CHAPTER : 7 ALTERNATING CURRENT

CATEGORY : I

Very Short Answer Type Questions (1 mark)

1. Write any two factors responsible for energy losses in actual transformers.

   Ans : Eddy currents, Flux leakage.

2. The rms value of AC is 10 A. What is its peak value?

   Ans : $i_{rms} = \frac{i_m}{\sqrt{2}}$ and Peak value, $i_m = \ = \sqrt{2} \times 10 = 14.1$ A

3. Can we use ordinary ammeters to measure AC?

   Ans: No, Hot wire Ammeters are used measure alternating current.

4. Define capacitive reactance. Write its S I Unit.

   Ans : It is the resistance offered by the capacitor to the flow of ac. Its S I unit is ohm(Ω).

5. Which is ahead in phase- current or voltage and by how much in an AC circuit containing a pure inductor ?

   Ans : voltage is ahead of the current by a phase angle $\frac{\pi}{2}$

6. Why is it not possible to have electrolysis by alternating current?

   Ans : Because AC keeps reversing its direction after every half cycle. So ions do not move towards the electrodes.

7. Can a series LCR ac circuit be made purely resistive ? How ?

   Ans : Yes. When $X_L = X_C$, then impedance, Z =R

8. Write the principle of AC generator.

   Ans : Electromagnetic Induction

9. Express the turn ratio of a transformer in terms of voltages.

Ans : $\frac{N_S}{N_P} = \frac{V_S}{V_P}$

10. What is the dimensional formula for $\sqrt{LC}$?

Ans : $M^0 L^0 T^1$

Assertion -Reason Type Questions :

Two statements are given- one labelled as Assertion (A) and the other labelled as 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

1. **Assertion** : If the frequency of alternating current in an AC circuit consisting of an Inductor is increased, then the current gets decreased.

   Reason : The current is inversely proportional to frequency of AC.

   Ans : (a)

   The maximum current through an AC circuit containing inductor is

   $i_m = \frac{V_m}{\omega L} = \frac{V_m}{2\pi \nu L}$

2. **Assertion :** In series LCR resonance circuit, the impedance is equal to the ohmic resistance.

   Reason : At resonance, the inductive reactance exceeds the capacitive reactance.

   Ans : (C)

   At resonance, $X_L = X_C$, therefore Z = R

3. **Assertion** : It is advantageous to transmit electric power at high voltage.

   Reason : High voltage implies high current

   Ans : (C)

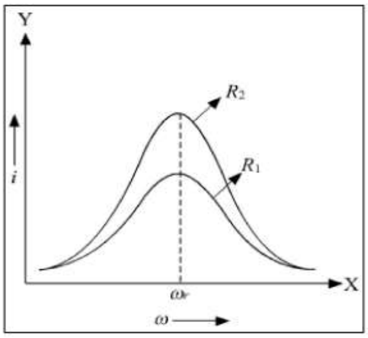
For a given electric power , P = V I , high voltage implies low current.

Short Answer Type Questions (2 marks)

1. Draw a graph showing the variation of amplitude of circuit current with changing frequency of applied voltage in a series LCR circuit of two different values of resistances R_1 and R_2 ($R_1 > R_2$).

Ans :

At resonance, $i_m = \frac{V_m}{R}$



2. Why is the use of AC voltage preferred over DC voltage? Give two reasons?

Ans : (i) AC can be easily and efficiently converted from one voltage to the other by using transformers.

(ii) AC can be transmitted over longer distances without much loss of energy

3. When an AC source is connected to an ideal capacitor, show that the average power supplied by the source over a complete cycle is zero.

Ans : $P_{inst} = v\,i = V_m \sin\omega t\; i_m \sin(\omega t + \frac{\pi}{2}) = V_m i_m \sin\omega t\,[\cos\omega t]$

$P_{inst} = \frac{V_m i_m}{2} \sin 2\omega t$

Average Power over one complete cycle , $P = \int_0^T P_{inst} = \frac{V_m i_m}{2} \int_0^T \sin \omega t \, dt = 0$

No Power is consumed when ac passes through a pure capacitor.

4. What is the expression for magnetic energy stored in an inductor. Compare it with the electrostatic energy stored in the capacitor?

