ELECTROMAGNETIC WAVES

8

basic concepts

1. Need for Displacement Current

Ampere's circuital law for conduction current during charging of a capacitor was found inconsistent. Therefore, Maxwell modified Ampere's circuital law by introducing displacement current. It is given by $I_d = \varepsilon_0 \dfrac{d\phi_E}{dt}$

Modified Ampere's circuital law is:

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

where ϕ_E = electric flux.

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

$\oint B \cdot dl = \mu_0 i_c + \mu_0 i_d = \mu_0 (i_c + i_d)$

2. Electromagnetic Waves

The waves propagating in space through electric and magnetic fields varying in space and time simultaneously are called electromagnetic waves.

The electromagnetic waves are produced by an accelerated or decelerated charge or LC circuit. The frequency of EM waves is

$$\nu = \frac{1}{2\pi\sqrt{LC}}$$

3. Characteristics of Electromagnetic Waves

(*i*) The electromagnetic waves travel in free-space with the speed of light ($c = 3 \times 10^8$ m/s) irrespective of their wavelength.

(*ii*) Electromagnetic waves are neutral, so they are not deflected by electric and magnetic fields.

(*iii*) The electromagnetic waves show properties of reflection, refraction, interference, diffraction and polarisation.

(*iv*) In electromagnetic wave the electric and magnetic fields are always in the same phase.

(*v*) The ratio of magnitudes of electric and magnetic field vectors in free space is constant equal to c.

$$\frac{E}{B} = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = c = 3 \times 10^8 \text{ m/s}$$

(*vi*) The speed of electromagnetic waves in a material medium is given by

$$v = \frac{1}{\sqrt{\mu\,\varepsilon}} = \frac{c}{\sqrt{\mu_r \varepsilon_r}} = \frac{c}{n},$$ where n is the refractive index.

[Note : We also use μ for refractive index]

(vii) In an electromagnetic wave the energy is propagated by means of electric and magnetic fi... vectors in the direction of propagation of wave.

(viii) In electromagnetic wave the average values of electric energy density and magnetic ener... density are equal

$$\left(\frac{1}{2}\varepsilon_0 E^2\right)_{av} = \left(\frac{B^2}{2\mu_0}\right)_{av}$$

(ix) The electric vector of electromagnetic wave is responsible for optical effects and is also call... the light vector.

(x) Electromagnetic waves carry energy and momentun $E = \frac{hc}{\lambda}, p = \frac{U}{c} = mc$

4. Transverse Nature of Electromagnetic Waves

The electromagnetic waves are transverse in nature. In electromagnetic waves the electric a... magnetic fields are mutually perpendicular and also perpendicular to the direction of wa... propagation, such that $\vec{E}$, $\vec{B}$ and $\vec{K}$ form a right handed set ($\vec{K}$ is propagation vector along t... direction of propagation).

5. Electromagnetic Spectrum

The electromagnetic waves have a continuous wavelength starting from short gamma rays to lon... radiowaves. The orderly distribution of wavelength of EM waves is called the electromagneti... spectrum. The complete spectrum is given in the following table:

S. No.	Name	Wavelength Range (m)	Frequency Range (Hz)
i.	Gamma rays	$10^{-13} - 10^{-10}$	$3 \times 10^{23} - 3 \times 10^{18}$
ii.	X-rays	$10^{-10} - 10^{-8}$	$3 \times 10^{18} - 3 \times 10^{16}$
iii.	Ultraviolet rays	$10^{-8} - 4 \times 10^{-7}$	$3 \times 10^{16} - 7.5 \times 10^{14}$
iv.	Visible light	$4 \times 10^{-7} - 7.5 \times 10^{-7}$	$7.5 \times 10^{14} - 4 \times 10^{14}$
v.	Infra red light	$7.5 \times 10^{-7} - 10^{-3}$	$4 \times 10^{14} - 3 \times 10^{12}$
vi.	Microwaves	$10^{-3} - 10^{-1}$	$3 \times 10^{12} - 10^{9}$
vii.	Radio waves	$10^{-1} - 10^{4}$	$10^{9} - 3 \times 10^{4}$

6. Wavelength Range of Visible Spectrum

Visible light has a continuous wavelength starting from 400 nm to 750 nm; for convenience it i... divided into 7 colours.

