

Chapter 17. Electromagnetics Waves

1. In an electromagnetic wave in free space the root mean square value of the electric field is $E_{\text{rms}} = 6 \text{ V m}^{-1}$. The peak value of the magnetic field is
 (a) $2.83 \times 10^{-8} \text{ T}$ (b) $0.70 \times 10^{-8} \text{ T}$
 (c) $4.23 \times 10^{-8} \text{ T}$ (d) $1.41 \times 10^{-8} \text{ T}$
 (NEET 2017)
2. A 100Ω resistance and a capacitor of 100Ω reactance are connected in series across a 220 V source. When the capacitor is 50% charged, the peak value of the displacement current is
 (a) 2.2 A (b) 11 A
 (c) 4.4 A (d) $11\sqrt{2} \text{ A}$
 (NEET-II 2016)
3. Out of the following options which one can be used to produce a propagating electromagnetic wave?
 (a) A chargeless particle
 (b) An accelerating charge
 (c) A charge moving at constant velocity
 (d) A stationary charge
 (NEET-I 2016)
4. The energy of the em waves is of the order of 15 keV . To which part of the spectrum does it belong?
 (a) Ultraviolet rays (b) γ -rays
 (c) X-rays (d) Infra-red rays
 (2015)
5. A radiation of energy ' E ' falls normally on a perfectly reflecting surface. The momentum transferred to the surface is (C = Velocity of light)
 (a) $\frac{2E}{C^2}$ (b) $\frac{E}{C^2}$
 (c) $\frac{E}{C}$ (d) $\frac{2E}{C}$
 (2015 Cancelled)
6. Light with an energy flux of $25 \times 10^4 \text{ W m}^{-2}$ falls on a perfectly reflecting surface at normal incidence. If the surface area is 15 cm^2 , the average force exerted on the surface is
 (a) $1.25 \times 10^{-6} \text{ N}$
 (b) $2.50 \times 10^{-6} \text{ N}$
 (c) $1.20 \times 10^{-6} \text{ N}$
 (d) $3.0 \times 10^{-6} \text{ N}$
 (2014)
7. The condition under which a microwave oven heats up a food item containing water molecules most efficiently is
 (a) Microwaves are heat waves, so always produce heating.
 (b) Infra-red waves produce heating in a microwave oven.
 (c) The frequency of the microwaves must match the resonant frequency of the water molecules.
 (d) The frequency of the microwaves has no relation with natural frequency of water molecules.
 (NEET 2013)
8. An electromagnetic wave of frequency $\nu = 3.0 \text{ MHz}$ passes from vacuum into a dielectric medium with relative permittivity $\epsilon = 4.0$. Then
 (a) Wavelength is doubled and frequency becomes half.
 (b) Wavelength is halved and frequency remains unchanged.
 (c) Wavelength and frequency both remain unchanged.
 (d) Wavelength is doubled and frequency unchanged.
 (Karnataka NEET 2013)
9. The electric field associated with an em wave in vacuum is given by $E = \hat{i} 40 \cos(kz - 6 \times 10^8 t)$ where E , z and t are in volt/m, meter and seconds respectively. The value of wave vector k is
 (a) 2 m^{-1} (b) 0.5 m^{-1}
 (c) 6 m^{-1} (d) 3 m^{-1}
 (2012)