Ans :

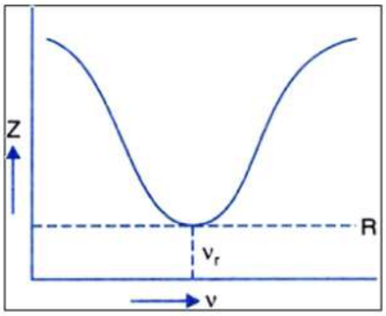
Magnetic energy = $\frac{1}{2} L I^2$

Electrostatic energy = $\frac{1}{2} CV^2$

5. Sketch a graph showing the variation of Impedance of LCR circuit with the frequency of applied voltage. Also write the expression for impedance.

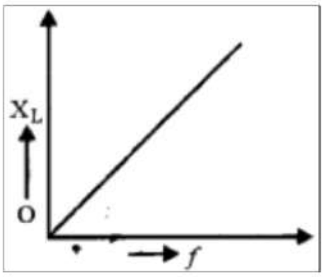
Ans :

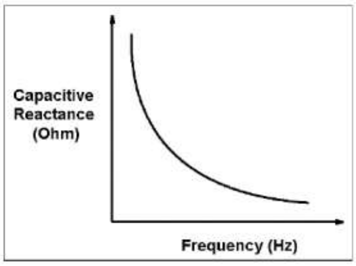
Impedance, $Z = \sqrt{R^2+(X_L - X_C)^2}$



6. Draw the graphs showing the variation of inductive reactance and capacitive reactance with frequency of applied AC source.

Ans :





7. Define rms value of alternating current and write its expression.

Ans : It is the equivalent direct current that would produce the same power loss as ac passes through the same resistor for a given time.

Heat energy produced in resistor for t time, $H = P_{ac}\, t = P_{dc}\, t$

$H = ½\, i_m^2 R\, t = I^2 Rt,\ \frac{i_m^2}{2} = I^2$

Therefore , $I = i_{rms} = \frac{i_m}{\sqrt{2}} = 70.7\ \%\ i_m$

<u>Short Answer Type Questions (3 marks)</u>

1. For a given AC, $i = i_m \sin\omega t$ = i_msinωt , show that the average power dissipated in a resistor R over a complete cycle is $½\, i_m^2 R$

Ans : Instantaneous Power through a resistor , $P = i^2 R = (i_m \sin\omega t\,)^2 R$

Average Power, $P = \langle\, (i_m \sin\omega t\,)^2 R \rangle = i_m^2 R \left\langle \frac{1-\cos2\omega t}{2} \right\rangle = ½\, i_m^2 R - ½\, i_m^2 R\, \langle \cos2\omega t \rangle$

$P = ½\, i_m^2 R$ since $\langle \cos2\omega t \rangle = 0$

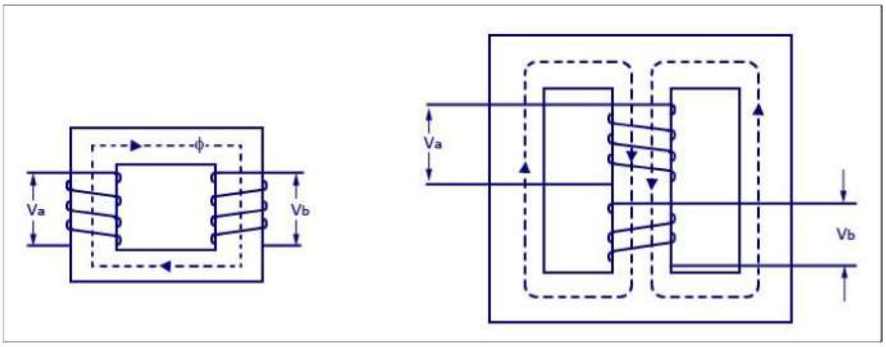
2. (a) Show diagrammatically the two different arrangements used for winding the primary and secondary coils in a transformer. Assuming the transformer to be ideal one, write the expression for the ratio of its

(i) output voltage to input voltage (ii) output current to input current .

(iii) Mention any two energy losses in an actual transformer.

Ans :

(a)



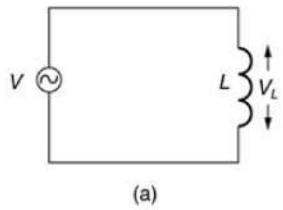
(i) $V_S / V_P = N_S / N_p$ (ii) $I_S / I_P = N_P / N_S$

(iii) Copper loss and Eddy current loss

3. Show that the current lags behind the voltage in phase by $\frac{\pi}{2}$ in an AC circuit containing an ideal inductor. Draw the phasor diagram to support your answer.

