EXERCISE QUESTIONS

CHAPTER -7 ALTERNATING CURRENT

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?
Ans - Here, the virtual a.c. voltage is 220 V with a 50 Hz frequency. So, the current rms value

(a) $I_{rms} = \frac{V_{rms}}{R} = \frac{220}{100} = 2 \cdot 20 \text{ A}$

(b) Net power $= V_{rms} \times I_{rms} = 220 \times 2 \cdot 20$
$= 484 \text{ W}$

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?
Ans - Peak voltage , V_0 = 300 V

(a) $V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{300}{\sqrt{2}} = 212 \cdot 1 \text{ V}$

(b) $I_{rms} = \frac{I_0}{\sqrt{2}}$ or $I_0 = I_{rms} \sqrt{2}$

i.e. $I_0 = 10 \times \sqrt{2} = 14 \cdot 1 \text{ A}.$

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.
Ans - : The inductor's inductance is L = 44 m H = 44 10 - 3 H.

Source voltage, V = 220 V

Source frequency, v = 50 Hz

Source's angular frequency, = 2

$$\therefore \quad I_{rms} = \frac{V_{rms}}{X_L} = \frac{220}{2\pi \times 50 \times 44 \times 10^{-3}}$$
$$= 15 \cdot 91 \text{ A}$$

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

Ans - Capacitance of capacitor, C = 60 μF = 60 × 10^{-6} F

Supply voltage, V = 110 V

$$\text{Here, reactance } X_C = \frac{1}{2\pi\nu C} = \frac{1}{2\pi \times 60 \times 60 \times 10^{-6}}$$

$$\therefore \quad I_{rms} = \frac{V_{rms}}{X_C} = \frac{110}{1/(2\pi \times 60 \times 60 \times 10^{-6})}$$
$$= 110\,(2\pi \times 60 \times 60 \times 10^{-6})$$
$$= 2 \cdot 49 \text{ A}$$

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.

Ans - There is no power loss in the case of a perfect inductor or capacitor.

7.6 Obtain the resonant frequency ωr of a series LCR circuit with L = 2.0H, C = 32 μF and R = 10 Ω. What is the Q-value of this circuit?

Ans - Inductance, L = 2.0 H

Capacitance, C = 32 μF = 32 × 10^{-6} F

$$\text{Using } \omega_r = \frac{1}{\sqrt{LC}}, \text{ we get}$$

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

$$\text{Then, } \quad Q = \frac{X_L}{R} = \frac{\omega_r L}{R} = \frac{125 \times 2}{10} = 25$$

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

Ans - Capacitance, $C = 30\mu F = 30\times10^{-6}F$

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

Using $\omega_r = \frac{1}{\sqrt{LC}}$, we get

$$\omega_r = \frac{1}{\sqrt{27\times10^{-3}\times30\times10^{-6}}}$$
$$= 1111 = 1{\cdot}1 \times 10^3\ s^{-1}$$

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?

Ans - The capacitor's capacitance is 30 F (30 ×10 -6 F).

The inductor's inductance is 27 mH, or 27 x10-3 H.

Charge applied to the capacitor: Q = 6 mC = 6 x10-3 C

The relation can be used to compute the total amount of energy held by the capacitor.

$$U = \frac{1}{2}\times\frac{6\times10^{-3}\times6\times10^{-3}}{30\times10^{-6}} = 0{\cdot}6\ J$$

7.9 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?

Ans - When an LCR circuit is in resonance, the supply power's frequency matches the LCR circuit's inherent frequency.

R = 20 is the resistance.

L = 1.5 H Inductance

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

$$\text{Using } P = \frac{V^2}{R}, \text{ we get } P = \frac{200 \times 200}{20}$$

$$= 2000 \text{ W}$$

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 μH, 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 radiowave.]

Ans - A radio's frequency (v) spans the 800 kHz to 1200 kHz range.

1 = 800 kHz = 800 x103 Hz is a lower tuning frequency.

Upper tuning frequency: 1200 kHz/2 = 103 Hz (1200 kHz/2 = 1200).

