

# Chapter 8. Electromagnetic Waves

## Electromagnetic Waves

### 1 Mark Questions

1. To which part of the electromagnetic spectrum does a wave of frequency  $5 \times 10^{19}$  Hz belong? [All India 2014]

Ans

A wave of frequency  $5 \times 10^{19}$  Hz belong to  $\gamma$ -rays of electromagnetic spectrum.

2. To which part of the electromagnetic spectrum does a wave of frequency  $3 \times 10^{13}$  Hz belong? [All India 2014]

Ans

The frequency of  $3 \times 10^{13}$  Hz belongs to the infrared waves.

3. Write the condition under which an electron will move undeflected in the presence of crossed electric and magnetic fields. [All India 2014c]

Ans

$v = \frac{E}{B}$ , where  $v$  is the speed of electron.

4. Welders wear special goggles or face masks with glass windows to protect their eyes from electromagnetic radiation. Name the radiations and write the range of their frequency. [All India 2013]

Ans

Welders wear special goggles or face mask with glass windows to protect the eyes from ultraviolet rays [UV rays]. The range of UV rays is  $4 \times 10^{-7}$  m (400 nm) to  $6 \times 10^{-10}$  m (0.6 nm). (1)

5. What are the directions of electric and magnetic field vectors relative to each other and relative to the direction of propagation of electromagnetic waves? [All India 2012]

Ans

Direction of electric field  $E$ , direction of magnetic field  $B$  and direction of propagation of wave are mutually perpendicular to one another. (1)

6. Name the electromagnetic waves which

- (i) maintain the earth's warmth and
- (ii) are used in aircraft navigation. [Foreign 2012]

Ans

- (i) Infrared rays maintain the earth's warmth.
- (ii) Microwaves are used in aircraft navigation due to their short wavelength.

7. A plane electromagnetic wave travels in vacuum along Z- direction. What can you say about the direction of electric and magnetic field vectors? [Delhi 2011]

Ans

The direction of electric and magnetic field vectors are along X and Y-directions respectively. (1)

Directions of electric field, magnetic field and propagation of wave are mutually perpendicular to one another.

8. Write two uses of microwaves. [Foreign 2011]

Ans

### Uses of Microwaves

- (i) In RADAR communication.
- (ii) In analysis of molecular and atomic structure. (1/2 × 2 = 1)

9. Write two uses of infrared rays. [Foreign 2011]

Ans

### Uses of Infrared Rays

- (i) In knowing the molecular structure.
- (ii) In remote control of TV, VCR, etc. (1/2 × 2 = 1)

10. Write two uses of X-rays. [Foreign 2011]

Ans

### Uses of X-rays

- (i) In medical diagnosis as they pass through the muscles not through the bones.
- (ii) In detecting faults, cracks, etc., in metal products. (1/2 × 2 = 1)

11. What is the frequency of electromagnetic waves produced by oscillating charge of frequency  $V = 10^5 \text{ Hz}$ ? [Delhi 2011C]

Ans

The frequency of electromagnetic waves produced by oscillating charge of frequency is radio wave ( $10^4 \text{ Hz}$  to  $10^8 \text{ Hz}$ ).

12. How are infrared waves produced? What is the range of their wavelength? [Delhi 2010c]

Ans

Hot objects and molecules are the sources of infrared wave. Range of wavelength =  $7 \times 10^{-7} \text{ m}$  to  $10^{-3} \text{ m}$ . (1)

13. Which of the following has the shortest wavelength? Microwaves, ultraviolet rays, X-rays. [All India 2010]

Ans

X-ray has shortest wavelength. (1)

14. Arrange the following in descending order of wavelength. X-rays, radiowaves, blue light, infrared light. [All India 2010]

Ans

Radio wave > Infrared > Blue light > X-ray is the descending order of wavelength. (1)

15. Which part of electromagnetic spectrum has largest penetrating power? [Delhi 2010]

Ans

$\gamma$ -rays have highest frequency range and hence highest penetrating power. (1)

16. Which part of electromagnetic spectrum is absorbed from sunlight by ozone layer? [Delhi 2010]

Ans

Ultraviolet ray of electromagnetic spectrum is absorbed from sunlight by ozone layer. (1)

