequency of the water molecules
(b) the frequency of the microwave has no relation with natural frequency of water molecules
(c) microwave are heat waves, so always produce heating
(d) infrared waves produce heating in a microwave oven

72. Radio wave diffract around building although light waves do not. The reason is that radio waves
(a) travel with speed target than c
(b) have much longer wavelength than light
(c) carry news
(d) are not electromagnetic waves

73. X-rays are not used for radar purposes, because they are not
(a) reflected by target
(b) partly absorbed by target
(c) electromagnetic waves
(d) completely absorbed by target

74. Molybdenum is used as a target element for the production of X-rays because it is
(a) light and can easily deflect electrons
(b) light and can absorb electrons
(c) a heavy element with a high melting point
(d) an element having high thermal conductivity

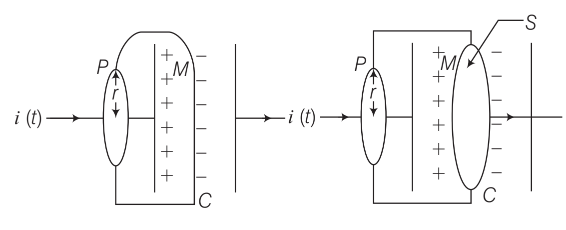
Special Format Questions

I. Assertion and Reason

■ **Directions** (Q. Nos. 75-78) *In the following questions, a statement of assertion is followed by a corresponding statement of reason. Of the following statements, choose the correct one.*

(a) Both Assertion and Reason are correct and Reason is the correct explanation of Assertion.
(b) Both Assertion and Reason are correct but Reason is not the correct explanation of Assertion.
(c) Assertion is correct but Reason is incorrect.
(d) Assertion is incorrect but Reason is correct.

75. **Assertion** While applying Ampere's circuital law to given surfaces with same perimeter, the left hand side $\oint B \cdot dl = \mu_0 i(t)$ has not changed but the right hand side is zero.



Reason No current passes through the surface.

76. **Assertion** We needed to do was to set up an AC circuit in which the current oscillate at the frequency of visible light *i.e.,* yellow.

Reason The above experiment demonstrates electromagnetic wave.

77. Assertion An oscillating charge produces an electric field in space, which produces an oscillating magnetic field, which in turn, is a source of electric field and so on.

Reason The oscillating electric and magnetic field thus regenerate each other, so to speak, as the wave propagates through the space.

78. Assertion When the sun shines on our hand, we feel the energy being absorbed from the electromagnetic waves (our hands get warm).

Reason Electromagnetic waves also transfer momentum to our hand but because c is very large, the amount of momentum transferred is extremely small and we do not feel the pressure.

II. Statement Based Questions Type I

■ **Directions** (Q. Nos. 79-81) *In the following questions, a statement I is followed by a corresponding statement II. Of the following statements, choose the correct one.*

(a) Both Statement I and Statement II are correct and Statement II is the correct explanation of Statement I.
(b) Both Statement I and Statement II are correct but Statement II is not the correct explanation of Statement I.
(c) Statement I is correct but Statement II is incorrect.
(d) Statement I is incorrect but Statement II is correct.

79. Statement I Infrared waves are sometimes referred to as heat waves.

Statement II Water molecules present in most materials readily absorb infrared waves. After absorption, their thermal motion increases, that is they heat up and heat their surroundings.

80. Statement I Welders wear special glass goggles or face masks with glass windows to protect their eyes from large amount of UV produced by welding arcs.

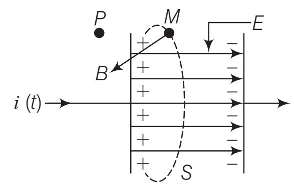
Statement II Due to shorter wavelength of UV, UV-radiations can be focussed into very narrow beams for high precision applications such as LASER eye surgery.

81. Statement I X-rays are used as a diagnostic tool in medicine and as a treatment for certain forms of cancer.

Statement II X-rays damage or destroy living tissues and organisms.

Statement Based Questions Type II

82. Which of the following statement(s) is/are correct?



I. The electric field **E** is perpendicular to the surface S in given figure.
II. It has the same magnitude over the area A of the capacitor plates, and vanishes outside it.
III. So, the electric flux ϕ_E through the surface S by using the Gauss law, is $\phi_E = |E| A = \frac{1}{\varepsilon_0} \frac{Q}{A} \cdot A = \frac{Q}{\varepsilon_0}$

(a) I and II
(b) II and III
(c) I and III
(d) All of these

83. I. In all respects, the displacement current has the same physical effects as the conduction current.
II. Due to electric fields in a conducting wire, the displacement current may be zero, since the electric field E does not change with time.
III. The charging capacitor, both conduction and displacement currents may be present in same regions of space.
IV. In most of the cases, they both may be present in the same region of space, as there exist no perfectly conducting or perfectly insulating medium.

(a) I and II (b) III and IV
(c) I, II and III (d) I, II and IV

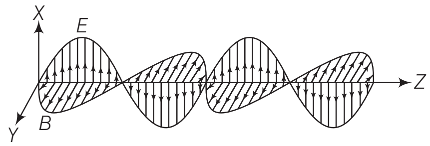
84. I. The total current i is the sum of the conduction current denoted by i_c, and the displacement current denoted by $i_d(t) = \varepsilon_0 (d\phi_E / dt)$.

So, $i = i_e + i_d = i_c + \varepsilon_0 \frac{d\phi_\varepsilon}{dt}$.

II. Outside the capacitor plates, we have only conduction current $i_c = i$ and no displacement current, $i_d = 0$.
III. Inside the capacitor, there is no conduction current $i_c = 0$ and there is only displacement current, so that $i_d = i$

Which of the above statements is/are correct? Choose the correct option.

(a) I and III (b) II and III
(c) I and III (d) All of these

85. 

Consider the figure. Which of the following statements are correct?

I. A plane electromagnetic wave propagating along the z-direction (the fields are shown as a function of the z-coordinate, at a given time t).

II. The electric field E_x is along the Y-axis and varies sinusoidally with z, at a given time.

III. The magnetic field B_y is along the Y-axis and again varies sinusoidally with z.

Choose the correct option.

(a) I and II (b) II and III (c) I and III (d) All of these

86. I. Electromagnetic waves are self-sustaining oscillations of electric and magnetic fields in free space or vacuum.

II. No material medium is involved in the vibrations of the electric and magnetic fields.

III. Sound waves in air are longitudinal waves of compression and refraction.

IV. Transverse waves on the surface of water consist of water moving up and down as the wave spreads horizontally and radially onwards.

Which of the following statements are correct? Choose the correct option.

(a) I, II and III (b) I, III and IV
(c) II, III and IV (d) All of these

87. I. The great technological importance of electromagnetic waves stems from their capability to carry energy from one place to another.

II. The radio and TV signals from broadcasting stations carry energy.

III. Light carries energy from the sun to the earth, thus making life possible on the earth.

Which of the following statement(s) is/are correct? Choose the correct option.

(a) I and II (b) II and III (c) I and III (d) All of these

88. Which of the following statement(s) is/are correct?

I. Radio waves are produced by the accelerated motion of charges in conducting wires.

II. Radio waves are used in radio and television communication systems.

III. Cellular phones use radio waves to transmit voice communication in the ultra high frequency.

(a) I and III (b) II and III
(c) I and II (d) All of these

89. I. Ultraviolet rays wavelength ranging about 4×10^{-7} m (400 nm) down to 6×10^{-10} m (0.6 nm).

II. UV radiation is produced by special lamps and very hot bodies.

III. The Sun is an important source of ultraviolet light.

IV. Most of the UV rays absorbed in the ozone ayer in the atmosphere at an altitude of about 40-50 km.

Which of the following statements are correct?

