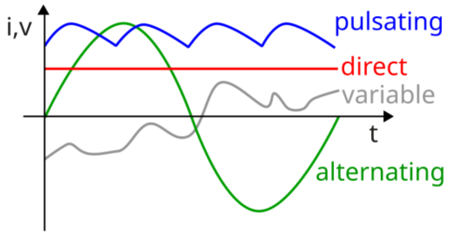
UNIT IV ELECTROMAGNETIC INDUCTION AND ALTERNATING CURRENT

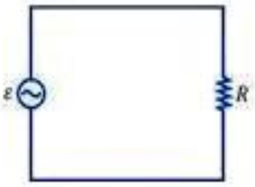
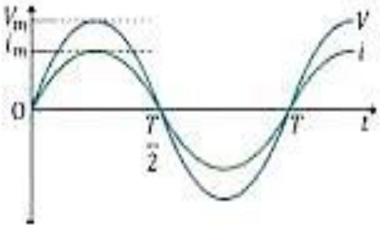
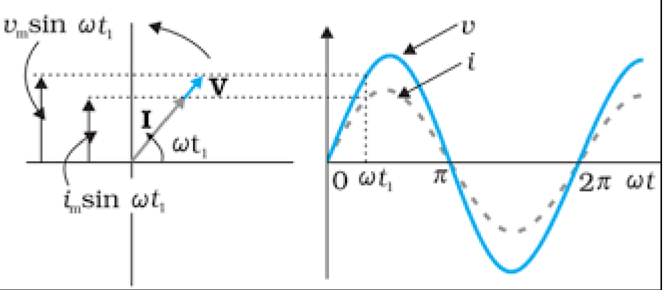
CH 7 ALTERNATING CURRENTS

GIST OF CHAPTER:

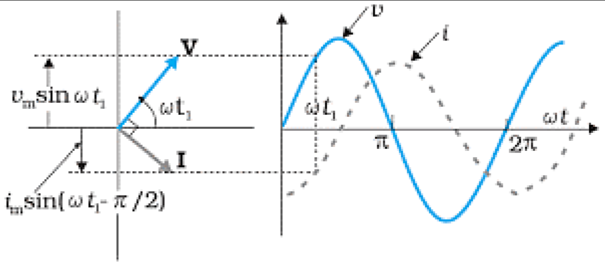
Alternating currents, peak and RMS value of alternating current/voltage, reactance and impedance, LCR series circuit (phasors only), resonance, power in AC circuits, power factor, wattless current, Transformer, AC generator.

Alternating currents: Alternating current (AC) is an *electric current that periodically reverses direction and changes its magnitude continuously* with time. $I = I_m sin\omega t$ $V = V_m sin\omega t$	
Direct current: flows with a constant magnitude and in same fixed direction.	
Advantages of AC over DC:	1) Easily and efficiently converted from one voltage to the other by means of transformers. 2) Transmitted economically over long distances.
Average value of AC over a one complete cycle	$I_{av} = \frac{q}{t} = 0$
Average value of AC over half of cycle	$I_{av} = \frac{2I_m}{\pi} = 0.637 I_m$ (I_m= peak value)
RMS value: To measure AC/AV heating effect of current is used which is independent of the direction. RMS value also known as Effective or Virtual value.	
Relation between RMS value and peak value	$I_{rms} = \frac{I_m}{\sqrt{2}}$ and $V_{rms} = \frac{V_m}{\sqrt{2}}$

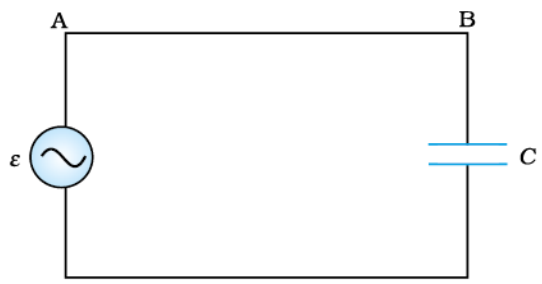
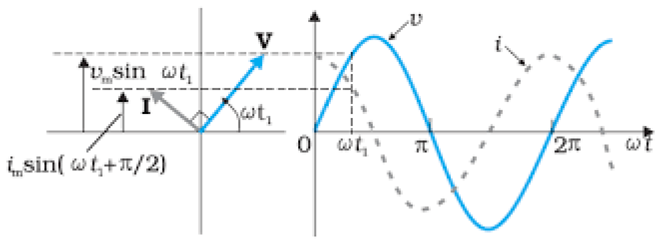
AC voltage applied to a Resistor:

	$V = V_m sin\omega t$ $V_m sin\omega t = iR$ (By Kirchhoff's loop rule) $i = \frac{V_m}{R} sin\omega t$ $i = i_m sin\omega t$ (where $i_m = \frac{V_m}{R}$)
	
	Voltage and current are in phase.

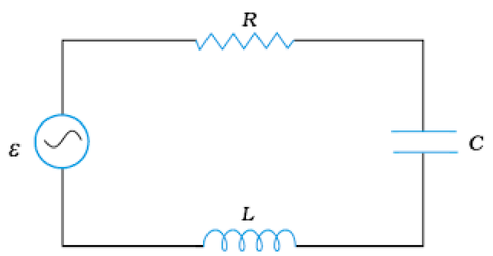
AC voltage applied to an Inductor:

	$V = V_m sin\omega t$ $V - L\frac{di}{dt} = 0$ (using Kirchhoff's rule) $\frac{di}{dt} = \frac{V}{L} = \frac{V_m}{L} sin\omega t$ $\int \frac{di}{dt} dt = \frac{V_m}{L} \int sin\omega t dt$ $i = -\frac{V_m}{\omega L} cos\omega t + C$ $i = i_m sin\left(\omega t - \frac{\pi}{2}\right)$ $\left(i_m = \frac{V_m}{\omega L}\right)$ Inductive reactance, $X_L = \omega L$
	Current lags behind the voltage in phase by $\frac{\pi}{2}$ rad. OR Voltage leads the current in phase by $\frac{\pi}{2}$ rad.

AC voltage applied to a capacitor:

	$V = V_m sin\omega t$ $V = \frac{q}{C}$ $V_m sin\omega t = \frac{q}{C}$ $i = \frac{dq}{dt} = \frac{d}{dt}(CV_m sin\omega t)$ $= \omega C V_m cos\omega t$ $= \frac{V_m}{1/\omega C} sin\left(\omega t + \frac{\pi}{2}\right)$ $= i_m sin\left(\omega t + \frac{\pi}{2}\right)$ Capacitive reactance, $X_C = \frac{1}{\omega C}$
	Current leads the voltage in phase by $\frac{\pi}{2}$ rad. OR Voltage lags behind the current in phase by $\frac{\pi}{2}$ rad.

