Unit V: Electromagnetic waves **04 Periods**

Chapter–8: Electromagnetic Waves

Basic idea of displacement current, Electromagnetic waves, their characteristics, their Transverse nature (qualitative ideas only).

Electromagnetic spectrum (radio waves, microwaves, infrared, visible, ultraviolet, X-rays, gamma rays) including elementary facts about their uses.

501. What is meant by displacement current ? **CBSE (AIC)-2010**

[**Ans. Displacement current** : A current which comes in to existence due to time varying electric field, is known as displacement current

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

502. In which situation there is a displacement current but no conduction current ? **CBSE (AI)-2016**

[**Ans.** Between the plates of capacitor during charging/discharging or in the regions of time varying electric field

503. The charging current for a capacitor is 0.25 A. What is the displacement current across its plates ? **CBSE (F)-2016**

[**Ans.** same as the convection current, i,e, $I_D = 0.25$ A

504. Why is the quantity $\varepsilon_0 \frac{d\phi_E}{dt}$ is called displacement current ? **CBSE (AIC)-2001**

[**Ans.** Because the quantity $\varepsilon_0 \frac{d\phi_E}{dt}$ has the dimensions of current and this current exists in a region between the two plates of a capacitor when displacement of charges occurs there ,i,e, during charging or discharging of capacitor

505. 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 displacement current in terms of the rate of change of electric flux. **CBSE (D)-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

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

506. Why does a galvanometer show a momentary deflection, at the time of charged or discharging a capacitor ? Write the necessary expression to explain this observation. **CBSE (AI)-2017,2016**

[**Ans.** During charging or discharging of the capacitor, displacement current between the plates is set up . Hence circuit becomes complete and galvanometer shows momentary deflection

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

507. A capacitor has been charged by a d.c. source. What are the magnitudes of conduction and displacement currents, when it is fully charged ? **CBSE (D) -2013**

[**Ans.** when fully charged then both $I = I_D = 0$ and during charging $I = I_D = \varepsilon_0 \frac{d\phi_E}{dt}$

508. What does the displacement current $I_D = \varepsilon_0 \frac{d\phi_E}{dt}$ signify ? **CBSE (D)-2012**

[**Ans.** It signifies that the changing electric field can give rise to a magnetic field

509. When an ideal capacitor is charged by a d.c. battery, no current flows. However, when an a.c. source is used, the current flows continuously. How does one explain this, based on the concept of displacement current ? **CBSE (AI)-2017,(D)-2012**

[**Ans.** In case of d.c. there is no change in electric flux and hence there is no displacement current. Circuit remains incomplete and capacitor does not conduct and no current flows

In case of a.c. source changing voltage causes change in electric flux and so displacement current ($I_D = \varepsilon_0 \frac{d\phi_E}{dt}$) is set up between the plates of capacitor. It completes the circuit and current flows continuously.

510. A capacitor made of two parallel plates each of plate area A and separation d, is being charged by an external a.c. source. Show that the displacement current inside the capacitor is same as the current charging the capacitor.

[**Ans.** Let applied alternating voltage **CBSE (AI)-2013**

$$V = V_0 \sin \omega t$$

At any instant, the conduction current

$$I = \frac{dq}{dt} = \frac{d}{dt}(CV) = \frac{d}{dt}(CV_0 \sin \omega t) = CV_0 \frac{d}{dt}(\sin \omega t) = \omega CV_0 \cos \omega t = I_0 \cos \omega t$$

Displacement current,

$$I_D = \varepsilon_0 \frac{d\phi_E}{dt} = \varepsilon_0 \frac{d}{dt}(E\,A) = \varepsilon_0 \frac{d}{dt}\left(\frac{q}{\varepsilon_0 A} A\right) = \frac{dq}{dt} = I = I_0 \cos \omega t$$

511. Write the expression for the generalized Ampere's circuital law. Through a suitable example, explain the significance of time dependent term. **CBSE (AI)-2015**

[**Ans. Generalized Ampere's circuital law** : $\oint \vec{B}.\vec{dl} = \mu_0 (I + \varepsilon_0 \frac{d\phi_E}{dt})$

Significance : Time dependent term i,e, $\varepsilon_0 \frac{d\phi_E}{dt}$ is the displacement current and it signifies that the changing electric field can give rise to a magnetic field

512. What are electromagnetic waves ? Are these waves transverse or longitudinal ? **CBSE (AIC)-2011,(AI)-2001**

[**Ans**. The waves produced by accelerated charged particles, in which there are sinusoidal variations of electric and magnetic field vectors at right angles to each other as well as at right angles to the direction of propagation of wave, are called electromagnetic waves

em waves are trans verse in nature

513. (i) How are electromagnetic waves produced ? Explain. **CBSE (F)-2017,(AI)-2016,2015**
(ii) What is the source of energy of these waves ?

