PRACTICE PAPER 07
CHAPTER 07 ALTERNATING CURRENT

SUBJECT: PHYSICS | **MAX. MARKS : 40**
CLASS : XII | **DURATION : 1½ hrs**

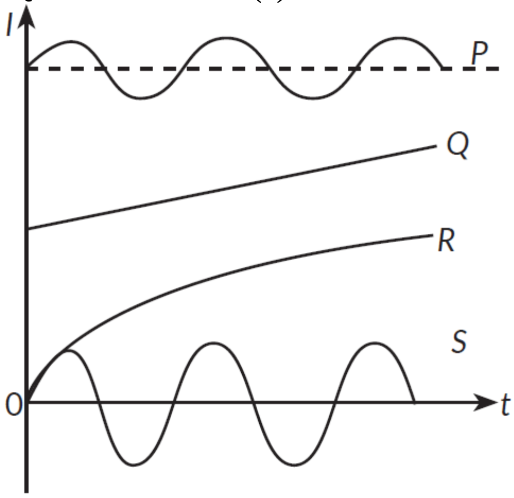
General Instructions:

(i). **All** questions are compulsory.
(ii). This question paper contains 2**0** questions divided into five Sections A, B, C, D and E.
(iii). **Section A** comprises of **10 MCQs** of **1 mark** each. **Section B** comprises of 4 questions of **2 marks** each. **Section C** comprises of 3 questions of **3 marks** each. **Section D** comprises of 1 question of **5 marks** each and **Section E** comprises of 2 Case Study Based Questions of **4 marks** each.
(iv). There is no overall choice.
(v). Use of Calculators is not permitted

SECTION – A

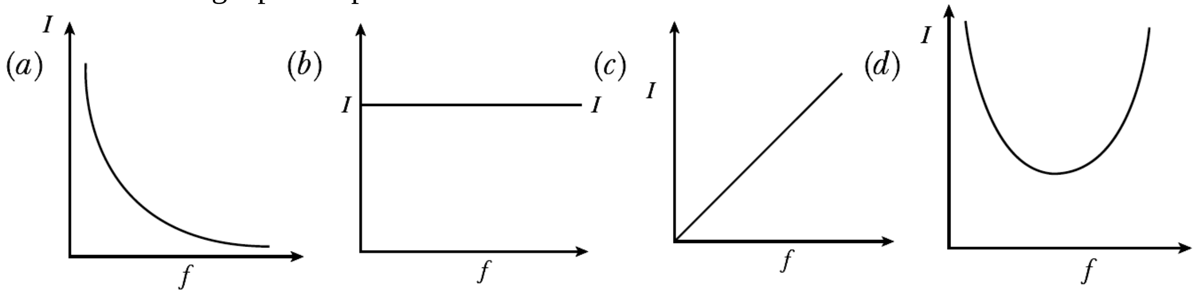
Questions 1 to 10 carry 1 mark each.

1. The figure shows variation of current (I) with time (t) in four devices P, Q, R and S. The device in which an alternating current flows is
(a) P (b) Q (c) R (d) S



2. An ac voltage v = v_0 sinωt is applied to a series combination of a resistor R and an element X. The instantaneous current in the circuit is $I = I_0 \sin\left(\omega t + \frac{\pi}{4}\right)$. Then which of the following is correct?
(a) X is a capacitor and $X_C = \sqrt{2}$ R (b) X is an inductor and X_L = R
(c) X is an inductor and $X_L = \sqrt{2}$ R (d) X is a capacitor and X_C = R

3. Which of the following graphs represent the variation of current (I) with frequency (f) in an AC circuit containing a pure capacitor?



4. An inductor, a capacitor and a resistor are connected in series across an ac source of voltage. If the frequency of the source is decreased gradually the reactance of
(a) both the inductor and the capacitor decreases.
(b) inductor decreases and the capacitor increases.
(c) both the inductor and the capacitor increases.
(d) inductor increases and the capacitor decreases.

5. If an AC voltage is applied to an LCR circuit, which of the following is true?
(a) I and V are out of phase with each other in R.
(b) I and V are in phase in L while in C, they are out of phase.
(c) I and V are out of phase in both C and L.
(d) I and V are out of phase in L and in phase in C.

6. An ac circuit has a resistance of 12 ohm and an impedance of 15 ohm. The power factor of the circuit will be
(a) 0.8 (b) 0.4 (c) 0.125 (d) 1.25

7. To reduce the resonant frequency in an LCR series circuit with a generator
(a) the generator frequency should be reduced.
(b) another capacitor should be added in parallel to the first.
(c) the iron core of the inductor should be removed.
(d) dielectric in the capacitor should be removed.

8. If the frequency of an AC is made 4 times of its initial value, the inductive reactance will be:
(a) 2 times (b) 3 times (c) 4 times (d) Unchanged

In the following questions 9 and 10, a statement of assertion (A) is followed by a statement of reason (R). Mark the correct choice as:
(a) Both assertion (A) and reason (R) are true and reason (R) is the correct explanation of assertion (A).
(b) Both assertion (A) and reason (R) are true but reason (R) is not the correct explanation of assertion (A).
(c) Assertion (A) is true but reason (R) is false.
(d) Assertion (A) is false but reason (R) is true.

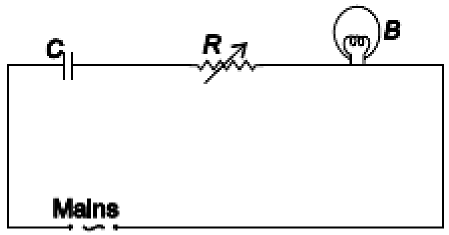
9. **Assertion (A):** The alternating current lags behind the emf by a phase angle of $\pi/2$, when AC flows through an inductor.
Reason (R): The inductive reactance increase as the frequency of AC source decrease.

10. **Assertion (A):** In series LCR resonance circuit, the impedance is equal to the ohmic resistance.
Reason (R): At resonance, the inductive reactance exceeds the capacitive reactance.

SECTION – B

Questions 11 to 14 carry 2 marks each.