LCR Series Circuit and Impedance:



$V = V_m sin\omega t$

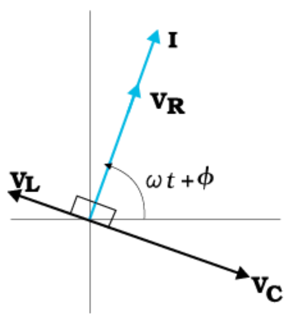
Resistor, inductor and capacitor are in series, the ac current in each element is same at any time, having the same amplitude and phase.

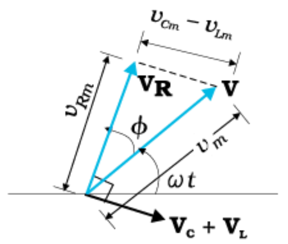
$I = I_m \sin(\omega t + \varphi)$

i) In resistive circuit voltage and current are in the same phase.

ii) In the inductive circuit, Current lags behind the voltage in phase by $\frac{\pi}{2}$ rad

iii) In the capacitive circuit, Current leads the voltage in phase by $\frac{\pi}{2}$ rad.





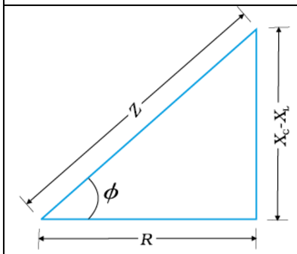
$V = V_R + V_L + V_C$

$V_m = |V| = \sqrt{V_R^2 + (V_C - V_L)^2}$

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

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

Impendance, $Z = \frac{V_m}{i_m} = \sqrt{(R)^2 + (X_C - X_L)^2}$



$$tan\emptyset = \frac{X_C - X_L}{R}$$

OR

$$tan\emptyset = \frac{V_{Cm} - V_{Lm}}{V_{Rm}}$$

i) If $X_C > X_L$, ∅ is positive and the circuit is predominantly capacitive.
Consequently, the current in the circuit leads the source voltage.

ii) If $X_C < X_L$, ∅ is negative and the circuit is predominantly inductive.
Consequently, the current in the circuit lags the source voltage.

Resonance and Resonant frequency:

Resonance: When natural frequency of the series LCR circuit becomes equal to frequency of ac source and current becomes the maximum then the phenomenon is called resonance.

Maximum Current at resonance, $i_m = \frac{Z}{R}$

Minimum impedance at resonance, Z_{min}=R

When X_C=X_L, current has its maximum value and impedance has minimum value.

Resonant Frequency:
If ω is varied, then at a particular frequency ω_0, X_C = X_L, and the impedance is minimum. This frequency is called the *resonant frequency*

X_C=X_L, $\frac{1}{\omega_0 C} = \omega_0 L$

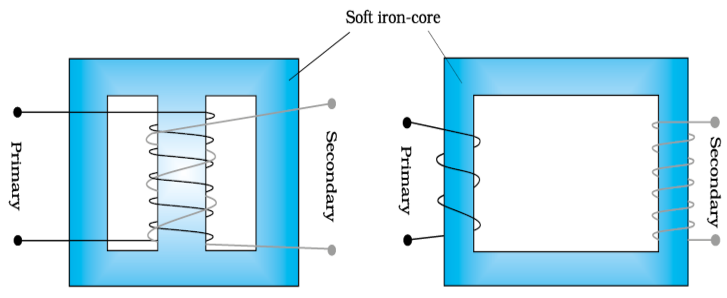
$$\omega_0 = \frac{1}{\sqrt{LC}}$$

$$\vartheta_0 = \frac{\omega_0}{2\pi} = \frac{1}{2\pi\sqrt{LC}}$$

Power in AC circuit: The Power Factor:

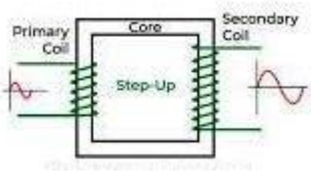
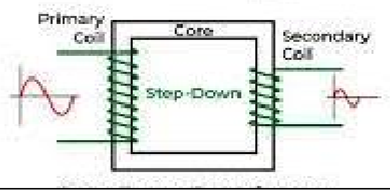
<table>
<tr><td colspan="2">We know that, an AC voltage $V = V_m sin\omega t$ applied to a series LCR circuit drives a current in the circuit given by $I = I_m \sin(\omega t + \varphi)$.</td></tr>
<tr><td colspan="2">Instantaneous Power = Instantaneous Voltage X Instantaneous Current</td></tr>
<tr><td>P = VI = $V_m sin\omega t$ X $I_m \sin(\omega t + \varphi)$
$P = \frac{V_m i_m}{2}[cos\emptyset - cos(2\omega t + \emptyset)]$
$P = \frac{V_m i_m}{2} cos\emptyset = \frac{V_m}{\sqrt{2}}\frac{i_m}{\sqrt{2}} cos\emptyset$
$P = V_{rms} i_{rms} cos\emptyset$
True power = virtual power X $cos\emptyset$
$P = I^2 Z cos\emptyset$</td><td>Power Factor = $cos\emptyset$= $\frac{True\ Power}{Apparent\ Power} = \frac{P_{av}}{V_{rms} i_{rms}}$
(i) If $\emptyset = 0^0, \cos 0^0 = 1$, then R=Z (pure Resistance)
(ii) If $\emptyset = 90^0, \cos 90^0 = 0$, then P=0 (pure inductive or capacitive)
The average power consumed over a cycle is zero and current is called **wattless current.**</td></tr>
<tr><td colspan="2">If circuit has all the three element R, L and C then
Power factor = $cos\emptyset = \frac{R}{Z} = \frac{R}{\sqrt{(R)^2 + (X_C - X_L)^2}}$</td></tr>
</table>

Transformer:

