NEHA. K ①
ECE-C

UNIT I : INTRODUCTION TO ELECTRICAL ENGINEERING AND DC CIRCUITS.

SHORT ANSWER QUESTIONS:

1Q) Define Potential Difference and Current.

Ans) The difference in potential energy between two charges is called potential difference. It is expressed in Volts (V).

Current is defined as the rate of flow of electrons. It is expressed in Amperes (A). $I = \frac{q}{t}$

2Q) Define active and passive elements.

Ans) Active elements are those which are capable of giving power or energy to other external devices.
Ex: Energy sources (Voltage sources or current sources).

Passive elements are those which are capable of receiving energy.
Ex: Resistors, inductors, capacitors etc.

3Q) Define unilateral and bilateral elements.

Ans) Unilateral elements are those in which voltage and current relationship is not same for current flowing in either directions. The elements allow current in one direction only.
Ex: Diodes, rectifiers.

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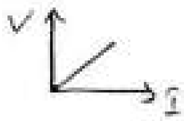
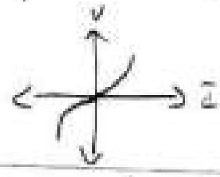
Bilateral elements are those in which voltage and current relationship is same for current flowing in both directions.
Ex: Resistors, inductors, capacitors.

4Q) Define linear and non-linear elements.

Ans) Linear elements are those which obey Ohm's law and their V-I relationship is linear.
Eg: Resistors, inductors, capacitors.



Non-linear elements are those which do not obey Ohm's law and their V-I relationship is non-linear.
Eg: Diodes, rectifiers



5Q) State Ohm's law. Write the limitations of Ohm's law.

Ans) Ohm's law states that "At any constant temperature, the current flowing through a material is directly proportional to the voltage across the material.

Limitations of Ohm's law:

(i) This law is applicable at constant temperatures only.
(ii) This law is applicable only for linear elements (Resistors, inductors, capacitors etc).
It is not applicable for non-linear elements like diodes, rectifiers etc.

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6Q) Write the difference between series and parallel resistive circuits.

Ans)

SERIES	PARALLEL
- The current flowing through all the elements is same but the voltage gets divided across each element	- The voltage across each element is same but the current gets divided across each element.
- A series resistive circuit acts as a voltage divider circuit.	- A parallel resistive circuit acts as a current divider circuit

7Q) Write voltage and current relationships for passive elements.

Ans) For Resistor,

$\boxed{V = IR}$ and $\boxed{I = \frac{V}{R}}$

For Inductor,

$\boxed{V(t) = L\frac{di(t)}{dt}}$ and $\boxed{i(t) = \frac{1}{L}\int v(t)\,dt}$.

For capacitor,

$\boxed{dv(t) = \frac{1}{C}\int i(t)\,dt}$ and $\boxed{i(t) = C\frac{dv(t)}{dt}}$

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8Q) The voltage across 4Ω resistor is 8V. Find the current and power dissipated in that resistor.

Ans) Given $V = 8V$, $R = 4\Omega$

$$V = IR \Rightarrow I = \frac{V}{R}$$

$$\Rightarrow I = \frac{8}{4} = \underline{2A}$$

$$P = VI = 8 \times 2 = \underline{16W}$$

9Q) A current $i = 10e^{-t}$ is applied to a 2H inductor. What is its respective voltage?

Ans) Given $i = 10e^{-t}$, $L = 2$

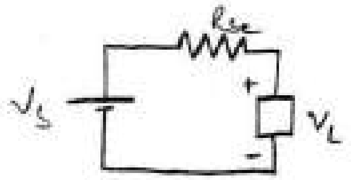
$$L = \frac{v(t)}{\left(\frac{di(t)}{dt}\right)}$$

$$\frac{di}{dt} = -10e^{-t}$$

$$2 = \frac{v(t)}{-10e^{-t}} \Rightarrow v(t) = \underline{-20e^{-t}}$$

10Q) What are practical and ideal voltage sources? Draw their V-I characteristics.

Ans) Practical voltage sources are those that have a small internal resistance (R_{se}) which will be connected in series to the ideal voltage source. Due to the internal resistance, if the load current increases, load voltage will decrease.



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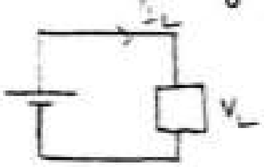
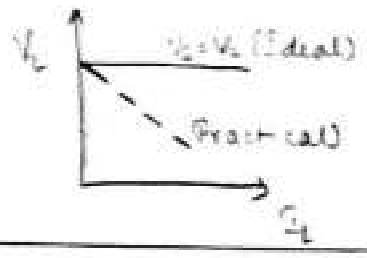
Ideal voltage sources are those which give constant voltage across the load terminals irrespective of the current flowing through the load terminals.

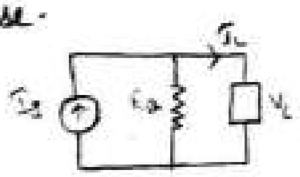


V-I characteristics:

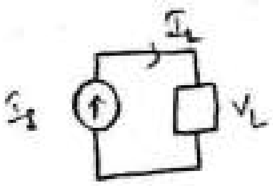


11Q) What are practical and ideal current sources? Draw their V-I characteristics.

Ans) Practical current sources are those ~~ra~~ which have large internal resistance connected in parallel to the ideal current source. With the increase in voltage due to the shunt resistance, load current will decrease.



Ideal current sources are those which give constant current through the load irrespective of the voltage that appears across the load terminals.



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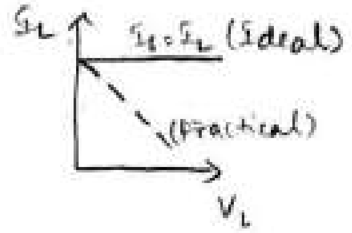
V-I characteristics:



12Q) What are the types of dependent sources?

Ans) There are two types of dependent sources:

(i) Voltage dependent sources

(ii) Current dependent sources.

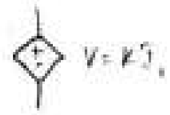
The voltage dependent sources are further divided into:

a) Voltage dependent voltage sources - These give voltage as a function of voltage:

$$V = KV_1$$

where K is a constant

b) Current dependent voltage sources - These give voltage as a function of current:



$$V = KI_1$$

where K is a constant.

The current dependent sources are further classified into:

a) Voltage dependent current sources - These give current as a function of voltage:

$$I = KV_1$$

where K is a constant

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b) Current dependent current sources – These give current as a function of current

$i = kI,$

where k is a constant.

13Q) Two resistors each of 4Ω and 12Ω are connected in parallel and the parallel combination is connected in series with a 2Ω resistor. What is the total resistance?

Ans)

Equivalent resistance of parallel combination:

$$R' = \frac{12 \times 4}{12+4} = \frac{48}{16} = 3\Omega.$$

$\therefore$ Total resistance $R = 3+2 = \underline{5\Omega}$

14Q) State Kirchhoff's laws.

Ans) (i) Kirchhoff's current law:

This law states that the algebraic sum of the currents entering into a node or junction point is equal to the algebraic sum of the currents leaving from the node or junction point.

$$i_1 + i_2 = i_3 + i_4$$

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(ii) Kirchhoff's voltage law:
This law states that the algebraic sum of the branch voltages around any closed path (mesh or loop) equals to zero.

$$V - IR_1 - IR_2 = 0.$$

15B) Write the expressions of delta to star transformation.

$$\boxed{R_1 = \frac{R_{12}R_{31}}{R_{12}+R_{23}+R_{31}}} \quad \boxed{R_2 = \frac{R_{23}R_{12}}{R_{12}+R_{23}+R_{31}}} \quad \boxed{R_3 = \frac{R_{31}R_{23}}{R_{12}+R_{23}+R_{31}}}$$

16a) Write the expressions of star to delta transformation.

$$\boxed{R_{12} = \frac{R_1R_2}{R_3} + R_1+R_2} \quad \boxed{R_{23} = \frac{R_2R_3}{R_1} + R_2+R_3}$$

$$\boxed{R_{31} = \frac{R_3R_1}{R_2} + R_3+R_1}$$

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17Q) Write the expressions for resistors, inductors and capacitors connected in series and parallel.