(a) I, II and III (b) II, III and IV
(c) I, III and IV (d) All of these

90. Which of the following statements are correct?

I. The wavelength of microwave is greater than that of UV-rays.

II. The wavelength of infrared rays is lesser than that of UV-rays.

III. The wavelength of microwave is lesser than that of infrared rays.

IV. Gamma rays have shortest wavelengths in the electromagnetic spectrum.

(a) I and II (b) II and III (c) III and IV (d) I and IV

III. Matching Type

91. Match the items of Column I with those of Column II and choose the correct option from the codes given below.

	Column I		Column II
A.	$\oint \mathbf{E}\, d\mathbf{A} = Q/\varepsilon_0$	1.	Faraday's law
B.	$\oint \mathbf{B}\, d\mathbf{A} = 0$	2.	Ampere-Maxwell law
C.	$\oint \mathbf{E}\, d\boldsymbol{l} = -\frac{d\phi_B}{dt}$	3.	Gauss law for electricity
D.	$\oint \mathbf{B}_i\, d\boldsymbol{l} = \mu_0 i_c + \mu_0\varepsilon_0 \frac{d\phi_E}{dt}$	4.	Gauss law for magnetism

	A	B	C	D		A	B	C	D
(a)	4	3	2	1	(b)	3	2	1	4
(c)	3	4	1	2	(d)	1	2	3	4

92. Match the items of Column I with the items of Column II and choose the correct option from the codes given below .

	Column I		Column II
A.	Radio	1.	54 MHz
B.	Amplitude modulated	2.	88 MHz to 108 MHz
C.	Short wave bands	3.	530 kHz to 1710 kHz
D.	TV wave	4.	500 kHz to 1000 MHz
E.	Frequency modulated	5.	54 MHz to 890 MHz

	A	B	C	D	E
(a)	3	1	5	2	4
(b)	1	5	2	3	4
(c)	4	1	5	2	3
(d)	4	3	1	5	2

93. Match List I (Electromagnetic wave type) with List II (Its association/application) and select the correct option from the choices given below the list. **[JEE Main 2014]**

List I		List II	
A.	Infrared waves	1.	To treat muscular strain
B.	Radio waves	2.	For broadcasting
C.	X-rays	3.	To detect fracture of bones
D.	Ultraviolet	4.	Absorbed by the ozone layer of the atmosphere

	A	B	C	D		A	B	C	D
(a)	4	3	2	1	(b)	1	2	4	3
(c)	3	2	1	4	(d)	1	2	3	4

IV. Passage Based Questions

■ **Directions** (Q. Nos. 94-96) *These questions are based on the following situation. Choose the correct options from those given below.*

The magnetic field in a plane electromagnetic wave is given by $B_y = 2\times10^{-7}\sin(0.5\times10^3 x + 1.5\times10t)$T.

94. What is the wavelength of the wave?

(a) 12.6 cm (b) 1.26 cm (c) 1. 26 m (d) 6.12 m

95. What is the frequency of the wave?

(a) 2.39 GHz (b) 23.9 MHz
(c) 23.9 GHz (d) 20.3 MHz

96. Write an expression for the electric field?

(a) $E_y = 60\sin(0.5\times10^3 x + 1.5\times10^{11} t)\ \text{Vm}^{-1}$

(b) $E_x = 60\sin(0.5\times10^3 x + 1.5\times10^{11} t)\ \text{Vm}^{-1}$

(c) $E_z = 60\sin(0.5\times10^3 x + 1.5\times10^{11} t)\ \text{Vm}^{-1}$

(d) $E_y = 60\cos(0.5\times10^3 x + 1.5\times10^{11} t)\ \text{Vm}^{-1}$

■ **Directions** (Q. Nos. 97-98) *These questions are based on the following situation. Choose the correct options from those given below.*

In a plane electromagnetic wave, the electric field oscillates sinusoidally at a frequency of 2.0×10^{10} Hz and amplitude 48 Vm^{-1}.

97. What is the wavelength of the wave?

(a) 1.5×10^{-2} m (b) 1.5×10^{-4} m
(c) 3×10^{-2} m (d) 3×10^{-4} m

98. What is the amplitude of the oscillating magnetic field?

(a) 0.8×10^{-7} T
(b) 1.6×10^{-7} T
(c) 3.2×10^{-8} T
(d) 6.4×10^{-8} T

V. More than One Option Correct

99. Which of the following statement is/are correct?

(a) Time dependent electric field gives rise to magnetic field.
(b) Time independent electric field gives rise to magnetic field.
(c) Time dependent magnetic field gives rise to electric field.
(d) Time independent magnetic field gives rise to electric field.

100. The electric field of an electromagnetic wave in free space is given by $\mathbf{E} = 10\cos(10t + kx)\,\mathbf{j}\ \text{Vm}^{-1}$, where t and x are in seconds and metres, respectively. It can be inferred that

(a) The wavelength λ is 188.4m
(b) The wave number k is 0.33 radm^{-1}
(c) The wave amplitude is 10Vm^{-1}
(d) The wave is propagating along $+x$-direction.

101. Which of the following have zero average value in a plane electromagnetic wave?

(a) Electric field
(b) Magnetic field
(c) Electric energy
(d) Magnetic energy

102. Which of the following statements about EM waves is/are correct?

(a) Electromagnetic waves having wavelength 1000 times smaller than light waves are called X-rays.
(b) Ultraviolet waves are used in treatment of swollen joints.
(c) de-Broglie waves are not electromagnetic in nature
(d) Electromagnetic waves exhibit polarisation while sound waves do not.

103. The wavelength of X-rays; γ-rays; ultraviolet rays and microwaves are *a, b, c* and *d*, respectively then

(a) $a > b$
(b) $d > c$
(c) $d < b$
(d) $c > a$

104. Which of the following relation are true for energy of X-rays (E_X), radiowaves (E_R) and microwave (E_M)?

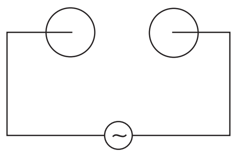
(a) $E_X > E_M$
(b) $E_X < E_M$
(c) $E_M > E_R$
(d) $E_M < E_R$

NCERT & NCERT Exemplar Questions

NCERT

■ **Directions** (Q. Nos. 105-107) *These questions are based on the following situation. Choose the correct options from those given below.*

A parallel plate capacitor made of circular plates each of radius $R = 6.0\,\text{cm}$, has a capacitance $C = 100\,\text{pF}$. The capacitor is connected to a 230 V AC supply with a frequency of 300 rads^{-1}.



105. What is the rms value of conduction current?

(a) 6.9×10^6 A (b) 6.9 μA
(c) 5.9×10^6 A (d) 5.9 μA

106. In the above question, is the conduction current equal to the displacement current?

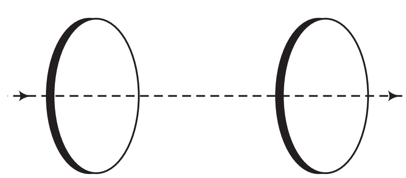
(a) Yes (b) No
(c) May be (d) Never possible

107. Determine the amplitude of B, at a point 3.0 cm from the axis between the plates.

(a) 1.62×10^{-11} T (b) 1.63×10^{11} T
(c) 1.62×10^{11} T (d) 1.63×10^{-11} T

■ **Direction** (Q. Nos. 108-110) *These questions are based on the following situation. Choose the correct options from those given below.*

Figure shows a capacitor made of two circular plates each of radius 12 cm and separated by 5.0 cm. The capacitor is being charged by an external source (not shown in the figure). The charging current is constant and equal to 0.15 A.



108. What is the capacitance of capacitor?

(a) 2pF (b) 4pF
(c) 6pF (d) 8pF

109. What is the rate of change of potential difference between the plates?

(a) $9.5 \times 10^9\ \text{Vs}^{-1}$ (b) $9.5 \times 10^{12}\ \text{Vs}^{-1}$
(c) $18.7 \times 10^9\ \text{Vs}^{-1}$ (d) $18.7 \times 10^{12}\ \text{Vs}^{-1}$

110. What is the displacement current across the plates?

(a) 0.15 A (b) 0.30 A
(c) 0.50 A (d) 1 A

■ **Directions** (Q. Nos. 111-114) *These questions are based on the following situation. Choose the correct options from those given below.*

Suppose that the electric field amplitude of an electromagnetic wave is $E_0 = 120\,\text{N/C}$ and that its frequency is $\nu = 50.0\,\text{MHz}$.

