

Alternating Current

CASE STUDY / PASSAGE BASED QUESTIONS

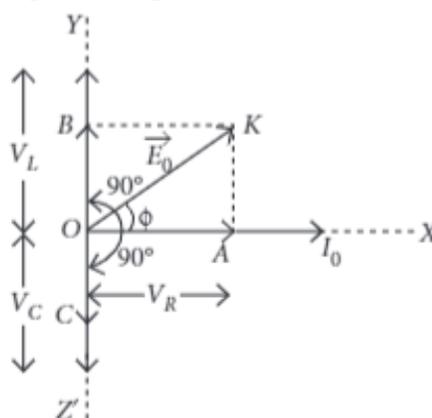
Questions 1-10 are Case Study based questions and are compulsory. Attempt any 4 sub parts from each question. Each question carries 1 mark.

1

LCR Circuit

When a pure resistance R , pure inductor L and an ideal capacitor of capacitance C is connected in series to a source of alternating e.m.f., then current at any instant through the three elements has the same amplitude and is represented as $I = I_0 \sin \omega t$. However, voltage across each element has a different phase relationship with the current as shown in graph.

The effective resistance of RLC circuit is called impedance (Z) of the circuit and the voltage leads the current by a phase angle ϕ .



A resistor of 12Ω , a capacitor of reactance 14Ω and a pure inductor of inductance 0.1 H are joined in series and placed across 200 V , 50 Hz a.c. supply.

(i) The value of inductive reactance is

- (a) 15Ω (b) 31.4Ω (c) 20Ω (d) 30Ω

(ii) The value of impedance is

- (a) 20Ω (b) 15Ω (c) 30Ω (d) 21.13Ω

(iii) What is the value of current in the circuit?

- (a) 5 A (b) 15 A (c) 10 A (d) 9.46 A

Syllabus

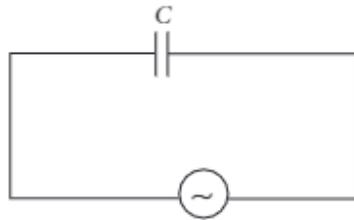
Alternating currents, peak and RMS value of alternating current/voltage; reactance and impedance; LC oscillations (qualitative treatment only), LCR series circuit, resonance; power in AC circuits. AC generator and transformer.

- (iv) What is the value of the phase angle between current and voltage?
 (a) $53^\circ 9'$ (b) $63^\circ 9'$ (c) $55^\circ 4'$ (d) 50°
- (v) From graph, which one is true from following?
 (a) $V_L \geq V_C$ (b) $V_L < V_C$ (c) $V_L > V_C$ (d) $V_L = V_C$

2

AC Voltage Applied to a Capacitor

Let a source of alternating e.m.f. $E = E_0 \sin \omega t$ be connected to a capacitor of capacitance C . If ' I ' is the instantaneous value of current in the circuit at instant t , then $I = \frac{E_0}{1/\omega C} \sin \left(\omega t + \frac{\pi}{2} \right)$. The capacitive reactance limits the amplitude of current in a purely capacitive circuit and it is given by $X_C = \frac{1}{\omega C}$.

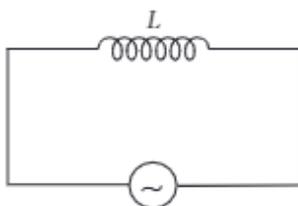


- (i) What is the unit of capacitive reactance?
 (a) farad (b) ampere (c) ohm (d) ohm^{-1}
- (ii) The capacitive reactance of a $5 \mu\text{F}$ capacitor for a frequency of 10^6 Hz is
 (a) 0.032Ω (b) 2.52Ω (c) 1.25Ω (d) 4.51Ω
- (iii) In a capacitive circuit, resistance to the flow of current is offered by
 (a) resistor (b) capacitor (c) inductor (d) frequency
- (iv) In a capacitive circuit, by what value of phase angle does alternating current leads the e.m.f?
 (a) 45° (b) 90° (c) 75° (d) 60°
- (v) One microfarad capacitor is joined to a 200 V, 50 Hz alternator. The rms current through capacitor is
 (a) 6.28×10^{-2} A (b) 7.5×10^{-4} A (c) 10.52×10^{-2} A (d) 15.25×10^{-2} A

3

AC Voltage Applied to an Inductor

Let a source of alternating e.m.f. $E = E_0 \sin \omega t$ be connected to a circuit containing a pure inductance L . If I is the value of instantaneous current in the circuit, then $I = I_0 \sin \left(\omega t - \frac{\pi}{2} \right)$. The inductive reactance limits the current in a purely inductive circuit and is given by $X_L = \omega L$.



