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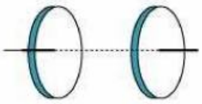
Question 8.1:

Figure 8.6 shows a capacitor made of two circular plates each of radius 12 cm, and separated by 5.0 cm. The capacitor is being charged by an external source (not shown in the figure). The charging current is constant and equal to 0.15 A.

(a) Calculate the capacitance and the rate of charge of potential difference between the plates.

(b) Obtain the displacement current across the plates.

(c) Is Kirchhoff's first rule (junction rule) valid at each plate of the capacitor? Explain.



Answer

Radius of each circular plate, r = 12 cm = 0.12 m

Distance between the plates, d = 5 cm = 0.05 m

Charging current, I = 0.15 A

Permittivity of free space, $\varepsilon_0 = 8.85 \times 10^{-12}\ C^2\ N^{-1}\ m^{-2}$

(a) Capacitance between the two plates is given by the relation,

$$C = \frac{\varepsilon_0 A}{d}$$

Where,

A = Area of each plate $= \pi r^2$

$$C = \frac{\varepsilon_0 \pi r^2}{d}$$

$$= \frac{8.85 \times 10^{-12} \times \pi \times (0.12)^2}{0.05}$$

$$= 8.0032 \times 10^{-12}\ \text{F} = 80.032\ \text{pF}$$

Charge on each plate, $q = CV$

Where,

V = Potential difference across the plates

Differentiation on both sides with respect to time (t) gives:

$$\frac{dq}{dt} = C\frac{dV}{dt}$$

But, $\frac{dq}{dt} = \text{current } (I)$

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

$$\Rightarrow \frac{0.15}{80.032\times 10^{-12}} = 1.87\times 10^{9}\ \text{V/s}$$

Therefore, the change in potential difference between the plates is 1.87×10^{9} V/s.

(b) The displacement current across the plates is the same as the conduction current. Hence, the displacement current, i_d is 0.15 A.

(c) Yes

Kirchhoff's first rule is valid at each plate of the capacitor provided that we take the sum of conduction and displacement for current.

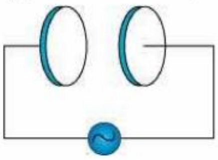
Question 8.2:

A parallel plate capacitor (Fig. 8.7) made of circular plates each of radius R = 6.0 cm has a capacitance C = 100 pF. The capacitor is connected to a 230 V ac supply with a (angular) frequency of 300 rad s^{-1}.

(a) What is the rms value of the conduction current?

(b) Is the conduction current equal to the displacement current?

(c) Determine the amplitude of **B** at a point 3.0 cm from the axis between the plates.



Answer

Radius of each circular plate, R = 6.0 cm = 0.06 m

Capacitance of a parallel plate capacitor, C = 100 pF = 100×10^{-12} F

Supply voltage, V = 230 V

Angular frequency, ω = 300 rad s^{-1}

(a) Rms value of conduction current, $I = \frac{V}{X_C}$

Where,

X_C = Capacitive reactance

$$= \frac{1}{\omega C}$$

$\therefore I = V \times \omega C$

$= 230 \times 300 \times 100 \times 10^{-12}$

$= 6.9 \times 10^{-6}$ A

= 6.9 μA

Hence, the rms value of conduction current is 6.9 μA.

(b) Yes, conduction current is equal to displacement current.

(c) Magnetic field is given as:

$$B = \frac{\mu_0 r}{2\pi R^2} I_0$$

Where,

μ_0 = Free space permeability $= 4\pi\times 10^{-7}\ \text{N A}^{-2}$

I_0 = Maximum value of current $= \sqrt{2}\, I$

r = Distance between the plates from the axis = 3.0 cm = 0.03 m

$$\therefore B = \frac{4\pi\times10^{-7}\times0.03\times\sqrt{2}\times6.9\times10^{-6}}{2\pi\times(0.06)^2}$$

$= 1.63 \times 10^{-11}$ T

Hence, the magnetic field at that point is 1.63×10^{-11} T.

Question 8.3:

What physical quantity is the same for X-rays of wavelength 10^{-10} m, red light of wavelength 6800 Å and radiowaves of wavelength 500 m?

Answer

The speed of light (3×10^8 m/s) in a vacuum is the same for all wavelengths. It is independent of the wavelength in the vacuum.

Question 8.4:

A plane electromagnetic wave travels in vacuum along z-direction. What can you say about the directions of its electric and magnetic field vectors? If the frequency of the wave is 30 MHz, what is its wavelength?

Answer

The electromagnetic wave travels in a vacuum along the z-direction. The electric field (*E*) and the magnetic field (*H*) are in the *x*-*y* plane. They are mutually perpendicular.

Frequency of the wave, $\nu = 30$ MHz $= 30 \times 10^6$ s^{-1}

Speed of light in a vacuum, $c = 3 \times 10^8$ m/s

Wavelength of a wave is given as:

$$\lambda = \frac{c}{\nu}$$

$$= \frac{3\times10^8}{30\times10^6} = 10 \text{ m}$$

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