DCAM classes
Dynamic Classes for Academic Mastery

imp quesrions on electromagnetic wave with solution

1 Mark Questions

1. Which part of the electromagnetic spectrum is used in radar? Give its frequency range.
2. How are electromagnetic waves produced by accelerating charges?
3. Name the electromagnetic radiations used for (a) water purification, and (b) eye surgery.
4. Do electromagnetic waves carry energy and momentum?
5. How is the speed of electromagnetic waves in vacuum determined by the electric and magnetic fields?
6. In which directions do the electric and magnetic field vectors oscillate in an electromagnetic wave propagating along the X-axis?
7. Why are microwaves considered suitable for radar systems used in aircraft navigation?
8. The charging current for a capacitor is 0.25 A. What is the displacement current across its plates?
9. To which part of the electromagnetic spectrum does a wave of frequency 5×10^{19}Hz belong?
10. To which part of the electromagnetic spectrum does a wave of frequency 3×10^{13}Hz belong?
11. Arrange the following electromagnetic waves in order of increasing frequency : γ-rays, microwaves, infrared rays and ultraviolet rays.
12. 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.
13. A capacitor has been charged by a DC source. What are the magnitude of conduction and displacement current, when it is fully charged?
14. What are the directions of electric and magnetic field vectors relative to each other and relative to the direction of propagation of electromagnetic waves?
15. Name the electromagnetic waves which
    (i) maintain the earth's warmth and
    (ii) are used in aircraft navigation.
16. A plane electromagnetic wave travels in vacuum along Z-direction. What can you say about the direction of electric and magnetic field vectors?
17. How are radio waves produced?
18. Write two uses of microwaves.
19. Write two uses of infrared rays.
20. Write two uses of X-rays.
21. What is the frequency of electromagnetic waves produced by oscillating charge of frequency $\nu = 10^5$ Hz?
22. How are infrared waves produced? What is the range of their wavelength?
23. Which of the following has the shortest wavelength?

    Microwaves, ultraviolet rays, X-rays.
24. Name the part of electromagnetic spectrum whose wavelength lies in the range of 10^{-10} m. Give its one use.
25. Arrange the following in descending order of wavelength.

    X-rays, radio waves, blue light, infrared light

26. Which part of electromagnetic spectrum has largest penetrating power?

27. Which part of electromagnetic spectrum is absorbed from sunlight by ozone layer?

28. Which part of electromagnetic spectrum is used in RADAR systems?

29. Name the electromagnetic radiation used to destroy cancer cells and write its frequency range.

30. Which part of the electromagnetic spectrum is used in satellite communication?

31. In what way, are the directions of the electric and magnetic field vectors representing an electromagnetic wave related to each other?

32. Express the velocity of propagation of an electromagnetic waves in terms of the peak value of the electric and magnetic fields.

2 Marks Questions

33. How is the equation for Ampere's circuital law modified in the presence of displacement current? Explain.

34. How are electromagnetic waves produced by oscillating charges? What is the source of the energy associated with the EM waves?

35. A capacitor made of two parallel plates, each of area A and separation d is charged by an external DC source. Show that during charging, the displacement current inside the capacitor is the same as the current charging the capacitor.

36. (a) Why are infrared waves often called heat waves? Explain.
    (b) What do you understand by the statement, "electromagnetic waves transport momentum"?

37. (a) Give one use of electromagnetic radiations obtained in nuclear disintegrations.
    (b) Give one example each to illustrate the situation where there is (i) displacement current but no conduction current and (ii) only conduction current but no displacement current.

38. Identify the electromagnetic waves whose wavelengths vary as
    (i) $10^{-12}\text{ m} < \lambda < 10^{-8}\text{ m}$
    (ii) $10^{-3}\text{ m} < \lambda < 10^{-1}\text{ m}$

    Write one use for each.

39. (i) How does oscillating charge produce electromagnetic waves?
    (ii) Sketch a schematic diagram depicting oscillating electric and magnetic fields of an EM wave propagating along positive Z-direction.

