CHAPTER 7

ALTERNATING CURRENT

CLASS 12TH

NCERT EXERCISE AND SOLUTIONS - PHYSICS

7.1 A 100 Ω resistor is connected to a 220 V, 50 Hz AC supply.

(a) What is the rms value of current in the circuit?

(b) What is the net power consumed over a full cycle?

SOLUTION:

Given – Resistance (R) = 100 Ω, Supply voltage (V) = 220 V, Frequency (ν) = 50 Hz.

(a) rms value of current in the circuit is:

$$I = \frac{V}{R}$$

$$I = \frac{220}{100} = 2.20A$$

(b) Net power consumption over a full cycle is:

P = VI

P = (220) × (2.20) = 484 W

7.2 (a) The peak voltage of an ac supply is 300 V. What is the rms voltage?

(b) The rms value of current in an ac circuit is 10 A. What is the peak current?

SOLUTION:

(a) Peak voltage (V0) = 300 V, rms voltage = ?

rms voltage is given by,

$$V = \frac{V_0}{\sqrt{2}}$$

$$V = \frac{300}{\sqrt{2}} = 212.1\text{V}$$

(b) rms current (I) = 10 A, peak current (I_0) =?

$$I_0 = \sqrt{2}I$$

$$I_0 = 10\sqrt{2} = 14.1\text{A}$$

7.3 A 44 mH inductor is connected to 220 V, 50 Hz ac supply. Determine the rms value of the current in the circuit.

SOLUTION:

Given – Inductance (L) = 44 mH = 44×10^{-3} H, Supply voltage (V) = 220 V, Frequency (ν) = 50 Hz.

rms value of current in an inductor circuit is given by,

$$I = \frac{V}{X_L} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(i)}$$

$\therefore X_L = \omega L = 2\pi\nu L \Rightarrow X_L = (2\pi) \times (50) \times (44 \times 10^{-3})\Omega$

Put this value of XL in equation (i) we get,

$$I = \frac{220}{2\pi \times 50 \times 44 \times 10^{-3}} = \frac{220}{2(3.14) \times 50 \times 44 \times 10^{-3}}$$

$$I = 15.92\,\text{A}$$

Therefore, the rms value of current is 15.92 A.

7.4 A 60 F capacitor is connected to a 110 V, 60 Hz ac supply. Determine the rms value of the current in the circuit.

SOLUTION:

Given – Capacitance (C) = 60 μF = 60×10^{-6} F, Supply voltage (V) = 110 V, Frequency (ν) = 60 Hz.

Need to find – rms value of current (I) in the circuit.

rms value of current in a capacitor circuit is given by,

$$I = \frac{V}{X_C} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(i)}$$

$$\therefore X_C = \frac{1}{\omega C} = \frac{1}{2\pi\nu C} \Rightarrow X_C = \frac{1}{2 \times 3.14 \times 60 \times 60 \times 10^{-6}}\Omega^{-1}$$

Put this value of XC in equation (i) we get,

$$I = \frac{110}{\frac{1}{2 \times (3.14) \times (60) \times (60 \times 10^{-6})}} = 110 \times 2 \times (3.14) \times (60) \times (60 \times 10^{-6})$$

$$\text{I} = 2.49\text{A}$$

Therefore, the rms value of current is 2.49 A.

7.5 In Exercises 7.3 and 7.4, what is the net power absorbed by each circuit over a complete cycle. Explain your answer.

SOLUTION:

Data given in exercise 7.3 and 7.4.

For exercise 7.3: Inductive circuit

rms current (I) = 15.92 A and rms voltage (V) = 220 V.
Net power absorbed by circuit over a complete cycle is:

$$P = VI\cos\Phi$$

∴ For pure inductive circuit, phase difference (Φ) = 90°

So, $P = VI\,\text{Cos}\,90^\circ = 0$

For exercise 7.4: Capacitive circuit

rms current (I) = 2.94 A and rms voltage (V) = 110 V.

Net power absorbed by circuit over a complete cycle is:

$$P = VIcos\Phi$$

∴ For pure inductive circuit, phase difference (Φ) = 90°

So, $P = VI\,\text{Cos}\,90^\circ = 0$

Therefore, the net power absorbed by each circuit over a complete circuit is zero.

7.6 A charged 30 µF capacitor is connected to a 27 mH inductor. What is the angular frequency of free oscillations of the circuit?

SOLUTION:

Given – Capacitance (C) = 30 F, Inductance (L) = 27 mH,

Need to find – Angular frequency (r) of free oscillation.

Angular frequency of free oscillation is given by,

$$\omega_r = \frac{1}{\sqrt{LC}}$$

$$\omega_r = \frac{1}{\sqrt{27\times10^{-3}\times30\times10^{-6}}} = \frac{1}{9\times10^{-4}}$$

$$\omega_r = 1.11\times10^3\, rad\,/\,\text{s}$$

Therefore, the angular frequency of free oscillation is $1.11\times10^3\, rad\,/\,\text{s}$.