Ans :

Let the instantaneous voltage , $V = V_m \sin\omega t$ ------------------
-(1)



Applying Kirchhoff's Rule to the Loop, $V - V_L = 0$

Emf across the inductor, $V_L = e = L \frac{di}{dt}$

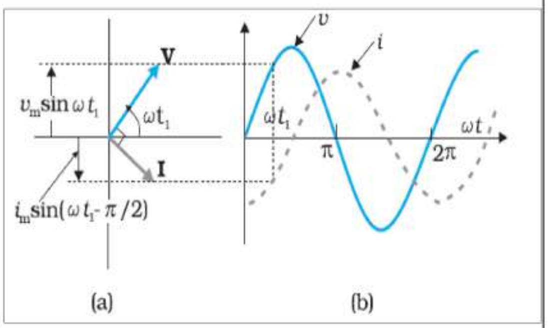
$V_m \text{Sin}\omega t = L \frac{di}{dt}$

$\frac{di}{dt} = \frac{V_m}{L} \sin\omega t$, $di = \frac{V_m}{L}$ V_m/L $\sin\omega t \, dt$

$i = \frac{V_m}{L} \int \sin\omega t \, dt = \frac{V_m}{L} [- \frac{\cos\omega t}{\omega}] = \frac{V_m}{\omega L}$

$\sin(\omega t - 90) = i_m \sin(\omega t - \frac{\pi}{2})$-------------(2)

where $i_m = \frac{V_m}{\omega L} = \frac{V_m}{X_L}$, where X_L is called Inductive reactance.[It is the resistance offered by the inductor to the flow of ac]



From (1) and (2) , the current lags behind the voltage by a phase angle $\frac{\pi}{2}$ when ac passes through an inductor.

4. A 1.5 μ F capacitor has a capacitive reactance of 12 Ω. What is the frequency of the source? If the frequency of the source is doubled, what will be the capacitive reactance?

Solution :

Capacitive reactance , $X_C = \frac{1}{\omega C} = \frac{1}{2\pi v C}$

$$12 = \frac{1}{2 \times 3.14 \times v \times 1.5 \times 10^{-6}}$$

v = 8846 Hz8846 Hz

When frequency is doubled, capacitive reactance becomes half, X_C = 6 Ω

5. In a Series LCR circuit, a resistance of 400Ω, capacitor of 2 μ F and an inductor of 100 mH are connected to an AC source, represented as

$V = V_0 \sin(1000t + \phi)$. Determine the phase difference between the current and voltage?

Solution :

$X_L = \omega L = 1000 \times 100 \times 10^{-3} = 100\Omega$

$X_C = \frac{1}{\omega C} = \frac{1}{1000 \times 2 \times 10^{-6}} = 500\Omega$

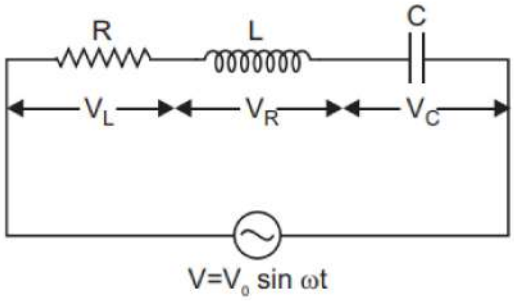
Phase difference between V and I is $\tan\varnothing = \frac{X_C - X_L}{R} = \frac{500-100}{400} = 1$

$\varnothing = \frac{\pi}{4}$ rad

Long Answer Type Questions (5 marks)

1. In a series LCR circuit, connected to an AC source, $V = V_m \sin\omega t$, use phasor diagram to derive an expression for the current in the circuit and hence impedance of the circuit.