Ans)

Resistors :	Inductors	Capacitors
Series : $R_{eq} = R_1 + R_2 + \dots R_n$	Series : $L_{eq} = L_1 + L_2 + \dots L_n$	Series : $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} \dots + \frac{1}{C_n}$
Parallel : $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \dots \frac{1}{R_n}$	Parallel : $\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2} \dots + \frac{1}{L_n}$	Parallel : $C_{eq} = C_1 + C_2 \dots + C_n$

18Q) If the resistors 2Ω and 3Ω are connected in parallel across a 10A source, find the current flowing in 2Ω resistor.

Ans)

$$I_2 = \frac{I R_1}{R_1 + R_2} \Rightarrow I_2 = \frac{10(3)}{3+2}$$

$$I_2 = \frac{30}{5} = \underline{6A}$$

19Q) State superposition theorem.

Ans) In any linear bilateral network consisting of two or more sources, the response in any element equals to the algebraic sum of the responses when the individual sources are acting alone.

20Q) State Thevenin's theorem.

Ans) Any linear bilateral network consisting of active and passive elements can be replaced with an equivalent circuit consisting of one equivalent voltage source (V_{TH}) and one equivalent resistance (R_{TH}) across the load terminals.

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LONG ANSWER QUESTIONS:

1Q) Explain active and passive elements in detail.

Ans) Active elements are those which are capable of giving power or energy to the other external devices.

Eg: Energy sources (voltage/ current sources).

If the network consists of at least one active element, that network is said to be an active network.

Energy sources can either be DC sources or AC sources.

The value of DC sources does not vary with time.

The value of AC sources varies with time.

The energy sources are classified as:

(i) Independent : The value of these sources does not depend on other voltages or currents in the circuit or network. These sources have fixed value.

(ii) Dependent : Refer Q12 in short questions

Passive elements: Refer Q2 in short questions.

A resistor is an element which opposes the flow of electrons by a certain amount called its resistance.

An inductor is an element which stores energy in the form of electromagnetic fields.

A capacitor is an element which stores energy in the form of electrostatic fields.

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2Q) Explain the types of sources and Kirchhoff's laws

Ans) Types of sources - Refer Q1 long answer questions.
Kirchhoff's laws - Refer Q14 short answer questions.

3Q) Derive the expressions for delta to star transformation

Ans)

The equivalent resistance between terminals 1 and 2 for star network $= R_1 + R_2$

The equivalent resistance between terminals 1 and 2 for delta network $= \dfrac{R_{12}R_{23} + R_{12}R_{31}}{R_{12} + R_{23} + R_{31}}$

If these two networks are equivalent,

$$R_1 + R_2 = \frac{R_{12}R_{23} + R_{12}R_{31}}{R_{12} + R_{23} + R_{31}} \quad \text{—(1)}$$

Similarly,

$$R_2 + R_3 = \frac{R_{23}R_{31} + R_{23}R_{12}}{R_{12} + R_{23} + R_{31}} \quad \text{—(2)}$$

Similarly,

$$R_3 + R_1 = \frac{R_{31}R_{12} + R_{31}R_{23}}{R_{31} + R_{12} + R_{23}} \quad \text{—(3)}$$

Eqn(1) − Eqn(2)

$$R_1 + \cancel{R_2} - \cancel{R_2} - R_3 = \frac{R_{12}\cancel{R_{23}} + R_{12}R_{31} - R_{23}R_{31} - \cancel{R_{23}}R_{12}}{R_{12} + R_{23} + R_{31}}$$

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$$R_1 - R_3 = \frac{R_{12}R_{31} - R_{23}R_{31}}{R_{12} + R_{23} + R_{31}} \quad — (4)$$

Eqn (3) + Eqn (4)

$$\cancel{R_3} + R_1 + R_1 - \cancel{R_3} = \frac{R_{31}R_{12} + \cancel{R_{31}R_{23}} + R_{12}R_{31} - \cancel{R_{23}R_{31}}}{R_{12} + R_{23} + R_{31}}$$

$$\cancel{2}R_1 = \frac{\cancel{2}R_{12}R_{31}}{R_{12}+R_{23}+R_{31}}$$

$$\boxed{R_1 = \frac{R_{12}R_{31}}{R_{12}+R_{23}+R_{31}}}$$

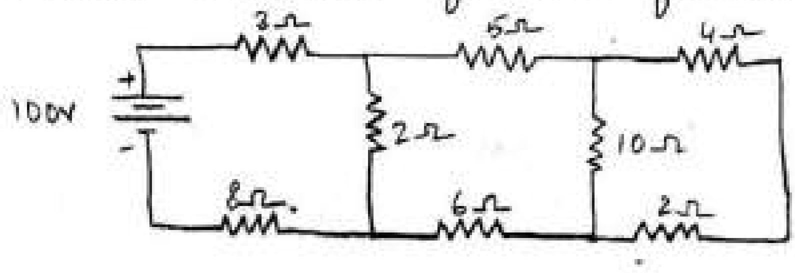
Similarly,

$$\boxed{R_2 = \frac{R_{23}R_{12}}{R_{12}+R_{23}+R_{31}}}$$

Similarly,

$$\boxed{R_3 = \frac{R_{31}R_{23}}{R_{12}+R_{23}+R_{31}}}$$

4Q) Calculate the R_{eq} across the terminals of the supply and total current for the following network:



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Combining series-parallel resistances,

$$R_{eq} = [\{((4+2) \| 10) + 5 + 6) \| 2\}] + 3 + 8$$

$$R_{eq} = \left[\left\{\left(\frac{6 \times 10}{6+10}\right) + 5 + 6\right\} \| 2\right] + 3 + 8$$

$$R_{eq} = \left[\left(\frac{60}{16} + 11\right) \| 2\right] + 11$$

$$R_{eq} = \left[\left(\frac{60 + 176}{16}\right) \| 2\right] + 11$$

$$R_{eq} = \left(\frac{236}{16} \| 2\right) + 11$$

$$R_{eq} = (14.75 \| 2) + 11$$

$$R_{eq} = \frac{14.75 \times 2}{14.75 + 2} + 11$$

$$R_{eq} = \frac{29.5}{16.75} + 11$$

$$R_{eq} = \frac{29.5 + 184.25}{16.75}$$

$$R_{eq} = \underline{12.76}\,\Omega$$

$$I = \frac{V}{R_{eq}} = \frac{100}{12.76} = \underline{7.84}\,A.$$

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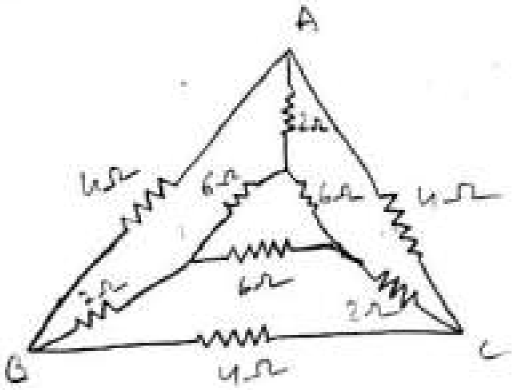
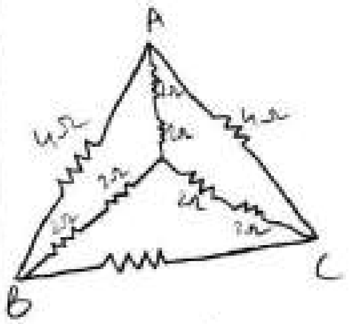
5Q) Obtain the equivalent resistance between B and C for the following network using Δ-Y and Y-Δ conversion.



