Class 12 Physics · Chapter 7: Alternating Current

Answer key and marking scheme · 20 marks · about 40 minutes · based on NCERT

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1. In a series LCR circuit R = 40 Ω, X_L = 10 Ω and X_C = 50 Ω. The current in the circuit [1]

(a) is in phase with the source voltage
(b) lags the source voltage by 45°
(c) leads the source voltage by 90°
(d) leads the source voltage by 45°

Answer: (d) $\tan\phi = (X_C - X_L)/R = (50 - 10)/40 = 1$, so $\phi = +45°$. ϕ is positive because $X_C > X_L$: the circuit is predominantly capacitive and the current leads.

2. An inductor of inductance (0.50/π) H and negligible resistance is connected to a 200 V (rms) source whose frequency can be changed. At what frequency does it draw an rms current of 2.0 A? [1]

(a) 628 Hz
(b) 100 Hz
(c) 141 Hz
(d) 71 Hz

Answer: (b) $X_L = V/I = 200/2.0 = 100\ \Omega$. $X_L = 2\pi\nu L$ gives $\nu = 100/(2\pi \times 0.50/\pi) = 100/1.0 = 100$ Hz. 628 is $\omega = X_L/L$ in rad s^{-1}, not ν; 141 Hz takes 2.0 A as the peak current; 71 Hz takes 200 V as the peak voltage.

3. An ac voltage is applied across an ideal inductor. The current in the inductor [1]

(a) lags the voltage by π/2
(b) leads the voltage by π/2
(c) is in phase with the voltage
(d) lags the voltage by π

Answer: (a) For a pure inductor $i = i_m \sin(\omega t - \pi/2)$: the current reaches its maximum a quarter period after the voltage, so it lags by π/2. A lead of π/2 is the capacitor's case; in phase is the resistor's.

4. An inductor of negligible resistance has a reactance of 30 Ω at 50 Hz. Its reactance at 150 Hz is [1]

(a) 30 Ω
(b) 10 Ω
(c) 90 Ω
(d) 270 Ω

Answer: (c) $X_L = 2\pi\nu L$ is directly proportional to ν: $X_L = 30 \times (150/50) = 90\ \Omega$. 10 Ω treats X_L as inversely proportional to ν; 270 Ω squares the ratio.

5. An ac voltmeter connected across a laboratory socket reads 230 V. During each cycle the voltage between the socket's terminals varies between [1]

(a) 325 V and −325 V
(b) 230 V and −230 V
(c) 163 V and −163 V
(d) 0 V and 325 V

Answer: (a) The meter reads the rms value V = 230 V. The peak is $v_m = \sqrt{2}\,V = 1.414 \times 230 \approx 325$ V, and the sinusoidal voltage swings from +325 V to −325 V. Taking the reading as the peak gives ±230 V; dividing by √2 instead of multiplying gives ±163 V; an ac voltage is not one-signed.

6. A coil of negligible resistance has a reactance of 40 Ω at 50 Hz. Find its inductance and its reactance at 200 Hz. [2]

$X_L = 2\pi\nu L$, so $L = 40/(2\pi \times 50) = 0.127$ H ≈ 0.13 H. X_L is proportional to ν, so at 200 Hz it is 40 × 4 = 160 Ω.

- $L = X_L/2\pi\nu = 0.13$ H (1)
- $X_L \propto \nu$, so 160 Ω at 200 Hz (1)

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7. An ideal capacitor is connected to a 50 Hz ac source. Which reaches its maximum first, the current or the voltage, and by how many milliseconds? [2]

In a capacitor the current leads the voltage by π/2, a quarter of a period. T = 1/50 s = 20 ms, so the current reaches its maximum T/4 = 5.0 ms before the voltage.

- current first (leads by π/2) (1)
- T/4 = 5.0 ms (1)

8. A resistor and an ideal inductor in series are connected to a 100 V (rms) ac source. The rms voltage across the resistor is 60 V. Meena says the voltage across the inductor must be 40 V. Is she right? Find the voltage across the inductor. [2]

No. V_L is π/2 ahead of V_R, so the source voltage is the hypotenuse of a right triangle: $V^2 = V_R^2 + V_L^2$. $V_L = \sqrt{(100^2 - 60^2)} = 80$ V. Subtracting 60 from 100 treats the two voltages as in phase.

- voltages add as phasors at right angles, not as numbers (1)
- $V_L = \sqrt{(100^2 - 60^2)} = 80$ V (1)

9. An ac voltage $v = v_m \sin \omega t$ is applied across an ideal inductor L. Obtain the expression for the current, and show that it lags the voltage by π/2. Write the expression for the inductive reactance. [3]

Kirchhoff's loop rule: $v - L\,di/dt = 0$, so $di/dt = (v_m/L) \sin \omega t$. Integrating, $i = -(v_m/\omega L) \cos \omega t$ + constant; the constant is zero because the current oscillates symmetrically about zero. Since $-\cos \omega t = \sin(\omega t - \pi/2)$, $i = i_m \sin(\omega t - \pi/2)$ with $i_m = v_m/\omega L$: the current lags the voltage by π/2. The inductive reactance $X_L = \omega L$, so $i_m = v_m/X_L$.

- $v = L\,di/dt$ from the loop rule (1)
- integration to $i = -(v_m/\omega L) \cos \omega t$, constant zero (1)
- $i = i_m \sin(\omega t - \pi/2)$: lag of π/2; $X_L = \omega L$ (1)

10. Explain how a radio set uses resonance to pick out one station. The tuning circuit of a receiver has an inductor of 0.25 mH. Find the capacitance needed to tune to a station broadcasting at 1.0 MHz, and how the capacitance must change to tune to 2.0 MHz. [3]

The antenna picks up signals of many frequencies and acts as the source; the capacitance is varied until the resonant frequency $1/2\pi\sqrt{(LC)}$ equals the wanted station's frequency, whose current is then maximum. $C = 1/(4\pi^2\nu^2 L) = 1/(4\pi^2 \times (1.0 \times 10^6)^2 \times 0.25 \times 10^{-3}) \approx 1.0 \times 10^{-10}$ F = 100 pF. Since $\nu \propto 1/\sqrt{C}$, doubling ν needs C reduced to a quarter, about 25 pF.

- resonant frequency matched to the station; its current is maximum (1)
- C ≈ 100 pF (1)
- C reduced to one quarter, ≈ 25 pF (1)

11. A series LCR circuit with L = 0.40 H and C = 2.5 μF is driven by a 50 V (rms) source of variable frequency. (a) Find the resonant angular frequency. (b) Find the resistance R for which the rms voltage across the capacitor at resonance is ten times the source voltage. (c) With this R, find the average power drawn from the source at resonance. [3]

(a) $\omega_0 = 1/\sqrt{(LC)} = 1/\sqrt{(0.40 \times 2.5 \times 10^{-6})} = 1/(1.0 \times 10^{-3}) = 1000$ rad s^{-1}. (b) At resonance $I = V/R$ and $V_C = IX_C = V(\omega_0 L)/R = QV$, so $Q = \omega_0 L/R = 10$: $R = 1000 \times 0.40/10 = 40\ \Omega$. (c) At resonance $\cos \phi = 1$ and $Z = R$: $P = V^2/R = 50^2/40 = 62.5$ W, all of it in R.

- $\omega_0 = 1000$ rad s^{-1} (1)
- $V_C/V = \omega_0 L/R = 10$ gives $R = 40\ \Omega$ (1)
- $P = V^2/R = 62.5$ W (1)