# **Question 7.1:**

A 100  $\Omega$  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?

## Answer 7.1:

Resistance of the resistor,  $R = 100 \ \Omega$ 

Supply voltage, V = 220 V

Frequency, v = 50 Hz

(a) The rms value of current in the circuit is given as  $I = \frac{V}{R} = \frac{220}{100} = 2.20 A$ 

(b) The net power consumed over a full cycle is given as:  $P = VI = 220 \times 2.2 = 484 W$ 

# **Question 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?

## Answer 7.2:

(a) Peak voltage of the ac supply,  $V_0 = 300 \text{ V}$ 

rms voltage is given as:

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

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(b) The rms value of current is given as:

I = 10 A

Now, peak current is given as:

$$I_o = \sqrt{2}I = \sqrt{2} \times 10 = 14.1 A$$

# **Question 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.

## Answer 7.3:

Inductance of inductor, L = 44 mH = 44 × 10<sup>-3</sup> H Supply voltage, V = 220 V Frequency, v = 50 Hz Angular frequency,  $\omega = 2\pi v$ Inductive reactance,  $X_L = \omega L = 2\pi vL = 2\pi \times 50 \times 44 \times 10^{-3} \Omega$ rms value of current is given as:

$$I = \frac{V}{X_L} = \frac{220}{2\pi \times 50 \times 44 \times 10^{-3}} = 15.92 \,A$$

Hence, the rms value of current in the circuit is 15.92 A.

# **Question 7.4:**

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

## Answer 7.4:

Capacitance of capacitor,  $C=60~\mu F=60\times 10^{-6}~F$ 

Supply voltage, V = 110 V Frequency, v = 60 Hz Angular frequency,  $\omega = 2\pi v$ Capacitive reactance,

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

rms value of current is given as:

$$I = \frac{V}{X_C} = \frac{220}{2\pi \times 60 \times 60 \times 10^{-6}} = 2.49 A$$

Hence, the rms value of current is 2.49 A.

## **Question 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.

## Answer 7.5:

In the inductive circuit,

Rms value of current, I = 15.92 A

Rms value of voltage, V = 220 V

Hence, the net power absorbed can be obtained by the relation,

$$P = VI \cos \Phi$$

Where,

 $\Phi$  = Phase difference between *V* and *I*.

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For a pure inductive circuit, the phase difference between alternating voltage

and current is 90° i.e.,  $\Phi = 90^{\circ}$ .

Hence, P = 0 i.e., the net power is zero.

In the capacitive circuit,

rms value of current, I = 2.49 A

rms value of voltage, V = 110 V

Hence, the net power absorbed can be obtained as:

 $P = VI \cos \Phi$ 

For a pure capacitive circuit, the phase difference between alternating voltage and current is 90° i.e.,  $\Phi = 90^{\circ}$ .

Hence, P = 0 i.e., the net power is zero.

#### **Question 7.6:**

Obtain the resonant frequency  $\omega r$  of a series LCR circuit with L = 2.0 H,  $C = 32 \ \mu F$  and  $R = 10 \ \Omega$ . What is the Q-value of this circuit?

#### Answer 7.6:

Inductance, L = 2.0 H

Capacitance, C = 32  $\mu$ F = 32  $\times$  10<sup>-6</sup> F

Resistance,  $R = 10 \Omega$ 

Resonant frequency is given by the relation,

$$\omega_r = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{2 \times 32 \times 10^{-6}}} = \frac{1}{8 \times 10^{-3}} = 125 \ rad/s.$$

Now, Q-value of the circuit is given as:

$$Q = \frac{1}{R} \sqrt{\frac{L}{C}} = \frac{1}{10} \sqrt{\frac{2}{32 \times 10^{-6}}} = \frac{1}{10 \times 4 \times 10^{-3}} = 25$$

Hence, the Q-Value of this circuit is 25.

## **Question 7.7:**

A charged 30  $\mu$ F capacitor is connected to a 27 mH inductor. What is the angular frequency of free oscillations of the circuit?

Answer 7.7: Capacitance, C =  $30\mu$ F =  $30 \times 10^{-6}$  F Inductance, L =  $27 \text{ mH} = 27 \times 10^{-3}$  H Angular frequency is given as:  $\omega_r = \frac{1}{\sqrt{LC}}$   $= \frac{1}{\sqrt{27 \times 10^{-3} \times 30 \times 10^{-6}}} = \frac{1}{9 \times 10^{-4}} = 1.11 \times 10^3 \text{ rad/s}$ 

Hence, the angular frequency of free oscillations of the circuit is  $1.11 \times 10^3$  rad/s.

#### **Question 7.8:**

Suppose the initial charge on the capacitor in Exercise 7.7 is 6 mC. What is the total energy stored in the circuit initially? What is the total energy at later time?

#### Answer 7.8:

Capacitance of the capacitor,  $C=30~\mu F=30{\times}10^{-6}\,F$ 

Inductance of the inductor,  $L=27\ mH=27\times 10^{-3}\ H$ 

Charge on the capacitor,  $Q = 6 \text{ mC} = 6 \times 10^{-3} \text{ C}$ 

Total energy stored in the capacitor can be calculated as:

$$E = \frac{1}{2} \frac{Q^2}{C} = \frac{1}{2} \frac{(6 \times 10^{-3})^2}{30 \times 10^{-6}} = \frac{6}{10} = 0.6 J$$

Total energy at a later time will remain the same because energy is shared between the capacitor and the inductor.

