Electromagnetic Waves

1. In the four regions, I, II, III and IV, the electric fields are described as: (2024)

Region I: $E_x = E_0 \sin(kz - \omega t)$

Region II: $E_x = E_0$

Region III: $E_x = E_0 \sin kz$

Region IV: $E_x = E_0 \cos kz$

The displacement current will exist in the region:

(A) I

(B) IV

(C) II

(D) III

Ans. (A) I

2. (a) "The wavelength of the electromagnetic wave is often correlated with the characteristic size of the system that radiates." Give two examples to justify this statement.

(b) (i) Long distance radio broadcasts use short-wave bands. Why?

(ii) Optical and radio telescopes are built on the ground, but X-ray astronomy is possible only from satellites orbiting the Earth. Why? (2024)

Ans. (a) Two examples

(b) (i) Reason for use of short waves bands

(ii) Reason for x-ray astronomy from satellites

(a) (Any Two)

- Gamma radiation having wavelength of 10^{-14} m to 10^{-15} m, typically originate from an atomic nucleus.
- X-rays are emitted from heavy atoms.
- Radio waves are produced by accelerating electrons in a circuit. A transmitting antenna can most efficiently radiate waves having a wavelength of about the same size as the antenna.

(b) (i) Ionosphere reflects waves in these bands

(ii) Atmosphere absorbs x-rays, while visible and radio waves can penetrate it

Note: Full credit to be given for part (b) for mere attempt.

Previous Years' CBSE Board Questions

8.2 Displacement Current

MCQ

1. Displacement current exists only when
   (a) electric field is changing.
   (b) magnetic field is changing.
   (c) electric field is not changing.
   (d) magnetic field is not changing. *(2020)*

VSA (1 mark)

2. How is displacement current produced between the plates of a parallel plate capacitor during charging? *(2020)*

3. The charging current for a capacitor is 0.25 A. What is the displacement current across its plates? *(Foreign 2016)* AP

SA I (2 marks)

4. What is a displacement current? How is it different from a conduction current? *(2023)* U

5. 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. *(AI 2019)* U

6. 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. *(Delhi 2017)* An

   describe briefly how the concept of displacement current is explained through charging/discharging of a capacitor in an electric circuit. *(AI 2015)* Cr

8.3 Electromagnetic Waves

MCQ

10. The oscillating electric and magnetic field vectors in an electromagnetic wave are
    (a) perpendicular to each other and opposite in phase.
    (b) parallel to each other and opposite in phase.
    (c) perpendicular to each other and in the same phase.
    (d) parallel to each other and in the same phase. *(2020C)*

VSA (1 mark)

11. What oscillates in an electromagnetic wave of frequency 10 MHz? *(2021C)*

12. Depict the field diagram of an electromagnetic wave propagating along positive *X*-axis with its electric field along *Y*-axis. *(2020)* U

13. Illustrate by giving suitable examples, how you can show that electromagnetic waves carry both energy and momentum. *(AI 2019)*

14. How is the speed of em waves in vacuum determined by the electric and magnetic fields? *(Delhi 2017)* R

    OR

    Write the relation for the speed of electromagnetic waves in terms of the amplitudes of electric and magnetic fields. *(AI 2017)*

(b) Write the relations (i) between the speed of light and the amplitudes of electric and magnetic fields, (ii) for the speed of em wave in terms of a permittivity ε_0, and magnetic permeability, μ_0, of the medium. *(2019C)*

19. What do you understand by the statement, "Electro-magnetic waves transport momentum"? *(1/2, 2018)*

SA II (3 marks)

20. Write the expression for the speed of light in a material medium of relative permittivity ε_r and relative magnetic permeability μ_r. *(1/3, 2020)*
21. Prove that the average energy density of the oscillating electric field is equal to that of the oscillating magnetic field. (2/3, *Delhi 2019*) U
22. 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. *(Delhi 2016)* Ev