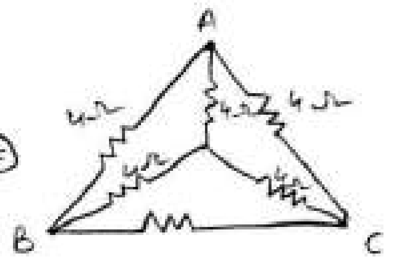
Converting inner 6Ω delta network into star, ~~we get~~, the value of each resistance in star network becomes:

$$R_1 = R_2 = R_3 = \frac{6(6)}{6+6+6} = \frac{36}{18} = 2\Omega$$

The network now becomes



Since the 2Ω resistors are in series ⇒



Converting inner 4Ω star network into delta network, each ~~to~~ resistance value of the delta network becomes

$$R_{12} = R_{23} = R_{31} = \frac{4(\cancel{4})}{\cancel{4}} + 4 + 4 = 12\Omega$$

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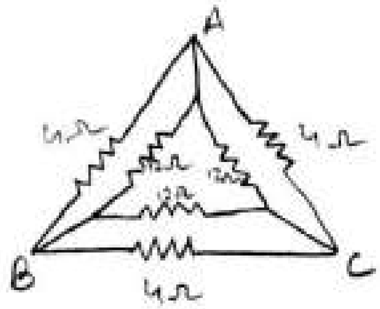
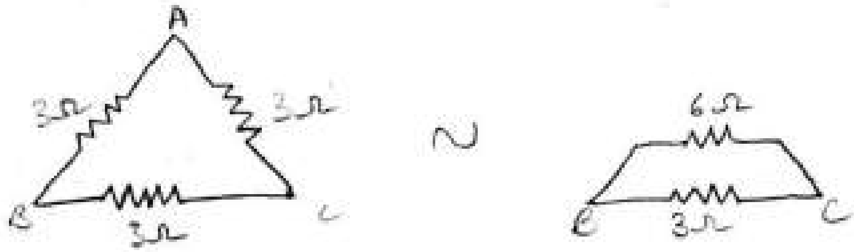
The network now becomes



Each 4Ω and 12Ω resistor combination is in parallel. ∴ It can be condensed into a single delta network of each resistance value equal to

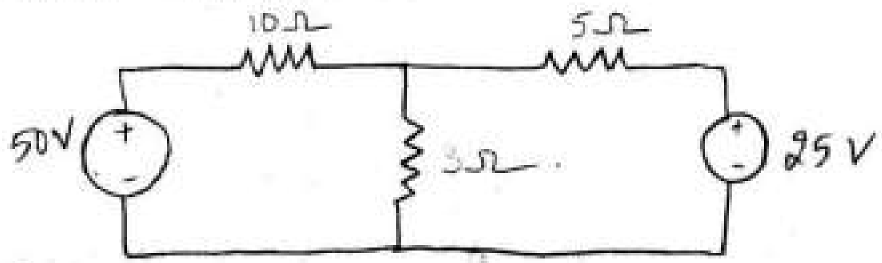
$$R_{AB} = R_{BC} = R_{CA} = \frac{12(4)}{12+4} = \frac{48}{16} = 3\Omega$$



Equivalent resistance between B and C

$$R_{eq} = \frac{6\times3}{6+3} = \frac{18}{9} = \underline{2\Omega}$$

6Q) Find the current in 10Ω resistor by using superposition theorem :



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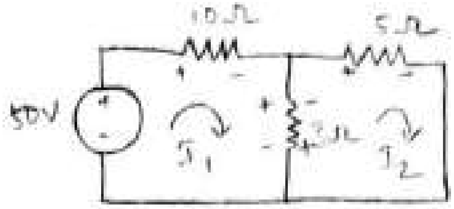
Step ①: 50 V source effect (25V source is short-circuited)



Applying mesh analysis,

$$50 - 10I_1 - 3(I_1 - I_2) = 0$$

$$13I_1 - 3I_2 = 50 \quad \text{— ①}$$

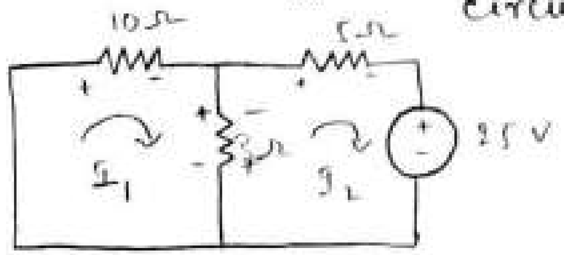
$$-5I_2 - 3(I_2 - I_1) = 0$$

$$3I_1 - 8I_2 = 0 \quad \text{— ②}$$

$I_1 = 4.21A$ $\quad$ $I_2 = 1.58A$

Current through 10Ω resistor $- I' = \underline{4.21A}$.

Step ②: 25V source effect (50V source is short-circuited)



Applying mesh analysis,

$$-10I_1 - 3(I_1 - I_2) = 0$$

$$-13I_1 + 3I_2 = 0 \quad \text{— ①}$$

$$-5I_2 - 25 - 3(I_2 - I_1) = 0$$

$$3I_1 - 8I_2 = 25 \quad \text{— ②}$$

$I_1 = -0.79A$ $\quad$ $I_2 = -3.42A$.

Current through 10Ω resistor $- I'' = \underline{-0.79A}$

Total current $= I' + I'' = 4.21 - 0.79 = \boxed{3.42A}$

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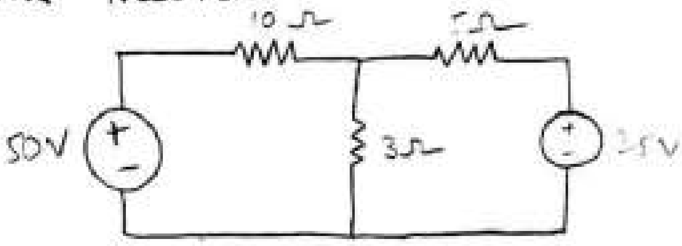
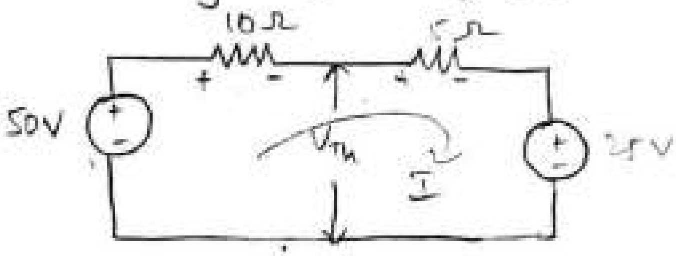
7Q) Find the current in 3Ω resistor by using Thevenin's theorem.



Ans) After removing $R_L = 3\Omega$, the network becomes:

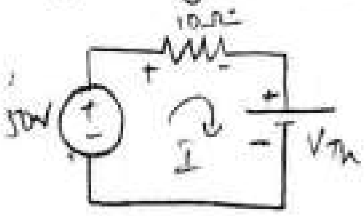


$$50 - 10I - 5I - 25 = 0$$

$$15I = 25$$

$$I = \frac{25}{15} = \underline{1.67A}$$

For finding V_{Th},



$$50 - 10I - V_{Th} = 0$$

$$V_{Th} = 50 - 10I$$

$$V_{Th} = 50 - 10(1.67)$$

$$V_{Th} = 50 - 16.7$$

$$V_{Th} = \underline{33.3V}.$$

For calculation of R_{Th}, short circuit the voltage sources and calculate the R_{eq} from the open circuited load terminals.

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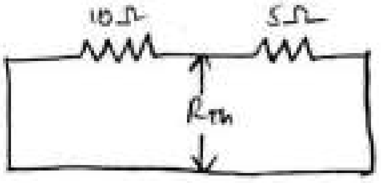

$$R_{Th} = \frac{10(5)}{10+5} = \frac{50}{15} = \underline{3.33\,\Omega}$$

Equivalent circuit:

$$I_L = \frac{33.3}{6.33} = \boxed{5.26\,A}$$

8Q) State Thevenin's theorem. Explain the procedure for finding a current in the branch of a network by using Thevenin's theorem.

Ans) Thevenin's theorem states that " – (Refer Q20, short answer questions).

Steps for applying Thevenin's theorem:

(i) Remove the load resistor (R_L) where the current is required to be calculated.