Circuit's effective inductance is 200 H, or 200 x10-6 H.

$$\text{Using } \nu = \frac{1}{2\pi\sqrt{LC}}, \text{ we get } C = \frac{1}{4\pi^2\nu^2 L}$$

(*i*) For $\nu = 800 \text{ kHz} = 800 \times 10^3 \text{ Hz}$

$$C = \frac{1}{4\pi^2(200 \times 10^{-6})(800 \times 10^3)^2}$$

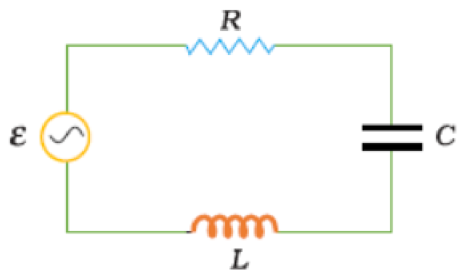
$$= 197 \cdot 8 \text{ pF} \simeq 198 \text{pF}$$

(*ii*) For $\nu = 1200 \text{ kHZ} = 1200 \times 10^3 \text{ Hz}$, we get

$$C = \frac{1}{(4\pi^2 \times 200 \times 10^{-6})(1200 \times 10^3)^2}$$

$$= 87 \cdot 9 \text{ pF} \simeq 88 \text{ pF}$$

7.11 Figure 7.21 shows a series LCR circuit connected to a variable frequency 230 V source. L = 5.0 H, C = 80μF, 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.
Ans - The inductor's inductance is L = 5.0 H.

The capacitor's capacitance is 80 F, or 80 x10-6 F.

R = 40 is the resistor's resistance.

Potential of the source of fluctuating voltage, V = 230 V

$$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{5 \times 80 \times 10^{-6}}}$$
$$= 50 \text{ rad s}^{-1}$$

(b) At resonance

$$Z = R = 40\ \Omega$$

$$\therefore \quad I_0 = \frac{V_0}{R} = \frac{\sqrt{2}\,V_{rms}}{R} = \frac{\sqrt{2} \times 230}{40} = 8{\cdot}1 \text{ A}$$

(c) Pot. drop across inductance

$$V_L = I_{rms} X_L = \frac{V_{rms}}{R} \omega L = \frac{230}{40} \times 50 \times 5$$
$$= 1437{\cdot}5 \text{ V}$$

Pot. drop across capacitance

$$V_C = I_{rms} X_C = \frac{V_{rms}}{R\omega c} = \frac{230}{40 \times 50 \times 80 \times 10^{-6}}$$
$$= 1437{\cdot}5 \text{ V}$$

Potential drop across LC combination

$$= V_L - V_C$$
$$= 1437{\cdot}5 - 1437{\cdot}5 = 0$$

$$\text{Pot. drop across R, } V_R = I_{rms} R = \frac{230}{40} \times 40 = 230 \text{ V}$$

7.12 An LC circuit contains a 20 mH inductor and a 50 μF capacitor with an initial charge of 10 mC. The resistance of the circuit is negligible. Let the instant the circuit is closed be t = 0.
(a) What is the total energy stored initially? Is it conserved during LC oscillations?
(b) What is the natural frequency of the circuit?
(c) At what time is the energy stored
(i) completely electrical (i.e., stored in the capacitor)?
(ii) completely magnetic (i.e., stored in the inductor)?
(d) At what times is the total energy shared equally between the inductor and the capacitor?
(e) If a resistor is inserted in the circuit, how much energy is eventually dissipated as heat?

Ans - The inductor's inductance is 20 mH (20 x10-3 H).

The capacitor's capacitance is 50 F, or 50x 10-6 F.

Capacitor initial charge: Q = 10 mC = 10 x10- 3 C

(a) Total initial energy

$$= \frac{Q^2}{2C} = \frac{10^{-4}}{2 \times 50 \times 10^{-6}} = 1J$$

Yes, total energy is conserved in LC oscillations as resistance of L – C circuit is negligible.

