

PHYSICS • CLASS 12

CHAPTER 8

Electromagnetic Waves

NCERT SOLUTIONS



CHARGING CAPACITOR — EXERCISE 8.1

Q. A capacitor consists of two circular plates each of radius 12 cm separated by 5.0 cm. It is being charged by a constant current of 0.15 A. (a) Find the capacitance and the rate of change of potential difference between the plates. (b) What is the displacement current? (c) Does Kirchhoff's first rule hold at each plate of the capacitor? Why?

Answer: (a)

Use $A = \pi r^2$, $C = \epsilon_0 \frac{A}{d}$ and $I_c = C \frac{dV}{dt}$.

Given $r = 0.12$ m, $d = 0.050$ m.

$$A = \pi(0.12)^2 = 4.52 \times 10^{-2} \text{ m}^2$$

$$C = \frac{\epsilon_0 A}{d} = \frac{(8.85 \times 10^{-12})(4.52 \times 10^{-2})}{0.050} \\ = 8.0 \times 10^{-12} \text{ F} = 8.0 \text{ pF}$$

$$\frac{dV}{dt} = \frac{I_c}{C} = \frac{0.15}{8.0 \times 10^{-12}} = 1.87 \times 10^{10} \text{ V s}^{-1}.$$

(b) Displacement current:

$$I_d = \epsilon_0 \frac{d\Phi_E}{dt} = C \frac{dV}{dt} = 0.15 \text{ A}.$$

(c) Kirchhoff's first rule:

Yes. The current remains continuous when the equal displacement current through the gap is included. Charge carriers do not cross the insulating gap; charge builds on the plates while the changing electric field continues the current.

AC CAPACITOR CURRENTS – EXERCISE 8.2(a,b)

Q. A parallel-plate capacitor with circular plates of radius $R = 6.0$ cm has a capacitance $C = 100$ pF and is connected to a 230 V (rms) AC source of angular frequency $\omega = 300$ rad s⁻¹.
(a) What is the rms conduction current through the capacitor? (b) Is the conduction current equal to the displacement current?

(a) **Answer:**

For an ideal capacitor, use $I_{rms} = \omega C V_{rms}$.

$$C = 100 \text{ pF} = 1.00 \times 10^{-10} \text{ F}$$

$$\begin{aligned} I_{c,rms} &= \omega C V_{rms} \\ &= (300)(1.00 \times 10^{-10})(230) \\ &= 6.90 \times 10^{-6} \text{ A} \\ &= 6.90 \text{ } \mu\text{A} \end{aligned}$$

(b) **Answer:**

Yes. At every instant, displacement current through the gap equals conduction current in the wires. Charge carriers do not cross the gap; the changing electric field accounts for its displacement current.

$$I_d(t) = I_c(t)$$

$$\text{so } I_{d,rms} = 6.90 \text{ } \mu\text{A}.$$

MAGNETIC FIELD IN THE GAP — EXERCISE 8.2(c)

Q. For the same AC capacitor, plate radius $R = 6.0 \text{ cm}$, $C = 100 \text{ pF}$, $V_{\text{rms}} = 230 \text{ V}$ and $\omega = 300 \text{ rad s}^{-1}$. Find magnetic-field AMPLITUDE B_0 at radius $r = 3.0 \text{ cm}$ from the axis, between plates.