111. The amplitude of B_0 is

(a) 200 nT (b) 300 nT (c) 400 nT (d) 500 nT

112. The value of ω is

(a) $3.14 \times 10^2\ \text{rads}^{-1}$ (b) $3.14 \times 10^8\ \text{rads}^{-1}$
(c) $6.28 \times 10^4\ \text{rads}^{-1}$ (d) $6.28 \times 10^8\ \text{rads}^{-1}$

113. The value of k is

(a) $0.5\,\text{radm}^{-1}$ (b) $1\ \text{radm}^{-1}$
(c) $2\ \text{radm}^{-1}$ (d) $4\ \text{radm}^{-1}$

114. The value of λ is

(a) 2 m (b) 4 m (c) 6 m (d) 8 m

115. About 5% of the power of a 100W light bulb is converted to visible radiation. What is the average intensity of visible radiation at a distance of 1m from the bulb? Assume that the radiations are emitted isotropically and neglect reflection.

(a) $0.2\ \text{Wm}^{-2}$ (b) $0.4\ \text{Wm}^{-2}$
(c) $0.8\ \text{Wm}^{-2}$ (d) $1.6\ \text{Wm}^{-2}$

116. The amplitude of the magnetic field part of a harmonic electromagnetic wave in vacuum is $B_0 = 510$ nT. What is the amplitude of the electric field part of the wave?

(a) 130 N/C (b) 153 N/C
(c) 170 N/C (d) 190 N/C

■ **Directions** (Q. Nos. 117-119) *These questions are based on the following situation. Choose the correct options from those given below.*

Suppose that the electric field part of an electromagnetic wave in vacuum is

$F = \{(3.1\ \text{NC}^{-1}) \cos\ [(1.8\ \text{radm}^{-1})y + (5.4 \times 10^6\ \text{rads}^{-1})t]\}$

117. What is the wavelength λ ?

(a) 1.5 m (b) 2.5 m (c) 3.5 m (d) 4.5 m

118. What is the frequency ν ?

(a) 0.74×10^4 Hz (b) 0.86×10^6 Hz
(c) 0.9×10^6 Hz (d) 10^7 Hz

119. What is the amplitude of the magnetic field part of the wave?

(a) 10^{-8} T (b) 10^{-7} T (c) 10^{-6} T (d) 10^{-5} T

NCERT Exemplar

120. 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

121. A linearly polarised electromagnetic wave given as $\mathbf{E} = E_0 \hat{\mathbf{i}} \cos(kz - \omega t)$ 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) $\mathbf{E}_r = E_0 \hat{\mathbf{i}}(kz - \omega t)$ (b) $\mathbf{E}_r = E_0 \hat{\mathbf{i}} \cos(kz + \omega t)$
(c) $\mathbf{E}_r = -E_0 \hat{\mathbf{i}} \cos(kz + \omega t)$ (d) $\mathbf{E}_r = E_0 \hat{\mathbf{i}} \sin(kz - \omega t)$

122. 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-ms^{-1} (b) 36×10^{-4} kg-ms^{-1}
(c) 108×10^{4} kg-ms^{-1} (d) 1.08×10^{7} kg-ms^{-1}

123. 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) $\sqrt{2}E$

124. 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**

125. 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) $\sqrt{c} : 1$

126. An electromagnetic wave travels in vacuum along z-direction $\mathbf{E} = (E_1 \hat{\mathbf{i}} - E_2 \hat{\mathbf{j}})\cos(kz - \omega t)$. Choose the correct options from the following.

(a) The associated magnetic field is given as
$$\mathbf{B} = \frac{1}{c}(E_1 \hat{\mathbf{i}} - E_2 \hat{\mathbf{j}})\cos(kz - \omega t)$$
(b) The associated magnetic field is given as
$$\mathbf{B} = \frac{1}{c}(E_1 \hat{\mathbf{i}} - E_2 \hat{\mathbf{j}})\cos(kz - \omega t)$$
(c) The given electromagnetic field is circularly polarised
(d) The given electromagnetic wave is plane polarised

127. An electromagnetic wave travelling along Z-axis is given as $\mathbf{E} = \mathbf{E}_0 \cos(kz - \omega t)$. Choose the correct options from the following.

(a) The associated magnetic field is given as $\mathbf{B} = \frac{1}{c}\hat{\mathbf{k}} \times \mathbf{E}$
(b) The electromagnetic field can be written in terms of the associated magnetic field as $\mathbf{E} = c(\mathbf{B} \times \hat{\mathbf{k}})$
(c) $\hat{\mathbf{k}} \cdot \mathbf{E} = 0, \hat{\mathbf{k}} \cdot \mathbf{B} = 0$
(d) $\hat{\mathbf{k}} \times \mathbf{E} = 0, \hat{\mathbf{k}} \times \mathbf{B} = 0$

128. A plane electromagnetic wave propagating along x-direction can have the following pairs of **E** and **B**.

(a) E_x, B_y (b) E_y, B_z
(c) B_x, E_y (d) E_z, B_y

129. A charged particle oscillates about its mean equilibrium position with a frequency of 10^9 Hz. The electromagnetic waves produced

(a) will have frequency of 10^9 Hz
(b) will have frequency of 2×10^9 Hz
(c) will have wavelength of 0.3 m
(d) fall in the region of radiowaves

130. The source of electromagnetic waves can be a charge

(a) moving with a constant velocity
(b) moving in a circular orbit
(c) at rest
(d) falling in an electric field

131. An EM wave of intensity I falls on a surface kept in vacuum and exerts radiation pressure p on it. Which of the following are true?

(a) Radiation pressure is $\frac{I}{c}$ if the wave is totally absorbed
(b) Radiation pressure is $\frac{I}{c}$ if the wave is totally reflected
(c) Radiation pressure is $\frac{2I}{c}$ if the wave is totally reflected
(d) Radiation pressure is in the range $\frac{I}{c} < p < \frac{2I}{c}$ for real surfaces

132. The magnetic field of a beam emerging from a filter facing a floodlight is given by
$$B_0 = 12 \times 10^{-8} \sin(1.20 \times 10^7 z - 3.60 \times 10^{15} t) \text{ T}.$$
What is the average intensity of the beam?

(a) 1.91 Wm^{-2} (b) 1.71 Wm^{-2}
(c) 200 Wm^{-2} (d) 1.5 Wm^{-2}

Answers

1.	(c)	**2.**	(c)	**3.**	(d)	**4.**	(a)	**5.**	(a)	**6.**	(a)	**7.**	(d)	**8.**	(d)	**9.**	(c)	**10.**	(c)	**11.**	(c)	**12.**	(b)	**13.**	(c)	**14.**	(d)	**15.**	(a)
16.	(a)	**17.**	(d)	**18.**	(a)	**19.**	(a)	**20.**	(b)	**21.**	(a)	**22.**	(d)	**23.**	(d)	**24**	(d)	**25.**	(d)	**26.**	(c)	**27.**	(c)	**28.**	(b)	**29.**	(a)	**30.**	(c)
31.	(b)	**32.**	(a)	**33.**	(a)	**34.**	(a)	**35.**	(d)	**36.**	(c)	**37.**	(c)	**38.**	(a)	**39.**	(a)	**40.**	(a)	**41.**	(c)	**42.**	(c)	**43.**	(b)	**44.**	(c)	**45.**	(c)
46.	(b)	**47.**	(a)	**48.**	(d)	**49.**	(b)	**50.**	(b)	**51.**	(c)	**52.**	(a)	**53.**	(a)	**54.**	(b)	**55.**	(a)	**56.**	(b)	**57.**	(c)	**58.**	(d)	**59.**	(b)	**60.**	(a)
61.	(d)	**62.**	(b)	**63.**	(b)	**64.**	(a)	**65.**	(a)	**66.**	(a)	**67.**	(a)	**68.**	(b)	**69.**	(a)	**70.**	(b)	**71.**	(a)	**72.**	(b)	**73.**	(a)	**74.**	(c)	**75.**	(a)
76.	(c)	**77.**	(a)	**78.**	(a)	**79.**	(a)	**80.**	(b)	**81.**	(a)	**82.**	(d)	**83.**	(d)	**84.**	(d)	**85.**	(c)	**86.**	(d)	**87.**	(d)	**88.**	(d)	**89.**	(d)	**90.**	(d)
91.	(c)	**92.**	(d)	**93.**	(d)	**94.**	(b)	**95.**	(c)	**96.**	(c)	**97.**	(a)	**98.**	(b)	**99.**	(a,c)	**100.**	(a,c)	**101.**	(a,b)	**102.**	(a,c,d)	**103.**	(a,b,d)	**104.**	(a,c)	**105.**	(b)
106.	(a)	**107.**	(d)	**108.**	(d)	**109.**	(c)	**110.**	(a)	**111.**	(c)	**112.**	(b)	**113.**	(b)	**114.**	(c)	**115.**	(b)	**116.**	(b)	**117.**	(c)	**118.**	(b)	**119.**	(a)	**120.**	(c)

Hints *and* Explanations

1. (*c*) In conductor, there is no storage of charge, so conduction current is the same as displacement current when sources are both Direct Current (DC) and Alternating Current (AC).