17. Which part of electromagnetic spectrum is used in RADAR systems? [Delhi 2010]

Ans Micro Waves

18. Name the electromagnetic radiation used to destroy cancer cells and write its frequency range. [Foreign 2010]

Ans

$\gamma$ -rays

Frequency range =  $10^{18}$  to  $10^{22}$  Hz. (1)

19. In what way, are the directions of the electric and magnetic field vectors representing an electromagnetic wave related to each other? [Delhi 2010c]

Ans

The direction of propagation of electromagnetic waves is along the direction of  $\mathbf{E} \times \mathbf{B}$ , where  $\mathbf{E}$  and  $\mathbf{B}$  are electric and magnetic fields.

20. Express the velocity of propagation of an electromagnetic wave in terms of the peak value of the electric and magnetic fields. [All India 2010C]

Ans

Velocity of propagation of EM wave in terms of peak values of electric and field

vectors.  $c = \frac{|\mathbf{E}_0|}{|\mathbf{B}_0|}$  (1)

21. Name the electromagnetic waves used for studying crystal structure of solids. What is its frequency range? [All India 2009]

Ans

X-rays are used to study the crystal structure of solids. Frequency range of X-rays is  $10^{16}$  Hz to  $10^{20}$  Hz. (1)

22. Write the following radiations in ascending order in respect of their frequencies X-rays, microwaves, ultraviolet rays and radiowaves. [Delhi 2009]

Ans

Radio waves < Microwaves < Ultraviolet rays < X-rays, is in ascending order of frequency. (1)

23. Name the electromagnetic radiation to which waves of wavelength in the range of  $10^{-2}$  m belongs. Give one use of this part of electromagnetic spectrum. [Delhi 2009, 2008]

Ans

Microwaves have their wavelength in the range of  $10^{-2}$  m, so they are used in RADAR communication. (1)

24. Name the electromagnetic radiation which can be produced by a klystron or a magnetron valve. [Foreign 2009]

Ans

Electromagnetic wave produced by klystron or a magnetron valve is microwave. (1)

25. Why is ozone layer on top of the stratosphere crucial for human survival? [All India 2009C]

Ans

Because ozone layer on top of stratosphere traps most of ultraviolet rays coming from the sun and prevents harmful impact of ultraviolet rays. (1)

26.State the reason why microwaves are best suited for long distance transmission of signals. [Foreign 2008]

Ans

Microwave can travel as a beam in a signal because of their shorter wavelength and hence best suited for long distance transmission of signals. (1)

27.Special devices like the klystron valve or the magnetron valve, are used for production of electromagnetic waves. Name these waves and also write one of their applications. [Delhi 2008C]

Electromagnetic wave produced by klystron or a magnetron valve is microwave. (1)

#### **Uses of Microwaves**

- (i) In RADAR communication.
- (ii) In analysis of molecular and atomic structure. (1/2 × 2 = 1)

#### **2 Marks Questions**

28.(a) How does oscillating charge produce electromagnetic waves?

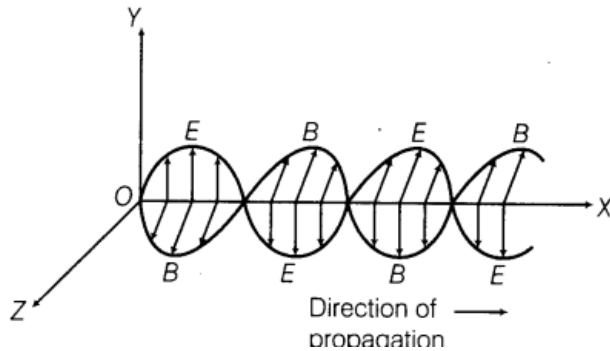
(b) Sketch a schematic diagram depicting oscillating electric and magnetic fields of an EM wave propagating along positive Z-direction. [Foreign 2014]

Ans

- (a) The oscillating charge produces an oscillating electric field and an oscillating electric field produces magnetic field which is then produces an oscillating emf. An oscillating voltage

(emf) produces an oscillating magnetic field and so on. In this way, the oscillating charges produce an electromagnetic waves.