8.4 Electromagnetic Spectrum

MCQ

23. Name the electromagnetic waves also known as 'heat waves'.
    (a) Radiowaves (b) Microwaves
    (c) X-rays (d) Infrared waves
    (2023)
24. Which one of the following electromagnetic radiation has the least wavelength?
    (a) Gamma rays (b) Microwaves
    (a) Gamma rays (b) Microwaves
    (c) Visible light (d) X-rays *(2023)* R
25. A welder wears special glasses to protect his eyes mostly from the harmful effect of
    (a) very intense visible light
    (b) infrared radiation
    (c) ultraviolet rays
    (d) microwaves. *(2020)* R
26. Electromagnetic waves used as a diagnostic tool in medicine are
    (a) X-rays (b) ultraviolet rays
    (c) infrared radiation (d) ultrasonic waves.
    (2020) R

next to infrared radiations in the electromagnetic spectrum on
(a) shorter wavelength side, and
(b) longer wavelength side. *(2020C)*

30. Which part of the electromagnetic spectrum is used in RADAR? Give its frequency range. *(2019)*
31. Name the part of the electromagnetic spectrum which has the longest wavelength and write its one use. *(2019C)*
32. The small ozone layer on top of the stratosphere is crucial for human survival. Why? *(AI 2019)* U
33. Name the electromagnetic radiations used for (a) water purification, and (b) eye surgery. *(2018)*
34. Why are microwaves considered suitable for radar systems used in aircraft navigation? *(Delhi 2016)*
35. To which part of the electromagnetic spectrum does a wave of frequency 5×10^{19} Hz belong? *(AI 2014)* R
36. Arrange the following electromagnetic waves in order of increasing frequency.
    γ-rays, Microwaves, Infrared rays and Ultraviolet rays. *(Foreign 2014)* Ap

SA I (2 marks)

37. Write any two characteristics of an electromagnetic wave. Why are microwaves used in radar systems? *(2023)* An
38. Which of the following electromagnetic waves has (a) minimum wavelength, and (b) minimum frequency? Write one use of each of these two waves.
    Infrared waves, Microwaves, γ-rays and X-rays
    (2020)
    (2020)
39. Gamma rays and radio waves travel with the same velocity in free space. Distinguish between them in terms of their origin and the main application. *(2020)* An
40. Why are infrared waves often called heat waves? Explain. *(1/2, 2018)*
41. Identify the electromagnetic waves whose wavelengths vary as
    (a) $10^{-12}\ m < \lambda < 10^{-8}\ m$
    (b) $10^{-3}\ m < \lambda < 10^{-1}\ m$
    Write one use for each. *(AI 2017)*
42. Identify the electromagnetic waves whose

VSA (1 mark)

27. Name the electromagnetic radiation used for killing germs in water purifiers. *(2021C)*

28. Write one use of the electromagnetic waves of frequency range from 10^{16} Hz to 10^{20} Hz. *(2020)*

29. Why are infrared radiations also referred to as heat waves? Write the names of radiations which lie

Write briefly a method of producing any one of these waves. *(AI 2015C)* Ev

SA II (3 marks)

44. (a) Electromagnetic waves of wavelength λ_1, λ_2 and λ_3 are used in radar systems, in water purifiers and in remote switches of TV, respectively.
    (i) Identify the electromagnetic waves, and
    (ii) Write one source of each of them.
    (Term II 2021-22)

45. 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. *(2/3, 2020)* R

46. Identify the part of the electromagnetic spectrum used in (i) radar and (ii) eye surgery. Write their frequency range. *(1/3, Delhi 2019)*

47. 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. *(2/3,AI 2016)* R

48. (i) Which segment of electromagnetic waves has highest frequency? How are these waves produced? Give one use of these waves.
    (ii) Which e.m. waves lie near the high frequency end of visible part of e.m. spectrum? Give its one use.

wavelengths vary as
(a) 10^{-11} m < λ < 10^{-14} m
(b) 10^{-4} m < λ < 10^{-6} m
Write one use of each. *(AI 2017)* R

43. Name the types of em radiations which
    (i) are used in destroying cancer cells,
    (ii) cause tanning of the skin and (iii) maintain the earth's warmth.