5. (*a*) The fact that an electric field changing with time gives rise to a magnetic field, is the symmetrical counterpart and is a consequence of the displacement current being a source of a magnetic field.

7. (*d*) Displacement current (I_d) is equal to charging current ($i_d = dq/dt$). Thus,

$$i_d = \frac{dq}{dt} = \frac{d}{dt}(q) = \frac{d}{dt}(q_0 \cos 2\pi\nu t)$$
$$= q_0 = (-\sin 2\pi\nu t)(2\pi\nu)$$
$$= -2\pi\, q_0\, \nu \sin(2\pi\nu t)$$

8. (*d*) Displacement current *i.e.,*

$$i_d = \varepsilon_0 \frac{d\phi_E}{dt} = \varepsilon_0 A \frac{d}{dt}\left(\frac{V}{d}\right)$$

$$\Rightarrow \quad i_d = \frac{\varepsilon_0 A}{d} \times \frac{dV}{dt} = C\frac{dV}{dt}$$

$$\Rightarrow \quad \frac{dV}{dt} = \frac{i_d}{C} = \frac{10}{10^{-6}} = 10^7 \text{ Vs}^{-1}$$

9. (*c*) As, we know, the displacement through the capacitor

i.e., $$i = \frac{dq}{dt} = \frac{d}{dt}(q_0 \sin 2\pi f t) = q_0 2\pi f \cos 2\pi f t.$$

10. (*c*) Here, cross-section area of a capacitor *i.e.,*

$$A = \pi R^2 = \pi (0.1 \text{ m})^2 = 3.14 \times 10^{-2} \text{ m}^2$$

i.e., $$\frac{dE}{dt} = 5 \times 10^{13} \text{ Vms}^{-1}$$

Thus, displacement current

i.e., $$i_d = \varepsilon_0 A \frac{dE}{dt}$$
$$= (8.85 \times 10^{-12} \text{ C}^2\text{Nm}^{-1})(3.14 \times 10^{-2} \text{ m}^2)$$
$$(5 \times 10^{13} \text{ Vms}^{-1}) = 13 \cdot 9 \text{ A}$$

11. (*c*) Here, $C = 8.00\,\mu\text{F} = 8.00 \times 10^{-6}$ F, $\nu = 3.00$ kHz,

$V_0 = 30.0$ V

Clearly, $\omega = 2\pi\nu = 2\pi \times (3.00 \times 10^3 \text{ s}^{-1}) = 6\pi \times 10^3 \text{ s}^{-1}$

Voltage across the capacitor, $V = V_0 \sin \omega t$

$$= (30.0) \sin (6\pi \times 10^3\, t)$$

Displacement current, $i_d = \dfrac{dq}{dt} = \dfrac{d}{dt}(q) = \dfrac{d}{dt}(CV) = C\dfrac{dV}{dt}$

$$= (8.00 \times 10^{-6}) \frac{d}{dt}[30.0 \sin (6\pi \times 10^3\, t)]$$
$$= (8.00 \times 10^{-6})(30.0) \frac{d}{dt}[\sin(6\pi \times 10^3\, t)]$$
$$= (8.00 \times 10^{-6})(30.0)[\cos(6\pi \times 10^3 t)] \frac{d}{dt}(6\pi \times 10^3 t)$$
$$= (8.00 \times 10^{-6})(30.0)(6\pi \times 10^3) \cos(6\pi \times 10^3\, t)$$
$$= (4.52 \text{ A}) \cos(6\pi \times 10^3\, t)$$

Hence, the displacement current varies sinusoidally with time and has a maximum value of 4.52 A.

12. (*b*) Here, $C = 2\mu$ F $= 2 \times 10^{-6}$ F

i_d (displacement current) $= 1$ mA $= 10^{-3}$ A

As, $$i_d = \frac{dq}{dt} = \frac{d}{dt}(CV) = C\frac{dV}{dt},$$

$$\frac{dV}{dt} = \left(\frac{1}{C}\right) i_d = \left(\frac{1}{2 \times 10^{-6} \text{ F}}\right)(10^{-3} \text{ A}) = 500 \text{ Vs}^{-1}$$

13. (*c*) Magnitude of displacement current is given by

$$I_d = I_C = \left|\frac{dq}{dt}\right| = 2 \times 10^{-7} \text{ Cs}^{-1} = 2 \times 10^{-7} \text{ A}$$

14. (*d*) The most important prediction to emerge from Maxwell's equations is the existence of electromagnetic waves, which are (coupled) time-varying electric and magnetic fields that propagate in space. The speed of the waves, according to these equations, turned out to be very close to the speed of light (3×10^8 ms^{-1}), obtained from optical measurements. This led to the remarkable conclusion that light is an electromagnetic waves.

15. (*a*) The total current passing through any surface of which the closed loop is the perimeter is the sum of the conduction current and the displacement current. The generalised law is $\oint B \cdot dl = \mu_0 \, i_c + \mu_0 \varepsilon_0 \frac{d\phi_E}{dt}$ and is known as Ampere-Maxwell law.

19. (*a*) Consider a loop of radius $r(< R)$ between the two circular plates, placed coaxially with them. The area of the loop $= \pi r^2$.

By symmetry, magnetic field is equal in magnitude at all points on the loop. If i_d is the displacement current crossing the loop and i_d is the total displacement current between plates $i_d = \frac{i_d}{\pi R^2} \times \pi r^2$.

Using Ampere-Maxwell's law, we have

$$\mathbf{B} \cdot d\mathbf{l} = \mu_0 i_d' \quad \text{or} \quad B \cdot 2\pi r = \mu_0 i_d \frac{\pi r^2}{\pi R^2} \quad \text{or} \quad B = \frac{\mu_0 i_d r}{2\pi R^2}$$

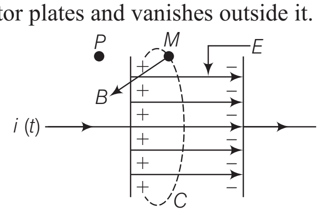
20. (*b*) Magnetic field strength B between the parallel plates capacitor *i.e.*, $B \cdot dt = \mu_0 i_d$

$$B = \frac{\mu_0 2 i_d}{4\pi r} = \frac{\mu_0}{4\pi} \frac{2 i_d}{r} = \frac{\mu_0}{4\pi} \frac{2}{r} \times \varepsilon_0 \frac{d\phi_E}{dt} \quad \left(\because i_d = \varepsilon_0 \frac{d\phi_E}{dt} \right)$$

$$(\because d\phi_E = dE \cdot A = dE \, \pi r^2)$$

$$= \frac{\mu_0 \varepsilon_0 \pi r^2 dE}{2\pi r \, dt} = \frac{\mu_0 \varepsilon_0 r}{2} \frac{dE}{dt}$$

21. (*a*) In parallel plate capacitor, electric field **E** is perpendicular to the surfaces. It has the same magnitude over the area A of the capacitor plates and vanishes outside it.



23. (*d*) In electromagnetic waves, the rest mass of a particle is zero, then net force exerted on a particle is zero. So, there is no deflection shown by a particle.