(ii) Calculate the voltage across the load terminals by using any of the network simplification techniques. This voltage is open circuited voltage or thevenin's voltage (V_{OC} or V_{Th}).

(iii) Calculate the equivalent resistance from the load terminals. This is Thevenin's resistance (R_{Th}).

(iv) Draw the Thevenin's equivalent circuit showing R_{Th} connected in series to V_{Th}.

(v) Reconnect the load resistor to the Thevenin's equivalent circuit and obtain the load current I_L by using the formula: $I_L = \dfrac{V_{Th}}{R_{Th}+R_L}$

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9Q) Obtain the current flowing through the 4Ω resistor for the following network.

Applying mesh analysis for the first loop,

$$60 - 5I_1 - 4(I_1 - I_2) - 15(I_1 - I_3) - 5I_1 = 0$$

$$60 - 5I_1 - 4I_1 + 4I_2 - 15I_1 + 15I_3 - 5I_1 = 0.$$

$$60 - 29I_1 + 4I_2 + 15I_3 = 0$$

$$29I_1 - 4I_2 - 15I_3 = 60 \quad -(1).$$

Applying mesh analysis for the second loop,

$$-10I_2 - 20I_2 - 8(I_2 - I_3) - 4(I_2 - I_1) = 0.$$

$$-10I_2 - 20I_2 - 8I_2 + 8I_3 - 4I_2 + 4I_1 = 0$$

$$4I_1 - 42I_2 + 8I_3 = 0 \quad -(2)$$

Applying mesh analysis for the third loop,

$$-12I_3 - 15(I_3 - I_1) - 8(I_3 - I_2) = 0$$

$$-12I_3 - 15I_3 + 15I_1 - 8I_3 + 8I_2 = 0$$

$$15I_1 + 8I_2 - 35I_3 = 0 \quad -(3)$$

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Solving equations 1, 2 and 3 simultaneously, we get :

$I_1 = 2.83 A$

$I_2 = 0.523 A$

$I_3 = 1.33 A$

Current flowing through 4Ω resistor

$I = I_1 - I_2$

$\boxed{I = 2.3 A}$

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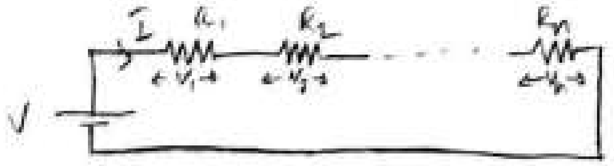
10Q) Derive the equivalent resistance and inductance for series and parallel circuits.

Ans) Resistors in series:



From the above circuit, the total voltage

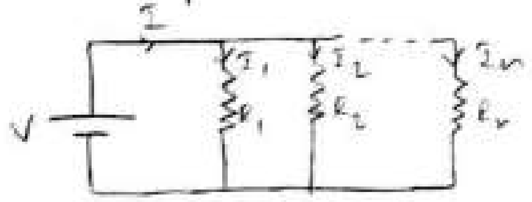
'V' = $V_1 + V_2 + \cdots + V_n$

$\Rightarrow I R_{eq} = IR_1 + IR_2 + \cdots IR_n$

$\Rightarrow \boxed{R_{eq} = R_1 + R_2 + \cdots R_n}$

where R_{eq} is the total resistance of the circuit.

Resistors in parallel:



From the above circuit, the total current

$I = I_1 + I_2 + \cdots + I_n$

$\Rightarrow \dfrac{V}{R_{eq}} = \dfrac{V}{R_1} + \dfrac{V}{R_2} + \cdots \dfrac{V}{R_n}$

$\Rightarrow \boxed{\dfrac{1}{R_{eq}} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \cdots \dfrac{1}{R_n}}$

where R_{eq} is the total resistance of the circuit.

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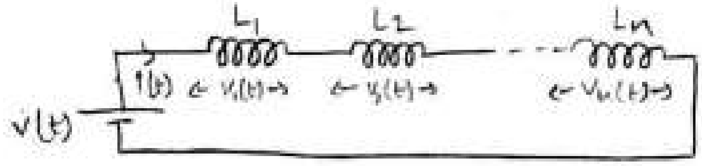
Inductors in series:



From the above circuit, the total voltage

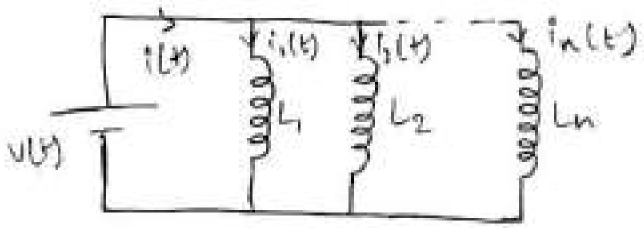
$$v(t) = v_1(t) + v_2(t) + \cdots v_n(t)$$

$$\Rightarrow L_{eq}\frac{di(t)}{dt} = L_1\frac{di(t)}{dt} + L_2\frac{di(t)}{dt} + \cdots L_n\frac{di(t)}{dt}$$

$$\Rightarrow \boxed{L_{eq} = L_1 + L_2 + \cdots L_n}$$

where L_{eq} is the equivalent inductance.

Inductors in parallel:



From the above circuit, the total current

$$i(t) = i_1(t) + i_2(t) + \cdots i_n(t)$$

$$\Rightarrow \frac{1}{L_{eq}}\int v(t)dt = \frac{1}{L_1}\int v(t)dt + \frac{1}{L_2}\int v(t)dt + \cdots \frac{1}{L_n}\int v(t)dt$$

$$\Rightarrow \boxed{\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2} + \cdots \frac{1}{L_n}}$$

where L_{eq} is the equivalent inductance.

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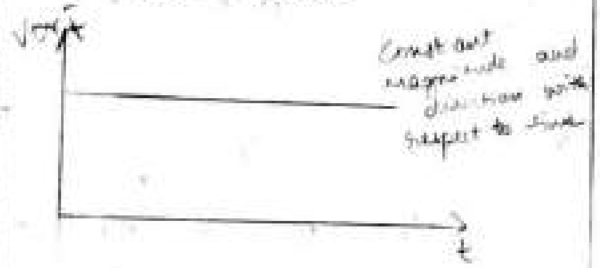
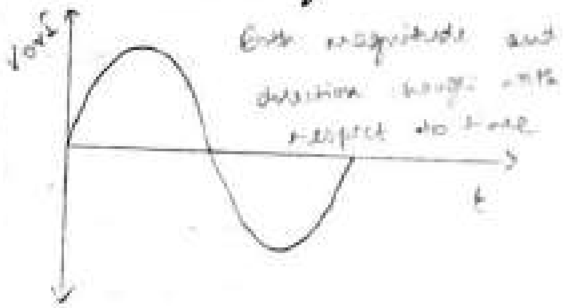
UNIT 2: AC CIRCUITS

SHORT ANSWER QUESTIONS

1Q) Differentiate DC and AC quantities.

DC	AC
- DC quantities will have constant magnitude and have a single direction.	- AC quantities periodically alternate between positive and negative values. Their magnitude varies and also direction changes.
- Frequency of DC quantities is zero.	- Frequency of AC quantities is not zero.
- The instantaneous value obtained at any instant is the same.	- The instantaneous value varies for different instants of time.
	

2Q) Define time period and frequency.

Ans) Time period : It is the time taken by an alternating quantity to complete one cycle.

Frequency: It is the number of cycles per second.
Unit for frequency is Hertz (Hz)

$$T = \frac{1}{f} \quad (\text{or}) \quad f = \frac{1}{T}$$

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39) Define peak value and instantaneous value.

Ans) Peak value: It is the maximum value of an alternating quantity during positive or negative half cycle.
It is also called maximum value / amplitude.

Instantaneous value: It is the value obtained at any particular instant of time.
For the sine wave form,
$v(t) = V_m \sin \omega t$ and
$i(t) = I_m \sin \omega t$.

40) Define RMS and average values of an alternating quantity.

Ans) RMS Value: It is the square root of average of the squares of instantaneous values over one cycle.