10. The ratio of amplitude of magnetic field to the amplitude of electric field for an electromagnetic wave propagating in vacuum is equal to
 (a) the speed of light in vacuum
 (b) reciprocal of speed of light in vacuum
 (c) the ratio of magnetic permeability to the electric susceptibility of vacuum
 (d) unity (Mains 2012)
11. The electric and the magnetic field, associated with an e.m. wave, propagating along the +z-axis, can be represented by
 (a) $\vec{E} = E_0 \hat{i}, \vec{B} = B_0 \hat{j}$
 (b) $\vec{E} = E_0 \hat{k}, \vec{B} = B_0 \hat{i}$
 (c) $\vec{E} = E_0 \hat{j}, \vec{B} = B_0 \hat{i}$
 (d) $\vec{E} = E_0 \hat{j}, \vec{B} = B_0 \hat{k}$ (2011)
12. The decreasing order of wavelength of infrared, microwave, ultraviolet and gamma rays is
 (a) microwave, infrared, ultraviolet, gamma rays
 (b) gamma rays, ultraviolet, infrared, microwaves
 (c) microwaves, gamma rays, infrared, ultraviolet
 (d) infrared, microwave, ultraviolet, gamma rays (2011)
13. Which of the following statement is false for the properties of electromagnetic waves?
 (a) Both electric and magnetic field vectors attain the maxima and minima at the same place and same time.
 (b) The energy in electromagnetic wave is divided equally between electric and magnetic vectors.
 (c) Both electric and magnetic field vectors are parallel to each other and perpendicular to the direction of propagation of wave.
 (d) These waves do not require any material medium for propagation. (2010)
14. The electric field of an electromagnetic wave in free space is given by $\vec{E} = 10 \cos(10^7 t + kx) \hat{j}$ V/m, where t and x are in seconds and metres respectively. It can be inferred that
 (1) the wavelength λ is 188.4 m.
 (2) the wave number k is 0.33 rad/m.
 (3) the wave amplitude is 10 V/m.
 (4) the wave is propagating along +x direction.
 Which one of the following pairs of statements is correct?
 (a) (3) and (4) (b) (1) and (2)
 (c) (2) and (3) (d) (1) and (3) (Mains 2010)
15. The electric field part of an electromagnetic wave in a medium is represented by $E_x = 0$;
 $E_y = 2.5 \frac{N}{C} \cos \left[\left(2\pi \times 10^6 \frac{\text{rad}}{\text{m}} \right) t - \left(\pi \times 10^{-2} \frac{\text{rad}}{\text{s}} \right) x \right]$;
 $E_z = 0$. The wave is
 (a) moving along x direction with frequency 10^6 Hz and wavelength 100 m.
 (b) moving along x direction with frequency 10^6 Hz and wavelength 200 m.
 (c) moving along -x direction with frequency 10^6 Hz and wavelength 200 m.
 (d) moving along y direction with frequency $2\pi \times 10^6$ Hz and wavelength 200 m. (2009)
16. The velocity of electromagnetic radiation in a medium of permittivity ϵ_0 and permeability μ_0 is given by
 (a) $\frac{1}{\sqrt{\mu_0 \epsilon_0}}$ (b) $\sqrt{\frac{\mu_0}{\epsilon_0}}$
 (c) $\sqrt{\frac{\epsilon_0}{\mu_0}}$ (d) $\sqrt{\mu_0 \epsilon_0}$ (2008)
17. The electric and magnetic field of an electromagnetic 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. (2007, 1994)
18. If λ_v , λ_x and λ_m represent the wavelengths of visible light, X-rays and microwaves respectively, then
 (a) $\lambda_m > \lambda_x > \lambda_v$ (b) $\lambda_m > \lambda_v > \lambda_x$
 (c) $\lambda_v > \lambda_x > \lambda_m$ (d) $\lambda_v > \lambda_m > \lambda_x$. (2005)

19. We consider the radiation emitted by the human body. Which one of the following statements is true?
 (a) The radiation emitted is in the infra-red region
 (b) The radiation is emitted only during the day
 (c) The radiation is emitted during the summers and absorbed during the winters
 (d) The radiation emitted lies in the ultraviolet region and hence is not visible (2003)
20. Which of the following rays are not electromagnetic waves?
 (a) X-rays (b) γ -rays
 (c) β -rays (d) heat rays (2003)
21. The velocity of electromagnetic wave is parallel to
 (a) $\vec{B} \times \vec{E}$ (b) $\vec{E} \times \vec{B}$
 (c) \vec{E} (d) \vec{B} . (2002)
22. What is the cause of Green house effect?
 (a) infra-red rays (b) ultra violet rays
 (c) X-rays (d) radio waves. (2002)
23. Biological importance of ozone layer is
 (a) it stops ultraviolet rays
 (b) ozone layer reduces green house effect
 (c) ozone layer reflects radio waves
 (d) ozone layer controls O_2/H_2 ratio in atmosphere. (2001)
24. The frequency order for γ -rays (B), X-rays (A), UV rays (C) is
 (a) $B > A > C$ (b) $A > B > C$
 (c) $C > B > A$ (d) $A > C > B$. (2000)
25. Ozone layer blocks the radiations of wavelength
 (a) more than 3×10^{-7} m
 (b) equal to 3×10^{-7} m
 (c) less than 3×10^{-7} m
 (d) all of these (1999)
26. Wavelength of light of frequency 100 Hz
 (a) 4×10^6 m (b) 3×10^6 m
 (c) 2×10^6 m (d) 5×10^{-5} m (1999)
27. If ϵ_0 and μ_0 are the electric permittivity and magnetic permeability in a free space, ϵ and μ are the corresponding quantities in medium, the index and refraction of the medium is
 (a) $\sqrt{\frac{\epsilon_0 \mu_0}{\epsilon \mu}}$ (b) $\sqrt{\frac{\epsilon \mu}{\epsilon_0 \mu_0}}$
 (c) $\sqrt{\frac{\epsilon_0 \mu}{\epsilon \mu_0}}$ (d) $\sqrt{\frac{\epsilon}{\epsilon_0}}$. (1997)
28. Which of the following electromagnetic radiations have the smaller wavelength?
 (a) X-rays (b) γ -rays
 (c) UV waves (d) microwaves. (1994)
29. A signal emitted by an antenna from a certain point can be received at another point of the surface in the form of
 (a) sky wave (b) ground wave
 (c) sea wave (d) both (a) and (b) (1993)
30. The structure of solids is investigated by using
 (a) cosmic rays
 (b) X-rays
 (c) γ -rays
 (d) infra-red radiations (1992)
31. The frequency of electromagnetic wave, which best suited to observe a particle of radius 3×10^{-4} cm is of the order of
 (a) 10^{15} (b) 10^{14}
 (c) 10^{13} (d) 10^{12} (1991)
32. In which of the following, emission of electrons does not take place
 (a) thermionic emission
 (b) X-rays emission
 (c) photoelectric emission
 (d) secondary emission (1990)
33. Which of the following electromagnetic radiations have the longest wavelength?
 (a) X-rays (b) γ -rays
 (c) Microwaves (d) Radiowaves (1989)