24. (*d*) Transverse elastic (sound) waves can also propagate in a solid, which is rigid and that resist shear.

27. (*c*) The velocity of light depends on electric and magnetic properties of the medium.

29. (*a*) Electromagnetic waves of different wavelengths that this velocity is the same (independent of wavelength) to within a few metres per second, out of the value of 3×10^8 ms^{-1}.

31. (*b*) Namely, the metre is now defined as the distance travelled by light in vacuum in a time $(1/c)$ seconds

$$= (2.99792458 \times 10^8)^{-1} \text{ s}.$$

33. (*a*) When the antenna is turned horizontal, the signal will be greatly diminished. Some portable radios have horizontal antenna (usually inside the case of radio), which are sensitive to the magnetic component of the electromagnetic wave. Such a radio must remain horizontal in order to receive the signal. In such cases, response also depends on the orientation of the radio with respect to the station.

39. (*a*) Solar radiation is transverse electromagnetic wave. It consists of electric and magnetic field components. These components are perpendicular to the direction of propagation of wave.

40. (*a*) According to Maxwell equation, the magnitude of the electric and magnetic fields in an electromagnetic wave are related as.

$$B = \frac{E}{c} = \frac{6.3 \text{ Vm}^{-1}}{3 \times 10^8 \text{ ms}^{-1}} = 2.1 \times 10^{-8} \, \hat{\mathbf{k}} \text{T}$$

41. (*c*) The total energy falling on the surface is

$$U = (18 \text{ Wcm}^{-2}) \times (20 \text{ cm}^2) \times (30 \times 60) = 6.48 \times 10^5 \text{ J}$$

Therefore, the total momentum delivered (for complete absorption) is

$$p = U/c = \frac{6.48 \times 10^5 \text{ J}}{3 \times 10^8 \text{ ms}^{-1}} = 2.16 \times 10^{-3} \text{ Jms}^{-1}$$

The average force exerted on the surface is

$$F = \frac{p}{t} = \frac{2.16 \times 10^{-3}}{0.18 \times 10^4} = 1.2 \times 10^{-6} \text{ N}$$

42. (*c*) Here, $I = 1300$ Wm^{-2}

As, $\quad I = \frac{1}{2} \varepsilon_0 c E_0^2$

As, we know, electric field *i.e.*, $E_0 = \sqrt{\frac{2I}{\varepsilon_0 c}}$

$$= \sqrt{\frac{2 \, (1300 \text{ Wm}^{-2})}{(8.85 \times 10^{-12} \text{C}^2\text{Nm}^{-2}) \, (3 \times 10^8 \text{ ms}^{-1})}}$$

or $\quad E_0 = 990$ NC^{-1}

So, magnetic field of sunlight *i.e.*,

$$B_0 = \frac{E_0}{c} = \frac{990 \text{ NC}^{-1}}{3 \times 10^8 \text{ ms}^{-1}} = 3.3 \times 10^{-6} \text{ T}$$

43. (*b*) Angular frequency, $\omega = 2\pi\nu = \frac{2\pi c}{\lambda} = \frac{2\pi \times 3 \times 10^8}{5 \times 10^{-3}}$

$$= 1.2\pi \times 10^{11} \text{ rads}^{-1}$$

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

$$E_x = E_0 \sin \omega \left(t - \frac{y}{c} \right) = 66 \sin 1.2\pi \times 10^{11} \, (t - y/c)$$

44. (*c*) Given, $E_0 = 120$ NC^{-1}, $\nu = 50.0$ MHz $= 50 \times 10^6$ Hz

As, we know, magnetic field

$$B_0 = \frac{E_0}{c} = \frac{120 \text{ NC}^{-1}}{3 \times 10^8 \text{ ms}^{-1}}$$

$$= 4 \times 10^{-7} \text{ T} = 400 \text{ nT}$$

$$\omega = 2\pi\nu = (2 \times 3.14 \text{ rad}) \, (50 \times 10^6 \text{ Hz})$$

$$= 3.14 \times 10^8 \text{ rads}^{-1}$$

Wave constant *i.e.,* $k = \frac{\omega}{c} = \frac{3.14\times 10^8 \text{ rads}^{-1}}{3\times 10^8 \text{ ms}^{-1}}$

$= 1.05 \text{ radm}^{-1}$

and wavelength *i.e.,* $\lambda = \frac{c}{\nu} = \frac{3\times 10^8 \text{ ms}^{-1}}{50\times 10^6 \text{ Hz}} = 6.00 \text{ m}$

If we take the wave to be propagating along X-axis, then **E** is along Y-axis and **B** is along Z-axis. Clearly,

$\mathbf{E} = E_0 \sin (kx - \omega t)\hat{\mathbf{j}}$

$= (120 \text{ N C}^{-1}) \sin \{(1.05 \text{ rad m}^{-1})x - (3.14\times 10^8 \text{ rads}^{-1})t)\}]\hat{\mathbf{j}}$

45. (*c*) Given, $B_y = 3\times 10^{-7} \sin (10^3 x + 6.28\times 10^{12} t)$

Comparing with the general equation

$B_y = B_0 \sin (kx + \omega t)$, we get

$k = 10^3 \Rightarrow \frac{2\pi}{\lambda} = 10^3 \qquad \left(\because k = \frac{2\pi}{\lambda}\right)$

$\Rightarrow$ Wavelength of electromagnetic wave

$\lambda = \frac{2\pi}{10^3} = 6.28\times 10^{-3} \text{ m} = 0.63 \text{ cm}$

46. (*b*) Here, energy flux, $\phi = 40 \text{ W cm}^{-2}$, surface area $(A) = 20 \text{ cm}^2$, time $(t) = 10 \text{ min} = 10\times 60 \text{ s}$.

Total energy falling on the surface in time t is

$U = \phi A t = 40\times 20\times (10\times 60)\text{J}$

Momentum of the incident light

$(p) = \frac{U}{c} = \frac{40\times 20\times (10\times 60)}{3\times 10^8}$

$= 24\times 10^{-4} \text{ kgs}^{-1}$

Momentum of the reflected light = 0

$\therefore$ Momentum delivered to the surface

$= 24\times 10^{-4} - 0$

$= 24\times 10^{-4} \text{ kg ms}^{-1}$

47. (*a*) In electromagnetic, the ratio of the amplitude of electric and magnetic field is always constant and it is equal to velocity of the electromagnetic waves.

i.e., $\frac{E}{B} = c \Rightarrow B = \frac{E}{c} = \frac{6}{3\times 10^8} = 2\times 10^{-8} \text{ T}$

Magnetic field of component B is 2×10^{-8} T along Z.

48. (*d*) Given refractive index *i.e.,* $n = 1.5$

Permeability of a medium *i.e.,* $\mu_0 = 5\times 10^{-7}$

$n = \frac{c}{v} \Rightarrow n = \sqrt{\mu_r \varepsilon_r}$

$\Rightarrow \varepsilon_r = \frac{n^2}{\mu_r} = \frac{n^2 \mu_0}{\mu} \qquad \left(\because \mu_r = \frac{\mu}{\mu_0}\right)$

$= \frac{(1.5)^2 \times 4\pi \times 10^{-7}}{5\times 10^{-7}} = 6 (\because \mu_0 = 4\pi \times 10^{-7} \text{Tm A}^{-1})$

49. (*b*) Velocity of light in vacuum $c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$

Velocity of light in medium $v = \frac{1}{\sqrt{\mu\varepsilon}}$

So, $\mu = \frac{c}{v} = \left(\frac{\mu\varepsilon}{\mu_0\varepsilon_0}\right)^{1/2}$

50. (*b*) Initial momentum of surface, $p_i = \frac{E}{c}$

where, c = velocity of light (constant) and E is energy

Since, the surface is perfectly reflecting, so the same momentum will be reflected completely.