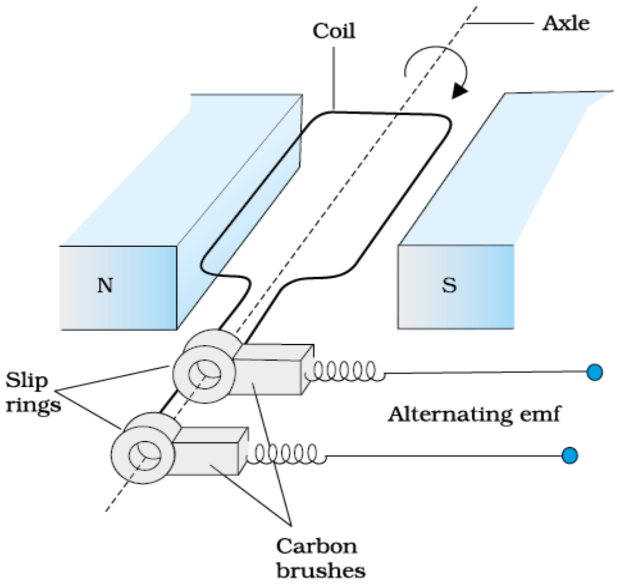
<table>
<tr><td colspan="2">

(a) (b)</td><td>Let N_p and N_s be the number of turns in the primary and secondary of the transformer. The voltage induced in the secondary is
$\varepsilon_S = -N_S \frac{d\emptyset}{dt}$
alternating flux f also induces an emf, called back emf in the primary
$\varepsilon_P = -N_P \frac{d\emptyset}{dt}$
$\frac{\varepsilon_S}{\varepsilon_P} = \frac{N_S}{N_P} = \frac{I_P}{I_S}$</td></tr>
<tr><td colspan="2">It is a device for covert an AC at low to high voltage or vice versa.
Principal: works on **Mutual induction**.
A transformer consists of two coils of insulated copper wire having different number of turns and wound on the same soft iron core. The coil to which electric energy is supplied is called the primary and the coil from which energy is drawn is called the secondary.
To prevent energy losses due to eddy currents, a laminated core is used.</td><td>Energy Loss:
(i) Copper loss
(ii) Eddy current loss
(iii) Flux leakage
(iv) Humming loss
(v) Hysteresis loss

Efficiency of transformer,
$\eta = \frac{Output\ power}{Input\ power} \times 100\%$</td></tr>
<tr><td colspan="3">Types:</td></tr>
<tr><td>Step up
$N_S > N_P, \varepsilon_S > \varepsilon_P, i_S < i_P$</td><td colspan="2">Step down
$N_S < N_P, \varepsilon_S < \varepsilon_P, i_S > i_P$</td></tr>
</table>

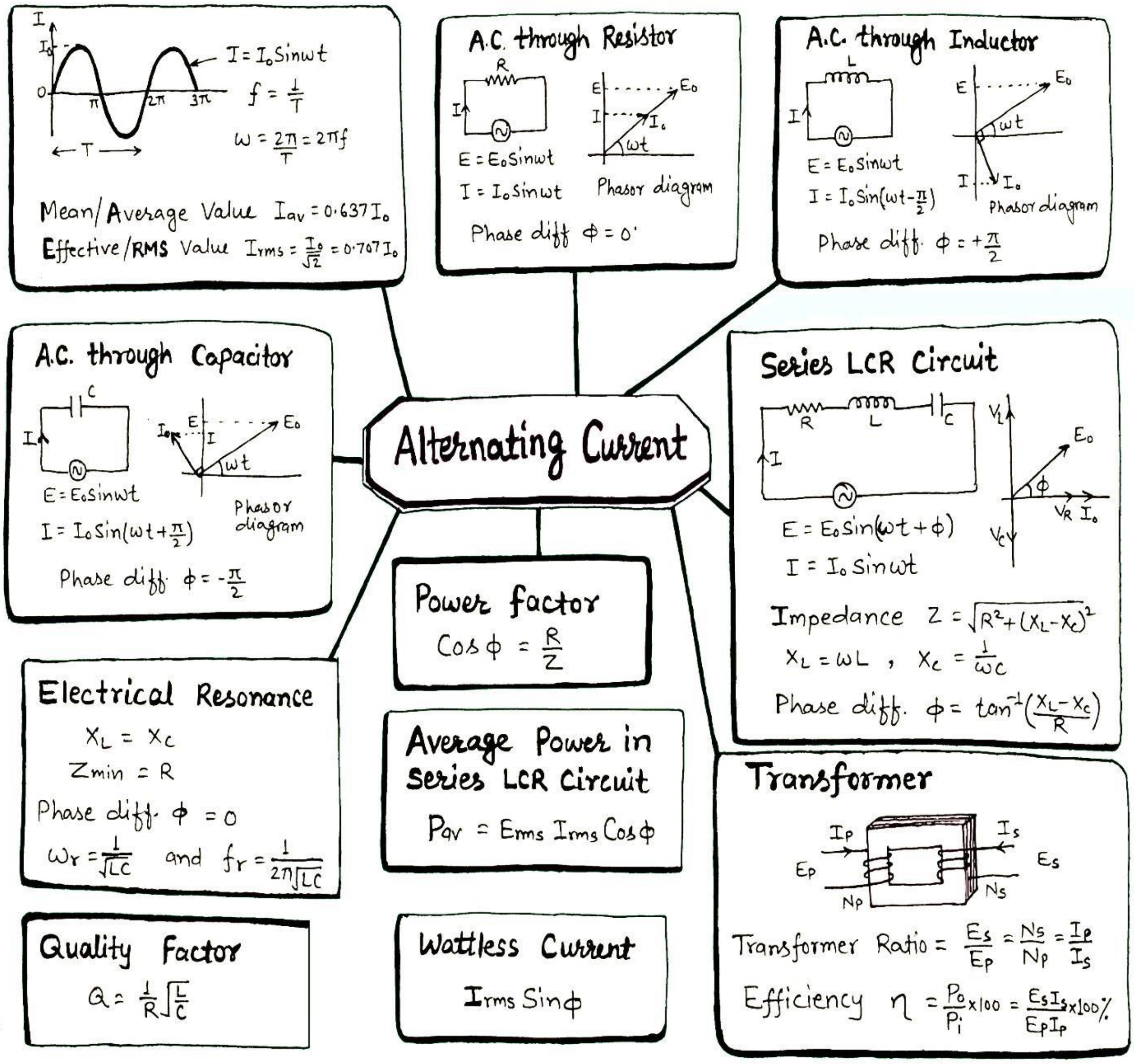
AC Generator:

It is a device which converts mechanical energy into an electrical energy and generates alternating current.	
Principle: Works on principle of electro-magnetic induction.	
	Construction: 1. Armature coil 2. Filed magnet 3. Slip rings 4. Brushes Theory: When the armature coil rotates between the pole pieces of field magnet, the effective area of the coil is A cos θ, The flux at any time is, $\emptyset = \vec{B}.\vec{A}$=NBA cos θ=NBA cosωt The induced emf is, $\varepsilon = -\frac{d\emptyset}{dt} = -\frac{d(NBAcos\omega t)}{dt}$ $V = \varepsilon = -NBA\omega sin\omega t$

Formulae:

$V = V_m sin\omega t = V_m sin2\pi\vartheta t$	$P = V_{rms} i_{rms} cos\emptyset$
$i = i_m sin\omega t = i_m sin2\pi\vartheta t$	Power factor = $cos\emptyset = \frac{R}{Z} = \frac{R}{\sqrt{(R)^2+(X_C-X_L)^2}}$
$I_{rms} = \frac{I_m}{\sqrt{2}} \quad and \quad V_{rms} = \frac{V_m}{\sqrt{2}}$	$\frac{\varepsilon_S}{\varepsilon_P} = \frac{N_S}{N_P} = \frac{I_P}{I_S}$
$X_L = \omega L$	$\eta = \frac{Output\ power}{Input\ power} \times 100\%$
$X_C = \frac{1}{\omega C}$	$V = \omega = -NBA\omega sin\omega t$
$Z = \frac{V_m}{i_m} = \sqrt{(R)^2 + (X_C - X_L)^2}$	
$tan\emptyset = \frac{X_C - X_L}{R}$	