Answer Key

1. (a) 2. (a) 3. (b) 4. (c) 5. (d) 6. (b) 7. (c) 8. (b) 9. (a) 10. (b)
 11. (a) 12. (a) 13. (c) 14. (d) 15. (b) 16. (a) 17. (c) 18. (b) 19. (a) 20. (c)
 21. (b) 22. (a) 23. (a) 24. (a) 25. (d) 26. (b) 27. (b) 28. (b) 29. (d) 30. (b)
 31. (b) 32. (b) 33. (d)

EXPLANATIONS

1. (a) : Given: $E_{\text{rms}} = 6 \text{ V m}^{-1}$

$$\frac{E_{\text{rms}}}{B_{\text{rms}}} = c \text{ or } B_{\text{rms}} = \frac{E_{\text{rms}}}{c}$$

$$B_{\text{rms}} = \frac{6}{3 \times 10^8} = 2 \times 10^{-8} \text{ T}$$

Since, $B_{\text{rms}} = \frac{B_0}{\sqrt{2}}$

where B_0 is the peak value of magnetic field.

$$\therefore B_0 = B_{\text{rms}} \sqrt{2} = 2 \times 10^{-8} \times \sqrt{2} \text{ T}$$

$$B_0 \approx 2.83 \times 10^{-8} \text{ T}$$

2. (a) : Here, $R = 100 \Omega$, $X_L = 100 \Omega$

Net impedance, $Z = \sqrt{R^2 + X_L^2} = 100\sqrt{2} \Omega$

Peak value of displacement current

= Maximum conduction current in the circuit

$$= \frac{\epsilon_0}{Z} = \frac{220\sqrt{2}}{100\sqrt{2}} = 2.2 \text{ A}$$

3. (b) : An accelerating charge is used to produce oscillating electric and magnetic fields, hence the electromagnetic wave.

4. (c) : As $\lambda = \frac{hc}{E}$

where the symbols have their usual meanings.

Here, $E = 15 \text{ keV} = 15 \times 10^3 \text{ V}$

and $hc = 1240 \text{ eV nm}$

$$\therefore \lambda = \frac{1240 \text{ eV nm}}{15 \times 10^3 \text{ eV}} = 0.083 \text{ nm}$$

As the wavelength range of X-rays is from 1 nm to 10^{-3} nm , so this wavelength belongs to X-rays.

5. (d) : Energy of radiation, $E = h\nu = \frac{hC}{\lambda}$

Also, its momentum $p = \frac{h}{\lambda} = \frac{E}{C} = p_i$

$$p_r = -p_i = -\frac{E}{C}$$

So, momentum transferred to the surface

$$= p_i - p_r = \frac{E}{C} - \left(-\frac{E}{C}\right) = \frac{2E}{C}$$

6. (b) : Here, Energy flux, $I = 25 \times 10^4 \text{ W m}^{-2}$

Area, $A = 15 \text{ cm}^2 = 15 \times 10^{-4} \text{ m}^2$

Speed of light, $c = 3 \times 10^8 \text{ m s}^{-1}$

For a perfectly reflecting surface, the average force exerted on the surface is

$$F = \frac{2IA}{c} = \frac{2 \times 25 \times 10^4 \text{ W m}^{-2} \times 15 \times 10^{-4} \text{ m}^2}{3 \times 10^8 \text{ m s}^{-1}}$$

$$= 250 \times 10^{-8} \text{ N} = 2.50 \times 10^{-6} \text{ N}$$

7. (c) : In microwave oven the frequency of the microwaves must match the resonant frequency of water molecules so that energy from the waves is transferred efficiently to the kinetic energy of the molecules.