11. A capacitor C, a variable resistor R and a bulb B are connected in series to the ac mains in circuit as shown. The bulb glows with some brightness. How will the glow of the bulb change if (i) a dielectric slab is introduced between the plates of the capacitor, keeping resistance R to be the same; (ii) the resistance R is increased keeping the same capacitance?



12. An alternating voltage of frequency f is applied across a series LCR circuit. Let f_r be the resonance frequency for the circuit. Will the current in the circuit lag, lead or remain in phase with the applied voltage when (i) $f > f_r$, (ii) $f < f_r$? Explain your answer in each case.

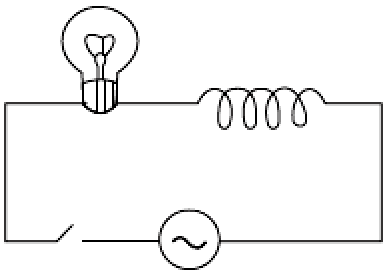
OR

In a series *LCR* circuit, obtain the conditions under which (i) the impedance of the circuit is minimum, and (ii) wattless current flows in the circuit.

13. Draw the graphs showing the variations of (i) inductive reactance, and (ii) capacitive reactance, with frequency of applied voltages in ac circuit. How do the values of (i) inductive, and (ii) capacitive reactance change, when the frequency of applied voltage is tripled?

OR

A light bulb and an open coil inductor are connected to an ac source through a key as shown in the figure.



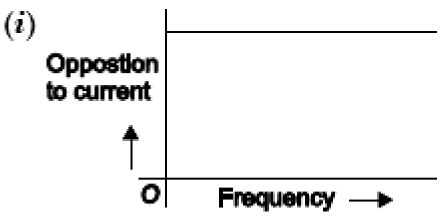
The switch is closed and after sometime, an iron rod is inserted into the interior of the inductor. The glow of the light bulb (a) increases; (b) decreases; (c) is unchanged, as the iron rod is inserted. Give your answer with reason. What will be your answer if ac source is replaced by a dc source?

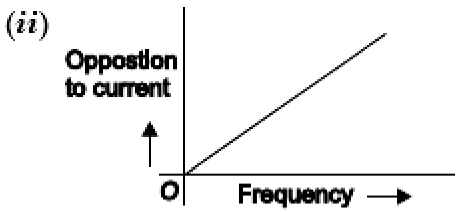
14. The coil of an ac generator consists of 100 turns of wire, each of area $0.5 m^2$. The resistance of the wire is 100 Ω. The coil is rotating in a magnetic field of 0.8 T perpendicular to its axis of rotation, at a constant angular speed of 60 radian per second. Calculate the maximum emf generated and power dissipated in the coil.

SECTION – C

Questions 15 to 17 carry 3 marks each.

15. (a) The graphs (i) and (ii) represent the variation of the opposition offered by the circuit element to the flow of alternating current with frequency of the applied emf. Identify the circuit element corresponding to each graph.





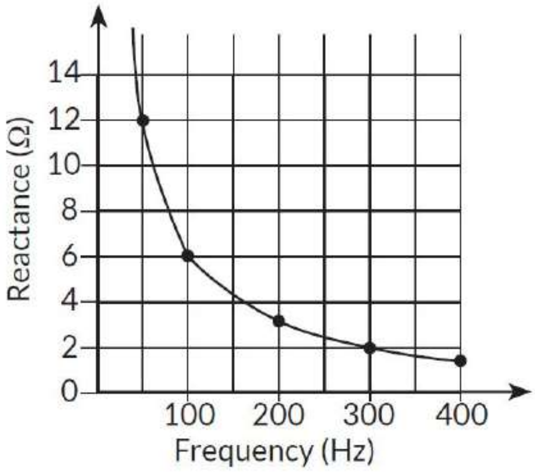
(b) Write the expression for the impedance offered by the series combinations of the above two elements connected across the ac. Which will be ahead in phase in this circuit, voltage or current?

16. Show that the current leads the voltage in phase by $\pi/2$ in an ac circuit containing an ideal capacitor.

17. The figure shows the graphical variation of the reactance of a capacitor with frequency of ac source.

(a) Find the capacitance of the capacitor.

(b) An ideal inductor has the same reactance at 100 Hz frequency as the capacitor has at the same frequency. Find the value of inductance of the inductor.
(c) Draw the graph showing the variation of the reactance of this inductor with frequency.



OR

A resistor of 30 Ω and a capacitor of $\frac{250}{\pi}$ μF are connected in series to a 200 V, 50 Hz ac source. Calculate (i) the current in the circuit, and (ii) voltage drops across the resistor and the capacitor (iii) Is the algebraic sum of these voltages more than the source voltage? If yes, solve the paradox.

SECTION – D

Questions 18 carry 5 marks.

18. (a) With the help of a labelled diagram, describe briefly the underlying principle and working of a step-up transformer.
(b) Write any two sources of energy loss in a transformer.
(c) A step-up transformer converts a low input voltage into a high output voltage. Does it violate law of conservation of energy? Explain.

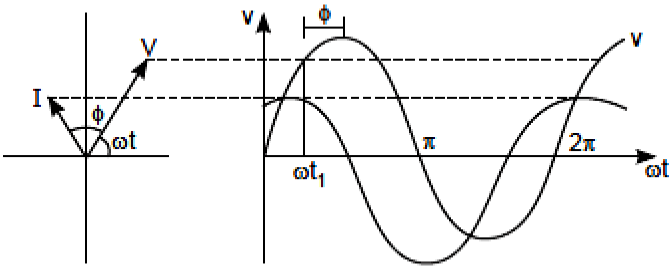
OR

Describe briefly, with the help of a labelled diagram, the basic elements of an ac generator. State its underlying principle. Show diagrammatically how an alternating emf is generated by a loop of wire rotating in a magnetic field. Write the expression for the instantaneous value of the emf induced in the rotating loop.

SECTION – E (Case Study Based Questions)

Questions 19 to 20 carry 4 marks each.

19. LCR circuit:
Phasor technique is used to determine the amplitude and phase of current for an LCR series circuit. The solution at v = 0 is called the transient solution. Impedance diagram can be made for LCR circuit which is a right angle triangle. The AC curent in each elements of LCR is same at any time having same amplitude and phase. $i = i_m \sin(\omega t + \phi)$.