$V_{rms} = \sqrt{\frac{1}{T}\int (v(t))^2 dt}$ and $I_{rms} = \sqrt{\frac{1}{T}(i(t))^2 dt}$

where T is the time period and v(t) is the instantaneous value of voltage and i(t) is the instantaneous value of current.

Average value: It is the ratio of area under the curve to the length of the curve.

$$V_{avg} = \frac{\int v(t)\, dt}{T}.$$

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Define form factor and peak factor. Write the values of same for sinusoidal waveform.

Ans) Form factor: It is the ratio of RMS value to the average value
(K_f)

For sinusoidal waveform,

$$K_f = \frac{V_{rms}}{V_{avg}} = \frac{(0.707)V_m}{(0.637)V_m} = 1.11.$$

Peak factor: It is the ratio of peak value to the RMS value. It is also known as crest factor.
(K_p)

$$K_p = \frac{\text{Peak value}}{V_{rms}} = \frac{V_m}{(0.707)V_m} = 1.414$$

6Q) What is phase and phase difference?

Ans) Phase is the angular measurement of the sine wave and it specifies the position of the sine wave. It will be measured from the X-axis.

Phase difference is the difference in phases of two alternating quantities.

7Q) What is the significance of j-operator?

Ans) j-operator is used to represent the alternating quantity in complex form (Rectangular form). $j = \sqrt{-1} = 1\angle 90^\circ$

If any phasor is multiplied with j, the angle changes in anti-clockwise direction with the phase difference of 90° but the magnitude remains the same.

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8Q) Define inductive and capacitive reactances. Write the expressions.

Ans) Inductive reactance is the resistance offered by the inductor to the flow of alternating current in the circuit. It is represented by X_L.

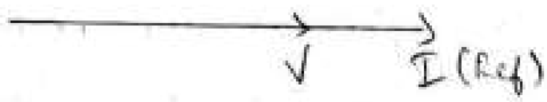
$$X_L = 2\pi f L$$

Capacitive reactance is the resistance offered by the capacitor to the flow of alternating current in the circuit. It is represented by X_C.

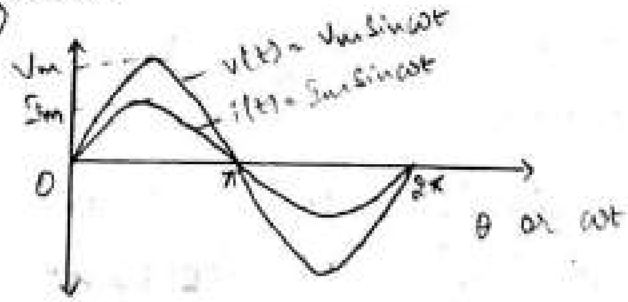
$$X_C = \frac{1}{2\pi f C}$$

9Q) Draw the waveforms and phasor diagram for pure R circuit to sinusoidal excitation.

Ans) Phasor diagram:

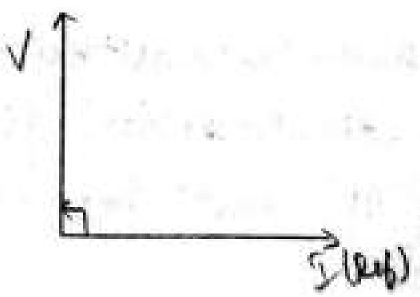


Wave form:



10Q) Draw the wave forms and phasor diagram for pure L circuit to sinusoidal excitation.

Ans) Phasor diagram:



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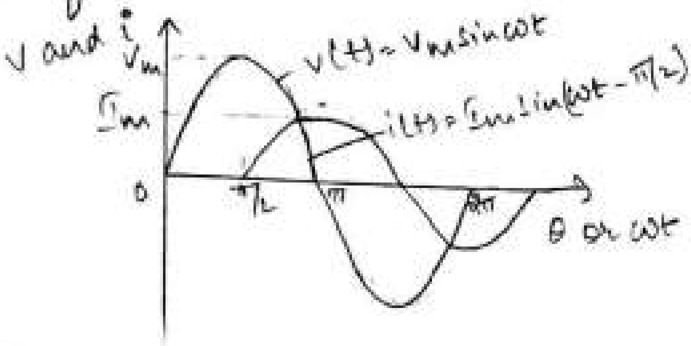
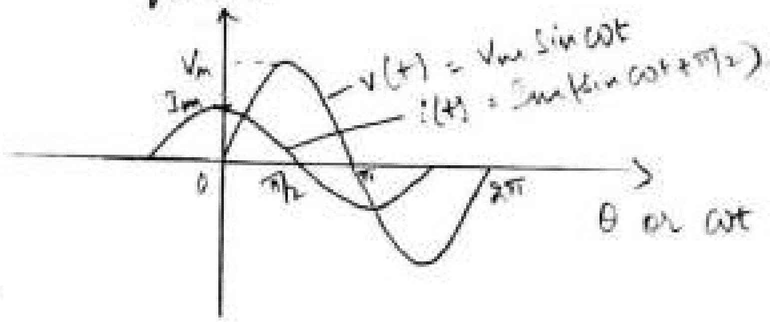
Wave form:



11Q) Draw the waveforms and phasor diagram for pure C circuit to sinusoidal excitation.

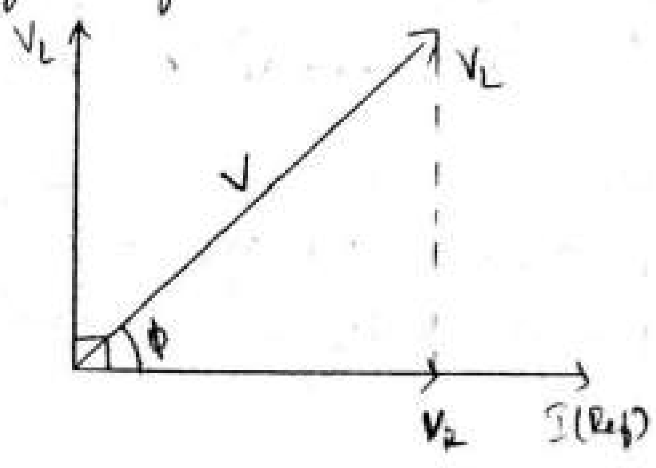
Ans) Phasor diagram:

Wave form:



12Q) Draw the phasor diagrams of series RL and RC circuit to sinusoidal excitation.

Ans) Phasor diagram for RL series circuit:



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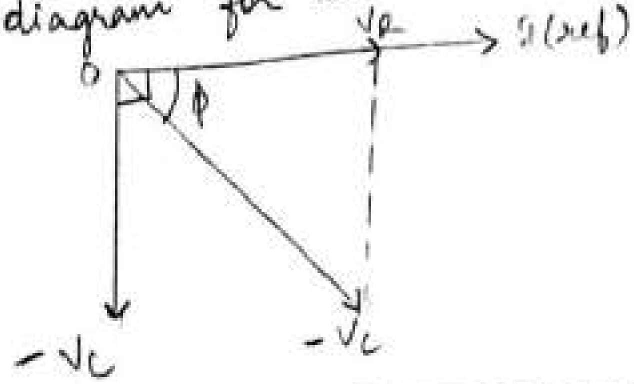
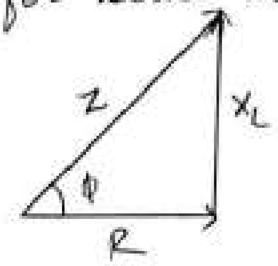
Phasor diagram for RC series circuit:

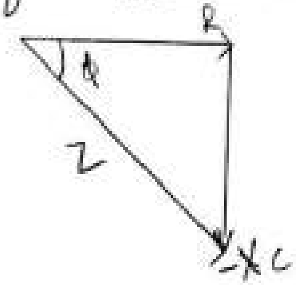


13Q) Draw the impedence triangle for series RL and RC circuits.

Ans) Impedence triangle for series RL circuit:



Impedence triangle for series RC circuit:



14Q) Define apparent, active and reactive powers.

