New

SURE SHOT QUESTIONS 2026

Chapter – 08 (Questions)

Electromagnetic Waves

➢ Question

1. Write the wavelength range and name of the electromagnetic waves which are used in
   (i) Radar systems for aircraft navigation, and
   (ii) Earth satellites to observe the growth of the crops.

2. Identify the part of the electromagnetic spectrum used in (i) radar and (ii) eye surgery. Write their frequency range.

3. Identify the part of the electromagnetic spectrum which is:
   (a) Suitable for radar system used in aircraft navigation,
   (b) Produced by bombarding a metal target by high speed electrons.

4. Answer the following questions:
   (a) Name the e.m. waves which are suitable for radar systems used in aircraft navigation. Write the range of frequency of these waves,
   (b) If the Earth did not have atmosphere, would its average surface temperature be higher or lower than what it is now? Explain,
   (c) An e.m. wave exerts pressure on the surface on which it is incident. Justify.

5. Answer the following questions:
   (i) Show, by giving a simple example, how e.m. waves carry energy and momentum,
   (ii) How are microwaves produced? Why is it necessary in microwave ovens to select the frequency of microwaves to match the resonant frequency of water molecules?
   (iii) Write two important uses of infrared waves.

6. Answer the following questions:
   (a) Name the e.m. waves which are suitable for radar systems used in aircraft navigation. Write the range of frequency of these waves.
   (b) if the earth did not have atmosphere, would its average surface temperature be higher or lower than what it is now? Explain.
   (c) An e.m. wave exerts pressure on the surface on which it is incident. Justify.

7. (a) On what factors does the speed of an electromagnetic wave in a medium depend?
   (b) How is an electromagnetic wave produced?
   (c) Sketch a schematic diagram depicting the electric and magnetic fields for an electromagnetic wave propagating along z-axis.

8. Name the part of the electromagnetic spectrum which are
   (i) stopped by face mask worn by welders.
   (ii) used in detectors in Earth satellites.
   (iii) used in 'short-wave band' in communication.
   Also write the order of wavelengths in each case.

9. A parallel plate capacitor of plate area A each and separation d, is being charged by an AC source. Show that the displacement current inside the capacitor is the same as the current charging the capacitor.

10. How does Ampere – Maxwell law explain the flow of current through a capacitor when it is being charged by a battery? Write the expression for the displacement current in terms of the rate of change of electric flux.

11. Write Maxwell's generalization of Ampere's circuital law. Show that in the process of charging a capacitor, the current produced within the plates of the capacitor is
   $$i = \varepsilon_0 \frac{d\phi_E}{dt}$$
   Where ϕ_E is the electric flux produced during charging of the capacitor plates.

12. Write the expression for the speed of light in a material medium of relative permittivity ε_r and relative magnetic permeability μ_r.

13. Prove that the average energy density of the oscillating electric field is equal to that of the oscillating magnetic field.

14. How are e.m. waves produced by oscillating charges ? Draw a sketch of linearly polarized e.m. waves propagating in the z-direction. Indicate the directions of the oscillating electric and magnetic fields.

15. (a) When the oscillating electric and magnetic fields are along the x-and y-direction respectively.
(i) point out the direction of propagation of electromagnetic wave.
(ii) express the velocity of propagation in terms of the amplitudes of the oscillating electric and magnetic fields.
(b) How do you show that the e.m. wave carries energy and momentum?

16. Arrange the following electromagnetic waves in the descending order of their wavelengths:
(i) Microwaves
(ii) Infra-red rays
(iii) Ultra – violet – radiation
(iv) Gamma rays
write one use each of any two of them.

17. Why are infrared waves often called heat waves? Explain.

18. What are the directions of electric and magnetic field vectors relative to each other and relative to the direction propagation of electromagnetic waves?