(i) What will be the length of the phasor in LCR circuit?
(a) $V_{Rm} = i_mR$, $V_{Lm} = i_m X_L$, $V_{Cm} = i_m X_C$

(b) $V_{Rm} = i_m R$, $V_{Lm} \neq i_m$ XL, $V_{Cm} = i_m X_C$
(c) $V_{Rm} = i_m$ XC, $V_{Lm} = i_m$ R, V_{Cm} = im X_L
(d) None of these

(ii) I is the current in the circuit and V_R, V_L and V_C represent the voltage across circuit. What is the phase difference between I and V_L?
(a) V_L is parallel to I
(b) V_L and I in same line
(c) V_C is ahead of I by $\frac{\pi}{2}$
(d) None of the above

(iii) How does the phase angle f depends on VC and VL?
(a) $\tan \phi = V_{Cm} + V_{Lm}$
(b) $\tan \phi = V_{Cm} - V_{Lm}$
(c) $\tan \phi \neq V_{Cm}$
(d) None of the above

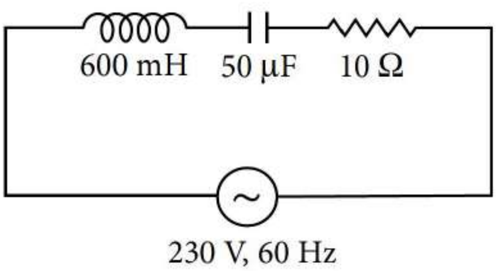
(iv) The phenomena of resonance occurs. When system
(a) oscillates at certain frequency.
(b) is having L and C.
(c) is having R and L only.
(d) none of the above.

OR

(iv) What is the condition for minimum impedance?
(a) $X_C = X_L$
(b) $X_C \neq X_L$
(c) $X_C = X_R$
(d) $X_C \neq X_R$

20. 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 μF capacitor are connected in series with 10 Ω 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

(iv) The total power transferred per cycle by all the three circuit elements is
(a) 17.42 W
(b) 10.45 W
(c) 12.45 W
(d) zero

OR

(iv) The electrical energy spend in running the circuit for one hour is
(a) 7.5×10^5 Joule
(b) 10×10^3 Joule
(c) 9.4×10^3 Joule
(d) 6.2×10^4 Joule

PRACTICE PAPER 07
CHAPTER 07 ALTERNATING CURRENT
(ANSWERS)

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(iv). There is no overall choice.
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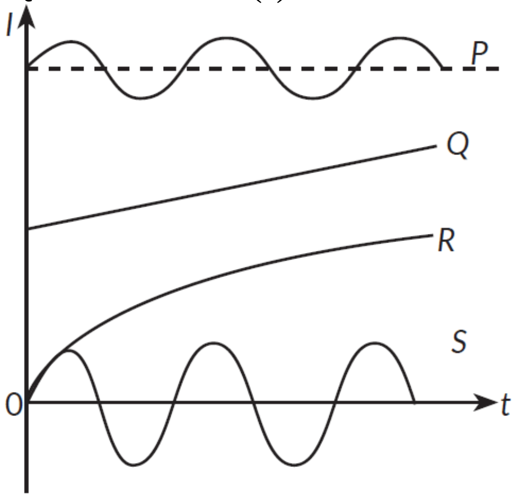
SECTION – A
Questions 1 to 10 carry 1 mark each.

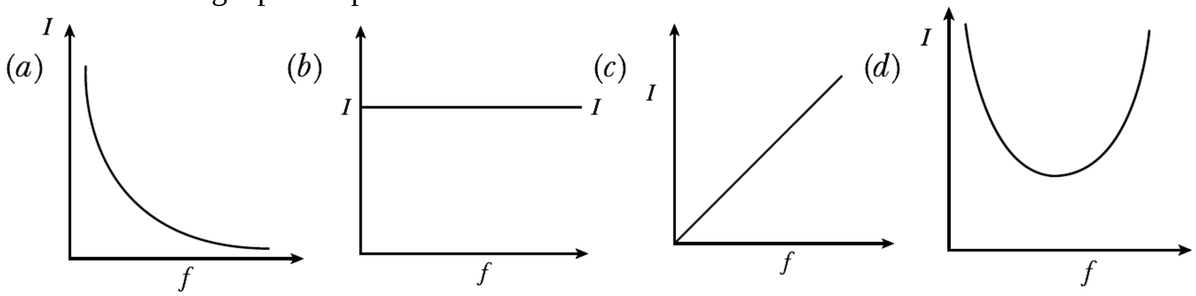
1. The figure shows variation of current (I) with time (t) in four devices P, Q, R and S. The device in which an alternating current flows is
(a) P (b) Q (c) R (d) S



Ans. (d) S
There are four devices connected with different sources.
In alternating current, the current changes its magnitudes sinusoidally with time and passing through origin.
Here, it is clear that Q and R are not alternating current flow.
Here, S-device shows the variation of current with time and P-device's current does not passing through origin.

2. An ac voltage v = v_0 sinωt is applied to a series combination of a resistor R and an element X. The instantaneous current in the circuit is $I = I_0 \sin\left(\omega t + \frac{\pi}{4}\right)$. Then which of the following is correct?
(a) X is a capacitor and $X_C = \sqrt{2}$ R
(b) X is an inductor and X_L = R
(c) X is an inductor and $X_L = \sqrt{2}$ R
(d) X is a capacitor and X_C = R
Ans. (d) X is a capacitor and X_C = R

3. Which of the following graphs represent the variation of current (I) with frequency (f) in an AC circuit containing a pure capacitor?



Ans. (c)

4. An inductor, a capacitor and a resistor are connected in series across an ac source of voltage. If the frequency of the source is decreased gradually the reactance of

(a) both the inductor and the capacitor decreases.
(b) inductor decreases and the capacitor increases.
(c) both the inductor and the capacitor increases.
(d) inductor increases and the capacitor decreases.
Ans. (b) inductor decreases and the capacitor increases.

5. If an AC voltage is applied to an LCR circuit, which of the following is true?

(a) I and V are out of phase with each other in R.
(b) I and V are in phase in L while in C, they are out of phase.
(c) I and V are out of phase in both C and L.
(d) I and V are out of phase in L and in phase in C.
Ans. (c) I and V are out of phase in both C and L.