(b) Using $\omega = \frac{1}{\sqrt{LC}}$, we get

$$\omega = \frac{1}{\sqrt{(20 \times 10^{-3})(50 \times 10^{-6})}} = 10^3 \text{ rad s}^{-1}$$

$$\text{and } \omega = 2\pi\nu \text{ or } \nu = \frac{\omega}{2\pi} = \frac{10^3}{2\pi} = 159 \text{ Hz}$$

(c) Let the charge on the capacitor at any instant during L – C oscillations is $q = q_0 \cos \omega t$

(i) The energy stored will be completely electrical if $q = \pm q_0$ (max.)

or $\cos \omega t = \pm 1$ or $\omega t = n\pi$, when $n = 0,1,2,3\ldots$

$$\text{or} \quad t = \frac{n\pi}{\omega} = \frac{n\pi}{2\pi}T \qquad (\because \omega = \frac{2\pi}{T})$$

$$= \frac{nT}{2}$$

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or energy stored will be completely electrical at

$t = 0, \frac{T}{2}, T, \frac{3T}{2}, 2T...$

(*ii*) The energy stored will be completely magnetic if electrical energy is zero.

or $q = 0$ or cost $\omega t = 0$ or $\omega t = (2n + 1)\frac{\pi}{2}$, $n = 0, 1, 2, ...$

$$t = \frac{(2n+1)\pi}{2\omega} = \frac{(2n+1)\pi T}{2 \times 2\pi} = \frac{(2n+1)T}{4}$$

Thus, energy stored will be completely magnetic at

$t = \frac{T}{4}, \frac{3T}{4}, \frac{5T}{4}, \frac{7T}{4}, ...$

(*d*) Total energy stored $= \frac{q_0^2}{2C}$. Let q be the charge on the capacitor, when energy stored in the capacitor is equal to $\frac{1}{2}$ the total energy stored *i.e.*

$$\frac{1}{2}\frac{q^2}{C} = \frac{1}{2}\left(\frac{q_0^2}{2C}\right) \text{ or } q = \pm\frac{q_0}{\sqrt{2}}$$

7.13 A coil of inductance 0.50 H and resistance 100 Ω is connected to a 240 V, 50 Hz ac supply.
(a) What is the maximum current in the coil?
(b) What is the time lag between the voltage maximum and the current maximum?
Ans -

nductance of the inductor, L = 0.50 H

Resistance of the resistor, R = 100 Ω

Potential of the supply voltage, V = 240 V

(a) Maximum current $I_0 = \frac{V_0}{\sqrt{R^2 + \omega^2 L^2}} = \frac{\sqrt{2}V_{rms}}{\sqrt{R^2 + \omega^2 L^2}}$

$$= \frac{240 \times \sqrt{2}}{\sqrt{100^2 + 0 \cdot 5^2 \times 4\pi^2 \times 2500}} \quad (\because \ \omega = 2\pi\nu)$$

$$= 1 \cdot 82 \text{ A}$$

(b) $\tan\phi = \frac{X_L}{R} = \frac{2\pi\nu L}{R}$

$$= \frac{2\pi \times 50 \times 0{\cdot}5}{100} = 1{\cdot}571$$

$$\Rightarrow \quad \phi = \tan^{-1} 1{\cdot}571 \simeq 57{\cdot}5°$$

$$= \frac{57 \cdot 5 \times \pi}{180} rad$$

$$\text{Time lag} = \frac{\phi}{\omega} = \frac{\phi}{2\pi\nu}$$

7.14 Obtain the answers (a) to (b) in Exercise 7.13 if the circuit is connected to a high frequency supply (240 V, 10 kHz). Hence, explain the statement that at very high frequency, an inductor in a circuit nearly amounts to an open circuit. How does an inductor behave in a dc circuit after the steady state?

Ans -

It can be inferred that an inductor behaves like an open circuit at high frequencies because

= 2 v = 2 x 104 rad s-1,

in this case, is too tiny.

Since v = 0 in a steady d.c. circuit, the inductor functions as a straightforward conductor.

7.15 A 100 μF capacitor in series with a 40 Ω resistance is connected to a 110 V, 60 Hz supply.

(a) What is the maximum current in the circuit?