Final momentum, $p_f = \frac{-E}{c}$ (negative value)

$\therefore$ Change in momentum, $\Delta p = p_f - p_i$

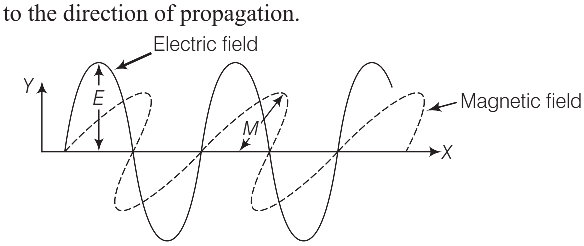
$= -\frac{E}{c} - \frac{E}{c} = -\frac{2E}{c}$

Thus, momentum transferred to the surface is

$\Delta p' = |\Delta p| = \frac{2E}{c}$.

51. (*c*) Electromagnetic radiation is a self propagating wave in space with electric and magnetic components.

These components oscillate at right angles to each other and to the direction of propagation.



Hence, B is along the Z-axis at that time.

52. (*a*) Electromagnetic wave equation

$E = E_0 \cos (kz - \omega t)$ ...(i)

Speed of electromagnetic wave $v = \frac{\omega}{k}$

Given, equation

$E = \hat{\mathbf{i}} 40 \cos (kz - 6\times 10^8 t)$ ...(ii)

Comparing Eqs. (i) and (ii), we get

$\omega = 6\times 10^8$ and $E_0 = 40\hat{\mathbf{i}}$

Here, wave factor $k = \frac{\omega}{v} = \frac{6\times 10^8}{3\times 10^8} = 2 \text{ m}^{-1}$

53. (*a*) Intensity or power per unit area of the radiations

$P = pv \Rightarrow p = \frac{P}{v}$

$= \frac{0.5}{3\times 10^8} = 0.166\times 10^{-8} \text{ Nm}^{-2}$

54. (*b*) As, $\mathbf{E} = \mathbf{B} \times \mathbf{c}$

where, E = electric field, B = magnetic field

c = speed of EM wave

On putting the values of electric field, we get

$$|\mathbf{E}| = |\mathbf{B}||\mathbf{c}|$$
$$= 20 \times 10^{-9} \times 3 \times 10^{-8} = 6\ \text{Vm}^{-1}$$

55. (*a*) When a charged particle q enters a region with velocity as v of charged particle is remaining constant, it means force acting on charged particle is zero.

So, $q\,(v \times B) = qE \Rightarrow v \times B = E$

Velocity of a charged particle

$$\therefore \quad v = \frac{E \times B}{B^2}, \quad \mathbf{v} = \frac{\mathbf{E} \times \mathbf{B}}{B^2}$$

56. (*b*) As I_E (intensity due to electric field) $= \frac{1}{2} c\varepsilon_0 E^2$

I_B (intensity due to magnetic field) $= \frac{cB^2}{2\mu_0}$

$$\frac{I_E}{I_B} = \frac{1/2 c\varepsilon_0 E^2}{cB^2/2\mu_0} = (\varepsilon_0 \mu_0)(E/B)^2 = \left(\frac{1}{c^2}\right)(c^2) = 1$$

$$\Rightarrow I_E = I_B = 4I_0 \qquad \left(\text{as } c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}} \text{ and } E/B = c\right)$$

58. (*d*) Electromagnetic waves include visible light, X-rays, gamma rays, radiowaves, microwaves and infrared waves.

60. (*a*) Infrared waves are produced by hot bodies and molecules. This band lies adjacent to the low-frequency or long-wavelength end of the visible spectrum.

61. (*d*) Infrared waves radiations, are trapped by greenhouse gases such as carbon dioxide and water vapour.

62. (*b*) Visible rays is the most familiar form of electromagnetic waves. It is the part of the spectrum that is detected by the human eye. It runs from about 4×10^{14} Hz to about 7×10^{14} Hz or a wavelength range of about 700-400 mm.

65. (*a*) UV-radiation is absorbed by ordinary glass.

66. (*a*) Given, energy of EM waves is of the order of 15 keV

i.e., $$E = h\nu = h \times \frac{c}{\lambda}$$

$$\Rightarrow \quad \lambda = \frac{h \times c}{E} = \frac{6.624 \times 10^{-34} \times 3 \times 10^{18}}{15 \times 10^3 \times 1.6 \times 10^{-19}}$$

$$= \frac{1.3248 \times 10^{-29}}{1.6 \times 10^{-19}} = 0.828 \times 10^{-10}\,\text{m}$$

$$\lambda = 0.828\ \text{Å} \qquad (\because 1\text{Å} = 10^{-10}\,\text{m})$$

Thus, this spectrum is a part of X-rays.

69. (*a*) One common way to generate X-rays is to bombard a metal target by high energy electrons. X-rays is to bombard a metal target by high energy electrons.

70. (*b*) In electromagnetic spectrum, all components of electric and magnetic fields in vacuum are carrying same velocity of light *i.e.,* $3 \times 10^8\,\text{ms}^{-1}$.

72. (*b*) Diffraction takes places when the wavelength of wave is comparable with the size of the obstacle in path. The wavelength of radiowaves is greater than the wavelength of light waves. Therefore, radio waves are diffracted around building.

73. (*a*) X-rays has wavelength about 1 nm to 10^{-3} nm which has minimum wavelength and carries maximum energy *i.e.,* $E \propto \frac{1}{\lambda}$. So, It penetrates the target and hence are not reflected back by target.

75. (*a*) On applying Ampere's circuital law to such surfaces with the same perimeter, we find that the left hand side of equation $\oint B.dl = \mu_0 i(t)$ has not changed but the right hand side is zero and not $\mu_0 i$. Since, no current passes through the surface.

76. (*c*) We needed to set up an AC circuit in which the current oscillate at the frequency of visible light, *i.e.,* yellow. The frequency of yellow light is about 6×10^{14} Hz, while the frequency that we get even with modern electronic circuits is hardly about 10^{11} Hz. This is why the experimental demonstration of electromagnetic wave had to come in the low frequency region (the radio wave region), as in the Hertz's experiment (1887).

77. (*a*) An oscillating charge produces an electric field in space, which produces an oscillating magnetic field, which in turn, is a source of electric field.

78. (*a*) When the sun shines on your hand, you feel the energy being absorbed from the electromagnetic waves (your hands get warm). Electromagnetic waves also transfer momentum to your hand but because c is very large, the amount of momentum transferred is extremely small and you do not feel the pressure.

79. (*a*) Infrared waves are sometimes referred to as heat waves. This is because water molecules present in most materials readily absorb infrared waves (many other molecules, *e.g.,* CO_2, NH_3, also absorb infrared waves). After absorption, their thermal motion increases, that is, they heat up and heat their surroundings.

80. (*b*) Due to its shorter wavelengths, UV-radiations can be focussed into very narrow beams for high precision applications such as LASIK (Laser assisted in situ keratomileusis) eye surgery, UV lamps are used to kill germs in water purifier.

81. (*a*) X-rays are used as a diagnostic tool in medicine and as a treatment for certain forms of cancer. Because X-rays damage or destroy living tissues and organisms, care must be taken to avoid unnecessary or over exposure.

82. (*d*) According to Gaussian surfaces, net electric flux *i.e.,*

$$\phi_E = |E|A = \left(\frac{1}{\varepsilon_0}\frac{Q}{A}\right) \times A = \frac{Q}{\varepsilon_0}$$

84. (*d*) The total current i is the sum of the conduction current denoted by i_c, and the displacement current denoted by i_d $[= \varepsilon_0 (d\phi_E/dt)]$. So, we have

$$i = i_c + i_d = i_c + \varepsilon_0 \frac{d\phi_E}{dt}$$

In explicit terms, this means that outside the capacitor plates, we have only conduction current $i_c = i$ and no displacement current *i.e.,* $i_c = 0$ and there is only displacement current, so that $i_d = i$.

86. (*d*) Electromagnetic waves are self-sustaining oscillation of electric and magnetic fields in free space, or vacuum. They differ from all the other waves we have studied so far, in respect that no material medium is involved in the vibration of the electric and magnetic fields.

Sound waves in air are longitudinal waves of compression and rarefaction. Transverse waves on the surface of water consist of water moving up and down as the wave spreads horizontally and radially onwards.