6. An ac circuit has a resistance of 12 ohm and an impedance of 15 ohm. The power factor of the circuit will be

(a) 0.8 (b) 0.4 (c) 0.125 (d) 1.25
Ans. (a) 0.8

Power factor, $\cos\phi = \frac{R}{Z} = \frac{12}{15} = 0.8$

7. To reduce the resonant frequency in an LCR series circuit with a generator

(a) the generator frequency should be reduced.
(b) another capacitor should be added in parallel to the first.
(c) the iron core of the inductor should be removed.
(d) dielectric in the capacitor should be removed.
Ans. (b) another capacitor should be added in parallel to the first.

8. If the frequency of an AC is made 4 times of its initial value, the inductive reactance will be:

(a) 2 times (b) 3 times (c) 4 times (d) Unchanged
Ans. (c) 4 times
Inductive reactance is given by $2\pi fL$.
Therefore, when frequency is made 4 times, inductive reactance also becomes 4 times.

In the following questions 9 and 10, a statement of assertion (A) is followed by a statement of reason (R). Mark the correct choice as:

(a) Both assertion (A) and reason (R) are true and reason (R) is the correct explanation of assertion (A).
(b) Both assertion (A) and reason (R) are true but reason (R) is not the correct explanation of assertion (A).
(c) Assertion (A) is true but reason (R) is false.
(d) Assertion (A) is false but reason (R) is true.

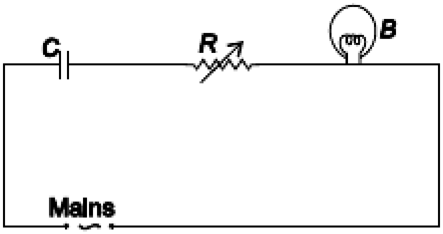
9. **Assertion (A):** The alternating current lags behind the emf by a phase angle of $\pi/2$, when AC flows through an inductor.
Reason (R): The inductive reactance increase as the frequency of AC source decrease.
Ans. (c) Assertion is true but Reason is false.
When AC pass through an inductor , current lags behind the emf by phase of $\pi/2$. Inductive reactance, $X_L = 2\pi fL$, so when frequency increases than value of inductive reactance also increases.

10. **Assertion (A):** In series LCR resonance circuit, the impedance is equal to the ohmic resistance.
Reason (R): At resonance, the inductive reactance exceeds the capacitive reactance.
Ans. (c) Assertion is true but Reason is false
At resonance, the inductive reactance X_L is **equal** to the capacitive reactance X_C, not exceeding it. This equality is what leads to the cancellation of the reactive components and results in the impedance being purely resistive.

SECTION – B

Questions 11 to 14 carry 2 marks each.

11. A capacitor C, a variable resistor R and a bulb B are connected in series to the ac mains in circuit as shown. The bulb glows with some brightness. How will the glow of the bulb change if (i) a dielectric slab is introduced between the plates of the capacitor, keeping resistance R to be the same; (ii) the resistance R is increased keeping the same capacitance?



Ans. It is a CR circuit connected with ac mains where the inductance of bulb remains constant. The current is $i = \frac{E}{Z} = \frac{E}{\sqrt{R^2 + X_C{}^2}}$

(i) If slab is inserted between the plates, capacitance will increase and as $X_C = \frac{1}{2\pi fC}$, X_C will decrease so Z will decrease making the current in bulb more and hence, the bulb will shine brighter.
(ii) If R is increased, Z will increase making the current less and again the bulb will glow dimly.

12. An alternating voltage of frequency f is applied across a series LCR circuit. Let f_r be the resonance frequency for the circuit. Will the current in the circuit lag, lead or remain in phase with the applied voltage when (i) $f > f_r$, (ii) $f < f_r$? Explain your answer in each case.

Ans. We know $X_L \propto f$ and $X_C \propto \frac{1}{f}$

As f increases X_C decreases and X_L increases. For a particular value of frequency called resonance frequency (f_r), X_L becomes equal to X_C. In case we keep on increasing frequency after this X_L becomes greater than X_C.
(i) Hence for $f >$ fr circuit turns inductive in nature and current lags behind the voltage by certain phase angle.
(ii) For $f < f_r$ circuit is capacitive in nature as $X_C > X_L$ and current leads the voltage by certain phase angle.

OR

In a series LCR circuit, obtain the conditions under which (i) the impedance of the circuit is minimum, and (ii) wattless current flows in the circuit.

Ans. In case of a series *LCR* circuit, the impedance of the circuit is given by

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

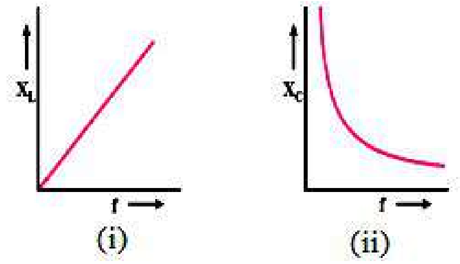
(i) The impedance of the circuit is minimum when $X_C = X_L$, i.e. capacitive reactance = inductive reactance.

Under this condition, $X_C = X_L$ gives $Z = R$, i.e. the circuit is resistive.

(ii) When the circuit is purely capacitive or inductive, wattless current flows in the circuit.

13. Draw the graphs showing the variations of (i) inductive reactance, and (ii) capacitive reactance, with frequency of applied voltages in ac circuit. How do the values of (i) inductive, and (ii) capacitive reactance change, when the frequency of applied voltage is tripled?

Ans. Graph:



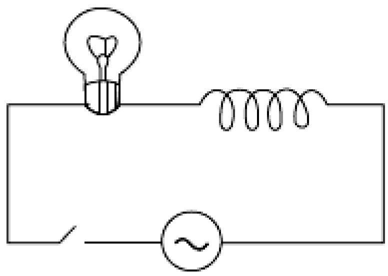
When frequency of applied voltage is tripled:

(i) Inductive reactance also gets tripled because $X_L = 2\pi \nu L$ *i.e.* $X_C \propto \nu$

(ii) Capacitive reactance reduces to one third because $X_C = \dfrac{1}{2\pi \nu C}$ *i.e.* $X_C \propto \dfrac{1}{\nu}$

OR

A light bulb and an open coil inductor are connected to an ac source through a key as shown in the figure.