(b) What is the time lag between the current maximum and the voltage maximum?

Ans - The capacitor's capacitance is C = 100 F = 100 x10-6 F.

R = 40 is the resistor's resistance.

Voltage of supply, V = 110 V

$$I_0 = \frac{V_0}{\sqrt{R^2 + X^2_C}} = \frac{\sqrt{2}\, V_{rms}}{\sqrt{R^2 + \frac{1}{C^2 \times 4\pi^2 \nu^2}}}$$

$$= \frac{110\sqrt{2}}{\sqrt{1600 + \frac{1}{4\pi^2 3600 \times 10^{-8}}}}$$

$$= 3{\cdot}23 \text{ A}$$

(b) $$\tan\phi = -\frac{X_C}{R} = -\frac{1}{\omega CR}$$

$$= -\frac{1}{2\pi \times 60 \times 10^{-4} \times 40}$$

$$= -0{\cdot}6631$$

$$\therefore \quad |\phi| = 33{\cdot}5^\circ = \frac{33\cdot 5 \times \pi}{180} rad$$

7.16 Obtain the answers to (a) and (b) in Exercise 7.15 if the circuit is connected to a 110 V, 12 kHz supply?
Hence, explain the statement that a capacitor is a conductor at very high frequencies. Compare this behaviour with that of a capacitor in a dc circuit after the steady state.

Ans -
The capacitor's capacitance is C = 100 F = 100 x10-6 F.

R = 40 is the resistor's resistance.

Voltage of supply, V = 110 V

$$I_0 = \frac{V_0}{\sqrt{R^2 + X^2_C}} = \frac{\sqrt{2}\, V_{rms}}{\sqrt{R^2 + \frac{1}{C^2 \times 4\pi^2 \nu^2}}}$$

$$= \frac{110\sqrt{2}}{\sqrt{1600 + \frac{1}{4\pi^2 3600 \times 10^{-8}}}}$$

$$= 3{\cdot}23 \text{ A}$$

(b) $$\tan\phi = -\frac{X_C}{R} = -\frac{1}{\omega CR}$$

$$= -\frac{1}{2\pi \times 60 \times 10^{-4} \times 40}$$

$$= -0{\cdot}6631$$

$$\therefore \quad |\phi| = 33{\cdot}5° = \frac{33 \cdot 5 \times \pi}{180} rad$$

7.17 Keeping the source frequency equal to the resonating frequency of the series LCR circuit, if the three elements, L, C and R are arranged in parallel, show that the total current in the parallel LCR circuit is minimum at this frequency. Obtain the current rms value in each branch of the circuit for the elements and source specified in Exercise 7.11 for this frequency.

Ans - In a circuit, an inductor (L), capacitor (C), and resistor (R) are linked in parallel with one another.

L = 5.0 H

In resistor $I_R = \frac{\upsilon_{rms}}{R} = \frac{230}{40} = 5{\cdot}75 \text{ A}$

In inductor $I_L = \frac{\upsilon_{rms}}{X_L} = \frac{\upsilon_{rms}}{\omega L} = \frac{230}{50 \times 5}$

$= 0{\cdot}92 \text{ A}$

In capacitor $I_C = \frac{\upsilon_{rms}}{X_C} = \upsilon_{rms}\, \omega_0\, C$

$= 230 \times 50 \times 80 \times 10^{-6}$

$= 0{\cdot}92 \text{ A}$

Total current $= 5{\cdot}75 \text{ A}$

($\because$ I_L and I_C are 180° out of phase at every instant, so they add up to zero)

7.18 A circuit containing a 80 mH inductor and a 60 μF capacitor in series is connected to a 230 V, 50 Hz supply. The resistance of the circuit is negligible.
(a) Obtain the current amplitude and rms values.
(b) Obtain the rms values of potential drops across each element.
(c) What is the average power transferred to the inductor?
(d) What is the average power transferred to the capacitor?
(e) What is the total average power absorbed by the circuit?
['Average' implies 'averaged over one cycle'.]