87. (*d*) The great technological importance of electromagnetic waves stems from their capability to carry energy from one place to another. The radio and TV signals from broadcasting stations carry energy. Light carries energy from the sun to the earth, thus making life possible on the earth.

88. (*d*) Radio waves are produced by the accelerated motion of charges in conducting wires. They are used in radio and television communication systems. They are generally in the frequency range from 500 kHz to about 1000 MHz. The AM (amplitude modulated) band is from 530 kHz to 1710 kHz.

Higher frequencies upto 54 MHz are used for short wave bands. TV waves range from 54 MHz to 890 MHz.

The FM (frequency modulated) radio band extends from 88 MHz to 108 MHz. Cellular phones use radio waves to transmit voice communication in the Ultra High Frequency (UHF) band.

89. (*d*) Ultraviolet rays covers wavelength ranging from about 4×10^{-7} m (400 nm) down to 6×10^{-10} m (0.6 nm). It is produced by special lamps and very hot bodies. The sun is an important source of ultraviolet light.

But fortunately, most of it is absorbed in the ozone layer in the atmosphere at an altitude of about 40-50 km.

91. (*c*) A. $\int \mathbf{E}\, d\mathbf{A} = q/\varepsilon_0$ (Gauss's law for electricity)

B. $\int \mathbf{B}\, dl = 0$ (Gauss's law for magnetism)

C. $\int \mathbf{E} dl = \frac{-d\phi_B}{dt}$ (Faraday's law)

D. $\int \mathbf{B}\, dl = \mu_0 i_c + \mu_0\varepsilon_0 \frac{d\phi_E}{dt}$ (Ampere-Maxwell law)

92. (*d*)

Column I	Column II
A. Radio	4. 500 kHz to 1000 MHz
B. Amplitude modulated	3. 530 kHz to 1710 kHz
C. Short wave bands	1. 54 MHz
D. TV wave	5. 54 MHz to 890 MHz
E. Frequency modulated	2. 88 MHz to 108 MHz

94. (*b*) Comparing the given equation with magnetic field in a plane

i.e., $B_y = B_0 \sin\left[2\pi\left(\frac{x}{\lambda} + \frac{t}{T}\right)\right]$

we get $\lambda = \frac{2\pi}{0.5\times 10^3}$ m= 1.26 cm

95. (*c*) As we know frequency *i.e.,* $\nu = \frac{1}{\text{Time taken}}$

$$\frac{1}{T} = \frac{\omega}{2\pi} = (1.5\times 10^{11})/2\pi = 23.9 \text{ GHz}$$

96. (*c*) According to Maxwell equation, electric field

i.e., $E_0 = B_0 c = 2\times 10^{-7} \times 3\times 10^8 \text{ ms}^{-1} = 6\times 10^1 \text{ Vm}^{-1}$.

The electric field component is perpendicular to the direction of propagation and the direction of magnetic field. Therefore, the electric field component along the *Z*-axis is obtained as

$$E_z = 60 \sin (0.5\times 10^3 x + 1.5\times 10^{11} t) \text{ Vm}^{-1}$$

97. (*a*) Wavelength of waves $\lambda = \frac{c}{f} = \frac{3\times 10^8}{2\times 10^{10}} = 1.5\times 10^{-2}$ m

98. (*b*) Using the formula, $c = \frac{E_0}{B_0}$

The amplitude of the oscillating magnetic field

$$B_0 = \frac{E_0}{c} = \frac{48}{3\times 10^8} = 1.6\times 10^{-7} \text{ T}$$

100. (*a,c*) Amplitude = 10 Vm^{-1}

$$c = \frac{\omega}{k} \Rightarrow 3\times 10^8 = \frac{10^7}{k}$$

$$\Rightarrow \quad k = \frac{1}{30}$$

$$\Rightarrow \quad \frac{2\pi}{\lambda} = \frac{1}{30} \Rightarrow \lambda = 188.4 \text{ m}$$

104. (*a,c*) $V_X > V_M > V_R$

$\therefore \quad E_X > E_M > E_R$

105. (*b*) Capacitive reactance,

$$X_c = \frac{1}{\omega C} = \frac{1}{300\times 10^{-10}}$$

$$X_c = \frac{10^8}{3}\ \Omega$$

If i_{rms} is the rms value of the conduction current.

Then, $i_{\text{rms}} = \frac{V_{\text{rms}}}{X_c} = \frac{230 \text{ V}}{(10^8/3)\Omega} = 6.9\times 10^{-6} \text{ A} = 6.9\mu \text{ A}$

107. (*d*) Given, the distance or point from the axis between the plates

$$r = 3 \text{ cm} = 3\times 10^{-2} \text{ m}$$

Radius of plates $R = 6 \text{ cm} = 6\times 10^{-2}$ m

The magnetic field at a point between the plates

$$B = \frac{\mu_0}{2\pi R^2} \cdot r \cdot I_d \quad \Rightarrow \quad B = \frac{\mu_0 r}{2\pi R^2} I \qquad (I_d = I)$$

If $I = I_0$, maximum value of current, then $I = \sqrt{2} I_{\text{rms}}$

$$B = \frac{\mu_0 r}{2\pi R^2} \sqrt{2} I_{\text{rms}}$$

$$B = \frac{4\pi \times 10^{-7} \times 0.03 \times \sqrt{2} \times 6.9 \times 10^{-6}}{2\pi \times 0.06 \times 0.06}$$

$$B = 1.63 \times 10^{-11} \text{ T}$$

108. (*d*) Capacitance of parallel plate capacitor

$$C = \frac{\varepsilon_0 A}{d}$$

where, A is the area of plates.

$$C = \frac{8.854 \times 10^{-12} \times 3.14 \, (12 \times 10^{-2})^2}{5 \times 10^{-2}}$$

$$\Rightarrow \quad C = \frac{8.854 \times 3.14 \times 144 \times 10^{-12-4+2}}{5}$$

$$\Rightarrow \quad C = 8.01 \times 10^{-14} \text{ F} = 8.01 \text{ pF}$$

109. (*c*) Charge on the plates of the capacitor

$$q = CV$$

$$\Rightarrow \quad \frac{dq}{dt} = C \cdot \frac{dV}{dt} \quad \Rightarrow \quad I = C \cdot \frac{dV}{dt} \quad \left(\because \frac{dq}{dt} = I \right)$$

$$\Rightarrow \quad \frac{dV}{dt} = \frac{I}{C} = \frac{0.15}{8.01 \times 10^{-12}} = 18.7 \times 10^9 \text{Vs}^{-1}$$

Thus, the rate of change of potential is 18.7×10^9 Vs^{-1}.

110. (*a*) The displacement current is equal to the conduction current

$$I_d = 0.15 \text{ A.}$$

111. (*c*) Speed of light in vacuum

$$c = \frac{E_0}{B_0} \quad \Rightarrow \quad B_0 = \frac{E_0}{c} = \frac{120}{3 \times 10^8} = 40 \times 10^{-8}$$

or $\quad B_0 = 400 \times 10^{-9} \text{ T} = 400 \text{ nT}$

112. (*b*) Angular frequency of wave,

$$\omega = 2\pi f = 2 \times 3.14 \times 50 \times 10^6$$

$$\Rightarrow \quad \omega = 3.14 \times 10^8 \text{ rads}^{-1}$$

113. (*b*) Wave number of electromagnetic waves

$$k = \frac{\omega}{c} = \frac{3.14 \times 10^8}{3 \times 10^8} = 1.05 \text{ radm}^{-1} = 1 \text{ rad m}^{-1}$$

114. (*c*) Wavelength of electromagnetic wave

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{50 \times 10^6} = 6.00 \text{ m}$$

115. (*b*) Total power = 100 W

Visible radiation power = 5% of total power

$$= \frac{5}{100} \times 100 = 5 \text{ W}$$

At a distance of 1m, the energy distributed in the form of sphere.