The switch is closed and after sometime, an iron rod is inserted into the interior of the inductor. The glow of the light bulb (a) increases; (b) decreases; (c) is unchanged, as the iron rod is inserted. Give your answer with reason. What will be your answer if ac source is replaced by a dc source?

Ans. When an iron core is inserted, it gets magnetised and the magnetic field inside the coil increases. The inductance of the coil increases. Consequently, the inductive reactance of the coil increases.

A large fraction of the applied ac voltage appears across the inductor and the voltage across the bulb decreases. Thus, the glow of the bulb decreases. In case of a dc source, the glow of the bulb does not change.

14. The coil of an ac generator consists of 100 turns of wire, each of area $0.5 m^2$. The resistance of the wire is 100 Ω. The coil is rotating in a magnetic field of 0.8 T perpendicular to its axis of rotation, at a constant angular speed of 60 radian per second. Calculate the maximum emf generated and power dissipated in the coil.

Ans. Given, N = 100, A = $0.5\ m^2$, R = 100 Ω, B = 0.8T, ω = 60 rad s^{-1}

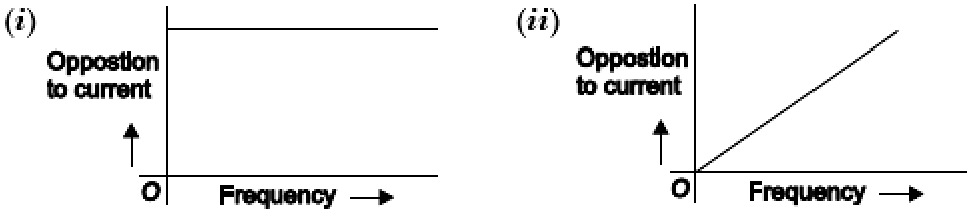
emf generate, ε_0 = NAωB = 100 × 0.5 × 60 × 0.8 = 2400 volt

Power dissipated, P = $\dfrac{\varepsilon_{rms}^2}{R} = \dfrac{\left(\dfrac{2400}{\sqrt{2}}\right)^2}{100}$ = 28.8 kW

SECTION – C

Questions 15 to 17 carry 3 marks each.

15. (a) The graphs (i) and (ii) represent the variation of the opposition offered by the circuit element to the flow of alternating current with frequency of the applied emf. Identify the circuit element corresponding to each graph.



(b) Write the expression for the impedance offered by the series combinations of the above two elements connected across the ac. Which will be ahead in phase in this circuit, voltage or current?

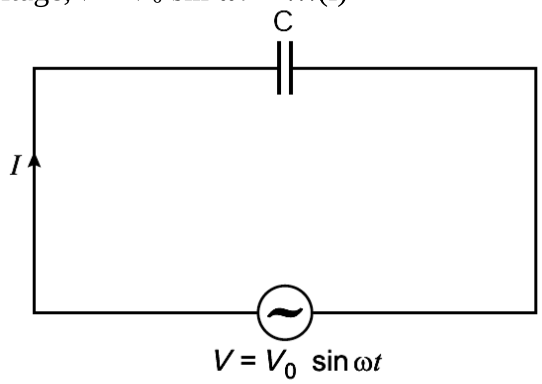
Ans. (a) In graph (i), the opposition to the flow of current does not depend upon frequency, the circuit element is a resistor. In graph (ii), the opposition increases with frequency, the current element is an inductor.

(b) When the resistor R and the inductance L are connected in series across an ac source, then impedance Z of the circuit is given by $Z = \sqrt{R^2 + X_L{}^2}$ where X_L is an inductive reactance

In an L-R circuit, the voltage is ahead of the current.

16. Show that the current leads the voltage in phase by π/2 in an ac circuit containing an ideal capacitor.

Ans. The instantaneous voltage, $V = V_0 \sin \omega t$ …(i)



Let q be the charge on capacitor and I, the current in the circuit at any instant, then instantaneous potential difference,

$V = q/C$ …(ii)

From (i) and (ii), we get $\frac{q}{C} = V_0 \sin \omega t \Rightarrow q = CV_0 \sin \omega t$

The instantaneous current, $I = \frac{dq}{dt} = \frac{d}{dt}(CV_0 \sin \omega t) = CV_0 \frac{d}{dt} \sin \omega t = CV_0 \omega \cos \omega t$

$\Rightarrow I = \frac{V_0}{1/\omega C} \cos \omega t \Rightarrow I = I_0 \sin\left(\omega t + \frac{\pi}{2}\right)$

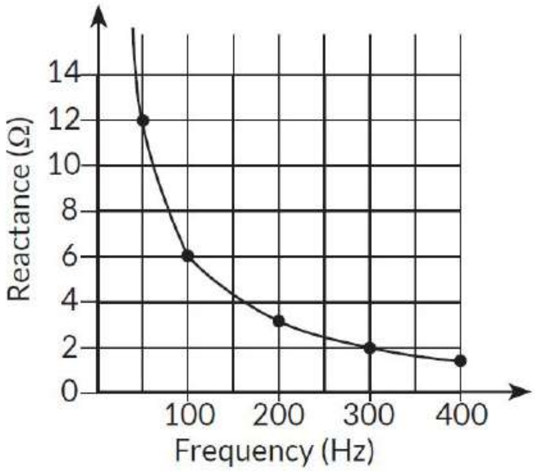
Hence, the current leads the applied voltage in phase by π/2.

17. The figure shows the graphical variation of the reactance of a capacitor with frequency of ac source.

(a) Find the capacitance of the capacitor.

(b) An ideal inductor has the same reactance at 100 Hz frequency as the capacitor has at the same frequency. Find the value of inductance of the inductor.

(c) Draw the graph showing the variation of the reactance of this inductor with frequency.