Ans :



(a)

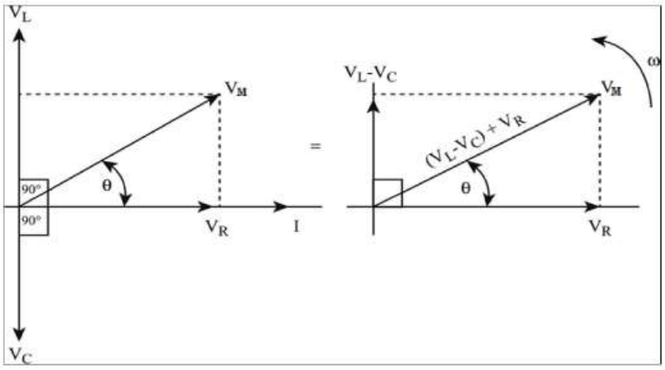
Instantaneous voltage , $V = V_m \sin\omega t$

At any instant, current , $i = i_m \sin(\omega t + \varnothing)$ where $\varnothing$ is the phase difference between the voltage across the source and the current.

Let V_L, V_R and V_C be the phasors representing voltage across the inductor, resistor and capacitor respectively.

V_R is parallel to current I , V_L is ahead I by $\frac{\pi}{2}$ and V_C is behind I by $\frac{\pi}{2}$.

Let us consider $V_L > V_C$. Since V_L and V_C are in same line and opposite direction, they can be combined to a single phasor $V_L - V_C$. The resultant of $V_L - V_C$ and V_R is $\mathbf{V_M}$.



By parallelogram law of vector addition, $V_M = \sqrt{V_R^2+(V_L - V_C)^2}$

$V_R = i_m R$, Maximum voltage across R

$V_L = i_m X_L$, Maximum voltage across L

$V_C = i_m X_C$, Maximum voltage across C

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

Current in the circuit, $i_m = \frac{V_m}{\sqrt{R^2+(X_L - X_C)^2}}$

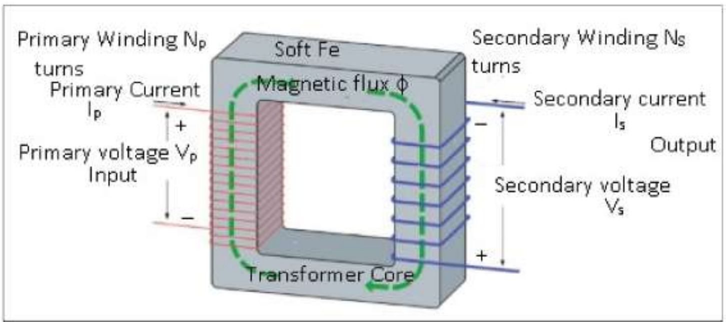
$\frac{V_m}{i_m} = \sqrt{R^2+(X_L - X_C)^2}$, $\frac{V_m}{i_m}$ = Z, Impedance of the LCR series circuit.

$Z = \sqrt{R^2+(X_L - X_C)^2}$, Impedance is the total resistance offered by the LCR series circuit to the flow of ac.

2. Draw a labelled circuit arrangement showing the windings of primary and secondary coils in a transformer. Explain the underlying principle and the working of a transformer.

Ans :

Principle : Mutual Induction



Construction:

It consists of two coils wound on a soft iron core . Let the number of turns in primary be N_P and that of secondary be N_S.

Input voltage is given to primary and output voltage is taken from secondary coil.

For step Up transformer $N_S > N_P$

For step down transformer $N_P > N_S$

Theory :

When ac passes , the flux linked with the coil changes. Let ∅ be the flux linked with the coil.

The induced emf induced in primary, $E_P = -N_P \frac{d\varnothing}{dt} = V_P$-------------------(1)

The induced emf induced in secondary, $E_S = -N_S \frac{d\varnothing}{dt} = V_S$-------------------(2)

From (1) and (2) $\frac{V_S}{V_P} = \frac{N_S}{N_P}$

If the transformer is assumed to be 100 % efficient,

Input power = Out put power

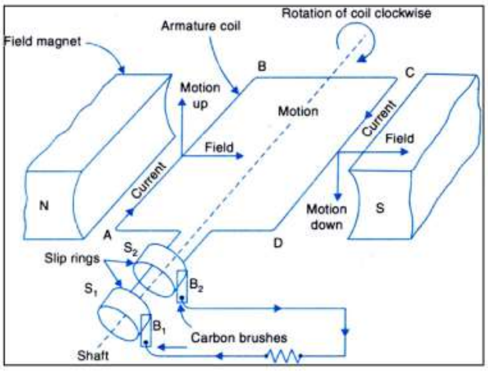
$V_P i_P = V_S i_S$

$\frac{V_S}{V_P} = \frac{N_S}{N_P} = \frac{i_P}{i_S}$ $\qquad\qquad$ $\frac{N_S}{N_P}$ = K, Transformer turn Ratio.