[**Ans.(i) Production of em waves** : em waves are produced by accelerated/ oscillating charges

A charge oscillating with some frequency, produces an oscillating electric field in space, which produces an oscillating magnetic field perpendicular to the electric field, which in turn is a source of electric field, this process goes on repeating, producing em waves in space perpendicular to both fields.

(ii) Source of energy of em waves is the energy of accelerated/ oscillating charge

514. What oscillates in electromagnetic waves ? **CBSE (DC)-2010**

[**Ans**. Electric and magnetic vectors oscillates in an em wave

515. What is the phase relationship between oscillating electric and magnetic fields in an em wave ? **CBSE (AIC)-2010**

[**Ans**. They are in the same phase

516. What is the frequency of em waves produced by oscillating charge of frequency ? **CBSE (AI)-2015,2010**

[**Ans**. Frequency of em wave = frequency of oscillating charge = ν

517. When can a charge acts as a source of em wave ? **CBSE (D)-2013,2005,(AI)-2012,(AIC)-2004**

[**Ans**. when charge is either accelerated or oscillating

518. Write the relation for the speed of electromagnetic waves in terms of the amplitudes of electric and magnetic fields.

[**Ans**. Speed of em waves is given by the ratio of the amplitudes of electric and magnetic field vectors. **CBSE (AI)-2017**

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

519. Write the expression for speed of electromagnetic waves in a medium of electrical permittivity ε and magnetic permeability μ.

[**Ans**. $\boldsymbol{c = \frac{1}{\sqrt{\mu\,\varepsilon}} = \frac{1}{\sqrt{\mu_0\mu_r\varepsilon_0\varepsilon_r}}}$ **CBSE (F)-2017**

520. What is meant by the transverse nature of electromagnetic waves ? **CBSE (AI)-2016,2015**

[**Ans**. Transverse nature means, $\vec{E}$ & $\vec{B}$ are $\perp$ to each other as well as $\perp$ to the direction of propagation of the wave

530. How are the directions of the electric and magnetic field vectors in an em wave are related to each other and to the direction of propagation of the em waves ? **CBSE (F)-2012**

[**Ans**. $\vec{E}$ & $\vec{B}$ are $\perp$ to each other as well as $\perp$ to the direction of propagation of the wave

531. In which directions do the electric and magnetic field vectors oscillate in an electromagnetic wave propagating along the x-axis ?

[**Ans**. $\vec{E}$ along y-axis and $\vec{B}$ along z-axis **CBSE (AI)-2017**

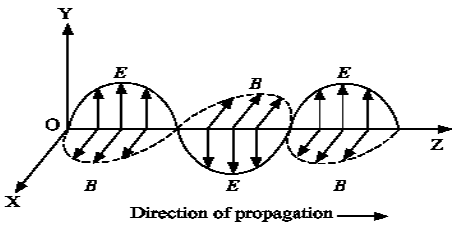
(Alternatively $\vec{E}$ along z-axis and $\vec{B}$ along y-axis

532. Write mathematical expression for electric and magnetic fields of an electromagnetic wave propagating along z-axis.

[**Ans**. $\overrightarrow{E_x} = E_0 \sin(Kz - \omega t)\,\hat{\imath}$ & $\overrightarrow{B_y} = B_0 \sin(Kz - \omega t)\,\hat{\jmath}$

533. Draw a sketch of linearly polarized em waves propagating in the Z-direction. Indicate the directions of the oscillating electric and magnetic fields. **CBSE (AI)-2016,2015,2010,(F)-2014,(D)-2009**

[**Ans**.