- (i) A 100 hertz a.c. is flowing in a 14 mH coil. The reactance is
 (a) 15Ω (b) 7.5Ω (c) 8.8Ω (d) 10Ω
- (ii) In a pure inductive circuit, resistance to the flow of current is offered by
 (a) resistor (b) inductor (c) capacitor (d) resistor and inductor
- (iii) In a inductive circuit, by what value of phase angle does alternating current lags behind e.m.f.?
 (a) 45° (b) 90° (c) 120° (d) 75°
- (iv) How much inductance should be connected to 200 V, 50 Hz a.c. supply so that a maximum current of 0.9 A flows through it?
 (a) 5 H (b) 1 H (c) 10 H (d) 4.5 H
- (v) The maximum value of current when inductance of 2 H is connected to 150 volt, 50 Hz supply is
 (a) 0.337 A (b) 0.721 A (c) 1.521 A (d) 2.522 A

4

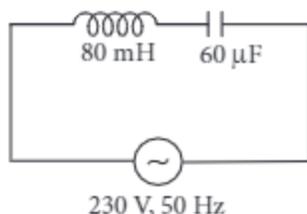
Average Power Associated with an Inductor and Capacitor

The power averaged over one full cycle of a.c. is known as average power. It is also known as true power.

$$P_{av} = V_{rms} I_{rms} \cos \phi = \frac{V_0 I_0}{2} \cos \phi.$$

Root mean square or simply rms watts refer to continuous power.

A circuit containing a 80 mH inductor and a $60 \mu\text{F}$ capacitor in series is connected to a 230 V, 50 Hz supply. The resistance of the circuit is negligible.



- (i) The value of current amplitude is
 (a) 15 A (b) 11.63 A (c) 17.65 A (d) 6.33 A
- (ii) Find rms value.
 (a) 6 A (b) 5.25 A (c) 8.23 A (d) 7.52 A
- (iii) The average power transferred to inductor is
 (a) zero (b) 7 W (c) 2.5 W (d) 5 W
- (iv) The average power transferred to the capacitor is
 (a) 5 W (b) zero (c) 11 W (d) 15 W
- (v) What is the total average power absorbed by the circuit?
 (a) zero (b) 10 W (c) 2.5 W (d) 15 W

Transformer

A transformer is essentially an a.c. device. It cannot work on d.c. It changes alternating voltages or currents. It does not affect the frequency of a.c. It is based on the phenomenon of mutual induction. A transformer essentially consists of two coils of insulated copper wire having different number of turns and wound on the same soft iron core.

The number of turns in the primary and secondary coils of an ideal transformer are 2000 and 50 respectively. The primary coil is connected to a main supply of 120 V and secondary coil is connected to a bulb of resistance 0.6Ω .

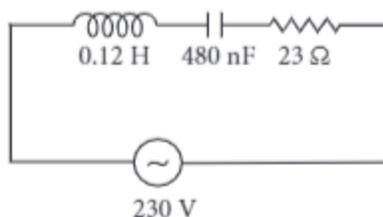
- (i) The value of voltage across the secondary coil is
 (a) 5 V (b) 2 V (c) 3 V (d) 10 V
- (ii) The value of current in the bulb is
 (a) 7 A (b) 15 A (c) 3 A (d) 5 A
- (iii) The value of current in primary coil is
 (a) 0.125 A (b) 2.52 A (c) 1.51 A (d) 3.52 A
- (iv) Power in primary coil is
 (a) 20 W (b) 5 W (c) 10 W (d) 15 W
- (v) Power in secondary coil is
 (a) 15 W (b) 20 W (c) 7 W (d) 8 W

Resonant Series LCR Circuit

When the frequency of ac supply is such that the inductive reactance and capacitive reactance become equal, the impedance of the series LCR circuit is equal to the ohmic resistance in the circuit. Such a series LCR circuit is known as resonant series LCR circuit and the frequency of the ac supply is known as resonant frequency.