V	Violet	400 nm — 420 nm
I	Indigo	420 nm — 450 nm
B	Blue	450 nm — 500 nm
G	Green	500 nm — 570 nm
Y	Yellow	570 nm — 600 nm
O	Orange	600 nm — 650 nm
R	Red	650 nm — 750 nm

7. Uses of Electromagnetic Spectrum

(i) γ-rays are highly penetrating, they can penetrate thick iron blocks. Due to high energy, they are used to initiate some nuclear reactions. γ-rays are produced in nuclear reactions. In medicine, they are used to destroy cancer cells.

(ii) X-rays are used in medical diagnostics to detect fractures in bones, tuberculosis of lungs, presence of stone in gallbladder and kidney. They are used in engineering to check flaws in bridges. In physics X-rays are used to study crystal structure.

(iii) Ultraviolet rays provide vitamin D. These are harmful for skin and eyes. They are used to sterilise drinking water and surgical instruments. They are used to detect invisible writing, forged documents, finger prints in forensic lab and to preserve food items.

(iv) **Infrared rays** are produced by hot bodies and molecules. These waves are used for long distance photography and for therapeutic purposes.

(v) **Microwaves** are produced by special vacuum tubes, namely; klystrons, magnetrons and gunn diodes. Their frequency range is 3 GHz to 300 GHz.

They are used in RADAR systems for aircraft navigation and microwave used in homes.

(vi) **Radiowaves** are used for broadcasting programmes to distant places. According to frequency range, they are divided into following groups

(a) Medium frequency band or medium waves 0·3 to 3 MHz

(b) Short waves or short frequency band 3 MHz — 30 MHz

(c) Very high frequency (VHF) band 30 MHz to 300 MHz

(d) Ultrahigh frequency (UHF) band 300 MHz to 3000 MHz

NCERT Textbook Questions

4. A radio can tune into any station in the 7.5 MHz to 12 MHz band. What is the corresponding wavelength band ?

S. Speed of wave $c = 3 \times 10^8\ ms^{-1}$

When frequency $\nu_1 = 7.5$ MHz $= 7.5 \times 10^6$ Hz, Wavelength $\lambda_1 = \frac{c}{\nu_1} = \frac{3 \times 10^8}{7.5 \times 10^6} = \mathbf{40\ m}$

When frequency $\nu_2 = 12$ MHz, wavelength $\lambda_2 = \frac{c}{\nu_2} = \frac{3 \times 10^8}{12 \times 10^6} = \mathbf{25\ m}$

Wavelength band is from **25 m** to **40 m.**

5. The amplitude of the magnetic field of a harmonic electromagnetic wave in vacuum is $B_0 = 510$ nT. What is the amplitude of the electric field part of the wave ?

S. The relation between magnitudes of magnetic and electric field vectors in vacuum is

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

Here, $B_0 = 510\ nT = 510 \times 10^{-9}\ T, c = 3 \times 10^8\ ms^{-1}$

$$E_0 = 510 \times 10^{-9} \times 3 \times 10^8 = \mathbf{153\ N/C.}$$

6. Suppose that the electric field amplitude of an electromagnetic wave is $E_0 = 120$ N/C and that its frequency $\nu = 50.0$ MHz. (*a*) Determine B_0, ω, k and λ (*b*) Find expressions for $\vec{E}$ and $\vec{B}$.

S. (*a*) We have $\frac{E_0}{B_0} = c \quad \Rightarrow \quad B_0 = \frac{E_0}{c} = \frac{120}{3 \times 10^8} = \mathbf{4 \times 10^{-7} T}$

$$\omega = 2\pi\nu = 2 \times 3.14 \times 50 \times 10^6 = \mathbf{3.14 \times 10^8\ rads^{-1}}$$

$$k = \frac{\omega}{c} = \frac{3.14 \times 10^8}{3 \times 10^8} = \mathbf{1.05\ radm^{-1}}$$

Wavelength, $\lambda = \frac{c}{\nu} = \frac{3 \times 10^8}{50.0 \times 10^6} = \mathbf{6.00\ m.}$

(*b*) If wave is propagating along X-axis, electric field will be along Y-axis and magnetic field along Z-axis.