19. (a) An EM wave is travelling in a medium with a velocity $v = v\hat{\imath}$. Draw a sketch showing the propagation of the EM wave, indicating the direction of the oscillating electric and magnetic fields.
(b) How are the magnitudes of the electric and magnetic fields related to velocity of the EM wave?

20. Answer the following :
(a) Name the e.m. waves which are used for the treatment of certain forms of cancer. Write their frequency range.
(b) why is the amount of the momentum transferred by the e.m. waves incident on the surface so small?

21. Answer the following :
(a) Name the e.m. waves which are suitable for radar systems used in aircraft navigation. Write the range of frequency of these waves.
(b) If the earth did not have atmosphere, would its average surface temperature be higher or lower than what it is now? Explain.
(c) An e.m. wave exerts pressure on the surface on which it is incident. Justify.

22. How are e.m. waves produces produced by oscillating charges? Draw a sketch of linearly polarized e.m. waves propagating in the Z-direction. Indicate the direction of the oscillating electric and magnetic fields.

23. Which of the following radiations are (i) heat radiation and (ii) used for long distance transmission? Infrared rays, gamma rays, ultraviolet rays, microwaves.

24. Why are Infra-red radiations referred to as heat waves? Name the radiations which are next to these radiations in the electromagnetic spectrum having (i) shorter wavelength (ii) longer wavelength.

25. What is the meant by the transverse nature of electromagnetic waves? Draw a diagram showing the propagation of an electromagnetic wave along X-direction, indicating clearly the directions of oscillating electric and magnetic fields associated with it.

26. Identify the following electromagnetic radiations as per the wavelengths given below:
(i) 10^{-3} nm
(ii) 10^{-3} m
(iii) 1 nm
Write one application of each

27. (i) How are microwaves produced? Why is it necessary in microwave ovens to select the frequency of microwaves to match the resonant frequency of water molecules?
(ii) Write two important uses of infrared waves

28. A plane electromagnetic wave of frequency 25 MHz travels in free space along the x-direction. At a particular point in space and time, $\vec{E} = 6.3\hat{\jmath}\ V/m$. At this point find $\vec{B}$.

Chapter – 08 (Solutions)

Electromagnetic Waves

➢ Solutions

1. Ans. (b) (i) Microwaves – $10^{-3} – 10^{-1}$ m

(ii) Infra red – $7.5 \times 10^{-7} – 10^{3}$ m

2. Ans.

	Uses	Part of electromagnetic spectrum	Frequency range
(i)	In radar system	Microwaves	3×10^{8} Hz To 3×10^{11} Hz
(ii)	In eye surgery	Ultraviolet	8×10^{14} Hz to 8×10^{16} Hz

3. Ans. (a) Microwaves are suitable for radar system used in aircraft navigation.

(b) X – rays are produced by bombarding a metal target by high speed electrons.

4. Ans. (a) Microwaves are suitable for the radar system used kin aircraft navigation. Range of frequency of microwaves is 10^{8} Hz to 10^{11} Hz.

(b) If the Earth did not have atmosphere, then there would be absence of green house effect of the atmosphere. Due to this reason, the temperature of the earth would be lower than what it is now.

(c) An e.m. wave carries momentum with itself and given by

$$p = \frac{Energy\ of\ wave(U)}{Speed\ of\ the\ wave(c)}$$

When it is incident upon a surface it exerts pressure on it.

5. Ans. (i) Consider a plane perpendicular to the direction of propagation of the wave. An electric charge, on the plane will be set in motion by the electric and magnetic fields of e.m. wave, incident on this plane. This illustrates that e.m. waves carry energy and momentum,

(ii) Microwaves are produced by special vacuum tube like the klystron, magnetron and Gunn diode. The frequency of microwaves is selected to match the resonant frequency of water molecules, so that energy is transformed efficiently to the kinetic energy of the molecules,

(iii) Uses of infra red waves :

(a) They are used in night vision devices during warfare. This is because they can pass through haze, fog and mist,

(b) Infra red waves are used in remote switches of household electrical appliances.