Ans - L = 80 mH = 80 x10-3 H inductance

Capacitance, C = 60 x10-6 F = 60

A supply voltage of 230 volts.

(a) $$I_0 = \frac{V_0}{\sqrt{R^2 + (X_L - X_C)^2}}$$

Here $R = 0, \omega = 2\pi \times 50$
$= 100\,\pi \text{ rad s}^{-1}$,

$V_0 \sqrt{2}\, V_{rms} = 230 \times \sqrt{2}$ V

$L = 80 \times 10^{-3}$, $C = 60 \times 10^{-6}$ F

$\therefore \quad X_L = \omega L = 100\,\pi \times 80 \times 10^{-3}$
$= 25 \cdot 14\ \Omega$

$$X_C = \frac{1}{\omega C} = \frac{1}{100\pi \times 60 \times 10^{-6}}$$
$= 53 \cdot 03\ \Omega$

Using these values

$I_0 = 11 \cdot 6$ A

$$I_{rms} = \frac{I_0}{\sqrt{2}} = \frac{11 \cdot 6}{\sqrt{2}} = 8 \cdot 24 \text{ A}$$

(b) $V_L = I_{rms} \times \omega L$
$= 8 \cdot 24 \times 100\,\pi \times 80 \times 10^{-3}$
$= 207$ V

$$V_C = I_{rms} \times \frac{1}{\omega C}$$

7.19 Suppose the circuit in Exercise 7.18 has a resistance of 15 Ω. Obtain the average power transferred to each element of the circuit, and the total power absorbed.

Ans - 788.44 W is the average power delivered to the resistor.

Average power to the capacitor transferred is 0 W.

788.44 W is the total power absorbed by the circuit.

Using $I_{rms} = \dfrac{V_{rms}}{\sqrt{R^2 + (X_L - X_C)^2}}$ and given worked out values

$$I_{rms} = \frac{230}{\sqrt{(15)^2 + (53\cdot03 - 25\cdot14)^2}}$$

$$= 7\cdot26 \text{ A}$$

Average power to inductance as well as to capacitor is zero.

Average power to resistance $= I^2_{rms} R$

$= (7\cdot26)^2 \times 15 = 791$ A

Thus total power consumed $= 791$ W

7.20 A series LCR circuit with L = 0.12 H, C = 480 nF, R = 23 Ω is connected to a 230 V variable frequency supply.

(a) What is the source frequency for which current amplitude is maximum. Obtain this maximum value.

(b) What is the source frequency for which average power absorbed by the circuit is maximum. Obtain the value of this maximum power.

(c) For which frequencies of the source is the power transferred to the circuit half the power at resonant frequency? What is the current amplitude at these frequencies?

(d) What is the Q-factor of the given circuit?

Ans - L = 0.12 H for inductance

Capacitance is defined as C = 480 nF = 480 x10-9 F.

R = 23 is the resistance.

A supply voltage of 230 volts.

(a) $$\omega_{resonance} = \frac{1}{\sqrt{LC}}$$

$$= \frac{1}{\sqrt{0 \cdot 12 \times 480 \times 10^{-9}}}$$

$$= 4167 \text{ rad s}^{-1}$$

$$\nu_{resonance} = \frac{\omega_{resonance}}{2\pi} = 663 \text{ Hz}$$

$$I_0 = \frac{V_0}{R} = \frac{\sqrt{2}V_{rms}}{R} = \frac{230\sqrt{2}}{23}$$

$$= 14 \cdot 14 \text{ A}$$

(b) $$P_{av} = \frac{1}{2} I^2_0 R$$

$$= \frac{1}{2}(14 \cdot 1)^2 \times 23 = 2300 \text{ W}$$

(c) Two angular frequencies at which the power transferred to the circuit is half the power at resonant frequency are

$$\omega = \omega_0 \pm \Delta\omega = \omega_0 \pm \frac{R}{2L}$$

or $$2\pi\nu = 2\pi\nu_0 \pm \frac{R}{2L} \text{ or } \nu = \nu_0 \pm \frac{1}{2\pi}\frac{R}{2L}$$

or $$\nu = 633 \pm \frac{1}{2 \times 3{\cdot}14} \times \frac{23}{2 \times 0{\cdot}12}$$

$$= 633 \pm 15 \text{ Hz} = 648 \text{ Hz and } 678 \text{ Hz}$$

Thus, the power transferred to the circuit is half the power at resonant frequency at 648 Hz and 678 Hz.