534. Write the expression for the energy density of an electromagnetic wave propagating in free space. **CBSE (AI)-2015**

[**Ans**. $u = u_E + u_B = \frac{1}{2}\varepsilon_0 E^2 + \frac{B^2}{2\mu_0}$

535. State any four properties of electromagnetic waves. **CBSE (AI)-2016,2015**

[Ans. (i) do not require any material medium for their propagation
(ii) transverse in nature
(iii) do not get deflected by electric or magnetic fields
(iv) same speed in vacuum for all waves

536. Do the electromagnetic waves carry energy and momentum ? **CBSE (AI)-2017**

[Ans. Yes

537. How can we show that em waves carry momentum ? **CBSE (AI)-2016,2015**

[Ans. Electric charges present on a plane, normal to the direction of propagation of an em wave can 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.
If the total energy transferred to a surface in time t is U, then the magnitude of the total momentum delivered to this surface (for complete absorption) is, $\mathrm{p} = \frac{\mathrm{U}}{c}$

538. Why is the amount of the momentum transferred by the EM waves incident on the surface so small ?

[Ans. momentum transferred by the em waves = energy/speed of light= $\mathrm{h}\nu/c = 10^{-22}$ **CBSE (D)-2014,(AI)-2009**
Which is very small

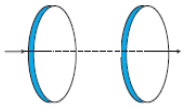
539. An em wave exerts pressure on the surface on which it is incident. Justify. **CBSE (F)-2012**

[Ans. em waves carry momentum $(\mathrm{p} = \frac{\mathrm{U}}{c})$ energy $(\mathrm{h}\nu)$ hence they exert a radiation pressure $P = \frac{F}{A} = \frac{1}{A}\frac{dp}{dt}$

540. Figure shows a capacitor made of two circular plates. The capacitor is being charged by an external source. The charging current is constant and equal to 0.15 A. **NCERT-2017**
(a) What is the displacement current across the plates.
(b) Is Kirchhoff's first rule (junction rule) valid at each plate of the capacitor? Explain.

[Ans. (a) displacement current = charging current $= 0.15\ A$

(b) As $(I + I_D)$ is continuous so Kirchhoff's first rule (junction rule) valid at each plate of the capacitor



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541. Which physical quantity, if any, has the same value for the waves belonging to the different parts of the electromagnetic spectrum ? **CBSE (AI)-2012,(AIC)-2004**

[Ans. Velocity

542. Name the physical quantity which remains same for microwaves of wavelength 1mm and UV radiations of 1600 A^0 in vacuum.

[Ans. Velocity c= 3 X 10^8 m/s **CBSE (D)-2012**

543. What is the ratio of speed of infrared and ultraviolet rays in vacuum ? **CBSE (D)-2001**

[Ans. 1:1

544. Give the ratio of velocities of wavelengths 4000 A^0 and 8000 A^0 in vacuum ? **CBSE (AI)-2001**

[Ans. 1:1

545. Welders wear special goggles or face masks with glass windows to protect their eyes from electromagnetic radiations. Name the radiations & write the range of their frequency. **CBSE (D)-2014,(AI)-2013,(F)-2010**

[Ans. Ultraviolet radiations, from 10^{14} Hz to 10^{16} Hz]

546. Why are microwaves found useful for the radar systems in aircraft navigation ?**CBSE (D) -2016,2004,(F)-2013**

OR

State the reason why microwaves are best suited for long distance transmission of signals ? **CBSE (F)-2008**

[Ans. Due to short wavelength, microwaves have high penetrating power with respect to atmosphere and are not diffracted by the obstacle in the path of their propagation

547. Why is the thin ozone layer on the top of stratosphere is crucial for human survival ? Identify to which part of electromagnetic spectrum does this radiation belong and write one important application of the radiation. **CBSE (AI)-2016,2009,(AIC)-2015,(D)-2014**

[Ans. Because ozone layer absorbs ultraviolet radiation coming from the sun and thus prevent these radiations from reaching the earth which causes Cancer
Identification : Ultraviolet radiations
Application : Water purification/ forensics

548. How are infrared rays produced ? Why are these referred to as " heat waves? Write their three important uses. Name the radiations which are next to these radiations in the electromagnetic spectrum having (a) shorter wavelength (b) longer wavelength. **CBSE (AI)-2016, (D)-2014,2011, (F) -2013,2010**

[Ans. Production : Infrared waves are produced by hot bodies due to the vibrations of their atoms/molecules. Infrared rays are called heat waves because they produce heat when they fall on any object.