$\vec{E} = E_0 \sin(kx - \omega t)\hat{j}$ where x is in m and t in s

$$\Rightarrow \quad \vec{E} = \mathbf{120 \sin(1.05\, x - 3.14 \times 10^8 t)\, \hat{j}\ N/C}$$

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

$$= \mathbf{(4 \times 10^{-7}) \sin(1.05\, x - 3.14 \times 10^8 t)\hat{k}\ tesla.}$$

7. In a plane electromagnetic wave, the electric field oscillates sinusoidally at a frequency of 2.0×10^{10} Hz and amplitude 48 Vm^{-1}.

(*a*) What is the wavelength of a wave?

(*b*) What is the amplitude of the oscillating magnetic field?

(*c*) Show that the average energy density of the electric field equals the average energy density of the *B* field. [$c = 3 \times 10^8\ ms^{-1}$]

S. (*a*) Wavelength $\lambda = \frac{c}{\nu} = \frac{3 \times 10^8}{2 \times 10^{10}} = \mathbf{1.5 \times 10^{-2}\ m}$

(*b*) $B_0 = \frac{E_0}{c} = \frac{48}{3 \times 10^8} = \mathbf{1.6 \times 10^{-7}\ tesla}$

(*c*) Energy density of electric field is

$$U_E = \frac{1}{2}\varepsilon_0 E^2$$

Energy density of Magnetic field

$$U_B = \frac{1}{2\mu_0}B^2$$

where ε_0 is permittivity of free space and

μ_0 is permeability of free space

We have, $E = cB$

$$\therefore \quad U_E = \frac{1}{2}\varepsilon_0 (cB)^2 = c^2\left(\frac{1}{2}\varepsilon_0 B^2\right)$$

But $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$

$$\therefore \quad U_E = \frac{1}{\mu_0 \varepsilon_0}\left(\frac{1}{2}\varepsilon_0 B^2\right) = \frac{1}{2\mu_0}B^2$$

$$\therefore \quad U_E = U_B$$

Q. 8. Suppose that the electric field of an electromagnetic wave in vacuum is

$$E = \{(3.1\text{ N/C})\cos(1.8\text{ rad/m})\, y + (5.4\times10^6\text{ rad/s})t\}\hat{i}$$

(a) What is the direction of propagation?

(b) What is the wavelength λ?

(c) What is the frequency ν?

(d) What is the amplitude of the magnetic field part of the wave?

(e) Write an expression for the magnetic field part of the wave.

Ans. (a) Wave is propagating along negative y-axis.

(b) Standard equation of wave is

$$\vec{E} = E_0 \cos(ky + \omega t)\hat{i}$$

Comparing the given equation with standard equation, we have

$E_0 = 3.1$ N/C, $k = 1.8$ rad/m, $\omega = 5.4 \times 10^6$ rad/s.

Propagation constant $k = \frac{2\pi}{\lambda}$

$$\lambda = \frac{2\pi}{k} = \frac{2\times 3.14}{1.8}\text{ m} = \mathbf{3.49\ m}$$

(c) We have $\omega = 5.4 \times 10^6$ rad/s

$$\text{Frequency, } \nu = \frac{\omega}{2\pi} = \frac{5.4\times10^6}{2\times3.14}\text{Hz} = \mathbf{8.6\times10^5\ Hz}$$

(d) Amplitude of magnetic field,

$$B_0 = \frac{E_0}{c} = \frac{3.1}{3\times10^8} = \mathbf{1.03\times10^{-8}\ T}$$

(e) The magnetic field is vibrating along Z-axis because $\vec{K}, \vec{E}, \vec{B}$ form a right handed syst

$$-\hat{j}\times\hat{i} = \hat{k}$$

$\therefore$ Expression for magnetic field is

$$\vec{B} = B_0\cos(ky + \omega t)\hat{k}$$

$$= [1.03\times10^{-8}\text{T}\cos\{1.8\text{ rad/m})\, y + (5.4\times10^6\text{rad/s})t\}]\hat{k}$$

24. **During the propagation of electromagnetic waves in a medium**

(a) electric energy density is double of the magnetic energy density.