(b) The propagation of electromagnetic wave is shown in figure.



29.(i) How are electromagnetic waves produced?

(ii) How do you convince yourself that electromagnetic waves carry energy and momentum?

[Delhi 2013c]

Ans

(i) A changing electric field produces a magnetic field and a changing magnetic field produces an electric field (Faraday's law), the result is a wave of electric and magnetic fields that can propagate through space. These propagating fields are called as electromagnetic waves. (1)

(ii) According to the quantum theory, electromagnetic radiation is made up of massless particles called photons. Momentum of the photon is expressed as

$$p = \frac{E}{c} \quad (1)$$

where,  $p$  = momentum,  $E$  = energy and  
 $c$  = speed of light.

Thus, I am convinced that electromagnetic wave carry energy and momentum.

30.(i) Arrange the following electromagnetic waves in the descending order of their wavelengths.

- Microwaves
- Infrared rays
- Ultraviolet radiation
- γ-rays

(ii) Write one use each of any two of them. [Delhi 2013C]

Ans

- (i) The decreasing order of wavelengths of electromagnetic waves are

Microwaves > Infrared > Ultraviolet  
>  $\gamma$ -rays (1)


- (ii) **Microwaves** They are used in RADAR devices.

**$\gamma$ -rays** It is used in radiotherapy. (1)

31.(i) An electromagnetic wave is travelling in a medium, with a velocity  $v = v_i$ . Draw a sketch showing the propagation of the electromagnetic wave, indicating the direction of the oscillating electric and magnetic fields.

- (ii) How are the magnitudes of the electric and magnetic fields related to velocity of the electromagnetic wave? [HOTS; Delhi 2013; All India 2008C]

Ans

 We are taking direction of electric field ( $E$ ) and magnetic field ( $B$ ) in such a way that these are follow the right handed system of axes.

- (i) Given that velocity,  $\mathbf{v} = v \hat{i}$  and electric field  $\mathbf{E}$  along Y-axis and magnetic field  $\mathbf{B}$  along Z-axis.

- (ii) Speed of electromagnetic wave can be given as 
$$c = \frac{E_0}{B_0} = \frac{E}{B}$$

where,  $E_0$  and  $B_0$  = peak value of  $E$  and  $B$ ,  $E$  and  $B$  are instantaneous value of  $E$  and  $B$ . (1)

32.A capacitor of capacitance  $C$  is being charged by connecting it across a DC source along with an ammeter. Will the ammeter show a momentary deflection during the process of charging? If so, how would you explain this momentary deflection and the resulting continuity of current in the circuit? Write the expression for the current inside the capacitor. [All India 2012]

Ans

The ammeter will show the momentary deflection. (1/2)

This momentary deflection occurs due to the fact that the conduction current flows through connection wires during the charging of capacitor. This lead to gathering of charge at two plates and hence varying electric field of increasing nature is produced between the plates which in turn produce displacement current in space between two plates. This maintains the continuity with the conduction current.

$$I_C = I_D \quad (1)$$

The current inside the capacitor

Displacement current,  $I_D$

and 
$$I_D = \epsilon_0 \frac{d\phi_E}{dt} \quad (1/2)$$

33. When an ideal capacitor is charged by a DC battery, no current flows. However, when an AC source is used, the current flows continuously. How does one explain this, based on the concept of displacement current? [Delhi 2012]

Ans

The capacitive reactance,

$$X_c = \frac{1}{\omega C} = \frac{1}{2\pi fC}.$$

In AC,  $X_c$  for ideal capacitor is unique and finite and hence current flows. (1)

In DC circuit momentarily current flows during charging of capacitor. This conduction current will be equal to the displacement current flowing between the plates of capacitor due to varying electric field, i.e.