Uses : (i) in photography during fog (ii) treating muscular strain (iii) in remote controls of electronic devices

Radiations : (a) Visible light (b) Microwaves

549. What role does infra radiation play in (i) maintain the Earth's warmth, and (ii) Physical therapy ?**CBSE (AI) -2015**

[Ans. (i) Infrared radiations are absorbed by the earth's surface and radiated as longer wavelength infrared radiations. These radiations are trapped by green house gases such as CO_2 and maintain the Earth's warmth.

(ii) Infrared radiations are easily absorbed by the water molecules present in the body. After absorption, their thermal motion increases causes heating which is used as physical therapy

550. If the earth did not have atmosphere, would its average surface temperature be higher or lower than what it is now ? Explain.

[Ans. lower because of absence of green house gases **CBSE (D)-2014,(AI)-2009**

551. State clearly how a microwave oven works to heat up a food item containing water molecules? **CBSE (F) -2013**

[Ans. In a microwave oven, frequency of microwaves matches the resonant frequency of water molecules for heating (about 3 GHz), so that the energy from the waves is transferred efficiently to the kinetic energy of the molecules. This raises the temperature of any food containing water

552. Which segment of electromagnetic waves has highest frequency ? How are these waves produced ? Give one use of these waves. **CBSE (F)-2016**

[Ans. $\gamma - rays$,

Production : these are produced by Radioactive decay of the nucleus,

Use : used in medicine to destroy cancer cells

553. 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. $Ultra\ violet\ rays$,

used in LASIK eye surgery, UV lamps to kill germs in water (water purification)

UV rays causes Skin Cancer/Sunburn/ harms eyes when exposed to direct UV rays

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554. Which of the following electromagnetic radiations has least frequency : **CBSE (AI)-2015**

UV radiations, X-rays, Microwaves

[Ans. Microwaves

555. Which of the following has the shortest wavelength : **CBSE (AI)-2010**

Microwaves, Ultraviolet rays, X-rays **[Ans.** X-rays

556. Arrange the following electromagnetic waves in order of increasing frequency : **CBSE (F)-2014,(D)-2009**

γ –rays, microwaves, infrared rays and Ultraviolet rays

[Ans. Microwaves, infrared rays, Ultraviolet rays, γ –rays

557. Arrange the following electromagnetic waves in order of decreasing frequency : **CBSE (F)-2014, (D)-2002**

x-rays, γ –rays, microwaves, UV rays and infrared rays

[Ans. γ –rays, x-rays, UV rays, infrared rays and Microwaves

558. Arrange the following em waves in order of their increasing wavelength : **CBSE (AI)-2015,(DC)-2001**

γ –rays, Microwaves, X-rays, U.V. rays and Radio waves

[Ans. γ –rays< X-rays ,UV rays < Microwaves < Radio waves

559. Arrange the following electromagnetic waves in decreasing order of wavelength : **CBSE (F)-2014**

γ –rays, infrared rays, x-rays and microwaves

[Ans. Microwaves, infrared rays, x-rays and γ –rays

560. Name the following constituent radiations of electromagnetic spectrum which- **CBSE (AI)-2016,2005**
(i) are used in satellite communication/in radar and geostationary satellite **CBSE (D) -2010, 2004**
(ii) are used for studying crystal structure of solids **CBSE (AI)-2007, (F)-2012,2005**
(iii) are similar to the radiations emitted during decay of radioactive nuclei **CBSE (AI)-2005, (AIC)-2005**
(iv) used for water purification/ are absorbed from sunlight by ozone layer **CBSE (AI)-2007, (F)-2005**
[Ans. (i) microwaves (ii) x- rays (iii) γ- rays (iv) UV rays

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561. Name the following constituent radiations of electromagnetic spectrum which- **CBSE (AI)-2016,2005**
(i) has its wavelength range between 390 nm to 770 nm **CBSE (AI)-2005, (AIC)-2005**
(ii) produce intense heating effect/ used in warfare to look through fog **CBSE (AI)-2007, (F)-2005**
(iii) are used for radar systems used in aircraft navigation **CBSE (D)-2015,(F)-2012,(AI)-2007**
[Ans. (i) visible light (ii) Infrared rays (iii) microwaves

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562. Name the following constituent radiations of electromagnetic spectrum which-
(i) are adjacent to the low frequency end of electromagnetic spectrum **CBSE (F)-2010**
(ii) produced by nuclear reactions/used to destroy cancer cells/treatment of cancer **CBSE (F)-2010**
(iii) produced by bombarding a metal target by high speed electrons. **CBSE (AI)-2016, (F)-2009**
(iv) maintains the earth's warmth/ used in remote sensing **CBSE (F) -2012 ,(AI) -2007**
[Ans. (i) microwaves (ii) γ- rays (iii) x- rays (iv) Infrared rays