Ans. (a) Capacitive reactance, $X_C = \frac{1}{\omega C} = \frac{1}{2\pi fC}$

From graph, for X_C = 12 Ω, f = 50 Hz

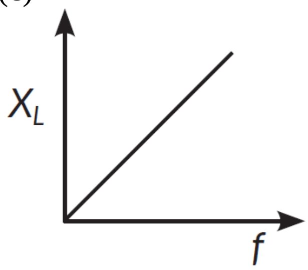
$\therefore\ 12 = \frac{1}{2\times 3.14\times 50\times C} \Rightarrow C = 265\mu F$

(b) Inductive reactance, $X_L = \omega L = 2\pi fL$

For f = 100 Hz, $X_C = X_L = 6\ \Omega$

$\therefore$ 6 = 2 × 3.14 × 100 × L ⇒ L = 9.6 mH

(c)



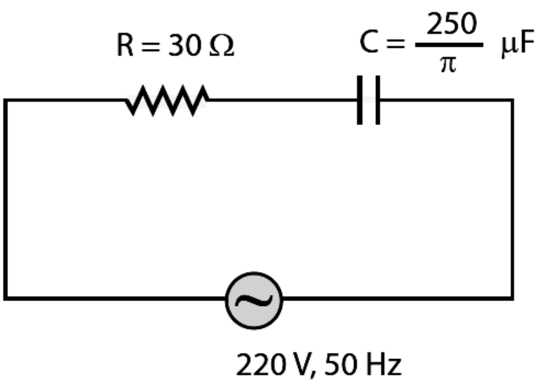
OR

A resistor of 30 Ω and a capacitor of $\frac{250}{\pi}$ μF are connected in series to a 200 V, 50 Hz ac source. Calculate (i) the current in the circuit, and (ii) voltage drops across the resistor and the capacitor (iii) Is the algebraic sum of these voltages more than the source voltage? If yes, solve the paradox.

Ans. (i) capacitive reactant, $X_C = \frac{1}{\omega C} = \frac{1}{2\pi\nu C} = \frac{1}{2\pi\times 50\times\frac{250}{\pi}\times 10^{-6}} = 40\Omega$

Impedance of the circuit, $Z = \sqrt{R^2 + X_C^{\ 2}} = \sqrt{30^2 + 40^2} = \sqrt{900+1600} = \sqrt{2500} = 50\Omega$

So, current in the circuit, $I_{rms} = \frac{E_{rms}}{Z} = \frac{200}{50} = 4A$



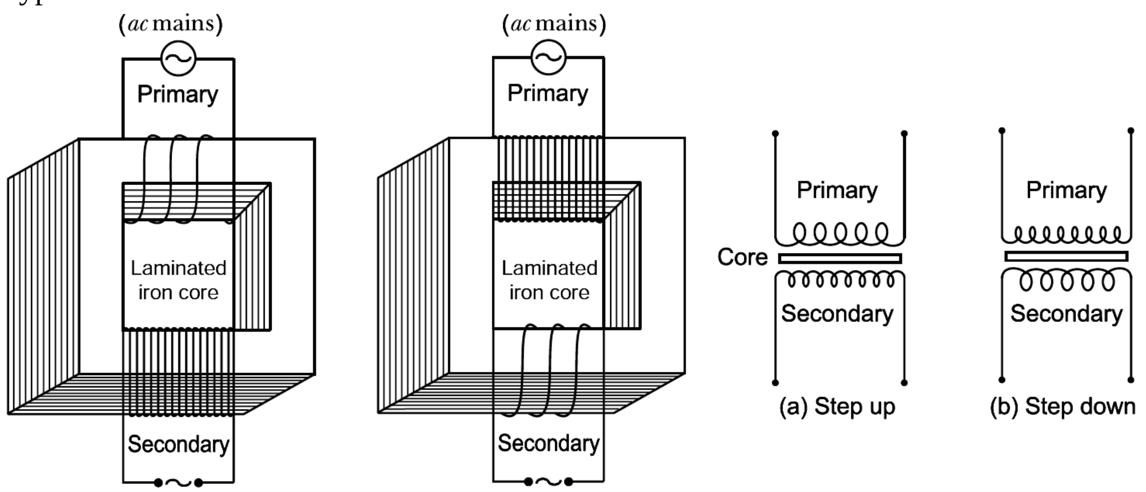
(ii) Voltage across resistor, $V_R = I_{rms}$ R = 4 × 30 = 120 V
Voltage across capacitor, $V_C = I_{rms} X_C$ = 4 × 40 = 160 V
(iii) The algebraic sum of voltages across the combination is
$V_{rms} = V_R + V_C$ = 120 + 160 = 280 V
While V_{rms} of the source is 200 V. Yes, the voltages across the combination is more than the voltage of the source. The voltage across the resistor and capacitor are not in phase.
This paradox can be resolved as when the current passes through the capacitor, it leads the voltage VC by phase π/2. So voltage of the source can be given as,

$$V_{rms} = \sqrt{V_R^2 + V_C^2} = \sqrt{120^2 + 160^2} = \sqrt{14400 + 25600} = \sqrt{40000} = 200V$$

SECTION – D

Questions 18 carry 5 marks.

18. (a) With the help of a labelled diagram, describe briefly the underlying principle and working of a step-up transformer.
(b) Write any two sources of energy loss in a transformer.
(c) A step-up transformer converts a low input voltage into a high output voltage. Does it violate law of conservation of energy? Explain.
Ans. (a) Transformer: A transformer converts low voltage into high voltage ac and vice-versa.
Construction: It consists of laminated core of soft iron, on which two coils of insulated copper wire are separately wound. These coils are kept insulated from each other and from the iron-core, but are coupled through mutual induction. The number of turns in these coils are different. Out of these coils one coil is called primary coil and other is called the secondary coil. The terminals of primary coils are connected to ac mains and the terminals of the secondary coil are connected to external circuit in which alternating current of desired voltage is required. Transformers are of two types:



(a) Step up Transformer (b) Step down Transformer

1. Step up Transformer: It transforms the alternating low voltage to alternating high voltage and in this the number of turns in secondary coil is more than that in primary coil (i.e., NS>NP).
2. Step down Transformer: It transforms the alternating high voltage to alternating low voltage and in this the number of turns in secondary coil is less than that in primary coil (i.e., NS<NP).
Working Principle: When alternating current source is connected to the ends of primary coil, the current changes continuously in the primary coil; due to which the magnetic flux linked with the secondary coil changes continuously, therefore the alternating emf of same frequency is developed across the secondary.
Let NP be the number of turns in primary coil, NS the number of turns in secondary coil and φ the magnetic flux linked with each turn. We assume that there is no leakage of flux so that the flux linked with each turn of primary coil and secondary coil is the same.
According to Faraday’s laws the emf induced in the primary coil

$$\varepsilon_P = -N_P \frac{\Delta\phi}{\Delta t} \qquad ...(i)$$

and emf induced in the secondary coil

$$\varepsilon_S = -N_S \frac{\Delta\phi}{\Delta t} \qquad ...(ii)$$

From (i) and (ii), we get $\frac{\varepsilon_S}{\varepsilon_P} = \frac{-N_S \frac{\Delta\phi}{\Delta t}}{-N_P \frac{\Delta\phi}{\Delta t}} = \frac{N_S}{N_P}$

If the resistance of primary coil is negligible, the emf (εP) induced in the primary coil, will be equal to the applied potential difference (VP) across its ends. Similarly if the secondary circuit is open, then the potential differenceVS across its ends will be equal to the emf (εS) induced in it; therefore $\frac{V_S}{V_P} = \frac{\varepsilon_S}{\varepsilon_P} = \frac{N_S}{N_P} = r(say)$

where $r = \frac{N_S}{N_P}$ is called the transformation ratio. If iP and iS are the instantaneous currents in primary and secondary coils and there is no loss of energy; then

For about 100% efficiency, Power in primary = Power in secondary

$V_P i_P = V_S i_S$

$\therefore \frac{i_S}{i_P} = \frac{V_P}{V_S} = \frac{N_P}{N_S} = \frac{1}{r}$

In step up transformer, $N_S > N_P \rightarrow r > 1$;

So, $V_S > V_P$ and $i_S < i_P$

i.e., step up transformer increases the voltage, but decreases the current.

In step down transformer, $N_S < N_P \rightarrow r < 1$;

So, $V_S < V_P$ and $i_S > i_P$

i.e., step down transformer decreases the voltage, but increases the current.

Laminated core: The core of a transformer is laminated to reduce the energy losses due to eddy currents, so that its efficiency may remain nearly 100%.

In a transformer with 100% efficiency (say),

Input power = output power (i.e., $V_P I_P = V_S I_S$)

(b) The sources of energy loss in a transformer are (i) eddy current losses due to iron core (ii) flux leakage losses. (iii) copper losses due to heating up of copper wires (iv) hysteresis losses due to magnetisation and demagnetisation of core.

(c) When output voltage increases, the output current automatically decreases to keep the power same. Thus, there is no violation of conservation of energy in a step up transformer.

OR

Describe briefly, with the help of a labelled diagram, the basic elements of an ac generator.

State its underlying principle. Show diagrammatically how an alternating emf is generated by a loop of wire rotating in a magnetic field. Write the expression for the instantaneous value of the emf induced in the rotating loop.

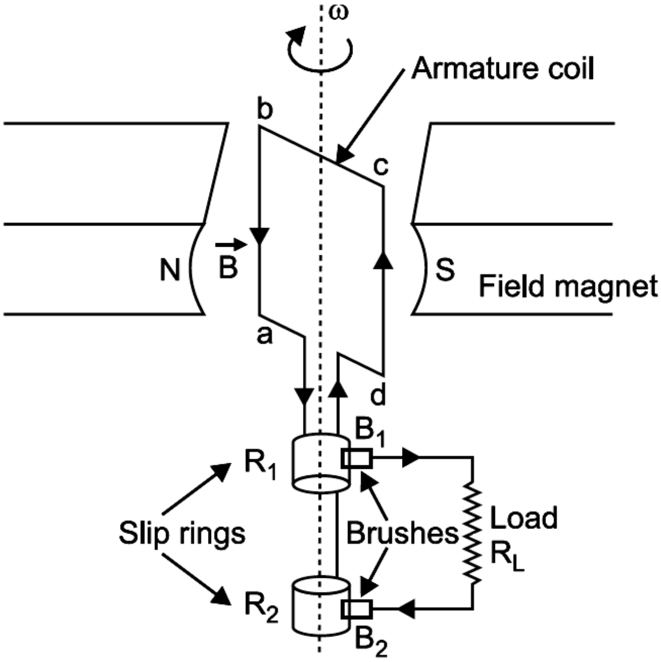
Ans. AC generator: A dynamo or generator is a device which converts mechanical energy into electrical energy.

Principle: It works on the principle of electromagnetic induction. When a coil rotates continuously in a magnetic field, the effective area of the coil linked normally with the magnetic field lines, changes continuously with time. This variation of magnetic flux with time results in the production of an alternating emf in the coil.

Construction: It consists of the four main parts:

(i) Field Magnet: It produces the magnetic field. In the case of a low power dynamo, the magnetic field is generated by a permanent magnet, while in the case of large power dynamo, the magnetic field is produced by an electromagnet.

(ii) Armature: It consists of a large number of turns of insulated wire in the soft iron drum or ring. It can revolve round an axle between the two poles of the field magnet. The drum or ring serves the two purposes: (a) It serves as a support to coils and (b) It increases the magnetic field due to air core being replaced by an iron core.
(iii) Slip Rings: The slip rings R_1 and R_2 are the two metal rings to which the ends of armature coil are connected. These rings are fixed to the shaft which rotates the armature coil so that the rings also rotate along with the armature.
(iv) Brushes: These are two flexible metal plates or carbon rods (B_1 and B_2) which are fixed and constantly touch the revolving rings. The output current in external load R_L is taken through these brushes.



Working: When the armature coil is rotated in the strong magnetic field, the magnetic flux linked with the coil changes and the current is induced in the coil, its direction being given by Fleming's right hand rule. Considering the armature to be in vertical position and as it rotates in clockwise direction, the wire *ab* moves downward and *cd* upward, so that the direction of induced current is shown in the above figure. In the external circuit, the current flows along $B_1R_LB_2$. The direction of current remains unchanged during the first half turn of armature. During the second half revolution, the wire *ab* moves upward and *cd* downward, so the direction of current is reversed and in external circuit it flows along $B_2R_LB_1$. Thus, the direction of induced emf and current changes in the external circuit after each half revolution.