Resonance phenomenon is exhibited by a circuit only if both L and C are present in the circuit. We cannot have resonance in a RL or RC circuit.

A series LCR circuit with $L = 0.12 \text{ H}$, $C = 480 \text{ nF}$, $R = 23 \Omega$ is connected to a 230 V variable frequency supply.



- (i) Find the value of source frequency for which current amplitude is maximum.
 (a) 222.32 Hz (b) 550.52 Hz (c) 663.48 Hz (d) 770 Hz
- (ii) The value of maximum current is
 (a) 14.14 A (b) 22.52 A (c) 50.25 A (d) 47.41 A

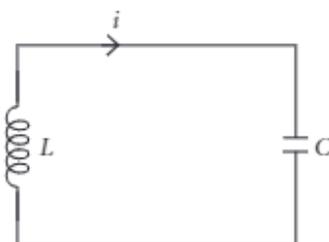
- (iii) The value of maximum power is
 (a) 2200 W (b) 2299.3 W (c) 5500 W (d) 4700 W
- (iv) What is the Q-factor of the given circuit?
 (a) 25 (b) 42.21 (c) 35.42 (d) 21.74
- (v) At resonance which of the following physical quantity is maximum?
 (a) Impedance (b) Current (c) Both (a) and (b) (d) Neither (a) nor (b)

7

LC Circuit

An LC circuit also called a resonant circuit, tank circuit or tuned circuit is an electric circuit consisting of an inductor represented by the letter L and a capacitor, represented by the letter C connected together. An LC circuit is an idealized model since it assumes there is no dissipation of energy due to resistance.

An LC circuit contains a 20 mH inductor and a 50 μ F capacitor with an initial charge of 10 mC. The resistance of the circuit is negligible. Let the instant the circuit is closed be $t = 0$.



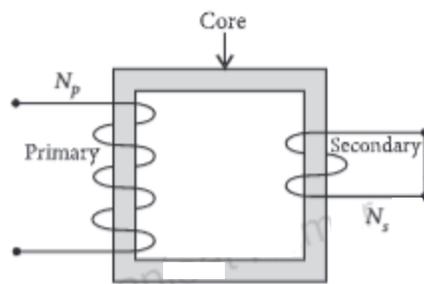
- (i) The total energy stored initially is
 (a) 5 J (b) 3 J (c) 10 J (d) 1 J
- (ii) The natural frequency of the circuit is
 (a) 159.24 Hz (b) 200.12 Hz (c) 110.25 Hz (d) 95 Hz
- (iii) At what time is the energy stored completely electrical?
 (a) $T, 5T, 9T$ (b) $\frac{T}{2}, \frac{5T}{2}, \frac{9T}{2}$ (c) $0, T, 2T, 3T$ (d) $0, \frac{T}{2}, T, \frac{3T}{2}$
- (iv) At what time is the energy stored completely magnetic?
 (a) $\frac{T}{2}, \frac{3T}{2}, \frac{T}{4}$ (b) $\frac{T}{3}, \frac{T}{9}, \frac{T}{12}$ (c) $0, 2T, 3T$ (d) $\frac{T}{4}, \frac{3T}{4}, \frac{5T}{4}$
- (v) The value of X_L is
 (a) 20Ω (b) 40Ω (c) 60Ω (d) 50Ω

8

Step-down Transformer in the Transmission of Electric Power

Step-down transformers are used to decrease or step-down voltages. These are used when voltages need to be lowered for use in homes and factories.

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 0.5Ω per km. The town gets power from the line through a 4000 - 220 V step-down transformer at a sub-station in the town.

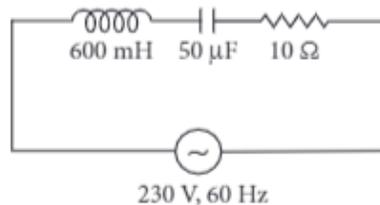


- (i) The value of total resistance of the wires is
 (a) 25Ω (b) 30Ω (c) 35Ω (d) 15Ω
- (ii) The line power loss in the form of heat is
 (a) 550 kW (b) 650 kW (c) 600 kW (d) 700 kW
- (iii) How much power must the plant supply, assuming there is negligible power loss due to leakage?
 (a) 600 kW (b) 1600 kW (c) 500 W (d) 1400 kW
- (iv) The voltage drop in the power line is
 (a) 1700 V (b) 3000 V (c) 2000 V (d) 2800 V
- (v) The total value of voltage transmitted from the plant is
 (a) 500 V (b) 4000 V (c) 3000 V (d) 7000 V

9

Power Associated with LCR Circuit

In an a.c. circuit, values of voltage and current change every instant. Therefore, power of an a.c. circuit at any instant is the product of instantaneous voltage (E) and instantaneous current (I). The average power supplied to a pure resistance R over a complete cycle of a.c. is $P = E_v I_v$. When circuit is inductive, average power per cycle is $E_v I_v \cos \phi$.