MIND MAP



Alternating Current
I = I₀ Sinωt
f = 1/T
ω = 2π/T = 2πf
Mean/Average Value Iav = 0.637 I₀
Effective/RMS Value Irms = I₀/√2 = 0.707 I₀
A.C. through Resistor
E = E₀Sinωt
I = I₀Sinωt
Phasor diagram
Phase diff φ = 0°
A.C. through Inductor
E = E₀Sinωt
I = I₀Sin(ωt − π/2)
Phasor diagram
Phase diff. φ = +π/2
A.C. through Capacitor
E = E₀Sinωt
I = I₀Sin(ωt + π/2)
Phasor diagram
Phase diff. φ = −π/2
Series LCR Circuit
E = E₀Sin(ωt + φ)
I = I₀ Sinωt
Impedance Z = √(R² + (XL − XC)²)
XL = ωL , XC = 1/ωC
Phase diff. φ = tan⁻¹((XL − XC)/R)
Power factor
Cos φ = R/Z
Electrical Resonance
XL = XC
Zmin = R
Phase diff. φ = 0
ωr = 1/√LC and fr = 1/2π√LC
Average Power in Series LCR Circuit
Pav = Erms Irms Cos φ
Transformer
Transformer Ratio = Es/Ep = Ns/Np = Ip/Is
Efficiency η = Po/Pi × 100 = EsIs/EpIp × 100%
Quality Factor
Q = 1/R √(L/C)
Wattless Current
Irms Sinφ

MCQ'S

Level – 1

Q.1 A DC ammeter cannot be used to measure an alternating current because
(a) DC ammeter will get damage
(b) average value of AC for complete cycle is zero
(c) alternating current cannot pass through DC ammeter
(d) alternating current changes its direction

Q.2 Why the use of ac voltage is preferred over dc voltage?
(a) Generation of ac is more economical than dc
(b) AC can be stepped up and stepped down
(c) It can be transmitted with lower energy loss
(d) All of the above

Q.3 Alternating current is transmitted at far off places
(a) at high voltage and low current.
(b) at high voltage and high current.
(c) at low voltage and low current.
(d) at low voltage and high current.

Q.4 In the case of an inductor
(a) voltage lags the current by $\frac{\pi}{2}$
(b) voltage leads the current by $\frac{\pi}{2}$
(c) voltage lags the current by $\frac{\pi}{3}$
(d) voltage lags the current by $\frac{\pi}{4}$

Q.5 When an AC voltage is applied to an series LCR circuit, which of the following true?
(a) I and V are out of phase with each other in R
(b) I and V are in phase in L with 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

Q.6 The power factor of series LCR circuit at resonance is
(a) Zero (c) 1.0
(b) 0.5 (d) depends on value of L,C and R

Q.7 Transformer is based upon the principal of
(a) Self induction (b) Mutual induction (c) Eddy current (d)None of the above

Q.8 The root mean square value of the alternating current is equal to
(a) Twice the peak value (b) Half the peak value
(c) $\frac{1}{\sqrt{2}}$ times the peak value (d) Equal to the peak value

Q.9 For high frequency, a capacitor offers
(a) More reactance (b) Less reactance
(c) Zero reactance (d) Infinite reactance

Q.10 In an A.C. circuit the current

(a) Always leads the voltage
(b) Always lags behind the voltage
(c) Is always in phase with the voltage
(d) May lead or lag behind or be in phase with the voltage

Q.11 Which of the following statements is true about the LCR circuit connected to an AC source at resonance?
(a) voltage across R equals the applied voltage
(b) voltage across R is zero
(c) voltage across C is zero
(d) voltage across L equals the applied voltage

Q.12 What happens to the inductive reactance when the frequency of the AC supply is increased?
(a) Increases (b) Decreases (c) Remains the same (d) Decreases inversely

Q.13 When is the current in a circuit wattless?
(a) When the inductance of the circuit is zero
(b) When the resistance of the circuit is zero.
(c) When the current is alternating.
(d) When both resistance and inductance are zero.

Q.14 L, C and R denote inductance, capacitance and resistance respectively. Pick out the combination which does not have the dimensions of frequency
(a) 1/RC (b) R/L (c) C/L (d) $1/\sqrt{LC}$

Q.15 What will be the phase difference between virtual voltage and virtual current, when the current in the circuit is wattless
(a) 90° (b) 45° (c) 180° (d) 60°

Q.16 The phase difference between the current and voltage of LCR circuit in series combination at resonance is
(a) 0 (b) $\frac{\pi}{2}$ (c) π (d) $-\pi$

Q.17 Power delivered by the source of the circuit becomes maximum, when
(a) $\omega L = \omega C$ $(b)\omega L = \frac{1}{\omega C}$ $(c)\omega L = \sqrt{\omega C}$ $(d)\omega L = -\frac{1}{\omega C}$

Q.18 When power is drawn from the secondary coil of the transformer, the dynamic resistance
(a) Increases (b) Decreases (c) Remains unchanged
(d)Changes erratically

Q.19 A transformer is employed to
(a) Obtain a suitable dc voltage
(b) Convert dc into ac
(c) Obtain a suitable ac voltage
(d) Convert ac into dc

Q.20 Quantity that remains unchanged in a transformer is
(a) Voltage (b) Current (c) Frequency (d) None of above

Level – 2

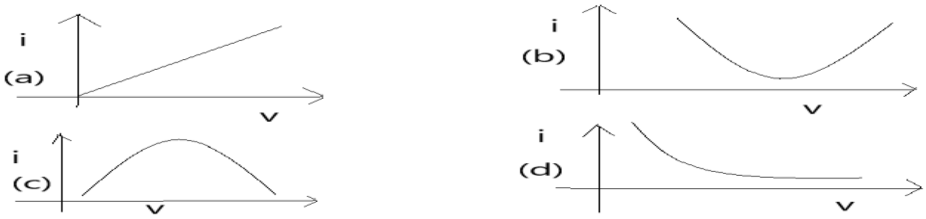
Q.1 In series LCR circuit, the capacitance is changed from C to 4C. For the same resonant frequency, the inductance should be changed from L to

(a) 2L (b) L / 2 (c) L / 4 (d) 4 L

Q.2 A bulb and a capacitor are connected in series to a source of alternating current. If its frequency is increased, while keeping the voltage of the source constant, then

(a) Bulb will give more intense light
(b) Bulb will give less intense light
(c) Bulb will give light of same intensity as before
(d) Bulb will stop radiating light

Q.3 The i-V curve for anti-resonant circuit is



Q.4 If rotational velocity of an a.c. generator armature is doubled, then induced e.m.f will become

(a) Half (b) Two times (c) Four times (d) Unchanged

Q.5 In a step-up transformer, the turn ratio is 1: 2. A Leclanche cell (e.m.f. 1.5V) is connected across the primary. The voltage developed in the secondary would be

(a) 3.0 V (b) 0.75 V (c) 1.5 V (d) Zero

Q.6 In a step-up transformer the turn's ratio is 1:10. A resistance of 200 ohm connected across the secondary is drawing a current of 0.5 A. What is the primary voltage and current?