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563. Which constituent radiations of electromagnetic spectrum is used - **CBSE (F)-2004**
(i) in Radar
(ii) in photographs of internal parts of human body/as a diagnostic tool in medicine **CBSE (D) -2015**
(iii) for taking photographs of sky, during night and fog conditions. **CBSE (D)-2004**
(iv) has the largest penetrating power **CBSE (D) -2010, 2004**
Give reason for your answer in each case.
[Ans. (i) microwaves because they go straight and are not absorbed by the atmosphere
(ii) x- rays because they can penetrate light elements (flesh)
(iii) Infrared rays, because they penetrate fog and are not absorbed by the atmosphere
(iv) $\gamma - rays$ as they have the highest frequency and hence highest energy

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564. Electromagnetic waves with wavelengths- **CBSE (Sample Paper)-2009**
(i) λ_1 are used to treat muscular strain **CBSE (D) -2015**
(ii) λ_2 are used by a F.M. radio station for broadcasting
(iii) λ_3 are used to detect fractures in bones **CBSE (D) -2015**
(iv) λ_4 are absorbed by ozone layer of the atmosphere **CBSE (D) -2010, 2004**
Identify the name and part of electromagnetic spectrum to which these radiations belong. Arrange these wavelengths in order of magnitude.
[Ans. (i) Infrared rays (ii) radio waves (iii) x- rays (iv) UV rays, $\lambda_2 > \lambda_1 > \lambda_4 > \lambda_3$

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565. Identify the electromagnetic waves whose wavelength vary as and also write one use for each. **CBSE (AI)-2017**
(i) $10^{-12}\, m < \lambda < 10^{-8}\, m$ (ii) $10^{-3}\, m < \lambda < 10^{-1}\, m$
[Ans. (i) X-rays/ $\gamma - rays$ used for medical purposes/ nuclear reactions (ii) Microwaves used for radar systems

566. Identify the electromagnetic waves whose wavelength vary as and also write one use for each. **CBSE (AI)-2017**
(i) $10^{-11}\, m < \lambda < 10^{-14}\, m$ (ii) $10^{-4}\, m < \lambda < 10^{-6}\, m$
[Ans. (i) X-rays/ $\gamma - rays$ used for medical purposes/ nuclear reactions
(ii) Infrared/ visible used for muscular treatment/ vision

567. Show that in the process of charging a capacitor, the current produced within the plates of the capacitor is

$$I_D = \varepsilon_0 \frac{d\phi_E}{dt}$$ **CBSE (D) -2016**

where ϕ_E is the electric flux produced during charging of the capacitor plates.

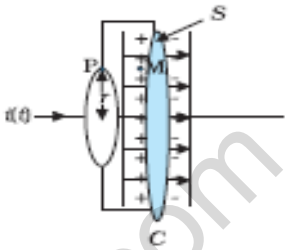
[Ans. Electric field between the plates of capacitor, $E = \frac{q}{\varepsilon_{0A}}$

⇨ electric flux, $\phi_E = E\,A = \frac{q}{\varepsilon_{0A}} A = \frac{q}{\varepsilon_0}$

⇨ $\frac{d\phi_E}{dt} = \frac{d}{dt}(\frac{q}{\varepsilon_0}) = \frac{1}{\varepsilon_0}\left(\frac{dq}{dt}\right)$

⇨ $\frac{dq}{dt} = \varepsilon_0 \frac{d\phi_E}{dt}$

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



568. Show that in the process of charging a capacitor, displacement current is always equal to conduction current.

[Ans. Displacement current between the plates of capacitor, during charging **CBSE (AIC) -2010**

$$I_D = \varepsilon_0 \frac{d\phi_E}{dt} = \varepsilon_0 \frac{d}{dt}(E\,A) = \varepsilon_0 \frac{d}{dt}\left(\frac{q}{\varepsilon_{0A}} A\right) = \frac{dq}{dt} = I$$

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569. Why does a galvanometer when connected in series with a capacitor show a momentary deflection, when it is Being charged or discharged ? How does this information lead to modify the Ampere's circuital law ? Hence write the generalized expression of Ampere's circuital law. **CBSE (F)-2015,(AI)-2014,2011**