8. (b) : Frequency of electromagnetic wave does not change with change in medium but wavelength and velocity of wave changes with change in medium.

Velocity of electromagnetic wave in vacuum

$$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}} = v \lambda_{\text{vacuum}} \quad \dots(i)$$

Velocity of electromagnetic wave in the medium

$$v_{\text{medium}} = \frac{1}{\sqrt{\mu_0 \mu_r \epsilon_0 \epsilon_r}} = \frac{c}{\sqrt{\mu_r \epsilon_r}}$$

where μ_r and ϵ_r be relative permeability and relative permittivity of the medium.

For dielectric medium, $\mu_r = 1$

$$\therefore v_{\text{medium}} = \frac{c}{\sqrt{\epsilon_r}}$$

Here, $\epsilon_r = 4.0$

$$\therefore v_{\text{medium}} = \frac{c}{\sqrt{4}} = \frac{c}{2} \quad \dots(ii)$$

Wavelength of the wave in medium

$$\lambda_{\text{medium}} = \frac{v_{\text{medium}}}{\nu} = \frac{c}{2\nu} = \frac{\lambda_{\text{vacuum}}}{2} \text{ (Using (i) and (ii))}$$

9. (a) : Compare the given equation with

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

we get, $\omega = 6 \times 10^8 \text{ s}^{-1}$

$$\text{Wave vector, } k = \frac{\omega}{c} = \frac{6 \times 10^8 \text{ s}^{-1}}{3 \times 10^8 \text{ m s}^{-1}} = 2 \text{ m}^{-1}$$

10. (b) : The amplitude of magnetic field and electric field for an electromagnetic wave propagating in vacuum are related as

$$E_0 = B_0 c$$

where c is the speed of light in vacuum.

$$\therefore \frac{B_0}{E_0} = \frac{1}{c}$$

11. (a) : The electromagnetic wave is propagating along the $+z$ axis.

Since the electric and magnetic fields are perpendicular to each other and also perpendicular to the direction of propagation of wave.

Also, $\vec{E} \times \vec{B}$ gives the direction of wave propagation.

$$\therefore \vec{E} = E_0 \hat{i}, \quad \vec{B} = B_0 \hat{j} \quad (\because \hat{i} \times \hat{j} = \hat{k})$$

12. (a) : The decreasing order of wavelength of the given electromagnetic waves is as follows :

$$\lambda_{\text{Microwave}} > \lambda_{\text{Infrared}} > \lambda_{\text{Ultraviolet}} > \lambda_{\text{Gamma rays}}$$

13. (c) : In an electromagnetic wave both electric and magnetic vectors are perpendicular to each other as well as perpendicular to the direction of propagation of wave.

14. (d) : As given

$$E = 10 \cos(10^7 t + kx) \quad \dots (i)$$

Comparing it with standard equation of e.m. wave,

$$E = E_0 \cos(\omega t + kx) \quad \dots (ii)$$

Amplitude $E_0 = 10 \text{ V/m}$ and $\omega = 10^7 \text{ rad/s}$

$$\therefore c = v\lambda = \frac{\omega\lambda}{2\pi}$$

$$\text{or } \lambda = \frac{2\pi c}{\omega} = \frac{2\pi \times 3 \times 10^8}{10^7} = 188.4 \text{ m}$$

$$\text{Also, } c = \frac{\omega}{k} \text{ or } k = \frac{\omega}{c} = \frac{10^7}{3 \times 10^8} = 0.033$$

The wave is propagating along y direction.

15. (b) :

$$E_y = 2.5 \frac{\text{N}}{\text{C}} \left[\left(2\pi \times 10^6 \frac{\text{rad}}{\text{m}} \right) t - \left(\pi \times 10^{-2} \frac{\text{rad}}{\text{s}} \right) x \right]$$

$$E_z = 0$$

The wave is moving in the positive direction of x .