Ans) Apparent power, also known as complex power is the product of applied voltage and current. Its units are VA (Volt Ampere) (or) kVA (kilo Volt Ampere)

Active power, also known as true power is the product of applied voltage and active component of current. Its units are W (Watt) or kW (kilowa

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Reactive power is the product of applied voltage and reactive component of current. Its units are VAR's (Volt Ampere Reactive) or KVAR's (kilovolt Ampere Reactive).

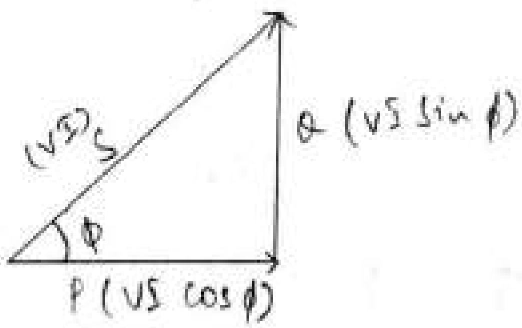
15Q) Define power factor. Write the importance.

Ans) The power factor of an AC electrical power system is defined as the ratio of the real power flowing to the load to the apparent power in the circuit.

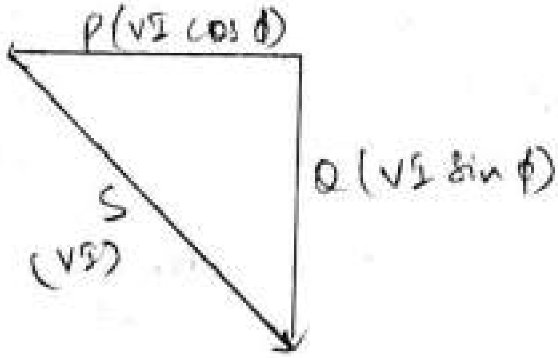
Importance: Improving the power factor reduces the losses in the system so that the efficiency of the system increases.

16Q) Draw the power triangle for series RL and RC circuits.

Ans) Power triangle for series RL circuit:



Power triangle for series RC circuit:



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17Q) What is the reactance of a 1H inductor for (i) DC (ii) 50Hz

Ans) (i) Reactance of 1H inductor for DC = 0 because

$X_L = 2\pi f L$

and $f = 0$ for a DC supply.

(ii) Reactance of 1H inductor for AC of 50Hz frequency

$X_L = 2\pi f L$

$= 2 \times 3.14 \times 50 \times 1$

$= 314\,\Omega$

18Q) The impedence of an electrical circuit is $(30-50j)\,\Omega$. Determine the resistance and capacitance, when the circuit is connected to a 230V, 50Hz supply.

Ans) $Z = (30-50j)\,\Omega$ — ①

We know that, for an RC circuit,

$Z = R - jX_C$.

Comparing with the above eqn,

$30 - 50j = R - jX_C$

$\Rightarrow \boxed{R = 30\,\Omega}$, $X_C = 50\,\Omega$

$X_C = \frac{1}{2\pi f C} \Rightarrow 50 = \frac{1}{2 \times 3.14 \times 50 \times C}$

$\Rightarrow \boxed{C = 63.7\mu F.}$

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19Q) Define resonance and write the expression for resonant frequency of series resonant circuit.

Ans) Under the condition of resonance, applied voltage and resulting current will be in-phase.

Power factor becomes unity.

Inductive reactance equals to capacitive reactance

i.e., $X_L = X_C$.

Resonant frequency of series resonant circuit:

$$\boxed{f_0 = \frac{1}{2\pi\sqrt{LC}}}$$

20Q) Write the voltage and current relations in star and delta connections for three phase balanced circuits.

Ans) (i) for star connected load,

line currents (I_L) = phase currents (I_{ph})

line voltage (V_L) = $\sqrt{3}$ phase voltage (V_{ph})

(ii) for delta connected load,

line currents (I_L) = $\sqrt{3}$ phase currents (I_{ph})

line voltage (V_L) = phase voltage (V_{ph})

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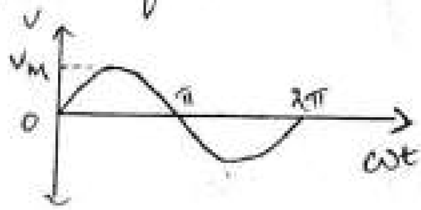
LONG ANSWER QUESTIONS:

1Q) Derive the RMS value and average value for sinusoidal waveform. Find form factor.

Ans) Sine wave form:



$T = 2\pi \qquad v(t) = V_m \sin \omega t$.

$$V_{RMS} = \sqrt{\frac{1}{T}\int (v(t))^2\, dt}$$

$$V_{RMS} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} V_m^2 \sin^2 \omega t \, d(\omega t)}$$

$$V_{RMS} = \sqrt{\frac{V_m^2}{2\pi}\int_0^{2\pi} \sin^2 \omega t \, d(\omega t)}$$

$$V_{RMS} = \left[\frac{V_m^2}{2\pi}\int_0^{2\pi} \frac{1-\cos 2\omega t}{2}\right]^{1/2}$$

$$V_{RMS} = \left(\frac{V_m^2}{2\pi}\left[\frac{1}{2}\int d\omega t - \frac{1}{2}\int \cos 2\omega t \, d\omega t\right]\right)^{1/2}$$

$$V_{RMS} = \left[\frac{V_m^2}{2\pi}\left(\frac{\omega t}{2} - \frac{1}{2}\,\frac{\sin 2\omega t}{2}\right)\right]^{1/2}$$

$$V_{RMS} = \left[\frac{V_m^2}{2\pi}\left[\frac{2(2\pi) - \cancelto{0}{\sin 2(2\pi)}}{4}\right]\right]^{1/2}$$

$$V_{RMS} = \left[\frac{V_m^2}{2\pi}\,\frac{4\pi}{4}\right]^{1/2} \Rightarrow \boxed{V_{RMS} = \frac{V_m}{\sqrt{2}} = 0.707\,V_m} \quad (1)$$

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$$V_{avg} = \frac{\int v(t)}{T} \qquad T = \pi$$

$$V_{avg} = \frac{1}{\pi} \int V_m \sin \omega t$$

$$V_{avg} = \frac{V_m}{\pi} \int \sin \omega t$$

$$V_{avg} = \frac{V_m}{\pi} \left[-\cos \omega t \right]_0^{2\pi}$$

$$V_{avg} = \frac{V_m}{\pi} \left[(-\cos \pi) - (-\cos 0) \right]$$

$$\boxed{V_{avg} = \frac{2V_m}{\pi} = 0.637 V_m}$$

$$\text{form factor} = \frac{V_{rms}}{V_{avg}} = \frac{(0.707)V_m}{(0.637)V_m} = 1.11.$$

Q) Prove that the average power consumed by a pure inductor is zero.

Ans) For a pure inductor,

Average power:

$$P_{avg} = \frac{1}{T} \int_0^T p(t)\, dt.$$

$$P_{avg} = \frac{1}{2\pi} \int_0^{2\pi} V_m I_m \sin \omega t \sin(\omega t - \pi/2)\, d(\omega t).$$

$$P_{avg} = -\frac{1}{2\pi} \int_0^{2\pi} V_m I_m \sin \omega t \cos \omega t\, d(\omega t).$$

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$$P_{Avg} = -\frac{V_m I_m}{2\pi} \times \frac{1}{2} \int_0^{2\pi} \sin(2\omega t)\, d(\omega t).$$

$$P_{Avg} = -\frac{V_m I_m}{4\pi} \left[\frac{-\cos(2\omega t)}{2} \right]_0^{2\pi}$$

$$P_{Avg} = -\frac{V_m I_m}{4\pi} \left[-\frac{\cos 4\pi}{2} - \left(-\frac{\cos 0}{2} \right) \right]$$

$$P_{Avg} = -\frac{V_m I_m}{4\pi} \left[-\frac{1}{2} + \frac{1}{2} \right] = \underline{0}.$$

Hence Proved.

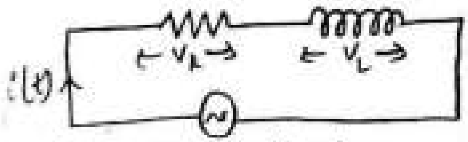
3Q) Explain the concept of phase, phase difference and j-notation in AC circuits.