In what way this component of light has harmful effects on humans? *(Foreign 2016)* Ap

49. Name the parts of the electromagnetic spectrum which is
    (a) suitable for radar systems used in aircraft navigation.
    (b) used to treat muscular strain.
    (c) used as a diagnostic tool in medicine.
    Write in brief, how these waves can be produced. *(Delhi 2015)* An

50. 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. *(Delhi 2014)* Cr

51. 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.
    (Delhi 2014C)

CBSE Sample Questions

8.3 Electromagnetic Waves

MCQ

1. Which of the following statement is NOT true about the properties of electromagnetic waves?
    (a) These waves do not require any material medium for their propagation.

8.4 Electromagnetic Spectrum

VSA (1 mark)

3. Mention one use of part of electromagnetic spectrum to which a wavelength of 21 cm (emitted by hydrogen in interstellar space) belongs. *(2020-21)*

(b) Both electric and magnetic field vectors attain the maxima and minima at the same time.
(c) The energy in electromagnetic wave is divided equally between electric and magnetic fields.
(d) Both electric and magnetic field vectors are parallel to each other. *(2022-23)*

VSA (1 mark)

2. Give the ratio of velocity of the two light waves of wavelengths 4000Å and 8000Å travelling in vacuum. *(2020-21)* R

SA I (2 marks)

4. Electromagnetic waves with wavelength
(i) λ_1 is suitable for radar systems used in aircraft navigation.
(ii) λ_2 is used to kill germs in water purifiers.
(iii) λ_3 is used to improve visibility in runways during fog and mist conditions.
Identify and name the part of the electromagnetic spectrum to which these radiations belong. Also arrange these wavelengths in ascending order of their magnitude. *(2022-23)*

Detailed SOLUTIONS

Previous Years' CBSE Board Questions

1. (a): Displacement current exist only when electric field is changing.

2. Displacement current is produced by the time varying electric flux or electric field across the dielectric medium between capacitor plates that leads to polarisation and displacement of charges.

3. The displacement current is equal to 0.25 A, as the charging current is 0.25 A.

4. Displacement current : It is the current which comes into play in the region, wherever the electric field and hence the electric flux is changing with time.

Displacement current is given by $I_D = \varepsilon_0 \frac{d\phi_E}{dt}$

where ε_0 is the permittivity of free space and $\frac{d\phi_E}{dt}$ is the rate of change of electric flux.

Conduction current is due to the flow of electrons in a circuit. It exists even if electrons flow at a uniform rate. Displacement current is due to the time varying electric field. It does not exist under steady conduction.

5. 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. Changing charge produces varying electric field between the plates of capacitor, 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 $i_d = i$.

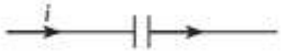
The displacement current is, $i_d = \varepsilon_0 \frac{d\phi_E}{dt}$

7. There is no AC voltage applied on a capacitor, when it is connected across a battery so no current flows in a capacitor. When a capacitor is charging, current flows towards the positive plate (as positive charge is added to that plate) and away from the negative plate. When the capacitor is discharging, current flows away from the positive and towards the negative plate, in the opposite direction.

8. Maxwell's generalization of Ampere's circuital law,

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

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 plates $= \frac{q}{A\varepsilon_0}$

$A \rightarrow$ Area of the plate

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

giving rise to displacement current $I_d = \varepsilon_0 \frac{d\phi_E}{dt}$.

[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, $I_d = \varepsilon_0 \frac{d\phi_E}{dt} = \varepsilon_0 \frac{d}{dt}\left(\frac{Q}{\varepsilon_0}\right) = \frac{dQ}{dt} = I_c$

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

Key Points

- In any general medium, both conduction and displacement current will be present. In conducting medium, conduction current dominates, whereas in an insulating medium, displacement current dominates.

