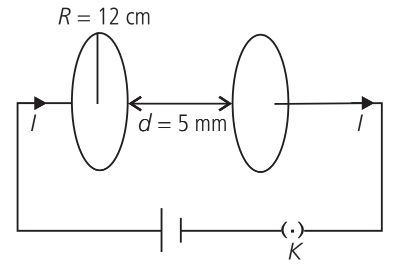
CHAPTER 8

Electromagnetic Waves

NCERT FOCUS **ANSWERS**

Topic 1

1.



(a) Capacitance of the parallel plate capacitor

$$C=\frac{\varepsilon_0 A}{d}=\frac{8.85\times10^{-12}\times\pi\times(12\times10^{-2})^2}{5\times10^{-3}}$$

$C = 80.1 \times 10^{-12}$ F = 80.1 pF

We know $Q = CV$

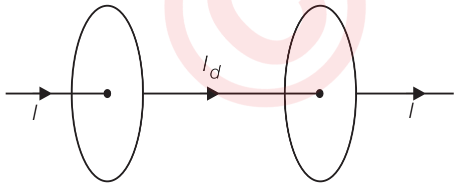
$$I=\frac{dQ}{dt}=C\frac{dV}{dt}$$

So, $\dfrac{dV}{dt}=\dfrac{I}{C}=\dfrac{0.15}{80.1\times10^{-12}}=1.875\times10^{9}\ \text{V s}^{-1}$

(b) The magnitude of displacement current is equal to conduction current.

$\therefore\quad I_d = I = 0.15$ A

(c) Yes, Kirchhoff's first law is very much applicable to each plate of capacitor as $I_d = I$. So current is continuous and constant across each plate.



2. (a) Capacity of capacitor $C = 100$ pF

Capacitive reactance $X_C=\dfrac{1}{\omega C}=\dfrac{1}{300\times100\times10^{-12}}$

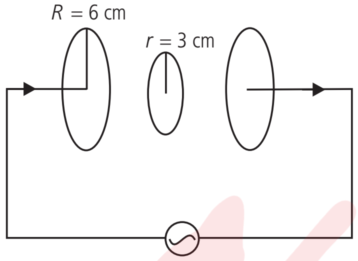
$\therefore\quad X_C=\dfrac{10^8}{3}\ \Omega$

If I_{rms} is the rms value of conduction current

$I_{rms}=\dfrac{E_{rms}}{X_C}=230\times3\times10^{-8}=690\times10^{-8}=6.9\ \mu\text{A}$

(b) Yes, the conduction current in wires always equal to displacement current within plates.

(c)



To find magnetic field B of a point 3 cm from the axis within plates, let us assume a loop of radius 3 cm with center on axis.

Now modified Ampere's Law.

$$\int\vec{B}\cdot\vec{dl}=\mu_0\left[\frac{I}{\pi R^2}\pi r^2\right]$$

$$B\times2\pi r=\frac{\mu_0 I r^2}{R^2}$$

For amplitude of magnetic field, we require

$I_0=I_{rms}\sqrt{2}=6.9\sqrt{2}\ \mu\text{A}$

So, $B_0=\dfrac{\mu_0}{2\pi}\times\dfrac{I_0 r}{R^2}=2\times10^{-7}\times\dfrac{6.9\sqrt{2}\times10^{-6}\times3\times10^{-2}}{(6\times10^{-2})^2}$

$B_0 = 1.63\times10^{-11}$ T

Topic 2

1. Though they all have different wavelengths and frequencies, but they have same speed *i.e.*, speed of light $3\times10^8\ \text{m s}^{-1}$ in vacuum.

2. The frequency of electromagnetic wave produced will be same as the frequency of oscillation of charged particles *i.e.*, 10^9 Hz.

3. We know the relation, $\dfrac{E_0}{B_0}=c$

$E_0=B_0c=510\times10^{-9}\times3\times10^8$

Peak value of $E_0=1530\times10^{-1}=153\ \text{N C}^{-1}$ electric field.