6. Soln. (a) Microwaves are suitable for the radar system used in aircraft navigation. Range of frequency of microwaves is 10^{8} Hz to 10^{11} Hz.

(b) If the Earth did not have atmosphere, then there would be absence of green house effect of the atmosphere. Due to this reason, the temperature of the earth would be lower than what it is now.

(c) An e.m. wave carries momentum with itself and given by

$$p = \frac{Energy\ of\ wave(U)}{Speed\ of\ the\ wave(c)}$$

When it is incident upon a surface it exerts pressure on it.

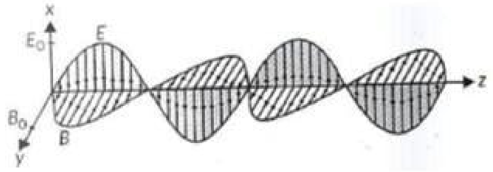
7. Ans. (a) Speed (v) of electromagnetic wave for a medium of electric permeability 'e' and magnetic permeability 'p' is given as.

$$v = \frac{1}{\sqrt{\varepsilon\mu}} = \frac{1}{\sqrt{\varepsilon_r \varepsilon_0 \mu_r \mu_o}} = \frac{c}{\sqrt{\varepsilon_r \mu_r}}$$

Hence, speed (v) depends on the electric and magnetic properties of the medium.

(b) According to the electromagnetic theory, accelerating charged particles radiate electromagnetic waves. An accelerated charged particle oscillating in space produces time varying electric field and time varying magnetic field. This process is repeated, again and again and hence an electromagnetic wave is produced.

(c) (i) The *e.m.* wave propagates along *z*-axis.



8. Ans. (i) Welders wear special type of face mask to protect their eyes from ultraviolet rays, which are in the range of $8\times10^{14} Hz$ to $3\times10^{16} Hz$ or wavelength of (100 - 380) nm.

(ii) Earth satellites uses radio waves for the communication and detection purposes. The wavelength of radio waves lies in the range 1 nm to 100 km.

(iii) For 'Short-wave band' radio-transmission is used where the wavelength range of (10 - 100) meters and frequency range of (3 - 30) MHz is used for communication.

9. Ans. When an ideal capacitor is charged by DC battery, no current flows as capacitor offers infinite resistance to DC. Whereas since a capacitor offers finite resistance to AC, when an AC source is connected then conduction current $I_C = \frac{dQ}{dt}$ flows in the connecting wire. Due to charging current, charge deposited on the plates of the capacitor changes with time. Charging charge produces varying electric field between the plates of capacitor, giving rise to displacement current

$$l_d = \varepsilon_0 \frac{d\phi_E}{dt}.$$

[As displacement current is proportional to the rate of flux variation].

The electric field between the plates is

$$E = \frac{\sigma}{\varepsilon_0} = \frac{Q}{A\varepsilon_0}$$

Electric flux, $\phi_E = EA = \frac{Q}{A\varepsilon_0}A = \frac{Q}{\varepsilon_0}$

So, $l_d = \varepsilon_0 \frac{d\phi_E}{dt} = \varepsilon_0 \frac{d}{dt}\left(\frac{Q}{\varepsilon_0}\right) = \frac{dQ}{dt} = l_c$

Displacement current brings continuity in the flow of current between the plates of the capacitor.