40. (i) How are electromagnetic waves produced?
    (ii) How do you convince yourself that electromagnetic waves carry energy and momentum?

41. (i) Arrange the following electromagnetic waves in the descending order of their wavelengths.
    (a) Microwaves
    (b) Infrared rays
    (c) Ultraviolet radiation
    (d) γ-rays
    (ii) Write one use each of any two of them.

42. (i) An electromagnetic wave is travelling in a medium, with a velocity $\mathbf{v} = v\hat{\mathbf{i}}$. 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?

43. 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.

44. 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?

45. 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?

46. Name the constituent radiation of electromagnetic spectrum which is used for
   (i) aircraft navigation
   (ii) studying the crystal structure
   Write the frequency range for each.

47. 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

48. Arrange the following electromagnetic radiations in ascending order of their frequencies.
   (i) Microwaves (ii) Radio waves
   (iii) X-rays (iv) γ-rays
   Write two uses of any one of thes

49. How are X-rays produced? Write their two important uses.

50. How are infrared rays produced? Write their two important uses.

51. How are microwaves produced? Write their two important uses.

3 Marks Questions

52. (a) Identify the part of the electromagnetic spectrum used in (i) radar and (ii) eye surgery. Write their frequency range.
   (b) Prove that the average energy density of the oscillating electric field is equal to that of the oscillating magnetic field.

53. How are electromagnetic waves produced by oscillating charges?
   Draw a sketch of linearly polarised electromagnetic waves propagating in the Z-direction. Indicate the directions of the oscillating electric and magnetic fields.

54. (i) 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.
   (ii) Why does galvanometer show a momentary deflection at time of charging and discharging a capacitor? Write the necessary expression to explain this observation.

55. (i) Which segment of electromagnetic waves has highest frequency? How are these waves produced? Give one use of these waves.
   (ii) Which EM waves lie near the high frequency end of visible part of EM spectrum? Give its one use. In what way, this component of light has harmful effects on humans?

56. Name the parts of the electromagnetic spectrum which is
   (i) suitable for RADAR systems in aircraft navigations.
   (ii) used to treat muscular strain.
   (iii) used as a diagnostic tool in medicine.
   Write in brief, how these waves can be produced.

57. Answer the following questions.

(i) Name the waves which are produced during radioactive decay of a nucleus. Write their frequency range.

(ii) Welders wear special glass goggles while working. Why? Explain.

(iii) Why are infrared waves often called as heat waves? Give their one application.

58. 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.

59. Answer the following questions:

(i) Name the EM waves which are used for the treatment of certain forms of cancer. Write their frequency range.

(ii) Thin ozone layer on top of stratosphere is crucial for human survival. Why?

(iii) Why is the amount of the momentum transferred by the EM waves incident on the surface so small?

60. Answer the following questions:

(i) Show, by giving a simple example, how EM waves carry energy and momentum.

(ii) How are microwaves produced? Why is it necessary in microwaves ovens to select the frequency of microwaves to match the resonant frequency of water molecules?

(iii) Write two important uses of infrared waves.

61. State clearly how a microwave oven works to heat up a food item containing water molecules.

Why are microwaves found useful for the raw systems in aircraft navigation?

62. (i) Describe briefly how electromagnetic waves are produced by oscillating charges?

(ii) Give one use of each of the following.

(a) Microwaves

(b) Ultraviolet rays

(c) Infrared rays

(d) γ-rays

Explanations

1. Microwaves are used in radar systems of aircraft navigation. Its frequency range is 1 GHz to 300 GHz. (1)

2. An oscillating charge is an example of accelerating charge. It produces an oscillating electric field, which produces an oscillating magnetic field, which in turn produces an oscillating electric field and so on. The oscillating electric and magnetic fields regenerate each other as a wave which propagates through space. (1)

3. (a) Ultraviolet radiation (1/2)

(b) Infrared radiation (1/2)

4. Yes, electromagnetic waves carry energy and momentum. Its momentum, $p = h/\lambda$ and energy density $= \frac{1}{2}\varepsilon_0 E^2$. (1)

5. To determine speed of light in vacuum, we use the formula, $c = E_0/B_0$

where, E_0 and B_0 are maximum electric field and magnetic field component respectively of electromagnetic waves. (1)

6. Electric field vector **E** and magnetic field vector **B** are always is perpendicular to each other and to direction of propagation of light. Also, direction of propagation is parallel to **E** × **B**.