(a) 50 V, 1 A (b) 10 V, 5 A (c) 25 V, 4 A (d) 20 V, 2 A

Q.7 The turns ratio of a transformer is given as 2:3.If the current through the primary coil is 3A, then the current in secondary coil is

(a) 1A (b) 4.5A (c) 2A (d) 1.5A

Q.8 The peak value of AC voltage on a 220 V mains is

(a) $110\sqrt{2}$ $(b) 200\sqrt{2}$ $(c) 240\sqrt{2}$ $(d) 220\sqrt{2}$

Q.9 In a series LCR circuit, resistance $R = 10\Omega$ and the impedance $Z = 20\Omega$. The phase difference between the current and the voltage is

(a) 30^{o} (b) 45^{o} (c) 60^{o} (d) 90^{o}

Q.10 The frequency for which a 5 μ*F* capacitor has a reactance of $\frac{1}{1000}\Omega$ is given by

(a) 1000 Hz (b) $\frac{1}{1000} Hz$ $(c)\frac{1000}{\pi} hz$ $(d)\frac{100}{\pi} MHz$

Level – 3

Q.1 An inductance of 1 mH a condenser of 10 μF and a resistance of 50 Ω are connected in series. The reactance of inductor and condensers are same. The reactance of either of them will be

(a) 100 Ω (b) 30 Ω (c) 3.2 Ω (d) 10 Ω

Q.2 An ac circuit consists of an inductor of inductance 0.5 H and a capacitor of capacitance 8 μF in series. The current in the circuit is maximum when the angular frequency of ac source is

(a) 500 rad/sec (b) $2X10^5$ rad/sec (c) 4000 rad/sec (d) 5000 rad/sec

Q.3 An inductive circuit contains a resistance of 10 Ω and an inductance of 2.0 H. If an ac voltage of 120 V and frequency of 60 Hz is applied to this circuit, the current in the circuit would be nearly

(a) 0.32 A (b) 0.16 A (c) 0.48 A (d) 0.80 A

Q.4 The power factor of an ac circuit having resistance (R) and inductance (L) connected in series and an angular velocity ω is

(a) $\frac{R}{\omega L}$ (b) $\frac{R}{\sqrt{(R^2+\omega^2L^2)}}$ (c) $\frac{\omega L}{R}$ (d) $\frac{R}{\sqrt{(R^2-\omega^2L^2)}}$

Q.5 A telephone wire of length 200 km has a capacitance of 0.014 μF per km. If it carries an ac of frequency 5 kHz, what should be the value of an inductor required to be connected in series so that the impedance of the circuit is minimum

(a) 0.35 mH (b) 35 mH (c) 3.5 mH (d) Zero

Q.6 An LCR series circuit with a resistance of 100 Ω is connected to an ac source of 200 V (r.m.s.) and angular frequency 300 rad/s. When only the capacitor is removed, the current lags behind the voltage by 60^0. When only the inductor is removed the current leads the voltage by 60^0. The average power dissipated is

(a) 50 W (b) 100 W (c) 200 W (d) 400W

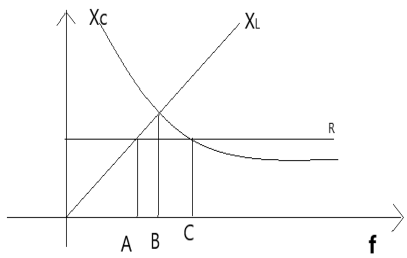
Q.7 A power transformer is used to step up an alternating e.m.f. of 220 V to 11 kV to transmit 4.4 kW of power. If the primary coil has 1000 turns, what is the current rating of the secondary? Assume 100% efficiency for the transformer

(a) 4 A (b) 0.4 A (c) 0.04 A (d) 0.2 A

Q.8 A loss free transformer has 500 turns on its primary winding and 2500 in secondary. The meters of the secondary indicate 200 volts at 8 amperes under these conditions. The voltage and current in the primary is

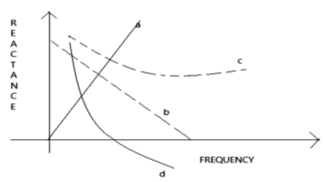
(a) 100 V, 16 A (b) 40 V, 40 A (c) 160 V, 10 A (d) 80 V, 20 A

Q.9 The figure shows variation of R, X_L and X_C with frequency f in a series L, C, R circuit. Then for what frequency point, the circuit is inductive



(a) A (b) B (c) C (d) All points

Q.10 Which of the following plots may represent the reactance of a series LC combination



(a) a (b) b (c) c (d) d

Assertion – Reason Questions:

(a) If both assertion and reason are true and the reason is the correct explanation of the assertion.

(b) If both assertion and reason are true but reason is not the correct explanation of the assertion.
(c) If assertion is true but reason is false.
(d) If the assertion and reason both are false

Q.1 **Assertion:** A bulb connected in series with a solenoid is connected to ac source. If a soft iron core is introduced in the solenoid, the bulb will glow brighter.
Reason: On introducing soft iron core in the solenoid, the inductance decreases.

Q.2 **Assertion:** Soft iron is used as a core of transformer.
Reason: Area of hysteresis is loop for soft iron is small.

Q.3 **Assertion:** When capacitive reactance is smaller than the inductive reactance in LCR current, e.m.f. leads the current.
Reason: The phase angle is the angle between the alternating e.m.f and alternating current of the circuit.

Q.4 **Assertion:** A capacitor of suitable capacitance can be used in an ac circuit in place of the choke coil.
Reason: A capacitor blocks dc and allows ac only.

Q.5 **Assertion:** A given transformer can be used to step-up or step-down the voltage.
Reason: The output voltage depends upon the ratio of the number of turns of the two coils of the transformer.

Q.6 **Assertion:** In series LCR circuit resonance can take place.
Reason: Resonance takes place if inductance and capacitive reactance's are equal and opposite.

Q.7 **Assertion:** The alternating current lags behind the e.m.f. by a phase angle of $\pi/2$, when ac flows through an inductor.
Reason: The inductive reactance increases as the frequency of ac source decreases.

Q.8 **Assertion:** Capacitor serves as a block for dc and offers an easy path to ac.
Reason: Capacitive reactance is inversely proportional to frequency.

Q.9 **Assertion:** When capacitive reactance is smaller than the inductive reactance in LCR current, e.m.f. leads the current .
Reason: The phase angle is the angle between the alternating e.m.f. and alternating current of the circuit.