In an a.c. circuit, 600 mH inductor and a $50 \mu\text{F}$ capacitor are connected in series with 10Ω resistance. The a.c. supply to the circuit is 230 V , 60 Hz .

- (i) The average power transferred per cycle to resistance is
 (a) 10.42 W (b) 15.25 W (c) 17.42 W (d) 13.45 W
- (ii) The average power transferred per cycle to capacitor is
 (a) zero (b) 10.42 W (c) 17.42 W (d) 15 W
- (iii) The average power transferred per cycle to inductor is
 (a) 25 W (b) 17.42 W (c) 16.52 W (d) zero

ASSERTION & REASON

For question numbers 11-30 two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

- (a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false and R is also false
11. **Assertion (A)** : The alternating current lags behind the e.m.f. by a phase angle of $\pi/2$, when A.C. flows through an inductor.
Reason (R) : The inductive reactance increases as the frequency of A.C. source decreases.
12. **Assertion (A)** : Capacitor serves as a block for D.C. and offers an easy path to A.C.
Reason (R) : Capacitive reactance is inversely proportional to frequency.
13. **Assertion (A)** : When capacitive reactance is smaller than the inductive reactance in *LCR* series circuit, e.m.f. leads the current.
Reason (R) : The phase angle is the angle between the alternating e.m.f. and alternating current of the circuit.
14. **Assertion (A)** : At resonance, *LCR* series circuit have a maximum current.
Reason (R) : At resonance, in *LCR* series circuit, the current and e.m.f are in phase with each other.
15. **Assertion (A)** : Long distance transmission of A.C. is carried out at extremely high voltage.
Reason (R) : For large distance, voltage has to be large.
16. **Assertion (A)** : An electric lamp connected in series with a variable capacitor and A.C. source, its brightness increases with increase in capacitance.
Reason (R) : Capacitive reactance decreases with increase in capacitance of capacitor.
17. **Assertion (A)** : A transformer cannot work on D.C. supply.
Reason (R) : D.C. changes neither in magnitude nor in direction.
18. **Assertion (A)** : Step-down transformer increases the current.
Reason (R) : Transformer obeys the law of conservation of energy.
19. **Assertion (A)** : Soft iron is used as a core of transformer.
Reason (R) : Area of hysteresis loop for soft iron is small.
20. **Assertion (A)** : The core of transformer is made laminated in order to increase the eddy currents.
Reason (R) : The sensitivity of transformer increases with increase in the eddy currents.
21. **Assertion (A)** : We use a thick wire in the secondary coil of a step down transformer to reduce the production of heat.
Reason (R) : When the plane of the armature is parallel to the line of force of magnetic field, the magnitude of induced e.m.f. is maximum.
22. **Assertion (A)** : An inductance and a resistance are connected in series with an A.C. circuit. In this circuit the current and the potential difference across the resistance lags behind potential difference across the inductance by an angle $\pi/2$.
Reason (R) : In *L-R* circuit voltage leads the current by phase angle which depends on the value of inductance and resistance both.

23. **Assertion (A)** : An alternating current shows magnetic effect.

Reason (R) : Magnitude of alternating current varies with time.

24. **Assertion (A)** : An electric heater is heated first by direct and then by alternating currents. For both the currents, the potential difference across the ends of the heater is the same. The rate of production of heat will be different in two cases.

Reason (R) : The resistance of a coil in alternating current will be more than the resistance of a coil in direct current, hence heat produced in case of direct current will be low.

25. **Assertion (A)** : A bulb connected in series with a solenoid is connected to A.C. source. If a soft iron core is introduced in the solenoid, the bulb will glow brighter.

Reason (R) : On introducing soft iron core in the solenoid, the inductance decreases.