(b) electric energy density is half of the magnetic energy density.

(c) electric energy density is equal to the magnetic energy density.

(d) both electric and magnetic energy densities are zero.

Answers

1. (c)	2. (b)	3. (b)	4. (b)	5. (b)	6. (a)
7. (d)	8. (d)	9. (b)	10. (c)	11. (d)	12. (a), (b),
13. (a)	14. (a)	15. (b)	16. (c)	17. (c)	18. (c)
19. (a)	20. (b), (d)	21. (a)	22. (c)	23. (a)	24. (c)

Very Short Answer Questions

Each of the following questions are of 1 mark.

Q. 1. How is the speed of EM-waves in vacuum determined by the electric and magnetic fields? *[CBSE Delhi 20*

Ans. Speed of EM waves is determined by the ratio of the peak values of electric field vector magnetic field vector.

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

Q. 2. Do electromagnetic waves carry energy and momentum? *[CBSE (AI) 2017; 2019, (55/4,*

Ans. Yes, EM waves carry energy E and momentum p. As electromagnetic waves contain both elec and magnetic fields, there is a non-zero energy density associated with it.

$$E = \frac{hc}{\lambda}$$

$$\Rightarrow \quad p = \frac{U}{c} = mc$$

Here, c = speed of EM wave in vacuum

λ = wavelength of EM wave

U = total energy transferred to the surface.

Q. 3. In which situation is there a displacement current but no conduction current? *[CBSE South 201*

Ans. During charging or discharging there is a displacement current but no conduction curre between plates of capacitor.

Q. 4. The charging current for a capacitor is 0.25 A. What is the displacement current across plates? *[CBSE (F) 201*

Ans. The displacement current is equal to the charging current. So, displacement current is al 0.25 A.

Q. 5. What are the directions of electric and magnetic field vectors relative to each other and relati to the direction of propagation of electromagnetic waves? *[CBSE (AI) 201*

Ans. Both electric field and magnetic fields are electromagnetic waves. These waves are perpendicul to each other and perpendicular to the direction of propagation.

Q. 6. How is displacement current produced between the plates of a parallel plate capacitor durin charging? *[CBSE 2020 (55/1/2*

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

Q. 7. Differentiate between conduction current and displacement current. [CBSE 2020 (55/1/3)]

Ans. Conduction current is established by actual movement of free electrons through a metallic conductor while displacement current is established by polarisation of molecules of a dielectric under the influence of an external electric field.

Q. 8. The speed of an electromagnetic wave in a material medium is given by $v = \frac{1}{\sqrt{\mu\varepsilon}}$, μ being the permeability of the medium and ε its permittivity. How does its frequency change? [CBSE (AI) 2012]

Ans. The frequency of electromagnetic waves does not change while travelling through a medium.

Q. 9. A plane electromagnetic wave travels in vacuum along Z-direction. What can you say about the direction of electric and magnetic field vectors ? [CBSE Delhi 2011]

Ans. Electric field vector along X-axis and Magnetic field vector along Y-axis.

Q. 10. Mention one use of part of electromagnetic spectrum to which a wavelength of 21 cm (emitted by hydrogen in interstellar space) belongs. [CBSE Sample Paper 2021]

Ans. This wavelength belongs to microwaves. It is used in radar system in aircraft navigation.

Q. 11. To which part of the electromagnetic spectrum does a wave of frequency 3×10^{13} Hz belong? [CBSE (AI) 2014]

Ans. Infrared radiation

Q. 12. Arrange the following electromagnetic waves in order of increasing frequency:
γ-rays, microwaves, infrared rays and ultraviolet rays. [CBSE (F) 2014]

Ans. Microwave < Infrared < Ultraviolet < γ-rays

Q. 13.. Arrange the following electromagnetic waves in decreasing order of wavelength:
γ-rays, infrared rays, X-rays and microwaves. [CBSE (F) 2014]

Ans. Microwave > Infrared > X-rays > γ-rays

Q. 14. Which part of the electromagnetic spectrum is used in operating a RADAR? [CBSE Delhi 2010; 2019 (55/2/1)]

Ans. Microwaves with frequency range between 10^{10} to 10^{12} Hz are used in operating a RADAR.