$$\text{Current amplitude} = \frac{I_0}{\sqrt{2}} = \frac{14 \cdot 1}{\sqrt{2}}$$

$$= 10 \text{ A}$$

(d) $$Q = \frac{X_L}{R} = \frac{\omega L}{R} = \frac{4167 \times 0 \cdot 12}{23} = 21 \cdot 7$$

7.21 Obtain the resonant frequency and Q-factor of a series LCR circuit with L = 3.0 H, C = 27 μF, and R = 7.4 Ω. It is desired to improve the sharpness of the resonance of the

circuit by reducing its 'full width at half maximum' by a factor of 2. Suggest a suitable way.

Ans -Inductance, L = 3.0 H

27 F = 27 106 F Capacitance

Resistivity, R, is 7.4.

For the specified LCR series circuit, the source's angular frequency at resonance is given as:

$$\omega_{resonance} = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{3 \times 27 \times 10^{-6}}}$$

$$= 111 \text{ rad s}^{-1}$$

$$Q = \frac{X_L}{R} = \frac{\omega_{resonance} \times L}{R} = \frac{111 \times 3}{7 \cdot 4}$$

$$= 45$$

For doubling Q for same $\omega_{resonance}$, R should be reduced to half *i.e.* $\frac{7 \cdot 4}{2} = 3 \cdot 7 \Omega$

7.22 Answer the following questions:

(a) In any ac circuit, is the applied instantaneous voltage equal to the algebraic sum of the instantaneous voltages across the series elements of the circuit? Is the same true for rms voltage?

(b) A capacitor is used in the primary circuit of an induction coil. (c) An applied voltage signal consists of a superposition of a dc voltage and an ac voltage of high frequency. The circuit consists of an inductor and a capacitor in series. Show that the dc signal will appear across C and the ac signal across L.

(d) A choke coil in series with a lamp is connected to a dc line. The lamp is seen to shine brightly. Insertion of an iron core in the choke causes no change in the lamp's brightness. Predict the corresponding observations if the connection is to an ac line.

(e) Why is choke coil needed in the use of fluorescent tubes with ac mains? Why can we not use an ordinary resistor instead of the choke coil?

Ans - (A) The instantaneous voltage that is being applied is equal to the algebraic sum of the instantaneous voltages across the circuit's series

components. It is as a result of an out of phase voltage across several elements.
For rms voltages, it is untrue. The reason for this is that the rms voltages across the various elements are out of phase.

(b) A significant induced emf is generated at the break. Sparking will occur if the capacitor is not connected. However, when the capacitor is used, the significant induced emf generated during break is consumed during capacitor charging and no sparking occurs.

(c) The dc signal will emerge across capacitor C because the impedance of a capacitor (C) is much higher than that of an inductor (L) for dc signals (almost infinite). A dc signal consequently arises over C. The impedance of L is high and that of C is relatively low for a high frequency ac signal. As a result, L is affected by a high frequency ac signal.

(d) The inductor does not inhibit the d.c. Since XL = 0, the iron core's insertion has no impact on the d.c. current or linked lamp's brightness. But the a.c. is undoubtedly affected. Current increases as the iron core is inserted, increasing L = m nl and XL (2L). A.c. IP = EXL decreases due to a reduction in current in the E circuit, and the bulb's brightness does too.
(e) If a fluorescent tube is connected directly across a 220 V source, it will draw a significant amount of current and could potentially harm the filaments. Therefore, a choke coil that operates as an L-R circuit decreases the current to the proper value while also causing reduced power loss.