HINTS & EXPLANATIONS

1. (b): Given : $R = 12 \Omega$, $X_C = 14 \Omega$, $L = 0.1 \text{ H}$

$$X_L = \omega L = 2\pi\nu L = 2 \times 3.14 \times 50 \times 0.1 = 31.4 \Omega$$

(ii) (d): Impedance, $Z = \sqrt{R^2 + (X_L - X_C)^2}$

$$= \sqrt{(12)^2 + (31.4 - 14)^2} = 21.13 \Omega$$

(iii) (d): $I_v = \frac{E_v}{Z} = \frac{200 \text{ V}}{21.13} = 9.46 \text{ A}$

(iv) (c): $\tan \phi = \frac{X_L - X_C}{R} = \frac{31.4 - 14}{12} = 1.45$

$$\phi = \tan^{-1}(1.45) = 55^\circ 4'$$

(v) (c)

2. (i) (c): Ohm is the unit of capacitive reactance.

(ii) (a): Capacitive reactance, $X_C = \frac{1}{\omega C} = \frac{1}{2\pi\nu C}$

$$= \frac{1}{2\pi \times 10^6 \times 5 \times 10^{-6}} = 0.032 \Omega$$

(iii) (b): In capacitive circuit, resistance to the flow of current is offered by the capacitor.

(iv) (b)

(v) (a): Current, $I_v = \frac{E_v}{X_C} = \frac{E_v}{1/2\pi\nu C} = (2\pi\nu C)E_v$

$$I_v = 2 \times 3.14 \times 50 \times 10^{-6} \times 200 = 6.28 \times 10^{-2} \text{ A}$$

3. (i) (c): Inductive reactance,

$$X_L = \omega L = 2\pi\nu L = 2\pi \times 100 \times 14 \times 10^{-3}$$

$$X_L = 8.8 \Omega$$

(ii) (b)

(iii) (b): In an inductor voltage leads the current by $\frac{\pi}{2}$ or current lags the voltage by $\frac{\pi}{2}$.

(iv) (b): The current in the inductor coil is given by

$$I_0 = \frac{E_0}{X_L} = \frac{\sqrt{2}E_v}{2\pi\nu L}$$

$$L = \frac{\sqrt{2}E_v}{2\pi\nu I_0} = \frac{1.414 \times 200}{2 \times 3.14 \times 50 \times 0.9} = 1 \text{ H}$$

(v) (a): Inductive reactance,

$$X_L = \omega L = 2\pi\nu L = 2 \times 3.14 \times 50 \times 2 = 628 \Omega$$

$$I_0 = \frac{E_0}{X_L} \Rightarrow I_0 = \frac{\sqrt{2} \times E_v}{X_L} = \frac{\sqrt{2} \times 150}{628} = 0.337 \text{ A}$$

4. (i) (b): Inductance, $L = 80 \text{ mH} = 80 \times 10^{-3} \text{ H}$

Capacitance, $C = 60 \mu\text{F} = 60 \times 10^{-6} \text{ F}$, $V = 230 \text{ V}$

Frequency, $\nu = 50 \text{ Hz}$

$$\omega = 2\pi\nu = 100\pi \text{ rad s}^{-1}$$

Peak voltage, $V_0 = V\sqrt{2} = 230\sqrt{2} \text{ V}$

Maximum current is given by, $I_0 = \frac{V_0}{\left(\omega L - \frac{1}{\omega C}\right)}$

$$I_0 = \frac{230\sqrt{2}}{\left(100\pi \times 80 \times 10^{-3} - \frac{1}{100\pi \times 60 \times 10^{-6}}\right)}$$

$$I_0 = \frac{230\sqrt{2}}{\left(8\pi - \frac{1000}{6\pi}\right)} = -11.63 \text{ A}$$

Amplitude of maximum current, $I_0 = 11.63 \text{ A}$

(ii) (c): rms value of current,

$$I = \frac{I_0}{\sqrt{2}} = \frac{-11.63}{\sqrt{2}} = -8.23 \text{ A}$$

Negative sign appears as $\omega L < \frac{1}{\omega C}$.

(iii) (a): Average power consumed by the inductor is zero because of phase difference of $\frac{\pi}{2}$ between voltage and current through inductor.

(iv) (b): Average power consumed by the capacitor is zero because of phase difference of $\frac{\pi}{2}$ between voltage and current through capacitor.