As, the wave is propagating along $\hat{\mathbf{i}}$ or X-axis.

Hence, **E** is along $\hat{\mathbf{j}}$ or $+Y$-axis and **B** is along $\hat{\mathbf{k}}$ o[r] $+Z$-axis. (1)

7. On account of smaller wavelengths of microwaves, they can be transmitted as beam signals in a particular direction. They also do not bend around the corners of the obstacles coming in their way. Thus, it is considered suitable for radar systems used in aircraft navigation system. (1)

8. The displacement current is equal to 0.25 A, as the charging current is 0.25 A. (1)

9. A wave of frequency 5×10^{19} Hz belong to γ-rays of electromagnetic spectrum. (1)

10. The waves of frequency of 3×10^{13} Hz belongs to the infrared waves. (1)

11. Electromagnetic waves arranged in increasing order of frequency is as follows : Microwaves < Infrared rays < Ultraviolet rays < γ-rays. (1)

12. Welders wear special goggles or face mask with glass windows to protect their eyes from ultraviolet rays (UV rays). The range of UV rays is 10^{15} Hz to 10^{17} Hz. (1)

13. Electric flux through plates of capacitor, $\phi_E = q/\varepsilon_0$

Displacement current, $I_D = \varepsilon_0 \frac{d\phi_E}{dt}$

$$= \varepsilon_0 \frac{d(q/\varepsilon_0)}{dt} = 0$$

∵ The capacitor has been fully charged, thus the charge would be constant.

Conduction current, $I = C\frac{dV}{dt} = 0$, as voltage becomes constant.

So, $I = I_D = 0$ for a charged capacitor. (1)

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

15. (i) Infrared rays maintain the earth's warmth.
(ii) Microwaves are used in aircraft navigation due to their short wavelength. (1)

16. As, directions of electric field, magnetic field and propagation of wave are mutually perpendicular to one another. Thus, the direction of electric and magnetic field vectors are along X and Y-directions respectively, as the wave travels in vacuum in Z-directions. (1)

17. Radio waves are the electromagnetic waves of frequency ranging from 500 kHz to about 1000 MHz. These waves are produced by oscillating electric circuits having inductor and capacitor. (1)

18. **Uses of Microwaves**
(i) In RADAR communication.
(ii) In analysis of molecular and atomic structure or in microwave oven for cooking food.
(1/2 × 2 = 1)

19. **Uses of Infrared Rays**
(i) In knowing the molecular structure and therapy to heal muscular pain.
(ii) In remote control of TV, VCR, etc. (1/2 × 2 = 1)

20. **Uses of X-rays**
(i) In medical diagnosis as they can pass through the muscles but not through the bones.
(ii) In detecting faults, cracks, etc. in metal products.
(1/2 × 2 = 1)

21. The frequency of electromagnetic waves produced by oscillating charge is equal to the frequency of the oscillating charge only i.e., $\nu_{wave} = 10^5$ Hz. (1)

22. Hot objects and vibration of atoms and molecules are the sources of infrared waves.
Range of infrared wavelength is 7×10^{-7} m to 10^{-3} m. (1)

23. X-ray has shortest wavelength. (1)

24. The wavelength range of 10^{-10} lies in X-rays. These are used as a diagnostic tool in medicine like in surgeries to detect the fracture, diseased organs, stones in the body etc. (1)

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

26. γ-rays have highest frequency range and hence highest penetrating power. (1)