Conduction current = Displacement current and  $I_D = \epsilon_0 \frac{d\phi_E}{dt}$  (1)

34. Explain briefly how electromagnetic waves are produced by an oscillating charge? How is the frequency of the electromagnetic waves produced related to that of the oscillating charge? [Foreign 2012]

Ans

An oscillating charge is considered as the accelerating charge. This produces an oscillating electric field in space, which produces an oscillating magnetic field, that in turn again produces oscillating electric field and so on. These oscillating electric

and magnetic fields thus keeps on regenerating each other as the wave propagates through the space. The frequency of the electromagnetic waves naturally equals the frequency of oscillation of the charge. (2)

35. Name the constituent radiation of electromagnetic spectrum which is used for

- aircraft navigation
- studying the crystal structure Write the frequency range for each. [Delhi 2011C]

Ans

(i) Microwaves are used for aircraft navigation, their frequency range is  $10^9$  Hz to  $10^{12}$  Hz. (1)

(ii) X-rays are used to study crystal structure, their frequency range is  $10^{16}$  Hz to  $10^{20}$  Hz. (1)

36. Draw a sketch of a plane electromagnetic wave propagating along the Z-direction. Depict

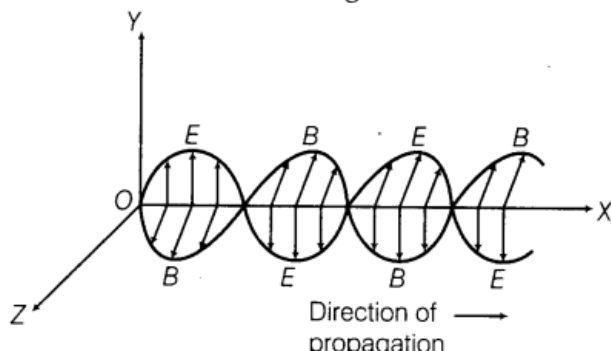


clearly the directions of electric and magnetic fields varying sinusoidally with  $Z$ . [All India 2011]

(a) The oscillating charge produces an oscillating electric field and an oscillating electric field produces magnetic field which is then produces an oscillating emf. An oscillating voltage

(emf) produces an oscillating magnetic field and so on. In this way, the oscillating charges produce an electromagnetic waves.

(b) The propagation of electromagnetic wave is shown in figure.



37. Arrange the following electromagnetic radiations in ascending order of their frequencies.

- Microwaves
- Radio waves
- X-rays
- $\gamma$ -rays

Write two uses of any one of these. [Delhi 2010]

Ans

Ascending order of the frequencies

Radiowaves < Microwaves < X-rays  
<  $\gamma$ -rays. (2)

**Uses of X-rays.**

- To cure untracable skin diseases and malignant growths (Radio therapy).
- For testing the uniformity of insulating material.

38. How are X-rays produced? Write their two important uses. [Foreign 2010; Delhi 2010]

Ans

X-rays can be produced by colliding fast moving electron beam on metal target. (1)

**Uses**

- Medical diagnosis.
- Study of crystal structure. (1)

39. How are infrared rays produced? Write their two important uses. [Foreign 2010; All India 2010 C]

Ans

**Source** Infrared waves are produced by hot objects and molecules. (1)

**Uses**

- (i) In remote control of TV, VCR, etc.
- (ii) In photography in thin mist. (1)

40. How are microwaves produced? Write their two important uses. [Foreign 2010]

Ans

Microwaves are produced by oscillating current in vacuum tubes like klystrons, magnetrons. (1)

**For applications** Refer to ans. 8. (1)

41. Answer the following questions.


- Optical and radio telescopes are built on the ground while X-ray astronomy is possible only from satellites orbiting the earth. Why?
- The small ozone layer on top of the stratosphere is crucial for human survival. Why? [All India 2009]

Ans

- (i) Because X-rays are shorter than ultraviolet rays and can pass through many forms of matter whereas light wave or radiowave cannot pass. Therefore, X-ray astronomy is possible from satellite. (1)
- (ii) Refer to ans. 25. (1)

42. How does a charge,  $q$  oscillating at certain frequency produce electromagnetic waves? Sketch a schematic diagram depicting electric and magnetic fields for an electromagnetic wave propagating along the Z- direction. [Delhi 2009]

Ans

 Due to an oscillating charged particle varying electric current is associated with the particle hence the magnetic as well as electric field will be associated which is varying in nature this property is utilised in electromagnetic wave.