(v) (a)

5. (i) (c): As $\frac{E_s}{E_p} = \frac{n_s}{n_p} \Rightarrow E_s = E_p \cdot \frac{n_s}{n_p}$

$$= \frac{120 \times 50}{2000} = 3 \text{ V}$$

(ii) (d): $I_s = \frac{E_s}{R} \Rightarrow I_s = \frac{3}{0.6} = 5 \text{ A}$

(iii) (a): As $\frac{I_p}{I_s} = \frac{E_s}{E_p}$

$$\Rightarrow I_p = \frac{E_s}{E_p} \times I_s = \frac{3}{120} \times 5 = 0.125 \text{ A}$$

(iv) (d): Power in primary, $P_p = E_p \times I_p = 120 \times 0.125 = 15 \text{ W}$

(v) (a): Power in secondary coil, $P_s = E_s \times I_s = 3 \times 5 = 15 \text{ W}$

6. (i) (c): Here, $L = 0.12 \text{ H}$, $C = 480 \text{ nF} = 480 \times 10^{-9} \text{ F}$
 $R = 23 \Omega$, $V = 230 \text{ V}$

$$V_0 = \sqrt{2} \times 230 = 325.22 \text{ V}$$

$$I_0 = \frac{V_0}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}}$$

At resonance, $\omega L - \frac{1}{\omega C} = 0$

$$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.12 \times 480 \times 10^9}} = 4166.67 \text{ rad s}^{-1}$$

$$\nu_R = \frac{4166.67}{2 \times 3.14} = 663.48 \text{ Hz}$$

(ii) (a): Current, $I_0 = \frac{V_0}{R} = \frac{325.22}{23} = 14.14 \text{ A}$

(iii) (b): Maximum power, $P_{\max} = \frac{1}{2}(I_0)^2 R$

$$= \frac{1}{2} \times (14.14)^2 \times 23 = 2299.3 \text{ W}$$

(iv) (d): Quality factor $Q = \frac{X_L}{R} = \frac{\omega_r L}{R}$

$$= \frac{4166.67 \times 0.12}{23} = 21.74$$

(v) (b)

7. (i) (d): Energy, $E = \frac{1}{2} \frac{Q^2}{C} = \frac{(10 \times 10^{-3})^2}{2 \times 50 \times 10^{-6}} = 1 \text{ J}$

(ii) (a): Frequency, $\nu = \frac{1}{2\pi\sqrt{LC}}$

$$= \frac{1}{2\pi\sqrt{20 \times 10^{-3} \times 50 \times 10^{-6}}} = \frac{10^3}{2\pi} = 159.24 \text{ Hz}$$

(iii) (d): Total time period, $T = \frac{1}{\nu} = \frac{1}{159.24} = 6.28 \text{ ms}$

Total charge on capacitor at time t , $Q' = Q \cos \frac{2\pi}{T} t$

For energy stored is electrical, we can write $Q' = \pm Q$. Hence, energy stored in the capacitor is completely electrical at, $t = 0, \frac{T}{2}, T, \frac{3T}{2}, \dots$

(iv) (d): Magnetic energy is maximum when electrical energy is equal to zero.

Hence $t = \frac{T}{4}, \frac{3T}{4}, \frac{5T}{4}, \dots$

(v) (a): $X_L = \omega L = 2\pi\nu L = 2 \times 3.14 \times 159.24 \times 20 \times 10^{-3}$

$$\Rightarrow X_L = 20 \Omega$$

8. (i) (d): Resistance of the two wire lines carrying power = $0.5 \Omega/\text{km}$

Total resistance = $(15 + 15)0.5 = 15 \Omega$

(ii) (c): Line power loss = $I^2 R$

RMS current in the coil,

$$I = \frac{P}{V_1} = \frac{800 \times 10^3}{4000} = 200 \text{ A}$$

$$\therefore \text{Power loss} = (200)^2 \times 15 = 600 \text{ kW}$$

(iii) (d): Assuming that the power loss is negligible due to the leakage of the current.