Q.10 **Assertion:** Chock coil is preferred over a resistor to adjust current in an ac circuit.
Reason: Power factor for inductance is zero.

Q.11 **Assertion:** If the frequency of alternating current in an ac circuit consisting of an inductance coil is increased then current gets decreased.
Reason: The current is inversely proportional to frequency of alternating current.

Q.12 **Assertion:** An alternating current does not show any magnetic effect.
Reason: Alternating current varies with time.

Q.13 **Assertion:** The dc and ac both can be measured by a hot wire instrument.
Reason: The hot wire instrument is based on the principle of magnetic effect of current.

Q.14 **Assertion:** ac is more dangerous than dc
Reason: Frequency of ac is dangerous for human body.

Q.15 **Assertion:** Average value of ac over a complete cycle is always zero.
Reason: Average value of ac is always defined over half cycle.

Q.16 **Assertion:** The divisions are equally marked on the scale of ac ammeter.
Reason: Heat produced is directly proportional to the current.

Q.17 **Assertion:** When ac circuit contain resistor only, its power is minimum.
Reason: Power of a circuit is independent of phase angle.

Q.18 **Assertion:** An electric lamp connected in series with a variable capacitor and ac source, its brightness increases with increase in capacitance.
Reason: Capacitive reactance decrease with increase in capacitance of capacitor.

Q.19 **Assertion:** An inductance and a resistance are connected in series with an ac circuit. In this circuit the current and the potential difference across the resistance lag behind potential difference across the inductance by an angle $\pi/2$.
Reason: In LR circuit voltage leads the current by phase angle which depends on the value of inductance and resistance both.

Q.20 **Assertion:** A capacitor of suitable capacitance can be used in an ac circuit in place of the choke coil.
Reason: A capacitor blocks dc and allows ac only.

SA – I (2 Marks each)
Level – 1

Q.1 (i) Define root mean square value of an alternating current.
(ii) Write the relation between peak and root mean square value of alternating current.

Q.2 Draw the graphs showing variation of inductive reactance and capacitive reactance with frequency of applied ac source.

Q.3 A lamp is connected in series with a capacitor. Predict your observation when this combination is connected in turn across
(i) AC source
(ii) a DC battery. What change would your notice in each case if the capacitance of the capacitor is increased?

Q.4 (i) Define capacitive reactance. Write its SI unit.
(ii) Why is the use of AC voltage preferred over DC voltage? Give two reasons.

Q.5 State the principal of a transformer. How is the large scale transmission of electric energy over long distances done with the use of transformers?

Q.6 Mention various energy losses in a transformer.

Q.7 At an airport, a person is made to walk through the doorway of a metal detector, for security reasons. If she/he is carrying anything made of metal, the detector emits a sound. On what principal does this detector work?

Q.8 (i) Define power factor of an ac circuit.
(ii) What are the maximum and minimum values of power factor of an ac circuit?

Level – 2

Q.1 Prove that an ideal capacitor in an ac circuit does not dissipate power.

Q.2 In a series LCR circuit, obtain the condition under which
(i) the impedance of circuit is minimum and
(ii) wattles current flows in the circuit.

Q.3 State the principal of working of a transformer. Can a transformer be used to step up or step down a DC voltage? Justify your answer.

Q.4 Differentiate between the term inductive reactance and capacitive reactance of an AC circuit.

Q.5 Write the expression for the impedance offered by the series combination of resistor, inductor and capacitor connected to an AC source of voltage, $V = V_0 sin\omega t$. Show on a graph the variation of the voltage and the current with ωt in the circuit.

Level – 3

Q.1 "An alternating current doesn't show any magnetic effect". True/false. Justify your answer.

Q.2 A power transmission line feeds input power at 2200 V to a step down transformer with its primary windings having 3000 turns. Find the number of turns in the secondary winding to get the power output at 220 V.

Q.3 A bulb B and a capacitor C are connected in series to the ac mains. The bulb glows with some brightness. How will the glow of the bulb change when a dielectric slab is introduced between the plates of the capacitor? Give reasons in support of your answer.

SA – II (3 Marks each)

Level – 1

Q.1 What is inductive reactance? If an AC voltage is applied across an inductance L, find an expression for the current I flowing in the circuit. Also show the phase relationship between current and voltage in a phasor diagram.

Q.2 What is capacitive reactance? If an ac voltage is applied across a capacitance C, find an expression for the current I flowing in the circuit. Also show the phase relationship between current and voltage in a phasor diagram.

Q.3 If the frequency of alternating current is tripled, how will it affect resistance R, inductive reactance X_L and capacitive reactance X_C?

Q.4 For a given ac circuit, differentiate between resistance, reactance and impedance.

Level – 2

Q.1 An alternating voltage $V = V_m sin\omega t$ applied to a series LCR circuit derives a current given by $i = i_m sin(\omega t + \emptyset)$. Deduce an expression for the average power dissipated over a cycle.

Q.2 When a capacitor is connected in series with a series LR circuit, the alternating current flowing in the circuit increases. Explain why.

Q.3 State the principal of an AC generator. Obtain the expression for the emf induced in a coil with labelled diagram.

Level – 3

Q.1 An inductor L of inductance X_L is connected in series with a bulb B and an AC source. How would brightness of the bulb change when (i) number of turns in the inductor is reduced. (ii) an iron rod is inserted in the inductor and (iii) a capacitor of reactance $X_C=X_L$ is inserted in series in the circuit. Justify your answer in each case.

Q.2 Does the current in an ac circuit lag, lead, or remain in phase with the voltage frequency applied to the circuit, when (i) $f=f_r$, (ii) $f<f_r$ and (iii) $f>f_r$, where f_r is the resonant frequency?

LA (5 Marks each)

Level – 1

Q.1 (i) Differentiate between the term inductive reactance and capacitive reactance of an ac circuit.

(ii) If an inductor and a resistor are connected in series in an ac circuit, what will be the mathematical expression for the impedance of this circuit. How will the impedance get affected when the frequency of applied signal is decreased and why?

Level –2

Q.1 A device X is connected across as AC source of voltage $V = V_m \sin \omega t$. The current through X is given as $i = i_m sin\left(\omega t + \frac{\pi}{2}\right)$.

(i) Identify the device X and write the expression for its reactance.

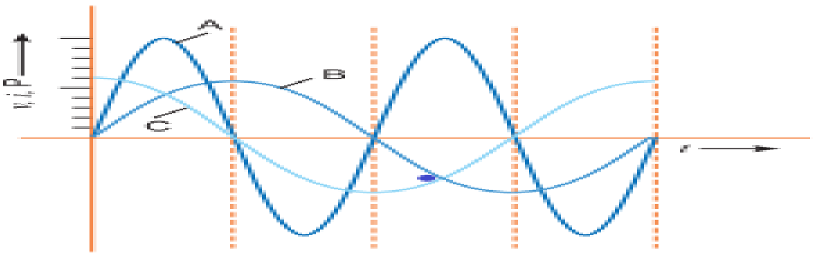
(ii) Draw graphs showing variation of voltage and current with time over one cycle of AC, for X

(iii) How does the reactance of the device X vary with frequency of the AC? Show this variation graphically.