10. Ans. According to Ampere – Maxwell law,

The total current is the sum of displacement current and the conduction current, i.e.;

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

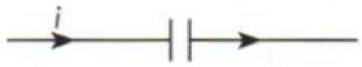
When a capacitor is charged through a battery then inside the capacitor plates there is no conduction current, i.e., $i_c = 0$ and there is only displacement current, so that $i_d = i$. The displacement current is,

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

11. Ans. Maxwell's generalization of Ampere's circuital law,

$$\oint \vec{B}.\vec{dl} = \mu_0(i + i_d) = \mu_0\left(i + \varepsilon_0 \frac{d\phi_E}{dt}\right)$$

In the process of charging the capacitor there is change in electric flux between the capacitor plates.



$$\frac{d\phi_E}{dt} = \frac{d}{dt}(EA)$$

$E \rightarrow$ Electric field between the plats = $\frac{q}{A\varepsilon_0}$

$A \rightarrow$ Area of the plates

So, $\frac{d\phi_E}{dt} = \frac{d}{dt}\left(\frac{q}{A\varepsilon_0} \times A\right) = \frac{1}{\varepsilon_0}\frac{dq}{dt} = \frac{i_d}{\varepsilon_0}$

$\therefore$ $id = i = \varepsilon_0 \frac{d\phi_E}{dt}$

12. Ans. The speed of electromagnetic wave in a medium, $v = \frac{1}{\sqrt{\mu\varepsilon}}$

$$= \frac{1}{\sqrt{\mu_0\mu_r\varepsilon_0\varepsilon_r}} = \frac{c}{\sqrt{\mu_r\varepsilon_r}}, where, c = \frac{1}{\sqrt{\mu_0\varepsilon_0}} = 3\times10^8 ms^{-1}$$

Is the speed of light.

13. Ans. In an electromagnetic wave, both $\vec{E}$ and $\vec{B}$ fields vary sinusoidally in space and time. The average energy density u of an e.m. wave can be obtained by replacing $\vec{E}$ and $\vec{B}$ by their rms value

$$u = \frac{1}{2}\varepsilon_0 E_{rms}^2 + \frac{1}{2\mu_0}B_{rms}^2 \text{ or } u = \frac{1}{4}\varepsilon_0 E_0^2 + \frac{1}{4\mu_0}B_0^2$$

$$\left[\because\ E_{rms} = \frac{E_0}{\sqrt{2}},\ B_{rms} = \frac{B_0}{\sqrt{2}}\right]$$

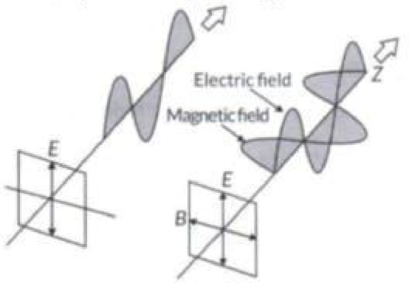
Moreover, $E_0 = cB_0$ and $c^2 = \frac{1}{\mu_0\varepsilon_0}$, therefore

$$u_E = \frac{1}{4}\varepsilon_0 E_0^2 = \frac{1}{4}\varepsilon_0 (cB_0)^2;$$

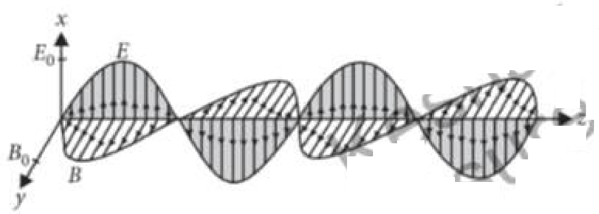
$$u_E = \frac{1}{4}\varepsilon_0 . \frac{B_0^2}{\mu_0 \varepsilon_0} = \frac{1}{4\mu_0} B_0^2 = u_B$$

14. Ans. An oscillating or accelerated charge is supposed to be source of an electromagnetic wave. An oscillating charge produces an oscillating electric field in space which further produces an oscillating magnetic field which in turn is a source of electric field. These oscillating electric and magnetic field hence, keep on regenerating each other and an electromagnetic wave is produced.

A plane electromagnetic wave is said to be linearly polarized. The transverse electric field wave accompanied by a magnetic field wave is illustrated.