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

28. Microwaves are used in RADAR system. (1)

29. γ-rays and frequency range is 10^{18} to 10^{22} Hz. (1)

30. Short radio waves of $\lambda > 0.1$ m or $\nu < 3 \times 10^9$ Hz are used in satellite communication. (1)

31. 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. (1)

32. Velocity of propagation of EM wave in terms of peak values of electric field $|\mathbf{E}_0|$ and magnetic field $|\mathbf{B}_0|$ vectors is given as $c = |\mathbf{E}_0|/|\mathbf{B}_0|$. (1)

33. Ampere's circuital law was modified to

$$\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 (I_c + I_d)$$

where, I_c = conduction current

and I_d = displacement current.

$$\Rightarrow \oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 \left(I_c + \varepsilon_0 \frac{d\phi_E}{dt} \right)$$ (1)

In order to overcome the inconsistency of this law. Maxwell introduced a term, i.e., displacement current to make it logically consistent.

Displacement current is that current which comes into play in the region in which the electric field and electric flux is changing with time. (1)

34. Refer to Sol. 2 on page 238. (1)

Electric and magnetic field are the source of energy associated with EM waves. (1)

35. Let the alternating emf charging the plates of capacitor be $V = V_0 \sin \omega t$ ...(i)

Charge on the capacitor,

$$q = CV = CV_0 \sin \omega t \quad \text{[from Eq.(i)]}$$

and instantaneous current,

$$I = \frac{dq}{dt} = \frac{d}{dt}(CV_0 \sin \omega t)$$

$$= \omega CV_0 \cos \omega t = I_0 \cos \omega t$$ (1)

where, $I_0 = \omega CV_0$

Displacement current,

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

$$\Rightarrow \varepsilon_0 A \frac{d(E)}{dt} = \varepsilon_0 A \frac{d}{dt}\left(\frac{q}{\varepsilon_0 A}\right)$$

$$= \varepsilon_0 A \frac{d}{dt}\left(\frac{CV_0 \sin \omega t}{\varepsilon_0 A}\right)$$

$$= \frac{d}{dt}(CV_0 \sin \omega t)$$

$$= \omega CV_0 \cos \omega t$$

$$= I_0 \cos \omega t$$

Thus, the displacement current inside the capacitor is the same as the current charging the capacitor. (1)

36. (a) Infrared waves have frequencies lower than those of visible light, vibrate not only the electrons, but also the entire atoms or molecules in the structure of the substance they encountered.

This vibration increases the internal energy and hence the temperature of the structure, which is why infrared waves are often called heat waves. (1)

(b) Electromagnetic wave transports linear momentum as it travels through space. If an electromagnetic wave transfer a total energy U to a completely absorbing surface in time t, then total linear momentum delivered to that surface is given as

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

where, c is the speed of electromagnetic wave. (1)

37. (a) Electromagnetic radiations obtained in nuclear disintegrations are used to study the structure of atomic nucles. (1)

(b) (i) Current in between capacitor's plates, is only displacement current but no conduction.

(ii) Current flowing through a metallic wire is conduction current, but no displacement current. (1)

38. (i) $10^{-12}\text{m} - 10^{-8}\text{m} = .01\,\text{Å} - 100\,\text{Å}$ — X-ray.

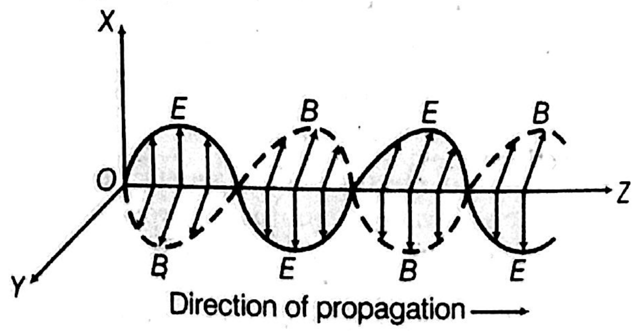
It is used in crystallography. (1)

(ii) $10^{-3}\text{m} - 10^{-1}\text{m} = 0.1\,\text{cm} - 10\,\text{cm}$ — Microwaves.