(iv) Draw the phasor diagram for the device X.

Level – 3

Q.1 A device 'X' is connected to an ac source. The variation of voltage, current and power in one complete cycle is shown in the figure



(i) Identify the device X.

(ii) Which of the curves A, B and C represent the voltage, current and the power consumed in the circuit? Justify the answer.

(iii) How does its impedance vary with frequency of the AC source? Show graphically.

(iv) Obtain an expression for the current in the circuit and its phase relation with AC voltage.

Numericals:

Level – 1

1. An alternating voltage given by V= 280 sin 50πt is connected across a pure resistor of 40 Ω. Find
   (i) the frequency of the source.
   (ii) the rms current through the resistor.
2. A light bulb is rated as 150 W for 220 V AC supply of 60 Hz. Calculate
   (i) resistance of the bulb
   (ii) the rms current through the bulb.
3. A power transmission line feeds input power at 2200 V to a step down transformer with its primary windings having 3000 turns. Find the number of turns in the secondary winding to get the power output at 220 V.

4 Calculate the quality factor of a series LCR circuit with L=2.0 H, C= 2 μF and R= 10 Ω

Level – 2

1. A circuit containing an 80 mH inductor and a 25 mF capacitor in series connected to a 240 V, 100 rad/s supply. The resistance of the circuit is negligible. (i) obtain rms value of current (ii) what is the total average power consumed by the circuit?
2. A circuit is set up by connecting inductance L = 100 mH, resistor R = 100 Ω and a capacitor of reactance 200 Ω in series. An alternating emf of 150√ 2 V, 500/π Hz is applied across this series combination. Calculate the power dissipated in the resistor.
3. A step down transformer operated on a 2.5 kV line. It supplies a load with 20 A. The ratio of the primary winding to the secondary is 10:1. If the transformer is 90% efficient, calculate (i) the power output (ii) the voltage and (iii) the current in the secondary coil.

Level – 3

1. A 2 μF capacitor, 100 Ω resistor and 8 H inductor are connected in series with a AC source.
   (i) What should be the frequency of the source such that current drawn in the circuit is maximum? What is this frequency called?
   (ii) If the peak value of emf of the source is 200 V, find the maximum current.
   (iii) Draw graph showing variation of amplitude of circuit current with changing frequency of applied voltage in a series LCR circuit for two different values of resistance R_1 and R_2 ($R_1 > R_2$).
   (iv) Define the term sharpness of resonance. Under what condition, does a circuit become more selective?
2. The primary coil of an ideal step up transformer has 100 turns and transformation ratio is also 100. The input voltage and power are respectively 220V and 1100 W. calculate
   (i) number of turns in secondary
   (ii) current in primary
   (iii) voltage across secondary
   (iv) current in secondary
   (v) power in secondary
3. A series LCR circuit with L= 4.0 H, C= 100 μF and R= 60 Ω is connected to a variable frequency 240 V source. Calculate
   (i) the angular frequency of the source which drives the circuit at resonance
   (ii) the current at the resonating frequency
   (iii) the rms potential drop across the inductor at resonance.

Case Based questions/Source based questions:

Q.1 When electric power is transmitted over great distances, it is economical to use a high voltage and a low current to minimize the I 2R loss in the transmission lines. Consequently, 350-kV lines are common, and in many areas even higher-voltage (765-kV) lines are under construction. At the receiving end of such lines, the consumer requires power at a low voltage (for safety and for efficiency in design). Therefore, a device is required that can change the alternating voltage and current without causing appreciable changes in the power delivered. The ac transformer is that device. In its simplest form, the ac transformer consists of two coils of wire wound around a core of iron. The coil on the left, which is connected to the input alternating voltage source and has N1 turns, is called the primary winding (or the primary). The coil on the right, consisting of N 2 turns and connected to a load resistor R, is called the secondary winding (or the secondary). The purpose of the iron core is to increase the magnetic flux through the coil and to provide a medium in which nearly all the flux through one coil passes through the other coil. Eddy current losses are reduced by using a laminated core. Iron is used as the core material because it is a soft ferromagnetic substance and hence reduces hysteresis losses. Typical transformers have power efficiencies from 90% to 99%. In the discussion that follows, we assume an ideal transformer, one in which the energy losses in the windings and core are zero.

1. Name the different types of losses involve in transformer.
2. How to minimise eddy current losses in transformer?
3. What cause the Hysteresis loss?
4. Which type of transformer used at the receiving end?

Competency based questions:

Q.1 An alternating current is that whose magnitude changes continuously with time and direction reverses periodically and the current that flows with same magnitude in same direction is direct current.

(i) If an ammeter is used to measure alternating current in circuit, which value of current will it read

(a) Peak (b) rms (c) Instantaneous (d) Average

(ii) If T is the time period of given alternating current, then how much time it requires to reach its peak value starting from zero

(a) T (b) T/2 (c) T/4 (d) T/8

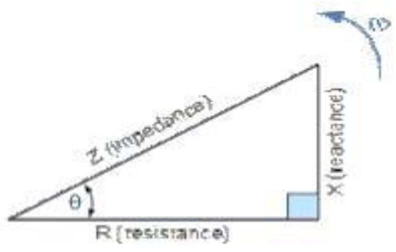
(iii) What is the average value of alternating current over one complete cycle

(a) 0 (b) I_m (c) $I_m/2$ (d) $I_m/4$

(iv)For a 220 V mains of alternating voltage peak value will be

(a) 220 V (b) $220/\sqrt{2}$ V (c) $220\sqrt{2}$ V (d) 110 V

Q.2 Quantity that measures the opposition offered by a circuit to the flow of current is called impedance. For an ac circuit, reactance corresponding to inductor and capacitor is also considered, along with resistance. So, impedance for the ac circuit can be given mathematically as $Z^2 = R^2 + X^2$, where X is the reactance.



Impedance Triangle

Impedance triangle is a right-angled triangle given as in the diagram and satisfy the above mathematical equation. Also phase angle ∅ between current and voltage can be given by using this impedance triangle.