6. According to Ampere-Maxwell law,

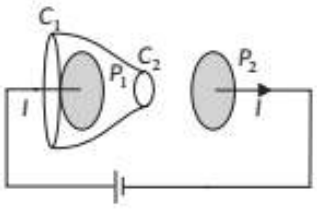
$$\int_{C_1} \vec{B}\cdot d\vec{l} = \oint B dl \cos 0° = B \times 2\pi r = \mu_0 I$$

$I \neq 0$ so $B \neq 0$

For loop C_2,

$$\int_{C_2} \vec{B}\cdot d\vec{l} = \mu_0 \times 0 \quad (\because I = 0)$$

$\Rightarrow \quad B = 0.$



So, magnetic field reduces 0 on right side from any value on left plate.

But in the actual, magnetic field is continuous in nature.

Modified Ampere's law by Maxwell

According to Maxwell,

$$\int \vec{B}\cdot d\vec{l} = \mu_0 (I + I_D) = \mu_0 \left(I + \varepsilon_0 \frac{d\phi_E}{dt}\right)$$

Thus, within the plates the displacement current which is due to changing electric flux in charging or discharging, maintains the continuity of current and magnetic field also within the plates of capacitor.

Concept Applied

- The line integral of magnetic field around any closed path is equal to μ_0 times the total current threading the closed path.

10. (c): The oscillating electric and magnetic field vectors in electromagnetic wave are perpendicular to each other and in the same phase.

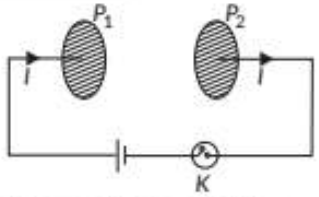
11. Electric and magnetic field of electromagnetic wave oscillate with the same frequency as that of

Commonly Made Mistake

- We think that conduction current flow through the wire, but there is no current across the capacitor gap, as no charge is transported across this gap. But, there is displacement current through the capacitor.

9. Generalized form of Ampere's circuital law :

$$\oint \vec{B}\cdot d\vec{l} = \mu_0 \left(I + \varepsilon_0 \frac{d\phi_E}{dt}\right)$$



Inconsistency of Ampere's circuital law :

If we observe the current through a charging capacitor, some of the questions arise.

(a) Current I enters at the left end of plate P_1 but no current at right side of plate P_1.

Hence, Kirchhoff's law violated.

(b) Ampere's law for loop C_1,

16. When an electromagnetic wave is propagating along the x-axis then, electric field vector oscillates in y-axis and magnetic field vector oscillates in z-axis.

17. (a) Here, electromagnetic waves is $E_x = E_0 \sin(\omega t + kz)$

(i) The wave is propagating in $-Z$ direction.

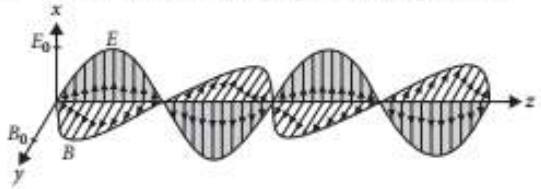
(ii) The magnetic field oscillate in $-Y$ direction.

(b) Characteristics of electromagnetic waves

(i) These waves do not carry any charge.

(ii) They travel with the speed of light, c ($= 3 \times 10^8$ m/s) in vacuum.

18. (a) The e.m. wave propagates along z-axis.



(b) (i) The speed of em waves in vacuum determined by the electric field (E_0) and magnetic field (B_0) as, $c = \frac{E_0}{B_0}$

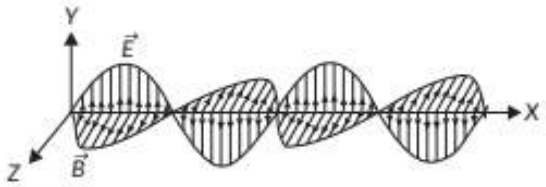
(ii) Given, permittivity, ε_0 and magnetic permeability, μ_0, of the medium.

The speed of em wave in medium, $v = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$

19. Electromagnetic waves transport momentum means that when electromagnetic waves carry momentum from one place to another is incident on a material surface then it is either completely absorbed or partially reflected. It delivers both energy (U) and momentum (P).

electromagnetic wave *i.e.*, 10 MHz.