The oscillation charge accelerates and hence equivalent to varying electric current which in turn changes the magnetic field. This leads to production of electric field. Thus, oscillatory charge produces time varying electric and magnetic fields. Hence, electromagnetic waves are produced. (1)

**For diagram** Refer to ans. 28. (1)

43. Name the electromagnetic radiations having the wavelength range from 1 mm to 700 nm. Give its two important applications. [Foreign 2009]

Ans

Infrared waves have the wavelength between 1 mm to 700 nm. (1)

**For uses** Refer to ans. 39. (1)

44. Name the electromagnetic radiation having the wavelength range from  $10^{-1}$  m to  $10^{-3}$

Give its two important applications. [Foreign 2009]

Ans

Microwaves have the wavelength between

$10^{-1}$  m and  $10^{-3}$  m. (1)

**For application** Refer to ans. 8. (1)

45. Name the electromagnetic radiations having the wavelength range from 1 nm to  $10^{-3}$

Give its two important applications. [Foreign 2009]

Ans

X-rays have the wavelength between 1 nm

and  $10^{-3}$  nm. (1)

**For uses** Refer to ans. 10. (1)

46. Identify the different types of electromagnetic radiations, which are used

- to kill germs,
- for physical therapy. [All India 2009c]

Ans

(i)  $\gamma$ -rays (1)

(ii) Infrared waves (1)

47. In an electromagnetic wave, the oscillating electric field having a frequency of  $3 \times 10^{10}$  Hz and an amplitude of 30 V/m propagates in the positive X-direction.

- What is the wavelength of the electromagnetic wave?
  - Write down the expression to represent the corresponding magnetic field.
- [Foreign 2008]

Ans

Given,  $\nu = 3 \times 10^{10}$  Hz,  $E_0 = 30$  V/m

$$(i) \therefore \lambda = \frac{c}{\nu} = \frac{3 \times 10^8}{3 \times 10^{10}} = 10^{-2} \text{ m} \quad (1)$$

$$(ii) \therefore c = \frac{E_0}{B_0} \\ \Rightarrow B_0 = \frac{E_0}{c} = \frac{30}{3 \times 10^8} = 1 \times 10^{-7} \text{ T}$$

$$B = B_0 \sin(\omega t - kx) \hat{k}$$

$$\omega = 2\pi\nu = 6\pi \times 10^{10} \text{ rad/s}$$

$$k = \frac{2\pi}{\lambda} = \frac{2\pi}{10^{-2}} = 200\pi$$

$$\Rightarrow B = (10^{-7} \text{ T}) \sin(6\pi \times 10^{10} t - 200\pi x) \hat{k} \quad (1)$$

48. The following table gives the wavelength range of some constituents of the electromagnetic spectrum.

S. No.	Wavelength range
1.	1 nm to 700 nm
2.	400 nm to 1 nm
3.	1 nm to $10^{-3}$ nm
4.	$<10^{-3}$ nm

Select the wavelength range and name of the electromagnetic waves that are

- widely used in the remote switches and household electronic devices.
- produced in nuclear reactions. [Delhi 2008C]

Ans

- (i) Infrared waves are used in remotes, switches and household circuits, their wavelength range is 1 mm to 700 nm. (1)
- (ii)  $\gamma$ -rays are produced in nuclear reactions their wavelength range is  $<10^{-3}$  nm. (1)

### 3 Marks Questions

49. Answer the following questions.

- Name the waves which are produced during radioactive decay of a nucleus. Write their frequency range.
- Welders wear special glass goggles while working. Why? Explain.
- Why are infrared waves often called as heat waves? Give their one application. [Delhi 2014]

Ans

- (i)  $\gamma$ -rays are produced during radioactive decay of a nucleus. Its frequency range is from  $3 \times 10^{18}$  to  $5 \times 10^{22}$  Hz. (1)
- (ii) Refer to Ans. 4.
- (iii) Infrared rays are called heat waves because they vary temperature. (1/2)
- They are used in physical therapy, weather forecasting. (1/2)