(i) Impedance for a purely capacitive circuit depends on

(a) f (b) 2f (c) 1/f (d) 1/2f

(ii) Impedance for a purely inductive circuit depends on

(a) f (b) 2f (c) 1/f (d) 1/2f

(iii) For ac circuit containing resistor only, value of Φ will be

(a)0 (b) π/2 (c) - π/2 (d) π

(iv) What is the impedance of a capacitor with capacitance C in an ac circuit having source of frequency 50 Hz

(a) 1/C (b) 1/50 C (c)1/100 C (d) 1/314 C

CCT Based Question:

Q.1 An airport metal is essentially a resonant circuit. The portal you step through is an inductor (a large loop of conducting wire) that is part of the circuit. The frequency of the circuit is tuned to the resonant frequency of the circuit when there is no metal in the inductor. Any metal on your body increases the effective inductance of the loop and changes the current in it. When you pass through a metal detector, you become part of a resonant circuit. As you step through the detector, the inductance of the circuit changes, and thus the current in the circuit changes.

1. What is resonance?
2. On what factors does resonance frequency depends?
3. For the metal detector to detect a small metal object the sharpness of the current versus frequency graph be more or less? Justify your answer.
4. What is impedance of the circuit at resonance?

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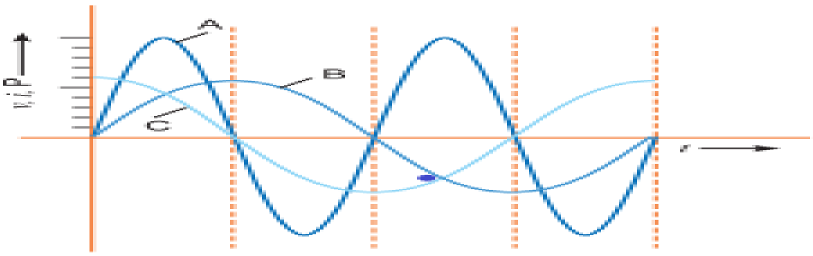
SELF ASSESSMENT

MAX. MARKS: 25 **TIME: 40 MIN.**

Q. No.	Questions	Marks
	GENERAL INSTRUCTIONS: **(1)** There are 12 questions in all. All questions are compulsory **(2)** This question paper has five sections: Section A, B, C, D and E. All the sections are compulsory. **(3)** Section A contains 4 MCQ and 2 assertion reason question of 1 mark each, Section B contains 2 questions of 2 mark each, Section C contains 2 questions of 3 marks, Section D contains 1 case study based question of 4 marks and Section E contains 1 long answer questions of 5 marks. **(4)** There is no overall choice. However, an internal choice has been provided in Section B, C, and E. You have to attempt only one of the choices in such questions. Use of calculators is not allowed.	
	Section – A	
1	In the case of an inductor (a) voltage lags the current by $\frac{\pi}{2}$ (b) voltage leads the current by $\frac{\pi}{2}$ (c) voltage lags the current by $\frac{\pi}{3}$ (d) voltage lags the current by $\frac{\pi}{4}$	1
2	In an A.C. circuit the current (a) Always leads the voltage (b) Always lags behind the voltage (c) Is always in phase with the voltage (d) May lead or lag behind or be in phase with the voltage	1
3	A power transformer is used to step up an alternating e.m.f. of 220 V to 11 kV to transmit 4.4 kW of power. If the primary coil has 1000 turns, what is the current rating of the secondary? Assume 100% efficiency for the transformer (a) 4 A (b) 0.4 A (c) 0.04 A (d) 0.2 A	1
4	The turns ratio of a transformer is given as 2:3.If the current through the primary coil is 3A, then the current in secondary coil is (a) 1A (b) 4.5A (c) 2A (d) 1.5A	1
	Directions for Q. No.5 and 6 (a) If both assertion and reason are true and the reason is the correct explanation of the assertion. (b) If both assertion and reason are true but reason is not the correct explanation of the assertion.	

	(c) If assertion is true but reason is false. (d) If the assertion and reason both are false	
5	**Assertion:** A given transformer can be used to step-up or step-down the voltage. **Reason:** The output voltage depends upon the ratio of the number of turns of the two coils of the transformer.	1
6	**Assertion:** In series LCR circuit resonance can take place. **Reason:** Resonance takes place if inductance and capacitive reactance's are equal and opposite.	1
	Section – B	
7	A resistor R and an element X are connected in series to an AC source of voltage. The voltage is found to lead the current in phase by $\frac{\pi}{4}$. If X is replaced by another element Y, the voltage lags behind the current by $\frac{\pi}{4}$. (i) Identify elements X and Y. (ii) When both X and Y are connected in series with R to the same source, will the power dissipated in the circuit be maximum or minimum? Justify your answer.	2
8	A power transmission line feeds power at 2200 V with a current of 5 A to step down transformer with its primary windings having 4000 turns. Calculate the number of turns and the current in the secondary in order to get output power at 220 V.s	2
	OR	
8	A resistor of resistance 400 Ω, and a capacitor of reactance 200 Ω, are connected in series to a 220V, 50 Hz ac source. If the current is 0.49 A, find Voltage across the resistor and capacitor.	2
	Section – C	
9	What is inductive reactance? If an AC voltage is applied across an inductance L, find an expression for the current I flowing in the circuit. Also show the phase relationship between current and voltage in a phasor diagram.	3
	OR	
9	What is capacitive reactance? If an ac voltage is applied across a capacitance C, find an expression for the current I flowing in the circuit. Also show the phase relationship between current and voltage in a phasor diagram.	3
10	In a series LCR circuit L= 10 H,C= 40 μF and R= 60 Ω are connected to a variable frequency 240 V source. Calculate (i) The angular frequency of the source which derives the circuit at resonance. (ii) The current at the resonating frequency. (iii) The rms potential drop across the inductor at resonance.	3
	Section – D	
	Case Study Based question.	
11	An alternating current is that whose magnitude changes continuously with time and direction reverses periodically and the current that flows with same magnitude in same direction is direct current.	4

	(i) If an ammeter is used to measure alternating current in circuit, which value of current will it read (a) Peak (b) rms (c) Instantaneous (d) Average (ii) If T is the time period of given alternating current, then how much time it requires to reach its peak value starting from zero (b) T (b) T/2 (c) T/4 (d) T/8 (iii) What is the average value of alternating current over one complete cycle (b) 0 (b) I_m (c) $I_m/2$ (d) $I_m/4$ (iv)For a 220 V mains of alternating voltage peak value will be (b) 220 V (b) $220/\sqrt{2}$ V (c) $220\sqrt{2}$ V (d) 110 V	
	Section – E	
12	Explain with the help of a labelled diagram, the principle and working of an ac generator. Write the expression for the emf generated in the coil in terms of speed of rotation. Can the current produced by an ac generator be measured with a moving coil galvanometer?	5
	OR	
12	(i) A device ‘X’ is connected to an ac source. The variation of voltage, current and power in one complete cycle is shown in the figure.  (a) Which curve shows power consumption over a full cycle? (b) What is the average power consumption over a cycle? (c) Identify the device ‘X’. (ii) A light bulb is rated as 150 W for 220 V AC supply of 60 Hz. Calculate (a) resistance of the bulb (b) the rms current through the bulb.	5

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