12. In figure, the velocity of propagation of e.m. wave is along *X*-axis $\vec{v}=v\hat{i}$ and electric field $\vec{E}$ along *Y*-axis and magnetic field $\vec{B}$ along *Z*-axis.



Answer Tips

- An electric field changing with time in a region produces a magnetic field there. Both these fields vary with time and space.

13. Electromagnetic waves like other waves carry energy and momentum as they travel through empty space. If light didn't carry energy and momentum, it wouldn't be able to heat stuff up or generate photocurrent in photocells.

14. The speed of em waves in vacuum determined by the electric (E_0) and magnetic fields (B_0) is, $c=\frac{E_0}{B_0}$

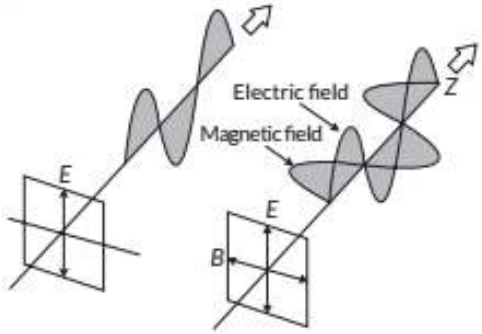
15. Yes, electromagnetic waves carry energy and momentum.

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

$$u_E=\frac{1}{4}\varepsilon_0E_0^2=\frac{1}{4}\varepsilon_0(cB_0)^2;\ u_E=\frac{1}{4}\varepsilon_0\cdot\frac{B_0^2}{\mu_0\varepsilon_0}=\frac{1}{4\mu_0}B_0^2=u_B$$

22. 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.



Concept Applied

- EM waves carry no mass, they carry energy which comes from the energy of their source. EM waves have momentum since it cannot exert pressure known as radiation pressure.

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

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

is the speed of light.

Key Points

- Maxwell concluded that electromagnetic wave is transverse in nature and light is electromagnetic wave.

21. 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

$$u=\frac{1}{2}\varepsilon_0E_{rms}^2+\frac{1}{2\mu_0}B_{rms}^2\ \text{or}\ u=\frac{1}{4}\varepsilon_0E_0^2+\frac{1}{4\mu_0}B_0^2$$

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

31. Radio waves has the longest wavelength in the em waves spectrum.

The wavelength range of radio wave of lie between 1 mm too thousands meters. They are used for radio and television broadcast.

32. The small ozone layer on the top of the atmosphere is crucial for human survival because it absorbs harmful ultraviolet radiations present in sunlight and prevents it from reaching the earth's surface. These radiations can penetrate our skin and can cause harmful diseases like skin cancer etc.

33. (a) Ultraviolet rays (b) Ultraviolet rays

34. Microwaves have short wavelengths so they are suitable for radar systems used in aircraft navigation. They can penetrate through clouds also.

35. X-rays.

36. Microwaves < Infra red rays < Ultraviolet rays < γ-rays.

37. Electromagnetic waves are those waves in which there is a sinusoidal variation of electric and magnetic field at right angles to each other as well as at right angle to the direction of wave propagation. Characteristics of em waves,

(i) These wave do not carry charge.

Key Points

- An oscillating charge in LC circuit has a non-zero acceleration, hence it emits electromagnetic waves having the same frequency.

23. (d) : Infrared waves are also known as heat waves because they raise the temperature of the object on which they fall.

24. (a) : The wavelength of gamma rays is least among all.

25. (c) : Welder wears special glasses to protect his eyes from harmful effect of ultraviolet rays.

26. (a): X-rays are used as diagnostic tool in medicine.

27. Ultraviolet waves of electromagnetic radiation are used for killing germs in water purifier.

28. Here, given frequency range of electromagnetic wave = 10^{16} Hz – 10^{20} Hz which corresponds to the X-ray region of em-spectrum.
X-rays are used for detection of fractures in bones.