It is used in microwave oven for cooking purpose. (1)

39. (i) 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. This in turn produces an oscillating electric fields and so on. This oscillating electric and magnetic fields regenerate each other as the wave propagates through space. In this way, the oscillating charges produce an electromagnetic waves. (1)

(ii) *The propagation of electromagnetic wave is shown in figure below.*



A plane electromagnetic wave travelling along Z-axis (1)

40. (i) Refer to Sol. 39 (i) (1)

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

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

Thus, I am convinced that electromagnetic waves carry energy and momentum. **(1)**

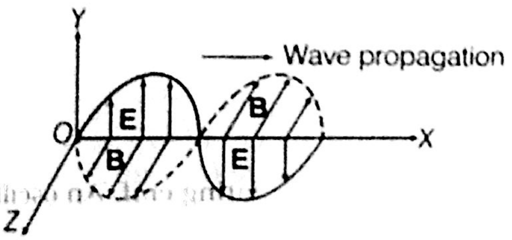
41. (i) The decreasing order of wavelengths of electromagnetic waves is

Microwaves > Infrared > Ultraviolet > γ-rays **(1)**

(ii) **Microwaves** They are used in RADAR devices.
γ-rays It is used in radio therapy. **(1)**

42. **Key Idea** 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, $\mathbf{v} = v\,\hat{\mathbf{i}}$, this means electric field $\mathbf{E}$ will be along Y-axis and magnetic field $\mathbf{B}$ will be along Z-axis because the two fields are perpendicular to each other and perpendicular to the direction of propagation of wave. **(1)**



A linearly polarised EM waves

(ii) Speed of electromagnetic wave can be given as

$$c = E_0/B_0 = E/B$$

where, E_0 and B_0 = peak value of $\mathbf{E}$ and $\mathbf{B}$, E and B are instantaneous value of $\mathbf{E}$ and $\mathbf{B}$. **(1)**

43. The ammeter will show the momentary deflection during charging only, after that the current in the circuit becomes zero. **(1/2)**

This momentary deflection occurs due to the fact that the conduction current flows through connecting wires during the charging of capacitor. This leads to gathering of charge at two plates and hence varying electric field of increasing nature is produced between the plates which in turn produces displacement current in space between two plates. Thus, maintains the continuity with the conduction current. **(1)**

The current inside the capacitor $I_C = I_D$

where, I_D is displacement current, $I_D = \varepsilon_0 \dfrac{d\phi_E}{dt}$ **(1/2)**

44. An ideal capacitor offers infinite resistance for an DC source. Thus, no current flows.

On the other hand, when AC source is connected to a capacitor, a conduction current continuously flows through the connecting wire to charge the capacitor. Due to this changing current, accumulation of the charges at the two plates changes. Due to this, a varying electric field of increasing nature is produced between the plates. This in turn produces a displacement current in between the plates. To maintain this continuity, this conduction current will be equal to the displacement current flowing, i.e.

Conduction current = Displacement current
and $I_D = \varepsilon_0\,(d\phi_E/dt)$ **(2)**

45. **For production of electromagnetic waves** Refer to Sol. 39 (i) **(1)**

The frequency of the electromagnetic waves naturally equals the frequency of oscillation of the charge. **(1)**

46. (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)**

47. The direction of propagation of electromagnetic wave is perpendicular to both electric field vector **E** and magnetic field vector **B**, i.e. in the direction of **E** × **B**. For figure refer to Sol. 39 (ii)

Here, electromagnetic wave is along the Z-direction which is given by the cross product of **E** and **B**. **(2)**