15. Soln. (i) An e.m. wave propagating along z-axis is.



(ii) Speed of e.m. wave can be given as the ratio of magnitude of electric field (E_0) to the magnitude of magnetic field (B_0), i.e., $c = \frac{E_0}{B_0}$

Electromagnetic waves or photons transport energy and momentum. When an electromagnetic wave interacts with a small particle, it can exchange energy and momentum with the particle. The force exerted on the particle is equal to the momentum transferred per unit time. Optical tweezers use this force to provide a non – invasive technique for manipulating microscopic – sized particles with light.

16. Soln. (a) Descending order of wavelength for given electromagnetic wave are:

Microwaves $(10^{-3} - 10^{-1})$

Infra – red rays $(7.5\times10^{-7} - 10^{-3})$

Ultra – red rays $(10^{-9} - 4\times10^{-7})$

Gamma rays $(< 10^{-12})$

(b) Microwaves:

Frequency range $\rightarrow 3\times10^{8}\,Hz - 3\times10^{11}\,Hz.$

These are suitable for the radar system, used in aircraft navigation.

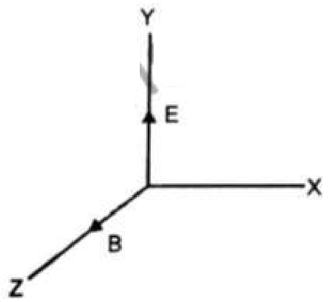
Gamma rays:

Frequency range $\longrightarrow > 3\times10^{21}\,Hz,$

These wave are used for the treatment of cancer cells.

17. Soln. Infrared waves incident on a substance increase the internal energy and hence the temperature of the substance. That is why they are called heat waves.

18. Soln. Since electromagnetic waves and transverse in nature. We have electric and magnetic fields associated with an electromagnetic wave perpendicular to each other and perpendicular to the direction of propagation of electromagnetic waves.

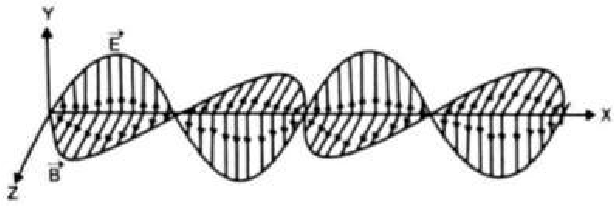


Let the direction of electric field and magnetic field is along Y and Z-axis then the direction of propagation of EM waves will be along positive X-axis.

19. Soln. (a) Given,

Velocity, $v = v\hat{i}$ and electric field, E along Y-axis and magnetic field, B along Z-axis.

The propagation of EM wave is shown below:



(b) Speed of EM wave can be given as the ratio of magnitude of electric field (E_0) to the magnitude of magnetic field (B_0),

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

20. Soln. (a) Gamma rays are used for the treatment of certain forms of cancer. Their frequency range is 3 x 10^{19} H_3 to 5 x 10^{20} Hz.

(b) The momentum transported by electromagnetic waves is given by

$$p = \frac{U}{c} = \frac{h\nu}{c}$$

Where U is the energy transported by electromagnetic waves in a given time and c is speed of electromagnetic waves in free space.

Now, h = $6.62 \times 10^{-34} J\ s,\ c = 3 \times 10^8\ ms^{-1}$

Therefore, even for γ-rays $(\nu \approx 10^{20}\ Hz)$,

$$p = \frac{6.62 \times 10^{-34} \times 10^{20}}{3 \times 10^8}$$
$$= 2.2 \times 10^{-22}\ kg\ ms^{-1}$$

Thus, the amount of the momentum transferred by the e.m. waves incident on a surface is very small.

21. Soln. (a) Microwaves are suitable for radar systems used in aircrafts navigation. The range of frequency for these waves is 10^9 Hz to 10^{12} Hz.