Expression for Induced emf: When the coil is rotated with a constant angular speed ω , the angle θ between the magnetic field vector B and the area vector A of the coil at any instant t is θ = ωt (assuming θ = 0° at t = 0). As a result, the effective area of the coil exposed to the magnetic field lines changes with time, the flux at any time t is
$\phi_B = BA\cos\theta = BA\cos\omega t$
From Faraday's law, the induced emf for the rotating coil of N turns is then,
$$\varepsilon = -N\frac{d\phi_B}{dt} = -NBA\frac{d}{dt}(\cos\omega t)$$
Thus, the instantaneous value of the emf is
$\varepsilon = NBA\,\omega\sin\omega t$
where $NBA\omega = 2\pi\upsilon NBA$ is the maximum value of the emf, which occurs when $\sin\omega t = \pm 1$.
If we denote NBAω as ε_0, then
$\varepsilon = \varepsilon_0 \sin\omega t \Rightarrow \varepsilon = \varepsilon_0 \sin 2\pi\nu t$
where ν is the frequency of revolution of the generator's coil.
Obviously, the emf produced is alternating and hence the current is also alternating.

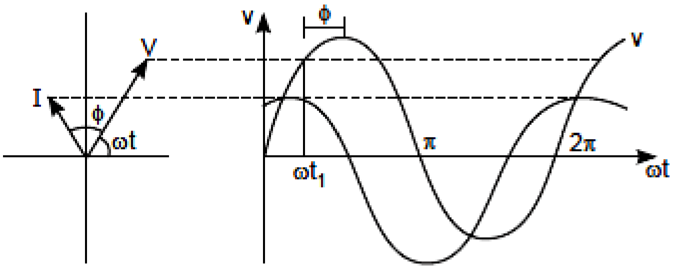
Current produced by an ac generator cannot be measured by moving coil ammeter; because the average value of ac over full cycle is zero.
The source of energy generation is the mechanical energy of rotation of armature coil.

SECTION – E (Case Study Based Questions)

Questions 19 to 20 carry 4 marks each.

19. LCR circuit:

Phasor technique is used to determine the amplitude and phase of current for an LCR series circuit. The solution at v = 0 is called the transient solution. Impedance diagram can be made for LCR circuit which is a right angle triangle. The AC curent in each elements of LCR is same at any time having same amplitude and phase. $i = i_m \sin(\omega t + \phi)$.



(i) What will be the length of the phasor in LCR circuit?

(a) $V_{Rm} = i_m R$, $V_{Lm} = i_m X_L$, $V_{Cm} = i_m X_C$
(b) $V_{Rm} = i_m R$, $V_{Lm} \neq i_m XL$, $V_{Cm} = i_m X_C$
(c) $V_{Rm} = i_m XC$, $V_{Lm} = i_m R$, $V_{Cm} = im X_L$
(d) None of these

(ii) I is the current in the circuit and V_R, V_L and V_C represent the voltage across circuit. What is the phase difference between I and V_L?

(a) V_L is parallel to I
(b) V_L and I in same line
(c) V_C is ahead of I by $\frac{\pi}{2}$
(d) None of the above

(iii) How does the phase angle f depends on VC and VL?

(a) $\tan\phi = V_{Cm} + V_{Lm}$
(b) $\tan\phi = V_{Cm} - V_{Lm}$
(c) $\tan\phi \neq V_{Cm}$
(d) None of the above

(iv) The phenomena of resonance occurs. When system

(a) oscillates at certain frequency.
(b) is having L and C.
(c) is having R and L only.
(d) none of the above.

OR

(iv) What is the condition for minimum impedance?

(a) $X_C = X_L$
(b) $X_C \neq X_L$
(c) $X_C = X_R$
(d) $X_C \neq X_R$

Ans. (i) (a) $V_{Rm} = i_m R$, $V_{Lm} = i_m X_L$, $V_{Cm} = i_m X_C$

(ii) (c) V_C is ahead of I by $\frac{\pi}{2}$

(iii) (b) $\tan\phi = V_{Cm} - V_{Lm}$

(iv) (a) oscillates at certain frequency

Resonance occurs when a system oscillates at its natural frequency, resulting in a maximum amplitude response. This is often observed in systems with inductance (L) and capacitance (C), but the primary condition is that the oscillation occurs at a specific frequency.

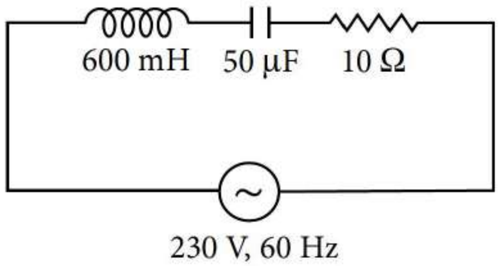
OR

(iv) (a) $X_C = X_L$

20. 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 μF capacitor are connected in series with 10 Ω 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

(iv) The total power transferred per cycle by all the three circuit elements is
(a) 17.42 W (b) 10.45 W (c) 12.45 W (d) zero

OR

(iv) The electrical energy spend in running the circuit for one hour is
(a) 7.5×10^5 Joule (b) 10×10^3 Joule (c) 9.4×10^3 Joule (d) 6.2×10^4 Joule

Ans. (i) (c) 17.42 W
Average power transferred per cycle to resistance is $P_v = I_v^2 R$

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

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi\upsilon C} = \frac{1}{2\times 22/7\times 60\times 50\times 10^{-6}} = 53.03\ \Omega$$

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

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

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

(ii) (a) zero
$P_C = E_v I_v \cos\phi$
In a capacitor, phase difference, $\phi = 90°$
$\therefore P_L = E_v I_v \cos 90° =$ zero
(iii) (d) zero
$P_L = E_v I_v \cos\phi$
In an inductor, phase difference, $\phi = 90°$
$\therefore P_L = E_v I_v \cos 90° =$ zero
(iv) (a) 17.42 W
Total power absorbed per cycle, $P = P_R + P_C + P_L = 17.42 + 0 + 0 = 17.42$ W

OR

(iv) (d) 6.2×10^4 Joule
Energy spent = power × time = $17.42 \times 60 \times 60 = 6.2 \times 10^4$ Joule