48. Ascending order of the frequencies of electromagnetic waves is

Radio waves < Microwaves < X-rays < γ-rays. **(1)**

Uses of X-rays. Refer to Sol. 20 **(1)**

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

For Uses Refer to Sol. 20 **(1)**

50. Infrared waves are produced by hot objects and vibration of atoms and molecules. **(1)**

For Uses Refer to Sol. 19 **(1)**

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

For Uses Refer to Sol. 18 **(1)**

52. (a) (i) Microwave - 1 GHz to 300 GHz.
(ii) Ultraviolet (by LASIK eye surgery) -10^{14} Hz to 10^{16} Hz. **(1)**

(b) The energy density (energy per unit volume) in an electric field E in vacuum is $\frac{1}{2}\varepsilon_0 E^2 (U_e)$ and that in magnetic field **B** is $\frac{B^2}{2\mu_0}(U_m)$.

$\therefore$ Energy associated with an electromagnetic wave is given by

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

Also, average energy density,

$$u_{av} = \frac{1}{4}\varepsilon_0 E_0^2 + \frac{1}{4}\frac{B_0^2}{\mu_0}$$

Since, we know that, the energy in electromagnetic waves is divided, on an average, equally between electric and magnetic fields.

$$U_e = U_m$$

So, $$u_{av} = \frac{1}{2}\varepsilon_0 E_0^2 = \frac{B_0^2}{2\mu_0}$$ **(2)**

53. For production of electromagnetic waves, refer to Sol. 39 (i) An oscillating *L-C* circuit can produce electromagnetic waves of frequency as charge oscillates across the capacitor's plates in this circuit. The frequency of oscillation is given by

$$\nu = 1/2\pi\sqrt{LC}$$ **(1½)**

This frequency is equal to the frequency of EM waves.

The sketch of linearly polarised EM wave propagating in *Z*-direction is shown.

For figure Refer to Sol. 39 (ii)

In this diagram, we see that permanent curve shows electric field **E** and dotted curve shows magnetic field **B**. They change continuously. Electromagnetic waves so produced have the direction perpendicular to **E** and **B**. **(1½)**

54. (i) (a) Microwaves are suitable for radar system used in aircraft navigation. **(1)**
(b) X-rays are produced by bombarding a metal target by high speed electrons.

(ii) During charging and discharging of capacitor, a conduction current is produced due to the flow of charges from battery to the plates, *vice-versa via* connecting wires. Due to this, galvanometer shows a momentary deflection. Now, when the capacitor is fully charged, the conduction current stops flowing. Also during charging and discharging, there is zero conduction current between the plates.

But it was found that an electric field exist inside the plates, therefore indicating existence of magnetic field which leads to inconsistency in the Ampere's circuital law. To account this problem, the concept of displacement current was introduced by Maxwell. He changed the Ampere's circuitallaw, ($\oint \mathbf{B}.dl = \mu_0 I$) to a modified form which is given as,

$$\oint \mathbf{B}.dl = \mu_0 I + \mu.I_D$$

where, I_D is the displacement current. **(2)**

55. (i) Gamma rays has the highest frequency in the electromagnetic waves. These rays are of the nuclear origin and are produced in the disintegration of radioactive atomic nuclei and in the decay of certain subatomic particles. They are used in the treatment of cancer and tumours. **(1½)**

(ii) Ultraviolet rays lie near the high-frequency end of visible part of EM spectrum. These rays are used to preserve food stuff. The harmful effect from exposure to ultraviolet (UV) radiation can be life threatening, and include premature aging of the skin, suppression of the immune systems, damage to the eyes and skin cancer. **(1½)**

56. (i) The EM waves suitable for RADAR system is microwaves.

These rays are produced by special vacuum tubes, namely klystrons, magnetrons and Gunn diodes. **(1)**

(ii) Infrared waves are used to treat muscular strain. These rays are produced by hot bodies and vibration of molecules and atoms. **(1)**

(iii) X-rays are used a diagnostic tool in medicine. These rays are produced when high energy electrons are stopped suddenly on a metal surface of high atomic number. **(1)**

57. (i) γ-rays are produced during radioactive decay of a nucleus. Its frequency range is from 3×10^{18} to 5×10^{22} Hz. **(1)**

(ii) Refer to Sol. 12 **(1)**

(iii) Infrared rays are called heat waves because they cause the atoms and molecules to vibrate when they encounter a substance.