3. Draw a schematic sketch of an AC generator. State briefly its working principle. Obtain the expression for the induced emf in a coil rotating with constant angular speed. Show a plot of variation of alternating emf versus angle.

Ans :

Principle : Electro Magnetic Induction



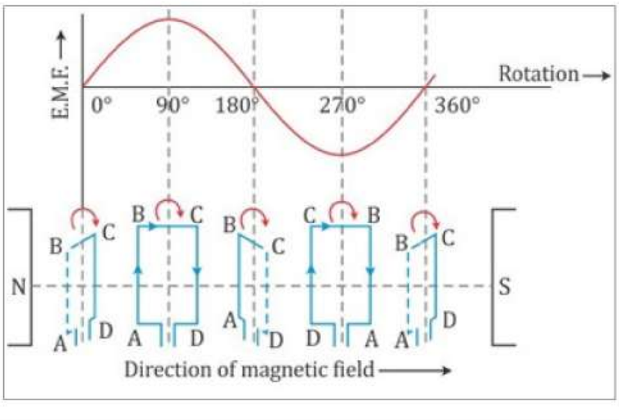
Theory :

When the coil is rotated with constant angular velocity 'ω', θ = ωt

The flux at any time, ∅ = BA Cos θ = BA Cos ωtBA Cos θ=BA Cos ωt

, the induced emf in the coil is

$E = -N\frac{d\varnothing}{dt} = -NBA\frac{d(\cos\omega t)}{dt}$ = NBAω sin ωt

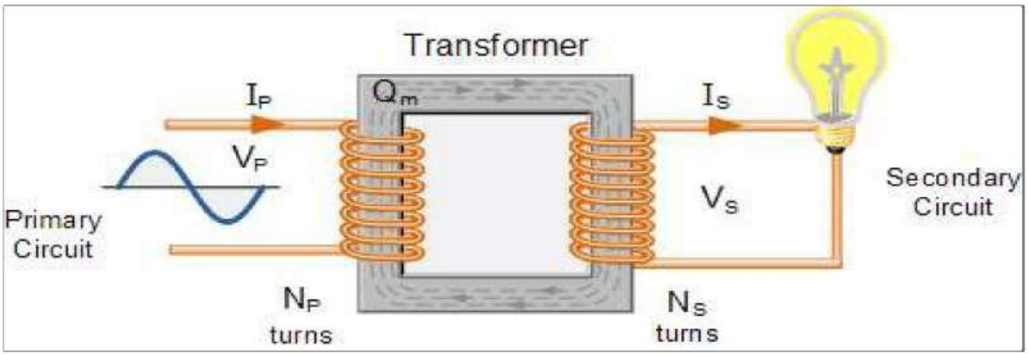


E = E_0 sin ωt where E_0 is the maximum value of emf .

ω = 2πν where ν is the frequency of revolution

Graph :

CASE BASED QUESTION : (4 MARKS)



A transformer is an electrical machine which transfers AC electrical power from one circuit to other at a constant frequency, but voltage can be altered according to the requirement. It works on the principle of mutual induction. Number of turns in the primary and secondary coil decides a transformer to be step up or step down. It is widely used for long distance power transmission.

(1) In a step up transformer, the number of turns in primary coil is

a) Less than that in secondary coil
b) More than that in secondary coil.
c) Same as that in secondary coil.
d) None of these

(2) Laminated iron core is used to reduce

(a) Hysteresis loss
(b)Eddy current loss
(c)Copper loss

(d) Flux loss

(3) In step up transformer Voltage is increased at the cost of

(a) Power is reduced & Current is constant

(b)Power & Current are reduced

(c)Power is constant & Current is reduced

(d)Power is increased & Current is reduced

(4) For an ideal Transformer, the efficiency(η) is

(a) greater than 1

(b) less than 1

(c) equal to 1

(d) zero

(5) In a transformer, the number of turns of primary and secondary coil are 500 and 400 respectively. If 200 V ac supply is given to primary coil, then the ratio of currents in primary and secondary coil is

(a) 4:5

(b) 5:4

(c) 5:9

(d) 9:5

Answers :

(1) a (2) b (3) C (4) C (5) a