Q. 15. Why are microwaves considered suitable for radar systems used in aircraft navigation? [CBSE Delhi 2016]

Ans. Microwaves are considered suitable for radar systems used in aircraft navigation due to their short wavelength or high frequency.

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

Ans. Ultraviolet light is absorbed by the ozone layer.

Q. 17. Welders wear special goggles or face masks with glass windows to protect their eyes from electromagnetic radiations. Name the radiations and write the range of their frequency. [CBSE (AI) 2013]

Ans. Ultraviolet radiations.
Frequency range $10^{15} - 10^{17}$Hz.
Hint: Frequency of visible light is of the order of 10^{14} Hz.

Q. 18. Name the electromagnetic waves, which (*i*) maintain the Earth's warmth and (*ii*) are used in aircraft navigation. [CBSE (F) 2012]

Ans.
(*i*) Infrared rays
(*ii*) Microwaves

Q. 19. Why are infra-red radiations referred to as heat waves? Name the radiations which are to these radiations in the electromagnetic spectrum having (i) shorter wavelength (ii) lo wavelength. [CBSE (F) 2

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

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

(ii) Electromagnetic wave having longer wavelength than infrared waves are microwaves, r waves.

Q. 20. How are X-rays produced? [CBSE (AI) 2

Ans. X-rays are produced when high energetic electron beam is made incident on a metallic targ high melting point and high atomic weight.

Q. 21. Write the following radiations in ascending order in respect of their frequencies: X-r microwaves, ultraviolet rays and radiowaves and gamma rays. [CBSE Delhi 2

Ans. In ascending order of frequencies: radiowaves, microwaves, ultraviolet rays, X-rays and gar rays.

Q. 22. It is necessary to use satellites for long distance T.V. transmission. Why? [CBSE Delhi 2

Ans. T.V. signals are not properly reflected by ionosphere. Therefore, signals are made to be refle to earth by using artificial satellites.

Q. 23. Optical and radiotelescopes are built on the ground but X-ray astronomy is possible only f a satellite orbiting the earth, why? [CBSE (AI) 2(

Ans. The visible radiations and radiowaves can penetrate the earth's atmosphere but X-rays absorbed by the atmosphere.

Q. 24. Name the electromagnetic radiations used for (a) water purification, and (b) eye surg [CBSE 20

Ans. (a) Ultraviolet rays

(b) Ultraviolet rays/laser

Q. 25. How are electromagnetic waves produced by accelerating charges? [CBSE 2019 (55/2

Ans. Accelerated charge produces an oscillating electric field which produces an oscillat magnetic field, which is a source of oscillating electric field, and so on. Thus electromagn waves are produced.

Q. 26. Why did Maxwell introduce displacement current in Ampere's circuital law?

Ans. Ampere's circuital law was found inconsistent when applied to the circuit for charging a capaci Therefore, Maxwell added displacement current to usual conduction current.

The displacement current is

$$I_d = \varepsilon_0 \frac{d\phi_E}{dt} \quad \text{where } \phi_E \text{ is the electric flux.}$$

Q. 27. From the following, identify the electromagnetic waves having the (i) Maximum (ii) Minimu frequency.

(a) Radio waves (b) Gamma-rays

(c) Visible light (d) Microwaves

(e) Ultraviolet rays, and (f) Infrared rays.

Ans. (i) The waves of maximum frequency are gamma rays.

(ii) The waves of minimum frequency are radio waves.

Q. 28. Why is the orientation of the portable radio with respect to broadcasting station important? **[NCERT Exemplar] [HOTS]**

Ans. As electromagnetic waves are plane polarised, so the receiving antenna should be parallel to electric/magnetic part of the wave.