50. Answer the following questions

- (i) Name the EM waves which are suitable for radar systems used in aircraft navigation. Write the range of frequency of these waves.
- (ii) If the earth did not have atmosphere, would its average surface temperature be higher or lower than what it is now? Explain.
- (iii) An EM wave exerts pressure on the surface on which it is incident. Justify. [Delhi 2014]

Ans

- (i) The EM waves suitable for RADAR system is microwaves. The range of frequency is  $3 \times 10^{11}$  to  $1 \times 10^8$  Hz. (1)
- (ii) The temperature of the earth would be lower because the greenhouse effect of the atmosphere would be absent. (1)
- (iii) An EM wave has momentum,  
i.e.  $p = \frac{\text{Energy (E)}}{\text{Velocity of light (c)}}$

When it is incident upon a surface it exerts pressure on it. (1)

51. Answer the following questions.

- Name the EM waves which are used for the treatment of certain forms of cancer. Write their frequency range.
- Thin ozone layer on top of stratosphere is crucial for human survival. Why?
- Why is the amount of the momentum transferred by the EM waves incident on the surface so small? [Delhi 2014]

Ans

- (i)  $\gamma$ -rays are used for the treatment of certain forms of cancer. Its frequency range is  $3 \times 10^{19}$  Hz to  $5 \times 10^{22}$  Hz. (1)
- (ii) The thin ozone layer on top of stratosphere absorbs most of the harmful ultraviolet rays coming from the sun towards the earth. They include UVA, UVB and UVC radiations, which can destroy the life system on the earth.  
Hence, this layer is crucial for human survival. (1)
- (iii) Momentum transferred = Energy  $\times$  speed of light  
 $= h\nu c = 10^{-22}$

Thus, the amount of the momentum transferred by the EM waves incident on the surface is very small. (1)

52. Answer the following questions:

- Show, by giving a simple example, how EM waves carry energy and momentum.
- 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?
- Write two important uses of infrared waves. [Delhi 2014 c]

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 EM wave, incident on this plane. This illustrates that EM 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) (a) Associated with the greenhouse effect.  
(b) In remote switches of household electrical appliances.

53.(i) Describe briefly how electromagnetic waves are produced by oscillating charges? (ii)  
Give one use of each of the following.

- Microwaves
- Ultraviolet rays
- Infrared rays
- $\gamma$ -rays [HOTS; All India 2011c]

Ans

- (i) **For electromagnetic waves** Refer to Ans. 42. **(1)**
- (ii) **For uses of microwaves, ultraviolet rays and infrared rays** Refer to ans. 8, 9. **(1)**

**Application of ultraviolet rays**

For checking the mineral samples through the property of ultraviolet rays causing fluorescence.

**Use of  $\gamma$ -rays**

In the treatment of cancer and tumour. **(1)**

54. How are electromagnetic waves produced by oscillating charges? Why is it not possible to produce electromagnetic waves in the visible region with modern electronic circuits in the laboratory? What is the method of production of X-rays? [Delhi 2009C]

Ans

The oscillating charge accelerates which in turn produces time varying current. This produces varying magnetic field. The varying magnetic field induces the varying electrical field. Thus, varying electric field and varying magnetic field becomes source of each other and hence, electromagnetic waves comes into existence. (1)

Electronic circuit can't produces electromagnetic waves in the visible region because their frequency is much higher than that of microwaves.

**For X-ray** Refer to ans. 38. (2)

55. Identify the following electromagnetic radiations as per the wavelengths given below. Write one application of each.

- $10^{-3}$  nm
- $10^{-3}$  m
- 1 nm [All India 2008]

Ans

- (i)  $10^{-3}$  nm X-rays, medical diagnosis.
- (ii)  $10^{-3}$  m Infrared, remote control of TV, VCR, etc.
- (iii) 1 nm UV rays, in food preservation. (1 × 3 = 3)

56. Identify the following electromagnetic radiations as per the frequencies given below. Write one application of each.

- $10^{20}$  Hz
- $10^{12}$  Hz
- $10^9$  Hz [All India 2008]

Ans

- (i)  **$\gamma$ -rays** As food preservation.
- (ii) **Infrared wave** Refer to ans. 55(ii).
- (iii) **Microwave** In RADAR communication. (1 × 3 = 3)