[Ans. During charging or discharging of the capacitor, displacement current between the plates is set up . Hence circuit becomes complete and galvanometer shows momentary deflection

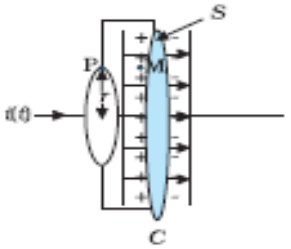
By Ampere's circuital law

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

Applying it to surface P, $\oint \vec{B}.\vec{dl} = \mu_0 I$

Applying it to surface S, $\oint \vec{B}.\vec{dl} = 0$

$\therefore \oint_p \vec{B}.\vec{dl} \neq \oint_s \vec{B}.\vec{dl}$.



This is in contradiction to Ampere's circuital law. Hence it needs modification.

In fact, during charging/ discharging of capacitor electric flux between the plates changes which produces current known as displacement current. Hence, there is a need to include displacement current.

Therefore, modified Ampere's circuital law is

$\oint \vec{B}.\vec{dl} = \mu_0 (I + I_D) = \mu_0 (I + \varepsilon_0 \frac{d\phi_E}{dt})$ Now for surface P, $\oint \vec{B}.\vec{dl} = (\mu_0 I + 0) = \mu_0 I$

For surface S, $\oint \vec{B}.\vec{dl} = (0 + I_D) = \mu_0 I_D = \mu_0 I$

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570. Write the generalized expression for Ampere's circuital law in terms of the conduction current and displacement current. Mention the situation when there is : **CBSE (F) -2013**

(i) only conduction current and no displacement current

(ii) only displacement current and no conduction current

[Ans. Generalized Ampere's circuital law : $\oint \vec{B}.\vec{dl} = \mu_0 (I + \varepsilon_0 \frac{d\phi_E}{dt})$

(i) In case of a steady current in conducting wire, electric field does not change with time, conduction current exists but displacement current is zero.

⇨ $\oint \vec{B}.\vec{dl} = \mu_0 I$

(ii) During charging of a capacitor displacement current flows in the space between the plates of capacitor but conduction current is zero.

⇨ $\oint \vec{B}.\vec{dl} = \mu_0 \varepsilon_0 \frac{d\phi_E}{dt} = \mu_0 I_D = \mu_0 I$

571. A plane electromagnetic wave of frequency 25 MHz travels in free space along the *x*-direction. At a particular point in space and time, $\vec{E}$ = 6.3 $\hat{j}$ V/m. What is $\vec{B}$ at this point ? **NCERT- 2017**

[**Ans.** $\frac{E}{B} = c \Rightarrow B = \frac{E}{c} = \frac{6.3}{3\ X\ 10^8} = 2.1 \text{ X } 10^{-8}\ \hat{k}$ Tesla]

572. In an electromagnetic wave the oscillating electric field having a frequency of 3 X 10^{10} H_Z and an amplitude of 30 V/m propagates in the positive x-direction. **CBSE (F)-2008**

(i) what is the wavelength of electromagnetic wave ?

(ii) write down the expression to represent the corresponding magnetic field.

[**Ans.** **(i)** $\lambda = \frac{c}{f} = \frac{3\ X\ 10^8}{3\ X\ 10^{10}} = 10^{-2}\ m$ **(ii)** $B_0 = \frac{E_0}{c} = \frac{30}{3\ X\ 10^8} = 10^{-7}\ T$

$\omega = 2\pi f = 2\pi\ X3\ X\ 10^{10} = 6\pi\ X\ 10^{10}$ rad/s & $K = \frac{2\pi}{\lambda} = \frac{2\pi}{10^{-2}} = 2\pi \text{ X } 10^2\ m^{-1}$

$\Rightarrow \quad B = B_0 \sin(\omega t - Kx) = 10^{-7} \sin(6\pi\ X\ 10^{10}\ t - 2\pi \text{ X } 10^2\ x)$]

573. In an electromagnetic wave propagating along x- direction, the magnetic field oscillates at a frequency of 3 X10^{10} H_Z and has an amplitude of 10^{-7} Tesla acting along the y-direction. **CBSE (F)-2008**

(i) what is the wavelength of electromagnetic wave ?

(ii) write the expression representing the corresponding oscillating electric field.