Q. 29. The charge on a parallel plate capacitor varies as $q = q_0 \cos 2\pi vt$. The plates are very large and close together (area = A, separation = d). Neglecting the edge effects, find the displacement current through the capacitor? **[NCERT Exemplar] [HOTS]**

Ans. Conduction current I_C = Displacement current I_D

$$I_C = I_D = \frac{dq}{dt} = \frac{d}{dt}(q_0 \cos 2\pi\nu t) = -2\pi q_0 \nu \sin 2\pi\nu t$$

Q. 30. A variable frequency ac source is connected to a capacitor. How will the displacement current change with decrease in frequency? **[NCERT Exemplar] [HOTS]**

Ans. On decreasing the frequency, reactance $X_C = \frac{1}{\omega C}$ will increase which will lead to decrease in conduction current. In this case $I_D = I_C$, hence displacement current will decrease.

Q. 31. Professor C.V. Raman surprised his students by suspending freely a tiny light ball in a transparent vacuum chamber by shining a laser beam on it. Which property of em waves was he exhibiting? Give one more example of this property. **[NCERT Exemplar] [HOTS]**

Ans. Electromagnetic waves exert radiation pressure. Tails of comets are due to solar radiation.

Short Answer Questions–I

Each of the following questions are of 2 marks.

Q. 1. State two properties of electromagnetic waves. How can we show that EM waves carry momentum? **[CBSE South 2016]**

Ans. Properties of electromagnetic waves:

(i) Transverse nature

(ii) Does not get deflected by electric or magnetic fields

(iii) Same speed in vacuum for all waves

(iv) No material medium required for propagation

(v) They get refracted, diffracted and polarised

Electric charges present on a plane, kept normal to the direction of propagation of an EM wave can be set and sustained in motion by the electric and magnetic field of the electromagnetic wave. The charges thus acquire energy and momentum from the waves.

Q. 2. 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. **[CBSE Delhi 2017]**

Ans. During charging, electric flux between the plates of capacitor keeps on changing; this results in the production of a displacement current between the plates.

$$I_d = \varepsilon_0 \left(\frac{d\phi_E}{dt}\right)$$

Q. 3. Write the generalised expression for the Ampere's circuital law in terms of the conduct current and the displacement current. Mention the situation when there is:

(i) only conduction current and no displacement current.

(ii) only displacement current and no conduction current.

[CBSE (F) 20...]

Ans. Generalised Ampere's circuital Law—

$$\oint \vec{B}\cdot\vec{dl} = \mu_0 I_C + \mu_0\varepsilon_0 \frac{d\phi_E}{dt}$$

Line integral of magnetic field over closed loop is equal to μ_0 times sum of conduction curr... and displacement current.

(i) In case of steady electric field in a conducting wire, electric field does not change w... time, conduction current exists in the wire but displacement current may be zero. S...

$\oint \vec{B}.\vec{dl} = \mu_0 I_C$.

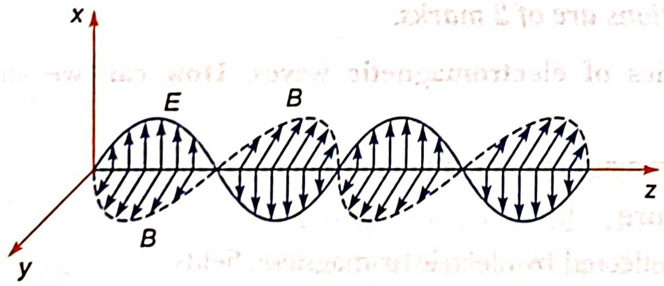
(ii) In large region of space, where there is no conduction current, but there is only a displacem... current due to time varying electric field (or flux). So, $\oint \vec{B}.\vec{dl} = \mu_0\varepsilon_0 \frac{d\phi_E}{dt}$.

Q. 4. (a) How does oscillating charge produce electromagnetic waves?

(b) Sketch a schematic diagram depicting oscillating electric and magnetic fields of an em w... propagating along + z-direction. [CBSE (F) 2014, Delhi 20...]

Ans. (a) An oscillating charge produces an oscillating electric field in space, which produces oscillating magnetic field. The oscillating electric and magnetic fields regenerate each ot... and this results in the production of em waves in space.