## **Question 7.9:**

A series LCR circuit with  $R = 20 \Omega$ , L = 1.5 H and  $C = 35 \mu F$  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?

### **Answer 7.9:**

At resonance, the frequency of the supply power equals the natural frequency of the given LCR circuit.

Resistance,  $R = 20 \Omega$ 

Inductance, L = 1.5 H

Capacitance, C = 35  $\mu$ F = 30 × 10<sup>-6</sup> F

AC supply voltage to the LCR circuit, V = 200 V

Impedance of the circuit is given by the relation,

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$
  
At resonance,  $X_L = X_C$ 

$$\therefore Z = R = 20 \ \Omega$$

Current in the circuit can be calculated as:

$$I = \frac{V}{Z} = \frac{200}{20} = 10 A$$

Hence, the average power transferred to the circuit in one complete cycle:

 $VI = 200 \times 10 = 2000 W.$ 

#### **Question 7.10:**

A radio can tune over the frequency range of a portion of MW broadcast band: (800 kHz to 1200 kHz). If its LC circuit has an effective inductance of 200  $\mu$ H, what must be the range of its variable capacitor? [Hint: For tuning, the natural frequency i.e., the frequency of free oscillations of the LC circuit should be equal to the frequency of the radio wave.]

#### **Answer 7.10:**

The range of frequency (v) of a radio is 800 kHz to 1200 kHz. Lower tuning frequency,  $v_1 = 800$  kHz =  $800 \times 10^3$  Hz

Upper tuning frequency,  $v_2 = 1200 \text{ kHz} = 1200 \times 10^3 \text{ Hz}$ 

Effective inductance of circuit  $L=200~\mu H=200\times 10^{-6}~H$ 

Capacitance of variable capacitor for  $v_1$  is given as:

$$C_1 = \frac{1}{\omega_1^2 L}$$

Where,

- $\omega_1$  = Angular frequency for capacitor C<sub>1</sub>
- $=2\pi\nu_1$
- $= 2\pi \times 800 \times 10^3 \ rad/s$

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$$\therefore C_1 = \frac{1}{(2\pi \times 800 \times 10^3)^2 \times 200 \times 10^{-6}}$$
$$= 1.9809 \times 10^{-10} F = 198 \, pF$$

Capacitance of variable capacitor for  $v_2$  is given as:

$$C_2 = \frac{1}{\omega_2^2 L}$$

Where,

$$ω_2$$
 = Angular frequency for capacitor C<sub>2</sub>  
= 2πν<sub>2</sub>  
= 2π × 1200 × 10<sup>3</sup> rad/s  
∴ C<sub>2</sub> =  $\frac{1}{(2π × 1200 × 10^3)^2 × 200 × 10^{-6}}$   
= 0.8804 × 10<sup>-10</sup> F = 88 pF

Hence, the range of the variable capacitor is from 88.04 pF to 198.1 pF.

## **Question 7.11:**

Figure 7.21 shows a series LCR circuit connected to a variable frequency 230 V source. L = 5.0 H, C =  $80\mu$ F, R =  $40 \Omega$ 



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- (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.

## **Answer 7.11:**

Inductance of the inductor, L = 5.0 H Capacitance of the capacitor, C = 80 µH = 80 × 10<sup>-6</sup> F Resistance of the resistor, R = 40 Ω Potential of the variable voltage source, V = 230 V (a) Resonance angular frequency is given as:  $\omega_r = \frac{1}{\sqrt{LC}}$   $= \frac{1}{\sqrt{LC}}$   $= \frac{1}{\sqrt{5 \times 80 \times 10^{-6}}} = \frac{10^3}{20} = 50 \text{ rad/s}$ 

Hence, the circuit will come in resonance for a source frequency of 50 rad/s.

(b) Impedance of the circuit is given by the relation:

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

At resonance,  $X_L = X_C \Rightarrow Z = R = 40 \ \Omega$ 

Amplitude of the current at the resonating frequency is given as:  $I_o = \frac{V_o}{Z}$ 

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Where,

 $V_o$  = Peak voltage =  $\sqrt{2} V$ 

$$\therefore I_o = \frac{\sqrt{2} V}{Z} = \frac{\sqrt{2} \times 230}{40} = 8.13 A$$

Hence, at resonance, the impedance of the circuit is 40  $\Omega$  and the amplitude of the current is 8.13 A.

(c) rms potential drop across the inductor,

$$(V_L)_{rms} = I \times \omega_r L$$

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Where,

$$I_{\rm rms} = \frac{I_o}{\sqrt{2}} = \frac{\sqrt{2} V}{\sqrt{2} Z} = \frac{230}{40} = \frac{23}{4} A$$
  
$$\therefore (V_L)_{\rm rms} = \frac{23}{4} \times 50 \times 5 = 1437.5 V$$

Potential drop across the capacitor:

$$\therefore (V_C)_{\rm rms} = I \times \frac{1}{\omega_r C} = \frac{23}{4} \times \frac{1}{50 \times 80 \times 10^{-6}} = 1437.5 \, V$$

Potential drop across the resistor: VEET CV

$$(V_R)_{\rm rms} = IR = \frac{23}{4} \times 40 = 230 V$$

Potential drop across the LC combination:

$$V_{LC} = I(X_L - X_C)$$

At resonance,  $X_L = X_C \implies V_{LC} = 0$ 

Hence, it is proved that the potential drop across the LC combination is zero at resonating frequency.