This increases the internal energy of atoms and molecules. Thereby, increasing the temperature of the substance. **(1/2)**

They are used in physical therapy and weather forecasting. **(1/2)**

58. (i) Refer to Sol. 56 (i)

Its frequency range is 10^9 Hz to 10^{12} 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 waves has momentum,

i.e. p = Energy (E) / Velocity of light (c)

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

59. (i) γ-rays are used for the treatment of certain forms of cancer. Its frequency range is 3×10^{19} Hz to 5×10^{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) An electromagnetic wave transports linear momentum as it travels through space. If an electromagnetic wave transfers a total energy U to a totally absorbing surface in time t, then total linear momentum delivered to the at surface is

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

This means, the momentum range of EM waves is 10^{-19} to 10^{-41}. Thus, the amount of momentum transferred by the EM waves incident on the surface is very small. **(1)**

60. (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 is only possible if EM wave constitutes momentum and energy. Thus, this illustrates that EM waves carry energy and momentum. **(1)**

(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 increase the kinetic energy of the molecules. Thus, facilitating the food to cook properly. **(1)**

(iii) Refer to Sol. 19 **(1)**

61. In microwave oven, the frequency of the microwaves is selected to match the resonant frequency of water molecules. This leads to the vibrations of these molecules. As these vibrations increase with time, the temperature increases leading to production of heat and this is the heat which is responsible for the cooking of food in the oven. **(2)**

As, microwaves are short wavelength radio waves, with frequency of order of GHz. Due to short wavelength, they have high penetrating power with respect to atmosphere and less diffraction in the atmospheric layers. So, these waves are suitable for the radar systems used in aircraft navigation. **(1)**

62. (i) **For electromagnetic waves**

Refer to Sol. 39 (i) **(1)**

(ii) **For uses of microwaves and infrared rays**

Refer to Sol. 18 and 19

Uses of ultraviolet rays

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

Use of γ-rays

In the treatment of cancer and tumours. **(2)**

Objective Questions

1 Mark Questions

1. In electromagnetic wave, according to Maxwell, changing electric field gives

(a) stationary magnetic field

(b) conduction current

(c) eddy current

(d) displacement current

2. The electric and magnetic fields of an electromagnetic wave are

(a) in phase and parallel to each other

(b) in opposite phase and perpendicular to each other

(c) in opposite phase and parallel to each other

(d) in phase and perpendicular to each other

3. For a medium with permittivity ε and permeability μ, the velocity of light is given by

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

4. The electric and the magnetic fields, associated with an electromagnetic wave, propagating along the + y-axis, can be represented by

(a) $[\mathbf{E} = E_0\,\hat{\mathbf{k}}, \mathbf{B} = B_0\hat{\mathbf{i}}\,]$
(b) $[\mathbf{E} = E_0\,\hat{\mathbf{j}}, \mathbf{B} = B_0\,\hat{\mathbf{i}}\,]$
(c) $[\mathbf{E} = E_0\,\hat{\mathbf{j}}, \mathbf{B} = B_0\,\hat{\mathbf{k}}]$
(d) $[\mathbf{E} = E_0\,\hat{\mathbf{i}}, \mathbf{B} = B_0\,\hat{\mathbf{j}}\,]$

5. A plane electromagnetic wave of frequency 20 MHz travels through a space along x-direction. If the electric field vector at a certain point in space is 6 Vm^{-1}, then what is the magnetic field vector at that point?