(b) Electric field is along x-axis and magnetic field is along y-axis.

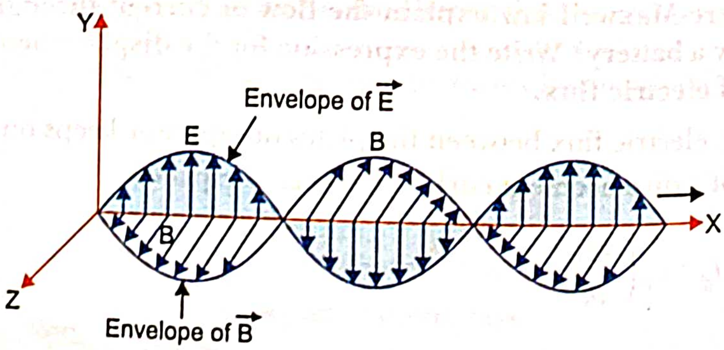


Q. 5. (a) An EM wave is travelling in a medium with a velocity $\vec{v} = v\hat{i}$. Draw a sketch showing ... propagation of the EM wave, indicating the direction of the oscillating electric and magne... fields.

(b) How are the magnitudes of the electric and magnetic fields related to the velocity of the ... wave? [CBSE Delhi 20...]

Ans. The direction of propagation of electromagnetic wave is given by $\vec{E}\times\vec{B}$

(a) $\hat{i} = \hat{j}\times\hat{k}$.



(b) The speed of electromagnetic wave $|c| = \frac{|E_0|}{|B_0|}$

Q. 6. 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

[*CBSE 2020 (55/2/1)*]

Ans. (*a*) Minimum wavelength: γ rays

(*b*) Minimum frequency: Microwaves

- γ rays are used to treat cancer.
- Microwaves are used for communication via satellite.

Q. 7. (*i*) How are infrared waves produced? Write their one important use.

(*ii*) The thin ozone layer on top of the stratosphere is crucial for human survival. Why?

[*CBSE East 2016; 2019 (55/4/1)*]

Ans. (*i*) Infrared waves are produced by hot bodies and molecules.

Important use:

(*a*) To treat muscular strains (*b*) To reveal the secret writings on the ancient walls (*c*) For producing dehydrated fruits (*d*) Solar heater (*e*) Solar cooker (*Any one*)

(*ii*) Ozone layer protects us from harmful UV rays.

Q. 8. (*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? [*CBSE (F) 2016*]

Ans. (*i*) Gamma rays have the highest frequency. These are produced during nuclear reactions and also emitted by radioactive nuclei. They are used in medicine to destroy cancer cells.

(*ii*) Ultraviolet rays lie near the high frequency end of visible part of EM spectrum. They are used to sterlise drinking water and surgical instruments. Exposure to UV radiation induces the production of more melanin, causing tanning of the skin.

Q. 9. Explain briefly how electromagnetic waves are produced by an oscillating charge. How is the frequency of EM waves produced related to that of the oscillating charge?

[*CBSE (F) 2012, 2019 (55/2/3)*]

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

The frequency of EM wave = Frequency of oscillating charge.

Q. 10. 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. [*CBSE (AI) 2017*]

Ans. (*a*) **X-rays:** Used as a diagnostic tool in medicine and as a treatment for certain forms of cancer.

(*b*) **Microwaves:** Used in radar systems for aircraft navigation.

Q. 11. (*a*) Explain briefly the fact that electromagnetic waves carry energy.

(*b*) Why do we not, feel the pressure due to sunshine? [*CBSE 2020 (55/3/1)*]

Ans. (*a*) Consider a plane perpendicular to the direction of propagation of the electromagnetic wave. If there are, on this plane, electric charges, they will be set and sustained in motion by the electric and magnetic fields of the electromagnetic wave. The charges thus acquire energy and momentum from the waves.

(*b*) The magnitude of total momentum delivered to a surface $p = \frac{U}{c}$, where U is the total energy transferred to a surface in time t.

When the sun shines on our hand. The energy is absorbed from the electromagnetic waves and it transfers momentum to our hand since c is very large, p is very small and we do not feel the pressure.