7.23 A power transmission line feeds input power at 2300 V to a stepdown transformer with its primary windings having 4000 turns. What should be the number of turns in the secondary in order to get output power at 230 V?
Ans - Voltage at input, V1 = 2300

4000 is the primary coil's n1 turn count.

Voltage at output, V2 = 230 V

Using $\frac{E_1}{E_2} = \frac{N_1}{N_2}$, we get

$$N_2 = \frac{N_1 E_2}{E_1} = \frac{4000 \times 230}{2300}$$

$= 400$ turns.

7.24 At a hydroelectric power plant, the water pressure head is at a height of 300 m and the water flow available is 100 m3 s –1. If the turbine generator efficiency is 60%, estimate the electric power available from the plant (g = 9.8 ms–2).

Ans - 300 m is the height of the water pressure head.

100 m3/s is the volume of water that flows each second.

Turbine generating efficiency, n = 60% = 0.6

Gravitational acceleration: g = 9.8 m/s2.

$$\text{Hydroelectric power} = \frac{\text{Work}}{\text{time}} = \frac{\text{Force} \times \text{distance}}{\text{time}}$$

=Column pressure × Volume of water flowing per second across a cross-section.

$= h\rho g\,(A\upsilon)$

$= 300 \times 9{\cdot}8 \times 10^3\,(100)$

Electric power $=$ 60% of hydroelectric power

7.25 A small town with a demand of 800 kW of electric power at 220 V is situated 15 km away from an electric plant generating power at 440 V. The resistance of the two wire line carrying power is 0.5 Ω per km. The town gets power from the line through a 4000-220 V step-down transformer at a sub-station in the town.

(a) Estimate the line power loss in the form of heat.

(b) How much power must the plant supply, assuming there is negligible power loss due to leakage?

(c) Characterise the step up transformer at the plant.

Ans - The total amount of electricity needed is 800 kW, or 800 103 W.

Voltage of supply, V = 220 V

V' = 440 V is the voltage at which the electric plant is generating power.

d = 15 km is the distance between the town and the power plant.

Total resistance of line = $0{\cdot}5 \times 30 = 15\ \Omega$

Power supplied to town sub-station = 800kW = 800×10^3 W

Voltage at which power is sent through line = 4000V

RMS value of current in line, $I_{rms} = \dfrac{\text{Power}}{\text{Voltage}}$

$$= \frac{800 \times 10^3\,\text{W}}{4000\,\text{V}} = 200\ \text{A}$$

(*a*) Line power loos, $P = I^2_{rms}\,R = (200)^2 \times 15$ = 600 kW

(*b*) Power supplied by plant = Power received + Line power loss = 800 + 600 = 400 kW

(*c*) Voltage drop on line, $V = I_{rms}\,R = 200 \times 15$ = 3000V.

Voltage output of the stop-up transformer at the plant = 4000 + 3000 = 7000 V

Therefore, the step-up transformer at the plant is 440 V – 7000 W.

7.26 Do the same exercise as above with the replacement of the earlier transformer by a 40,000-220 V step-down transformer (Neglect, as before, leakage losses though this may not be a good assumption any longer because of the very high voltage transmission involved). Hence, explain why high voltage transmission is preferred?

Ans - A step-down transformer has a 40000 V–220 V rating.

Voltage at input, V1 = 40000 V

V2 = the output voltage in volts

The total amount of electricity needed is 800 kW, or 800 x103 W.

V = 220 V Source Potential

In this case I_{rms} on line

$$= \frac{\text{Power}}{\text{Voltage}} = \frac{800 \times 1000}{40000} = 20 \text{ A}$$

(a) Line power loss $= I^2 R = (20)^2 \times 15$
$= 6$ kW

(b) Power supplied $= 800 + 6 = 806$ kW

(c) Voltage dropped $=$ IR $= 20 \times 15$
$= 300$ V

(d) Step up transformer should be of 440 V– 40300 V

Power loss in Ex. 7·25

$$= \frac{600}{1400} \times 100 = 43\%$$

$$\text{Power loss} = \frac{6}{806} \times 100 = 0{\cdot}74 \ \%$$

Thus, Power losses reduce a lot if power is transmitted at high voltage.