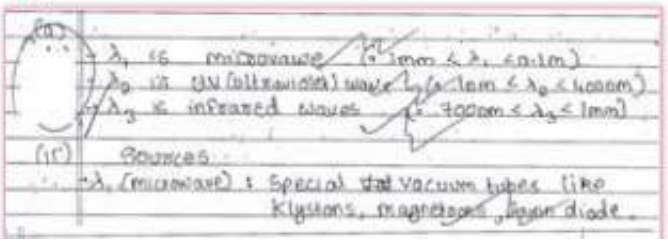
29. Infrared waves incident on a substance increase the internal energy and hence the temperature of the substance. That is why they are referred as heat waves.
(a) Visible light lie next to shorter wavelength of infrared light.
(b) Microwave lie next to longer wavelength of infrared light.

30. Microwaves are used in RADAR systems.
It's frequencies range lies between 3×10^9 Hz to 3×10^{11} Hz.

(b) Infrared waves lie between 10^{-4} m to 10^{-6} m. These waves are used in taking photographs during conditions of fog, smoke etc., as these waves are scattered less than visible rays.

43. (i) Gamma rays
(ii) UV rays
(iii) Infrared radiations
Infra red waves are produced by hot bodies and molecules. Infra red waves are referred to as heat waves, because water molecules present in most materials readily absorb infrared waves (many other molecules, for example, CO_2, NH_3 also absorb infrared waves). After absorption, their thermal motion increases, that is they heat up and heat their surroundings.

44.



(ii) These waves are not deflected by electric and magnetic fields.
Microwaves have short wavelength so they are suitable for radar systems. They can penetrate through clouds also.

38. (a) γ rays (b) Microwaves
(i) X-rays are used as a diagnostic tool in medicine.
(ii) Microwaves : These are used in Radar system for aircraft navigation.
(iii) Infra red rays : These are used to treat muscular pain.
(iv) Gamma rays : These are used for the treatment of cancer.

39. Gamma rays : These rays are of 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 tumors.
Radiowaves : These waves are produced by the accelerated motion of charges in conducting wires or oscillating electric circuits having inductor and capacitor. These are used in satellite, radio and television communication

40. 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.

41. (a) X-rays - used to study atomic structure.
(b) Microwaves - used in radar application.

42. (a) Gamma rays lie between 10^{-11} m to 10^{-14} m.
These rays are used in radiotherapy to treat certain cancers and tumors.

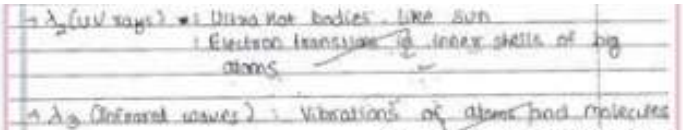
include premature aging of the skin, suppression of the immune systems, damage to the eyes and skin cancer.

49. (a) Microwaves are suitable for radar systems used in aircraft navigation.
These waves are produced by special vacuum tubes, namely klystrons, magnetrons and Gunn diodes.
(b) Infrared waves are used to treat muscular pain. These waves are produced by hot bodies and molecules.
(c) X-rays are used as a diagnostic tool in medicine. These are produced when high energy electrons are stopped suddenly on a metal of high atomic number.

50. (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

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

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



[Topper's Answer, 2022]

45. (b) (i) Microwaves - 10^{-3} – 10^{-1} m
(ii) Infra red - 7.5×10^{-7} – 10^{3} m

46.

	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

47. (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.

48. (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 tumors.
(ii) Ultraviolet rays lie near the high-frequency end of visible part of e.m. spectrum. These rays are used to preserve food stuff. The harmful effect from exposure to ultraviolet (UV) radiation can be life threatening, and

51. (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.

CBSE Sample Questions

1. (d) : Electromagnetic waves are the combination of mutually perpendicular electric and magnetic fields. So, option (d) is not correct. **(1)**

2. The ratio is 1 : 1. This is because in vacuum, all colours travel with the same velocity. **(1)**

3. Uses of microwaves :
(i) In long distance communication
(ii) In radar systems used in aircraft navigation **(1)**

4. (i) λ_1 - Microwave ; (ii) λ_2 - Ultraviolet ; (iii) λ_3 - Infrared **(1)**
Ascending order - $\lambda_2 < \lambda_3 < \lambda_1$ **(1)**