Area of sphere = 4π (radius)^2

Intensity of visible radiation

$$= \frac{\text{Power}}{\text{Area}} = \frac{5}{4 \times 3.14 \times (1)^2} = 0.4 \text{ Wm}^{-2}$$

116. (*b*) Given, magnetic field part of harmonic electromagnetic wave

$$B_0 = 510 \text{ nT}$$

Speed of light in vacuum $c = \dfrac{E_0}{B_0}$

where, E_0 is the electric part of the wave

$$3 \times 10^8 = \frac{E_0}{510 \times 10^{-9}} \quad \text{or} \quad E_0 = 153 \text{ NC}^{-1}$$

Thus, the amplitude of the electric field part of wave is 153 NC^{-1}.

117. (*c*) The electric part of electromagnetic wave in vacuum

$$E = 3.1 \cos(1.8Y + 5.4 \times 10^6 t) \,\hat{\mathbf{i}}$$

Comparing with standard equation

$$E = E_0 \cos(ky + \omega t), \text{ we get}$$

Angular frequency $\omega = 5.4 \times 10^6$ rads^{-1}

Wave number, $k = 1.8 \text{ radm}^{-1}$

The amplitude of the electric field part of the wave

$$E_0 = 3.1 \text{ NC}^{-1}$$

$$\lambda = \frac{2\pi}{k} = \frac{2\pi}{1.8} = 3.492 \text{ m}$$

$$\lambda = 3.5 \text{ m}$$

118. (*b*) As, $\omega = 2\pi\nu$

$$\nu = \frac{\omega}{2\pi} = \frac{5.4 \times 10^6 \times 7}{2 \times 22} = 0.86 \times 10^6 \text{ Hz}$$

119. (*a*) $c = \dfrac{E_0}{B_0}$

Amplitude of magnetic field

$$B_0 = \frac{E_0}{c} = \frac{3.1}{3 \times 10^8} = 1.03 \times 10^{-8} \text{ T} \approx 10^{-8} \text{ T}$$

120. (*c*) Given, energy required to dissociate a carbon monoxide molecule into carbon and oxygen atoms $E = 11 \text{ eV}$

We know that, $E = h\nu$

where $\quad h = 6.62 \times 10^{-34} \text{J-s} \quad \Rightarrow \quad 11 \text{ eV} = h\nu$

$$\Rightarrow \quad \nu = \frac{11 \times 1.6 \times 10^{-19}}{h} \text{ J} = 2.65 \times 10^{15} \text{Hz}$$

This frequency radiation belongs to ultraviolet region.

121. (*b*) The incident electromagnetic wave is,

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

The reflected electromagnetic wave is given by

$$\mathbf{E}_r = E_0(-\hat{\mathbf{i}}) \cos[k(-z) - \omega t + \pi]$$

$$= -E_0 \hat{\mathbf{i}} \cos[-(kz + \omega t) + \pi]$$

$$= E_0 \hat{\mathbf{i}} \cos[-(kz + \omega t) = E_0 \hat{\mathbf{i}} \cos(kz + \omega t)]$$

122. *(b)* Given, energy flux $\phi = 20 \text{Wcm}^{-2}$

$A = 30\text{cm}^2$, $t = 30 \min = 30 \times 60$ s

Now, total energy falling on the surface in time t is,
$U = \phi A t = 20 \times 30 \times (30 \times 60)$ J

Momentum of the incident light $= \dfrac{U}{c}$

$$= \frac{20 \times 30 \times (30 \times 60)}{3 \times 10^8} = 36 \times 10^{-4} \text{ kg-ms}^{-1}$$

Momentum of the reflected light = 0
∴ Momentum delivered to the surface

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

123. (*a*) We know that, $E_0 \propto \sqrt{P_{\text{av}}}$

$$\therefore \quad \frac{(E_0)_1}{(E_0)_2} = \sqrt{\frac{(P_{\text{av}})_1}{(P_{\text{av}})_2}} \Rightarrow \frac{E}{(E_0)_2} = \sqrt{\frac{1000}{50}}$$

$$(E_0)_2 = E / \sqrt{2}$$

Now according to question, $P' = 50$ W, $P = 100$ W

∴ Putting these value in above equation, we get

$$\frac{E'}{E} = \frac{50}{100} \Rightarrow \frac{E'}{E} = \frac{1}{2} \quad \Rightarrow \quad E' = \frac{E}{2}$$

125. (*c*) Intensity in terms of electric field, $U_{\text{av}} = \dfrac{1}{2}\varepsilon_0 E_0^2$

Intensity in terms of magnetic field, $U_{\text{av}} = \dfrac{1}{2}\dfrac{B_0^2}{\mu_0}$

Now taking the intensity in terms of electric field.

$$(U_{\text{av}})_{\text{electric field}} = \frac{1}{2}\varepsilon_0 E_0^2 = \frac{1}{2}\varepsilon_0 (cB_0)^2 \qquad (\because E_0 = cB_0)$$

$$= \frac{1}{2}\varepsilon_0 \times c^2 B_0{}^2$$

But, $\quad c = \dfrac{1}{\sqrt{\mu_0 \varepsilon_0}}$

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

$$= (U_{\text{av}})_{\text{magnetic field}}$$

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

Therefore, the ratio of contributions by the electric field and magnetic field components to the intensity of an electromagnetic wave is 1 : 1.

126. (*d*) Here, in electromagnetic wave, the electric field vector is given as,

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

In electromagnetic wave, the associated magnetic field vector,

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

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

127. (*a,b,c*) Suppose an electromagnetic wave is travelling along negative *z*-direction. Its electric field is given by

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

which is perpendicular to *Z*-axis. It acts along negative *y*-direction.

The associated magnetic field **B** in electromagnetic wave is along *X*-axis *i.e.,* along $\hat{\mathbf{k}} \times \mathbf{E}$.

As, $\quad B_0 = \dfrac{E_0}{c} \quad \Rightarrow \quad \mathbf{B} = \dfrac{1}{c}(\hat{\mathbf{k}} \times \mathbf{E})$

The associated electric field can be written in terms of magnetic field as

$$\mathbf{E} = c\,(\mathbf{B} \times \hat{\mathbf{k}}).$$

Angle between $\hat{\mathbf{k}}$ and **E** is 90° between $\hat{\mathbf{k}}$ and **B** is 90°.
Therefore, $\mathbf{E} = 1E \cos 90° = 0$ and $\hat{\mathbf{k}} \cdot \mathbf{B} = 1\,E \cos 90° = 0$.

129. (*a, c, d*) Given, frequency by which the charged particles oscillates about its mean equilibrium position $= 10^9$Hz.

So, frequency of electromagnetic waves produced by the charged particle is $\nu = 10^9$ Hz.

$$\text{Wavelength } \lambda = \frac{c}{\nu} = \frac{3 \times 10^8}{10^9} = 0.3 \text{ m}$$

Also, frequency of 10^9 Hz fall in the region of radiowaves.

130. (*b, d*) Here, in option (b) charge is moving in a circular orbit.
In circular motion, the direction of the motion of charge is changing continuously, thus it is an accelerated motion and this option is correct.
Also, we know that a charge starts accelerating when it falls in an electric field.

131. (*a, c, d*) When wave is fully absorbed by the surface, the momentum of the reflected wave per unit time per unit area = 0.

Radiation pressure (p) = change in momentum per unit time per unit area $= \dfrac{\Delta I}{c} = \dfrac{I}{c} - 0 = \dfrac{I}{c}$.

When wave is totally reflected, then momentum of the reflected wave per unit time per unit area $= -\dfrac{I}{c}$,

Radiation pressure $p = \dfrac{I}{c} - \left(-\dfrac{I}{c}\right) = \dfrac{2I}{c}$.

Here, p lies between $\dfrac{I}{c}$ and $\dfrac{2I}{c}$.

132. (*b*) Magnetic field $\mathbf{B} = B_0 \sin \omega t$

Given, equation $B = 12 \times 10^{-8} \sin(1.20 \times 10^7 z - 3.60 \times 10^{15} t)$ T.

On comparing this equation with standard equation, we get

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

The average intensity of the beam $I_{\text{av}} = \dfrac{1}{2}\dfrac{B_0^2}{\mu_0} \cdot c$

$$= \frac{1}{2} \times \frac{(12 \times 10^{-8})^2 \times 3 \times 10^8}{4\pi \times 10^{-7}} = 1.71 \text{ W/m}^2$$