This is the form $E_y = E_0(\omega t - kx)$

$$\omega = 2\pi \times 10^6$$

$$2\pi v = 2\pi \times 10^6 \Rightarrow v = 10^6 \text{ Hz}$$

$$\frac{2\pi}{\lambda} = k \Rightarrow \frac{2\pi}{\lambda} = \pi \times 10^{-2}$$

$$\Rightarrow \lambda = \frac{2\pi}{\pi \times 10^{-2}} = 2 \times 10^2 = 200 \text{ m.}$$

16. (a) : The velocity of electromagnetic radiation in vacuum is $\frac{1}{\sqrt{\mu_0 \epsilon_0}}$, where μ_0 and ϵ_0 are the permeability and permittivity of vacuum.

17. (c) : In electromagnetic wave, electric and magnetic field are in phase and perpendicular to each other and also perpendicular to the direction of the propagation of the wave.

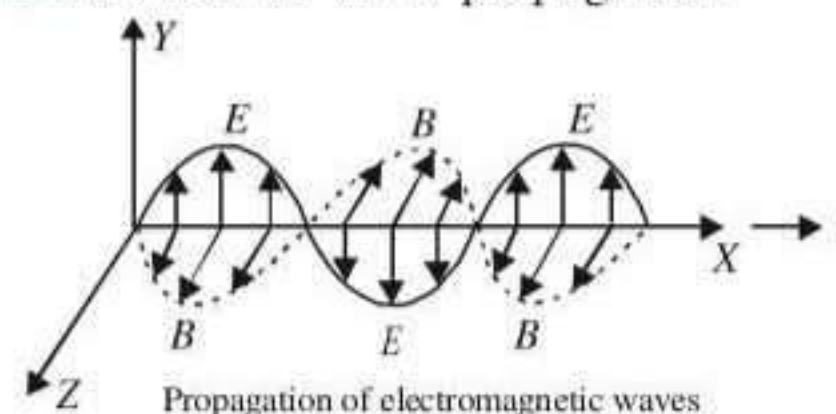
18. (b) : $\lambda_m > \lambda_v > \lambda_x$.

In spectrum X-rays has minimum wavelength and microwave has maximum wavelength.

19. (a) : Every body at all time, at all temperatures emit radiation (except at $T = 0$), which fall in the infrared region.

20. (c)

21. (b) : According to Maxwell, the electromagnetic waves are those waves in which there are sinusoidal variation of electric and magnetic field vectors at right angles to each other as well as at right angles to the direction of wave propagation.



If the electric field (\vec{E}) and magnetic field (\vec{B}) are vibrating along Y and Z direction, propagation of electromagnetic wave will be along the X -axis. Therefore, the velocity of electromagnetic wave is parallel to $\vec{E} \times \vec{B}$.

22. (a) : As the electro-magnetic radiations from Sun pass through the atmosphere, some of them are absorbed by it while other reach the surface of earth. The range of wavelength which reaches earth lies in infrared region. This part of the radiation from the sun has shorter wavelength and can penetrate through the layer of gases like CO_2 and reach earth surface. But the radiation from the earth being of longer wavelength can escape through this layer. As a result the earth surface gets warm. This is known as green house effect.

23. (a) : The ozone layer absorbs the harmful ultraviolet rays coming from sun.

24. (a)

25. (d) : The range is from 380 nm to even 200 nm to 120 nm

26. (b) : $\lambda = \frac{3 \times 10^8}{100 \text{ Hz}} = 3 \times 10^6 \text{ m}$

27. (b) : $c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$ (free space)

$v = \frac{1}{\sqrt{\mu \epsilon}}$ (medium)

$\therefore \mu = \frac{c}{v} = \sqrt{\frac{\mu \epsilon}{\mu_0 \epsilon_0}}$

28. (b)

29. (d)

30. (b) : X-rays are used for the investigation of structure of solids.

31. (b) : The wave length of radiation used should be less than the size of the particle

Size of particle = $\lambda = \frac{c}{\nu}$

$3 \times 10^{-4} = \frac{3 \times 10^{10}}{\nu}$ or $\nu = 10^{14}$ hertz

However, when frequency is higher than this, wavelength is still smaller. Resolution becomes better.

32. (b) : Thermionic emission : When a metal is heated to a high temperature, the free electron gain kinetic energy and escape from the surface of the metal.

Secondary emission : When an electron strikes the surface of a metallic plate, it emits other electrons from the surface.

Photoelectric emission : Emission of electrons from the metal surface on irradiation with radiation of suitable frequency.

X-rays emission : They are due to transitions in the inner energy levels of the atom.

33. (d) : Radiations

Wavelength

[Range in m]

X-rays

1×10^{-11} to 3×10^{-8}

γ -rays

6×10^{-14} to 1×10^{-11}

Microwaves

10^{-3} to 0.3

Radiowaves

10 to 10^4