[**Ans.** **(i)** $\lambda = \frac{c}{f} = \frac{3\ X\ 10^8}{3\ X\ 10^{10}} = 10^{-2}\ m$ (ii) $\frac{E_0}{B_0} = c \Rightarrow E_0 = B_0\ c = 10^{-7} \text{ X } 3\ X\ 10^8 = 30\ V/m$

$\omega = 2\pi f = 2\pi\ X3\ X\ 10^{10} = 6\pi\ X\ 10^{10}$ rad/s & $K = \frac{2\pi}{\lambda} = \frac{2\pi}{10^{-2}} = 2\pi \text{ X } 10^2\ m^{-1}$

$\Rightarrow E = E_0 \sin(\omega t - Kx)\ \hat{k} = 30 \sin(6\pi\ X\ 10^{10}\ t - 2\pi \text{ X } 10^2\ x)\ \hat{k} \quad V/m$]

574. The oscillating magnetic field in a plane electromagnetic wave is given by **CBSE (D)-2008**

B_y = 8 X 10^{-6} sin (2 x 10^{11} t + 300 πx)] T

(i) calculate the wavelength of electromagnetic wave ?

(ii) write down the expression for the oscillating electric field.

[**Ans.** B_y = 8 X 10^{-6} sin (2 x 10^{11} t + 300 πx)] T Comparing with $B_y = B_0 \sin(\omega t + Kx)$

B_0 = 8 X10^{-6} T, ω = 2 x 10^{11} rad/s and $K = 300\,\pi$

(i) $K = \frac{2\pi}{\lambda} \Rightarrow \frac{2\pi}{\lambda} = 300\,\pi \Rightarrow \lambda = \frac{1}{150}\ m = \frac{100}{150}\ cm = \frac{2}{3}\ cm$

(ii) $\frac{E_0}{B_0} = c \Rightarrow E_0 = B_0\ c = 8\ X\ 10^{-6} \text{ X } 3\ X\ 10^8 = 2400\ V/m$

$\Rightarrow E_z = E_0 \sin(\omega t + Kx)\ \hat{k} = 2400 \sin(2\ X\ 10^{11}\ t + 300\,\pi\ x)\ \hat{k} \quad V/m$]

575. The oscillating electric field of an electromagnetic wave is given by **CBSE (D)-2008**

E_y = 30 sin(2 x 10^{11} t + 300πx)] V/m

(i) obtain the value of the wavelength of electromagnetic wave ?

(ii) write down the expression for the oscillating magnetic field.

[**Ans.** E_Y = 30 sin(2 x 10^{11} t + 300πx)] Comparing with $E_y = E_0 \sin(\omega t + Kx)$

E_0 = 30 V/m, ω = 2 x 10^{11} rad/s and $K = 300\,\pi$

(i) $K = \frac{2\pi}{\lambda} \Rightarrow \frac{2\pi}{\lambda} = 300\,\pi \Rightarrow \lambda = \frac{1}{150}\ m = \frac{100}{150}\ cm = \frac{2}{3}\ cm$

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

$\Rightarrow B_z = B_0 \sin(\omega t + Kx)\ \hat{k} = 10^{-7} \sin(2\ X\ 10^{11}\ t + 300\,\pi\ x)\ \hat{k} \quad T$]

576. In a plane em wave, the electric field oscillates sinusoidally at a frequency of 2.0 X 10^{10} H_Z and amplitude 48 V/m.

(i) what is the wavelength of the wave ? **NCERT- 2017,CBSE (AI)-2001,(AIC)-2002**

(ii) what is the amplitude of oscillating magnetic field ?

(iii) show that the average energy density of the $\vec{E}$ field equals the average energy density of the $\vec{B}$ field.

[**Ans.** (i) $\lambda = \frac{c}{f} = \frac{3\ X\ 10^8}{2\ X\ 10^{10}} = 1.5\ X\ 10^{-2}\ m$ (ii) $\frac{E_0}{B_0} = c \Rightarrow B_0 = \frac{E_0}{c} = \frac{48}{3\ X\ 10^8} = 1.6\ X10^{-7}\ T$

(iii) $u_E = \frac{1}{2}\ \varepsilon_0\ E^2 = \frac{1}{2}\ \varepsilon_0\ (Bc)^2 = \frac{1}{2}\ \varepsilon_0\ B^2 (\frac{1}{\sqrt{\mu_0 \varepsilon_0}})^2 = \frac{B^2}{2\mu_0} = u_B$]

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