The total power supplied by the plant
 $= 800 \text{ kW} + 600 \text{ kW} = 1400 \text{ kW}$

(iv) (b): Voltage drop in the power line = IR
 $= 200 \times 15 = 3000 \text{ V}$

(v) (d): Total voltage transmitted from the plant
 $= 3000 \text{ V} + 4000 \text{ V} = 7000 \text{ V}$

9. (i) (c): Average power transferred per cycle to resistance is $P_v = I_v^2 R$

As $X_L = \omega L = 2\pi\nu L = 2 \times \frac{22}{7} \times 60 \times 0.6 = 226.28 \Omega$

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi\nu C} = \frac{1}{2 \times 22/7 \times 60 \times 50 \times 10^{-6}}$$

$$= 53.03 \Omega$$

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

$$= \sqrt{(10)^2 + (226.28 - 53.03)^2} = 173.53 \Omega$$

$$I_v = \frac{E_v}{Z} = \frac{230}{173.53} = 1.32 \text{ A}$$

$$P_v = I_v^2 R = (1.32)^2 \times 10 = 17.42 \text{ W}$$

(ii) (a): $P_C = E_v I_v \cos\phi$

In a capacitor, phase difference, $\phi = 90^\circ$

$$\therefore P_L = E_v I_v \cos 90^\circ = \text{zero}$$

(iii) (d): $P_L = E_v I_v \cos\phi$

In an inductor, phase difference, $\phi = 90^\circ$

$$P_L = E_v I_v \cos 90^\circ = \text{zero}$$

(iv) (a): Total power absorbed per cycle

$$P = P_R + P_C + P_L = 17.42 + 0 + 0 = 17.42 \text{ W}$$

(v) (d): Energy spent = power \times time

$$= 17.42 \times 60 \times 60 = 6.2 \times 10^4 \text{ Joule}$$

10. (i) (c): In an ideal transformer, there is no power loss. The efficiency of an ideal transformer is $\eta = 1$ (i.e. 100%) i.e. input power = output power.

(ii) (d): Transformer is used to obtain desired ac voltage and current.

(iii) (c): For a transformer, $\frac{V_s}{V_p} = \frac{N_s}{N_p}$

where N denotes number of turns and $V =$ voltage.

$$\therefore \frac{V_s}{220} = \frac{10}{20} \therefore V_s = 110 \text{ ac V}$$

(iv) (a): In a transformer the primary and secondary currents are related by

$$I_s = \left(\frac{N_p}{N_s} \right) I_p$$

and the voltages are related by

$$V_s = \left(\frac{N_s}{N_p} \right) V_p$$

where subscripts p and s refer to the primary and secondary of the transformer.

Here, $V_p = V$, $\frac{N_p}{N_s} = 4 \therefore I_s = 4I_p$

and $V_s = \left(\frac{1}{4} \right) V = \frac{V}{4}$

(v) (c): The efficiency of the transformer is

$$\eta = \frac{\text{Output power } (P_{\text{out}})}{\text{Input power } (P_{\text{in}})} \times 100$$

Here, $P_{\text{out}} = 100 \text{ W}$, $P_{\text{in}} = (220 \text{ V})(0.5 \text{ A}) = 110 \text{ W}$

$$\therefore \eta = \frac{100 \text{ W}}{110 \text{ W}} \times 100 \approx 90\%$$

11. (c): When pure inductor is connected to source of an alternating emf, then instantaneous value of alternating emf is given by $E = E_0 \sin\omega t$, and corresponding alternating current is given by $I = I_0 \sin(\omega t - \pi/2)$. From these two equations, it follows that alternating current lags behind e.m.f. by a phase angle of $\pi/2$. The inductive reactance, $X_L = \omega L = 2\pi fL$, so when frequency increases correspondingly inductive reactance also increases.

12. (a): The capacitive reactance of capacitor is given by

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi fC}$$

So this is infinite for D.C. ($f = 0$) and has a finite value for A.C. Therefore a capacitor blocks D.C. and offers an easy path for A.C.

13. (b): The phase angle for the LCR series circuit is given by $\tan\theta = \frac{X_L - X_C}{R} = \frac{\omega L - 1/\omega C}{R}$

where X_L , X_C are inductive reactance and capacitive reactance respectively. When $X_L > X_C$ then $\tan\theta$ is positive i.e. θ is positive (between 0 and $\pi/2$). Hence emf leads the current.

14. (b): At resonance $X_L = X_C$ or $\omega L = \frac{1}{\omega C}$. Because

of this impedance of LCR series circuit become equal

to resistance of circuit $\left(Z = \sqrt{R^2 + (X_L - X_C)^2} \right)$.