Ans) Refer 6Q and 7Q - short questions.

4Q) Explain the steady state analysis of series RL circuit for sinusoidal excitation.

Ans) Consider a series RL circuit which is supplied by an alternating voltage:

$$v(t) = V_m \sin \omega t.$$



$v(t) = V_m \sin\omega t$

The voltage across resistor : $V_R = IR$.

The voltage across inductor : $V_L = IX_L$

where X_L is the inductive reactance.

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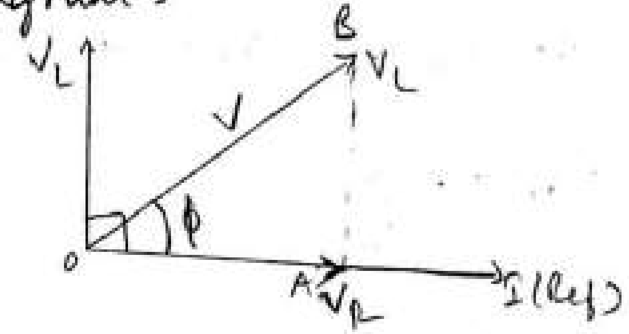
The total voltage 'V' of the circuit equals to the vector sum of voltages across the resistor and voltage across inductor.

i.e., $\bar{V} = \bar{V}_R + \bar{V}_L$

$$\bar{V} = \bar{I}R + \bar{I}X_L$$

Phasor diagram:



Since V_R will be in phase with current I and V_L leads current I by an angle $90°$. The total supply voltage leads current by an angle ϕ.

From ΔOAB,

$$V^2 = V_R^2 + V_L^2$$

$$V^2 = (IR)^2 + (IX_L)^2$$

$$V^2 = I^2 (R^2 + X_L^2)$$

$$V = I\sqrt{R^2 + X_L^2}$$

$$V = I\,|Z|$$

where $|Z| = \sqrt{R^2 + X_L^2}$ and Z is the impedence of the circuit.

This is the resistance offered by the series RL circuit.

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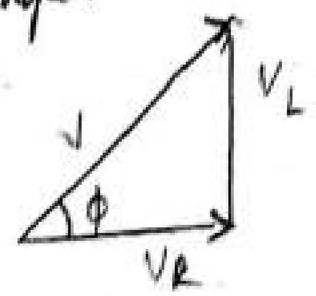
Voltage triangle:

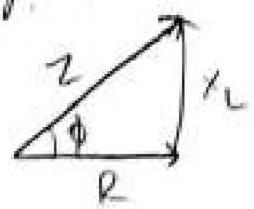


Power factor $\cos\phi = \frac{V_R}{V} \Rightarrow V_R = V\cos\phi$

$\sin\phi = \frac{V_L}{V} \Rightarrow V_L = V\sin\phi$

$$\boxed{\tan\phi = \frac{V_L}{V_R}}$$

Impedence triangle:



Power factor $\cos\phi = \frac{R}{Z}$

$\tan\phi = \frac{X_L}{R}$

$$\boxed{\phi = \tan^{-1}\frac{X_L}{R}}$$

From the impedence triangle, the impedence can be expressed as:

$Z = R + jX_L$ in Rectangular form

$|Z| = \sqrt{R^2 + X_L^2}$ $\quad \phi = \tan^{-1}(X_L/R)$

and $|Z| \angle \phi$ in polar form.

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Power triangle:

Total voltage $\bar{V} = \bar{V}_R + \bar{V}_L$

from the voltage triangle,

$V_R = V\cos\phi$ and $V_L = V\sin\phi$.

$\rightarrow V = V\cos\phi + jV\sin\phi$.

Multiplying both sides with I,

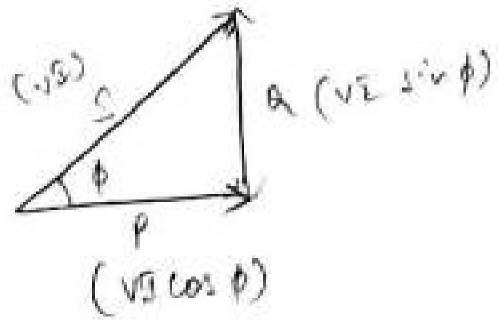
$VI = VI\cos\phi + jVI\sin\phi$.

$\Rightarrow \boxed{S = P + jQ}$

where $S = VI$ is the apparent power,

$P = VI\cos\phi$ is the active power,

$Q = VI\sin\phi$ is the reactive power.



Instantaneous power $p(t) = v(t)\, i(t)$

$= V_m \sin\omega t \, I_m \sin(\omega t - \phi)$

Average power:

$P_{avg} = \frac{1}{T}\int_0^T p(t)\, dt \qquad T = 2\pi$

$= \frac{1}{2\pi}\int_0^{2\pi} V_m I_m \sin\omega t \, \sin(\omega t - \phi)\, d(\omega t)$

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$$P_{AVG} = \frac{1}{2\pi} V_m I_m \times \frac{1}{2} \int_0^{2\pi} 2 \sin\omega t \sin(\omega t - \phi)\, d(\omega t).$$

$$P_{AVG} = \frac{1}{4\pi} V_m I_m \int_0^{2\pi} \cos(\cancel{\omega t} - \cancel{\omega t} + \phi) - \cos(\omega t + \omega t - \phi)\, d\omega t$$

$$P_{AVG} = \frac{1}{4\pi} V_m I_m \int_0^{2\pi} \cos\phi - \cos(2\omega t - \phi)\, d\omega t.$$

$$P_{AVG} = \frac{1}{4\pi} V_m I_m \left[\int_0^{2\pi} \cos\phi\, d\omega t - \int_0^{2\pi} \cancel{\cos(2\omega t - \phi)}^{\,0}\, d\omega t \right]$$

$$P_{AVG} = \frac{1}{\cancel{4}\cancel{\pi}_{2}} V_m I_m \cos\phi\, (\cancel{2}\cancel{\pi}).$$

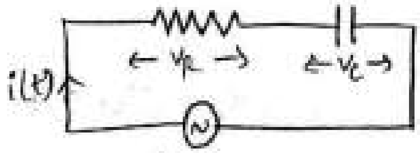
$$P_{AVG} = \frac{V_m I_m}{2} \cos\phi$$

$$P_{AVG} = \frac{V_m}{\sqrt{2}} \frac{I_m}{\sqrt{2}} \cos\phi$$

$$P_{AVG} = V_{rms} I_{rms} \cos\phi$$

5a) Derive the steady state analysis of series RC circuit for sinusoidal excitation.

Ans) Consider a series RC circuit which is supplied by an alternating voltage $v(t) = V_m \sin\omega t$



$v(t) = V_m \sin\omega t$.

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Voltage across resistor : $V_R = IR$
Voltage across capacitor : $V_C = IX_C$
where X_C is the capacitive reactance.

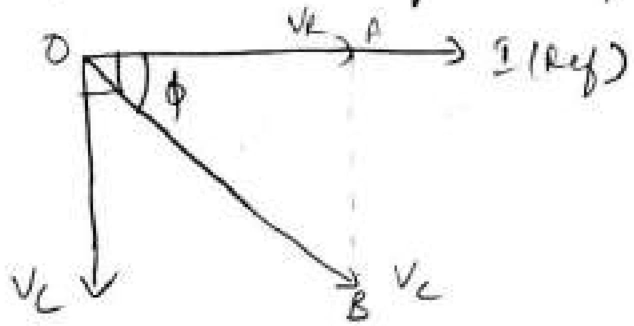
The total voltage 'V' of the circuit equals to the vector sum of voltage across the resistor and voltage across the capacitor.

i.e., $\bar{V} = \bar{V}_R + \bar{V}_C$

$\bar{V} = \bar{I}R + \bar{I}X_C$

Phasor diagram:

Considering I as the reference phasor,



Since V_R will be in phase with current I and V_C lags current I by an angle $90°$. The total supply voltage leads current I by an angle ϕ.

from ΔOAB, $V^2 = V_R^2 + V_C^2$

$$V^2 = (IR)^2 + (IX_C)^2$$

$$V^2 = I^2 (R^2 + X_C^2)$$

$$V = I\sqrt{R^2 + X_C^2}$$

$$V = I\,|Z|$$

where $|Z| = \sqrt{R^2 + X_C^2}$ and Z is the impedence of

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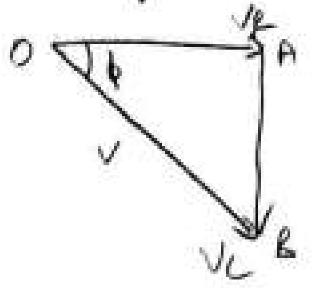
the circuit.
It is the resistance offered by the series RC circuit.