4. (a) By relation, $\dfrac{E_0}{B_0}=c$

Peak value of magnetic field

$$B_0=\frac{E_0}{c}=\frac{120}{3\times10^8}=40\times10^{-8}\ \text{T}$$

Angular frequency, $\omega=2\pi\upsilon=100\pi\times10^6$ Hz.

Speed of light $c=\upsilon\lambda$

Wavelength, $\lambda = \frac{c}{\upsilon} = \frac{3\times10^8}{50\times10^6}$, $\lambda = 6$ m

Propagation constant,

$$k = \frac{2\pi}{\lambda} = \frac{\pi}{3}\ \text{m}^{-1} = 1.05\ \text{m}^{-1}$$

(b) Let the wave is propagating along x-direction, electric field $\vec{E}$ is along y - direction and magnetic field $\vec{B}$ along z-direction.

$$\vec{E}_y = E_0 \sin(kx - \omega t)\hat{j}$$

$$\vec{E}_y = 120\sin\left(\frac{\pi}{3}x - 100\pi\times10^6 t\right)\hat{j}$$

$$\vec{B}_z = B_0 \sin(kx - \omega t)\hat{k} = 40\times10^{-8}\sin\left(\frac{\pi}{3}x - \pi\times10^8 t\right)\hat{k}$$

5. (a) Wavelength of electromagnetic wave is

$$\lambda = \frac{c}{\upsilon} = \frac{3\times10^8}{2\times10^{10}} = 1.5\times10^{-2}\ \text{m}$$

(b) Amplitude of magnetic field, $\frac{E_0}{B_0} = c$

$$B_0 = \frac{E_0}{c} = \frac{48}{3\times10^8} = 16\times10^{-8}\ \text{T}$$

(c) Energy density as electric field,

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

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

So, $u_E = \frac{1}{2}\varepsilon_0 c^2 B^2$

where speed of electromagnetic wave,

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

So $\quad u_E = \frac{1}{2}\frac{\varepsilon_0}{\mu_0\varepsilon_0}B^2$

$$u_E = \frac{B^2}{2\mu_0} = u_B$$

[Energy density as magnetic field]

5. The photon of given energy are released during transition between energy levels in the atom and the emitted photon energy is equal to difference of energies of energy levels, among which the transition has taken place.

For example photon energy for

$\lambda = 1$ m can be calculated

$$E = h\upsilon = \frac{hc}{\lambda} = \frac{6.63\times10^{-34}\times3\times10^8}{1}\ \text{J}$$

$$E = \frac{19.88\times10^{-26}}{1.6\times10^{-19}}\ \text{eV} = 12.425\times10^{-7}\ \text{eV}$$

So, for emission of radio waves the energy difference between energy levels should be 12.425×10^{-7} eV.

Similarly, photon energy for other wavelengths can also be calculated

Types of radiation	Wavelength of radiation	Photon energy
1. Radio waves	1 m	12.425×10^{-7} eV
2. Micro waves	3×10^{-3} m	4.14×10^{-4} eV
3. Infrared waves	3×10^{-5} m	4.14×10^{-2} eV
4. Visible waves	5×10^{-7} m	2.485 eV
5. Ultraviolet rays	3×10^{-7} m	4.14 eV
6. X-rays	10^{-10} m	12.425×10^{3} eV
7. γ-rays	10^{-12} m	12.425×10^{5} eV

So, for emission of γ -rays the energy difference among energy levels should be of the order of MeV, where for visible radiation it should be of the order of eV.

6. In electromagnetic wave, the electric field vector $\vec{E}$ and magnetic field vector $\vec{B}$ show their variations perpendicular to the direction of propagation of wave as well as perpendicular to each other. As the electromagnetic wave is travelling along z-direction, hence $\vec{E}$ and $\vec{B}$ show their variation in x-y plane.

Wavelength, $\lambda = \frac{c}{\upsilon} = \frac{3\times10^8\ \text{m/s}}{30\times10^6\ \text{s}^{-1}} = 10$ m.