7.7 A series LCR circuit with *R* = 20 Ω, L = 1.5 H and C = 35 µF is connected to a variable-frequency 200 V ac supply. When the frequency of the supply equals the natural frequency of the circuit, what is the average power transferred to the circuit in one complete cycle?

SOLUTION:

Given – Resistance (R) = 20 Ω, Inductance (L) = 1.5 H, Capacitance (C) = 35 mF,

Supply voltage (V) = 200 v.

Need to find – Average power transferred to the circuit in one complete cycle (When supply frequency = natural frequency).

Average power transferred to the circuit in one complete cycle is given by,

$$P = VI \qquad \ldots\ldots\ldots\ldots\ (i)$$

Current in the circuit is given by,

$$I = \frac{V}{Z} \qquad \text{.............. (ii)}$$

Impedance of the LCR circuit is given by,

$$Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

At resonance, $\omega L = \frac{1}{\omega C}$ then,

$$Z = R = 20 \qquad \text{.............. (iii)}$$

Put the value of Z in equation (ii) we get,

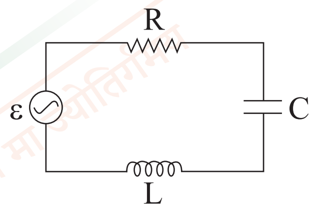
$$I = \frac{200}{20} = 10\,\text{A}$$

Put the value of I in equation (i) we get,

$$P = (200) \times (10) = 2000\ \text{W}$$

Therefore, the average power transferred to the circuit in one complete cycle is 2000 W.

7.8 Figure shows a series LCR circuit connected to a variable frequency 230 V source. L = 5.0 H, C = 80 μF, R = 40 Ω.



(a) Determine the source frequency which drives the circuit in resonance.

(b) Obtain the impedance of the circuit and the amplitude of current at the resonating frequency.

(c) Determine the rms potential drops across the three elements of the circuit.

Show that the potential drop across the LC combination is zero at the resonating frequency.

SOLUTION:

Given – Potential of variable voltage source (V) = 230 V, Inductance (L) = 5.0 H,
Capacitance (C) = 80 μF, Resistance (R) = 40 Ω.

(a) Resonance angular frequency is given by,

$$\omega_r = \frac{1}{\sqrt{LC}}$$

$$\omega_r = \frac{1}{\sqrt{5 \times 80 \times 10^{-6}}} = \frac{10^3}{20}$$

$$\omega_r = 50\,\text{rad/s}$$

Therefore, the resonance angular frequency is 50 rad/s.

(b) Impedance of the circuit is given by,

$$Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

At resonance: $\omega L = \frac{1}{\omega C}$ i.e. $\quad Z = R = 40\ \Omega.$

Amplitude of the current at the resonance is given by,

$$I_0 = \frac{V_0}{Z} \qquad \left(\therefore V = \frac{V_0}{\sqrt{2}}\right)$$

$$I_0 = \frac{\sqrt{2}V}{Z}$$

$$I_0 = \frac{\sqrt{2}(230)}{40} = 8.13\,\text{A}$$

Therefore, at resonance the impedance of the circuit is 40 Ω and the amplitude of the current is 8.13 A.

(c) rms potential drop across the inductor is:

$$(V_L) = IX_L = I \times \omega_r L$$

At resonance: Z = R = 40 Ω and $I = \frac{I_0}{\sqrt{2}} = \frac{\sqrt{2}V}{\sqrt{2}Z} = \frac{230}{40}\,\text{A}$ $\qquad \left(\therefore\ I_0 = \frac{V_0}{Z} \text{ and } V_0 = \sqrt{2}V\right)$

then,

$$(V_L) = \frac{230}{40} \times 50 \times 5 = 1437.5\text{V}$$

Similarly, rms potential drop across the capacitor is:

$$(V_C) = IX_C = I \times \frac{1}{\omega_r C}$$

$$(V_C) = \frac{230}{40} \times \frac{1}{50 \times 80 \times 10^{-6}} = 1437.5\text{V}$$

And

rms potential drop across the resistor is:

$$(V_R) = IR$$

$$(V_R) = \frac{230}{40} \times 40 = 230\text{V}$$

Potential drop across the LC combination is:

$$V_{LC} = I\left(\omega_R L - \frac{1}{\omega_R C}\right)$$

At resonance: $\omega_R L = \frac{1}{\omega_R C}$

i.e. $\qquad V_{LC} = 0$

Therefore, the potential drop across inductive circuit is 1437.5 V, capacitive circuit is 1437.5 V, and resistive circuit is 230 V.

Also, the potential drop across the LC combination is zero.