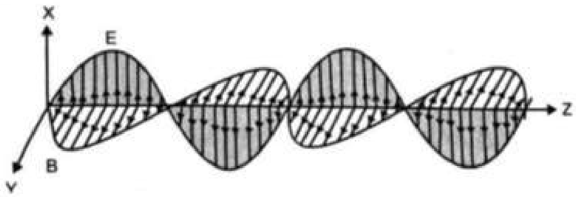
(b) In the absence of atmosphere, there would be no greenhouse effect on the surface of the Earth. As a result, the temperature of the Earth would decrease rapidly, making it difficult for human survival.

(c) The momentum transported by electromagnetic waves is given by

$$p = \frac{U}{c}$$

Where U is the energy transported by electromagnetic waves in a given time and c is speed of electromagnetic waves in a given time and c is speed of electromagnetic waves in free space. As a result, when these waves strike a surface, pressure and hence force is exerted by them on the surface.

22. Soln. A charge oscillating with some frequency, produces an oscillating electric field in space, which in turn produces an oscillating magnetic field perpendicular to the electric field. This process goes on repeating, producing e.m. waves in space perpendicular to both the fields.



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

23. Soln. Infrared rays are heat radiations, Microwaves are used for long distance transmission.

24. Soln. Infrared waves are produced by hot bodies and molecules, so are referred to as heat waves.

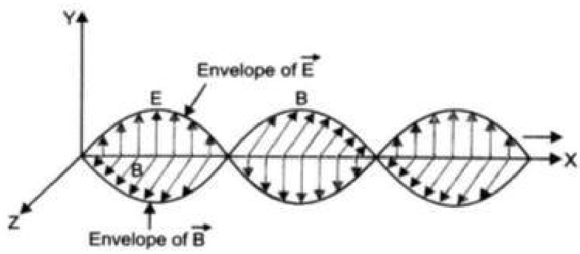
(i) Em wave having short wavelength than infrared waves are visible, UV, X-rays and γ-rays.

(ii) Em wave having longer wavelength than infrared waves are microwaves, radio waves.

25. Soln. Transverse Nature of Electromagnetic Waves:

In an electromagnetic wave, the electric and magnetic field vectors oscillate, perpendicular to the direction of propagation of wave. This is called transverse nature of electromagnetic wave.

In an electromagnetic wave, the three vectors $\vec{E}, \vec{B}$ and $\vec{K}$ form a right-handed system. Accordingly if a wave is propagating along X-axis, the electric field vector oscillates along Y-axis and magnetic field vector oscillates along Z-axis. Diagram is shown in figure.



26. Soln. (a) 10^{-3} nm $\longrightarrow$ gamma radiation.

Application: Radio therapy or to initiate nuclear reactions.

(b) $10^{-3}\ m \longrightarrow$ microwaves

Application: In RADAR for aircraft navigation.

(c) $1nm \longrightarrow X - ray$.

Application: In medical science for detection of fractures, stones in kidney, gallbladder etc.

27. Soln. (i) Microwaves are produced by special vacuum tubes like the Klystron / Magnetron / Gunn diode.

The frequency of microwaves is selected to match the resonant frequency of water molecules, so that energy is transferred efficiently to the kinetic energy of the molecules.

(ii) (a) Associated with the greenhouse effect.

(b) In remote switches of household electricalappliances.

28. Soln. Here, $\vec{E} = 6.3\hat{j}\ V/m$

The magnitude of $\vec{B}$ is

$$B = \frac{E}{c} = \frac{(6.3\text{V/m})}{(3\times10^{8}\text{m/s})} = 2.1\times10^{-8}T$$

$\vec{E}$ is along y-direction and the wave propagates along x-axis. Therefore, $\vec{B}$ should be in a direction perpendicular to both x and y-axis. Using vector algebra $\vec{E}\times\vec{B}$ should be along x-direction.

Since $(+\hat{j})\times(+\hat{k}) = \hat{i}, \vec{B}$ is along z-direction.

Thus $\vec{B} = 2.1\times10^{-8}\,\hat{k}T$