Therefore from $I = \frac{E}{Z} = \frac{E}{R}$, at resonance, current in LCR series circuit is maximum. Correspondingly phase angle is also equal to zero. Therefore emf and current are in phase in LCR series circuit.

15. (c): The transmission is done at high voltage due to which current through the wire is reduced.

By reduction in current corresponding dissipation of energy is also reduced (as $H \propto I^2 R$). If transmission is done at low voltage then we have to use thick wire in order to reduce the dissipation of energy. This increase the cost of transmission lines wires. In order to reduce both energy dissipation and cost of transmission wire, transmission is done at high voltage by using step-up transformers.

16. (a): Capacitive reactance $X_C = \frac{1}{\omega C}$. When capacitance C increases, the capacitive reactance decreases. Due to decrease in its values, the current in the circuit will increase $\left(I = \frac{E}{\sqrt{R^2 + X_C^2}} \right)$ and hence brightness of source (or electric lamp) will also increase.

17. (a): Transformer works on the principle of mutual induction *i.e.*, if two coils are inductively coupled and when current or magnetic flux is changed through one of the two coils, then induced e.m.f. is produced in the other coil. So whenever there is change in current or magnetic flux, only then e.m.f. is induced. But in case of D.C. current or voltage, e.m.f. is not induced because it remain constant throughout and never changes its direction and magnitude. Therefore transformer cannot work when D.C. is applied.

18. (b): If there is no loss of energy in transformer, then instantaneous output power is equal to

instantaneous input power. From this we get $\frac{e_s}{e_p} = \frac{I_p}{I_s}$.

So in step up transformer voltage increases by decreasing the current. Similarly, step-down transformer decreases the voltage by increasing current. Therefore transformer simply transforms the voltage and current, obeying the law of conservation of energy.

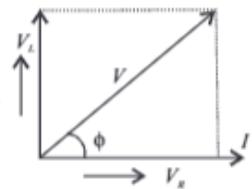
19. (a): The alternating current flowing through the coils, magnetises and demagnetises the iron core again and again over complete cycles. During each cycle of magnetisation, some energy is lost due to hysteresis, the energy lost during a cycle of magnetisation being equal to area of hysteresis loop (in magnitude). Energy loss can be reduce by selecting the material core, which has narrow hysteresis loop, that is why soft iron core is used.

20. (d): Eddy current is produced in the iron core due to induced e.m.f. Since resistance of the iron core is

quite small, the magnitude of eddy currents is quite large. As a result, large amount of heat is produced. To avoid it, a laminated core is used in a transformer. In laminated core iron stripes are quite thin and each strip possesses very large resistance, the magnitude of eddy currents produced is quite small and hence only a small amount of heat is produced.

21. (b): A step-down transformer converts electrical energy from a high voltage to one at a low voltage. Accordingly the current in the secondary will be larger than that in the primary. In order to produce less heat in the secondary, we use a wire of lesser resistance *i.e.* thick wire. We also know that when the plane of the armature is parallel to the lines of force of magnetic field, the rate of change of magnetic flux linked with it is maximum. Therefore the e.m.f. induced in the armature in this orientation is maximum.

22. (b): As both the inductance and resistance are joined in series, hence current through both will be same. But in case of resistance, both the current and potential vary simultaneously, hence they are in same phase. While in case of an inductance when current is zero, potential difference across it is maximum and when current reaches maximum (at $\omega t = \pi/2$), potential difference across it becomes zero *i.e.*, potential difference leads the current by $\pi/2$ or current lags behind the potential difference by $\pi/2$. Phase angle in case of LR circuit is given as



$$\phi = \tan^{-1} \left(\frac{\omega L}{R} \right).$$

23. (b): Like direct current, an alternating current also produces magnetic field. But the magnitude and direction of the field goes on changing continuously with time.

24. (a): The element of the heater is in the form of a coil so that it has inductance L also besides the resistance R . So, for the alternating current, the effective resistance of the heater would be $\sqrt{R^2 + (\omega L)^2}$ which is larger than the resistance R for the direct current. Hence on heating by alternating current, heat produced per second would be less.

($H = V^2/R$ and V is same in both the cases).

25. (d): On introducing soft iron core, the bulb will glow dimmer. This is because on introducing soft iron core in the solenoid, its inductance L increases, the inductive reactance, $X_L = \omega L$ increases and hence the current through the bulb decreases.