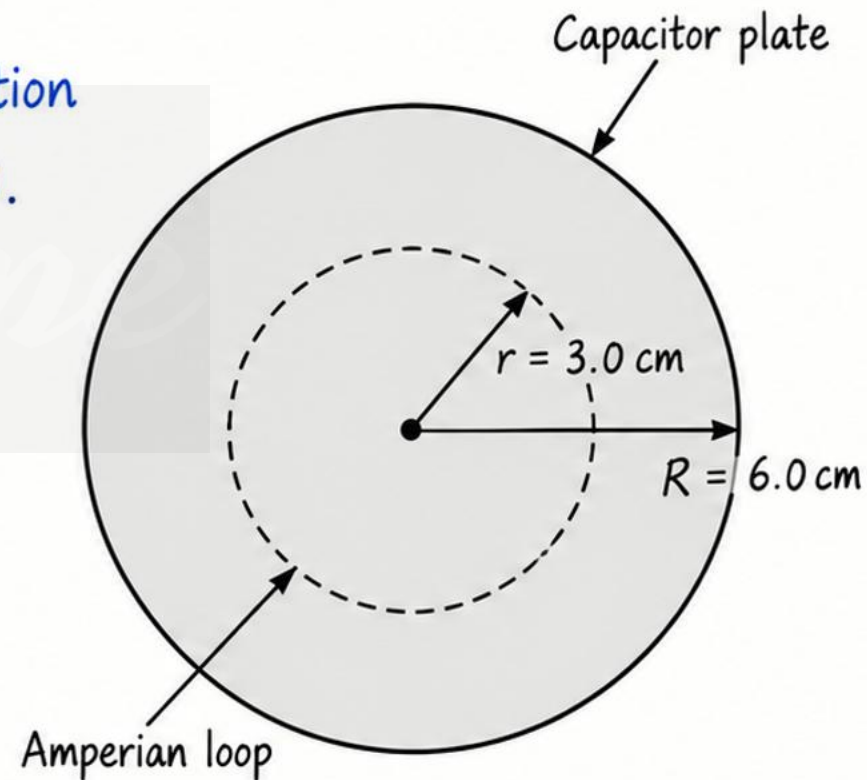
Answer: At $r < R$, a circular Amperian loop encloses only fraction r^2/R^2 of the plate's displacement current (uniform ideal field). Use current amplitude, not rms current, for B amplitude.

$$I_{\text{rms}} = \omega C V_{\text{rms}} = 6.90 \mu\text{A}; \quad I_0 = \sqrt{2} I_{\text{rms}} = 9.76 \mu\text{A}.$$

$$B_0(2\pi r) = \mu_0 I_0 \left(\frac{r^2}{R^2} \right).$$

$$B_0 = \mu_0 I_0 \frac{r}{2\pi R^2} = \frac{(4\pi \times 10^{-7})(9.76 \times 10^{-6})(0.030)}{2\pi (0.060)^2}$$

$$B_0 = 1.63 \times 10^{-11} \text{ T}.$$



WAVE SPEED AND DIRECTIONS – EXERCISES 8.3 – 8.4

Q.8.3 What physical quantity is the same for X-rays ($\lambda = 10^{-10}$ m), red light ($\lambda = 6800$ Å) and radio waves ($\lambda = 500$ m)?

Answer:

All are electromagnetic waves in vacuum; their wavelengths and frequencies differ.

The physical quantity that is the same for X-rays, red light and radio waves is their speed in vacuum.

$$c = 3.0 \times 10^8 \text{ m s}^{-1}$$

Q.8.4 A plane electromagnetic wave travels in vacuum along the +z direction. What are the directions of its electric and magnetic vectors? If its frequency is 30 MHz, find its wavelength.

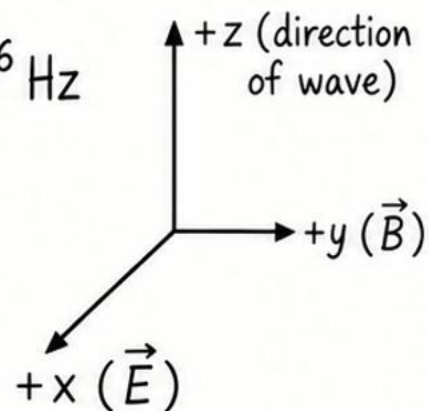
Answer:

$\vec{E}$ and $\vec{B}$ are perpendicular to each other and to +z. Their cross product $\vec{E} \times \vec{B}$ points in the direction of travel. One choice: $\vec{E}$ along +x, $\vec{B}$ along +y.

Given frequency $f = 30 \text{ MHz} = 30 \times 10^6 \text{ Hz}$

Wavelength,

$$\lambda = \frac{c}{f} = \frac{3.0 \times 10^8}{30 \times 10^6} = 10 \text{ m}$$





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