(a) $2\times10^{-8}\text{T}$ (b) $\frac{1}{2}\times10^{-8}\text{T}$
(c) 2 T (d) $\frac{1}{2}\text{T}$

6. The average magnetic energy density of an electromagnetic wave of wavelength λ travelling in free space is given by

(a) $\frac{B^2}{2\lambda}$ (b) $\frac{B^2}{2\mu_0}$
(c) $\frac{2B^2}{\mu_0\lambda}$ (d) $\frac{B}{\mu_0\lambda}$

7. The magnetic field of plane electromagnetic wave is given by $B_y = 2\times 10^{-7}\sin(0.5\times10^3\,x + 1.5\times10^{11}\,t)$. This electromagnetic wave is

(a) a visible light
(b) an infrared wave
(c) a microwave
(d) a radio wave

8. Which of the following waves has the maximum wavelength?

(a) X-rays (b) Infrared rays
(c) Ultraviolet rays (d) Radio waves

9. The wavelength of a radio wave of frequency of 1 MHz is

(a) 400 m (b) 300 m
(c) 350 m (d) 200 m

10. In the electromagnetic spectrum, the visible spectrum lies between

(a) radio waves and microwaves
(b) infrared and ultraviolet rays
(c) microwaves and infrared spectrum
(d) X-ray and gamma ray spectrum

11. The part of the spectrum of the electromagnetic radiation used to cook food is

(a) ultraviolet rays
(b) cosmic rays
(c) X-rays
(d) microwaves

12. Which of the following shows greenhouse effect?

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

Explanations

1. *(d)* According to Maxwell, time varying electric field produce displacement current

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

2. *(d)* As, $E = E_0 \sin(kx - \omega t)$

$\Rightarrow B = B_0 \sin(kx - \omega t)$

Hence, electric field and magnetic field are in same phase and perpendicular to each other.

3. *(c)* Velocity of light $= 1/\sqrt{\mu\varepsilon}$, where μ is permeability and ε is permittivity of the medium.

4. *(a)* In electromagnetic waves, electric vector, magnetic vector and velocity of wave are perpendicular to one another.

Hence, As $\mathbf{v} = v_0\hat{\mathbf{j}}$

$$\Rightarrow \left.\begin{array}{l}\mathbf{E} = E_0\hat{\mathbf{k}}\\ \mathbf{B} = B_0\hat{\mathbf{i}}\end{array}\right\} \Rightarrow \hat{\mathbf{k}}\times\hat{\mathbf{i}} = \hat{\mathbf{j}}$$

5. (a) The magnetic field,

$$B = \frac{E}{c},$$

where $c = 3 \times 10^8$ m/s

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

6. (b) Energy density of an electromagnetic wave is

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

So, the average magnetic energy density is $\frac{B^2}{2\mu_0}$.

7. (c) We have,

$$B_y = 2 \times 10^{-7} \sin (0.5 \times 10^3 x + 1.5 \times 10^{11} t)$$

Comparing with the standard equation, we get

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

$$\Rightarrow \quad k = 0.5 \times 10^3$$

$$\Rightarrow \quad \lambda = \frac{2\pi}{0.5 \times 10^3} = 0.01256$$

The wavelength range of microwaves is 10^{-3} to 0.3. The wavelength of this wave lies between 10^{-3} to 0.3, so the equation represents a microwave.

8. (d) The wavelength order is

$$\lambda_{\text{Radio waves}} > \lambda_{\text{UV rays}} > \lambda_{\text{IR rays}} > \lambda_{\text{X-rays}}$$

9. (b) We know that, wavelength,

$$\lambda = \frac{c}{\nu} = \frac{3 \times 10^8}{1 \times 10^6} = 3 \times 10^2 = 300\ \text{m}$$

10. (b) Electromagnetic waves have wavelengths as small as 30 Fm to as large as 30 km.

For the figure of electromagnetic spectrum Refer to page 233 (Electromagnetic spectrum).

Hence, visible spectrum lies between infrared and ultraviolet rays.

11. (d) The part of the spectrum of the electromagnetic radiation used to cook food is microwaves.

12. (b) Infrared radiations are reflected by low lying clouds and keep the earth warm.