Voltage triangle:

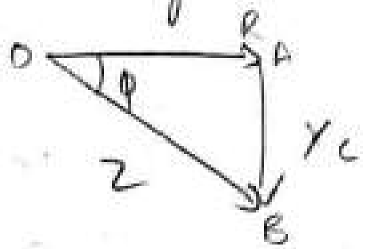


Power factor $\cos\phi = \frac{V_R}{V} \Rightarrow V_R = V\cos\phi$

$\sin\phi = -\frac{V_C}{V} \Rightarrow V_C = -V\sin\phi$

$$\boxed{\tan\phi = -\frac{V_C}{V_R}}$$

Impedence triangle:



Power factor $\cos\phi = \frac{R}{Z}$

$\tan\phi = -\frac{X_C}{R}$

$$\boxed{\phi = \tan^{-1}\left(-\frac{X_C}{R}\right)}$$

From the impedence triangle, the impedence can be expressed as

$Z = R - jX_C$ in Rectangular form

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$$|Z| = \sqrt{R^2 + X_C^2}$$

$$\phi = Tan^{-1}(-X_C/R)$$

and $|Z| \angle -\phi$ in polar form.

Power triangle:

Total voltage $\bar{V} = \bar{V}_R + \bar{V}_C$

From the voltage triangle, $V_R = V\cos\phi$, $V_C = -V\sin\phi$

$\Rightarrow V = V\cos\phi - jV\sin\phi$

Multiplying both sides with I,

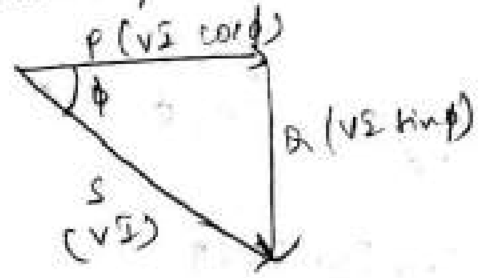
$$VI = VI\cos\phi - jVI\sin\phi$$

$$\boxed{S = P - jQ}$$

where $S = VI$ is apparent power

$P = VI\cos\phi$ is active power

$Q = VI\sin\phi$ is reactive power.



Instantaneous power $p(t) = v(t)\, i(t)$

$= V_m \sin \omega t \cdot I_m \sin(\omega t + \phi)$

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Average power:

$$P_{AVG} = \frac{1}{T}\int_0^T p(t)\,dt \qquad T = 2\pi$$

$$P_{AVG} = \frac{1}{2\pi}\int_0^{2\pi} V_m \sin\omega t \; I_m \sin(\omega t + \phi)\, d\omega t$$

$$P_{AVG} = \frac{1}{2\pi} V_m I_m \frac{1}{2}\int_0 2\sin\omega t \sin(\omega t + \phi)\, d\omega t$$

$$P_{AVG} = \frac{1}{4\pi} V_m I_m \int_0^{2\pi} \cos(\omega t + \omega t + \phi) - \cos(\cancel{\omega t} - \cancel{\omega t} - \phi)\, d\omega t$$

$$P_{AVG} = \frac{1}{4\pi} V_m I_m \int_0^{2\pi} \cos(2\omega t + \phi) - \cos(\phi)\, d\omega t.$$

$$P_{AVG} = \frac{1}{4\pi} V_m I_m \left(\int_0^{2\pi} \cancel{\cos(2\omega t + \phi)}^{\,0}\, d\omega t - \int_0^{2\pi} \cos(-\phi)\, d\omega t\right)$$

$$P_{AVG} = \frac{1}{4\pi} V_m I_m \int_0^{2\pi} \cos\phi \, d\omega t.$$

$$P_{AVG} = \frac{V_m I_m}{2\cancel{4}\cancel{\pi}} \times \cos\phi\,(\cancel{2\pi})$$

$$P_{AVG} = \frac{V_m I_m}{2}\cos\phi$$

$$P_{AVG} = \frac{V_m}{\sqrt{2}}\frac{I_m}{\sqrt{2}}\cos\phi$$

$$P_{AVG} = V_{rms} I_{rms} \cos\phi.$$

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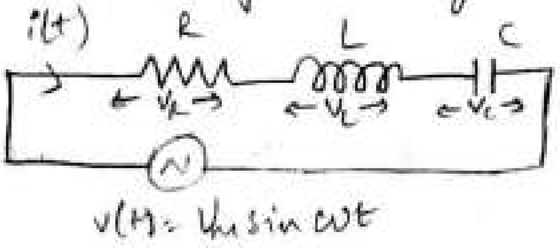
1) Explain the steady state analysis of series RLC circuit for sinusoidal excitation.

Ans) Consider a series RLC circuit which is supplied by an alternating voltage of $v(t) = V_m \sin \omega t$



$V_R = IR \qquad V_L = IX_L \qquad V_C = IX_C$

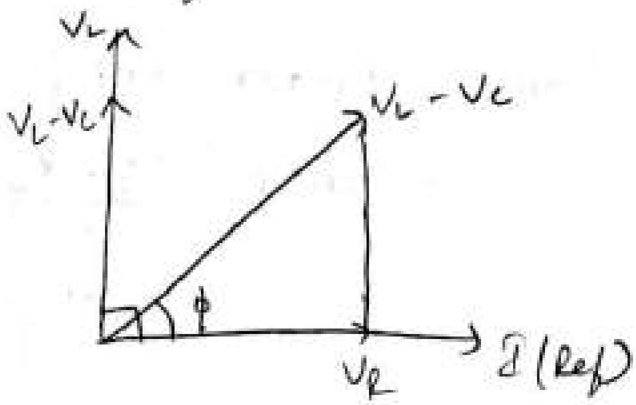
Total voltage = phasor sum of individual voltages across each element.

$$\bar{V} = \bar{V}_R + \bar{V}_L + \bar{V}_C$$

Case (i) : If $X_L > X_C$

If the inductive reactance is greater than capacitive reactance, then, voltage across the inductor will be greater than voltage across the capacitor. The circuit is said to be inductive in nature.

Then, the difference of $V_L - V_C$ will be directed towards V_L



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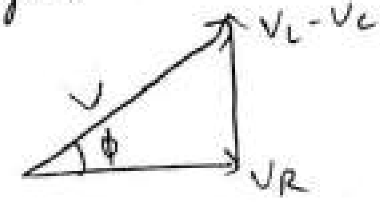
$$V^2 = V_R^2 + (V_L - V_C)^2$$
$$V^2 = (IR)^2 + (IX_L - IX_C)^2$$
$$V^2 = I^2\left(R^2 + (X_L - X_C)^2\right)$$
$$V = I\sqrt{R^2 + (X_L - X_C)^2}$$
$$V = I\,|Z|$$

where $|Z| = \sqrt{R^2 + (X_L - X_C)^2}$ and Z is the impedence of the total circuit.

This is the resistance offered by the series LCR circuit.

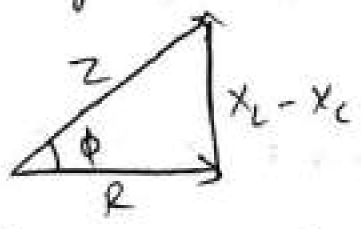
Voltage triangle:



Power factor $\cos\phi = \frac{V_R}{V} \Rightarrow V_R = V\cos\phi$

$$\tan\phi = \frac{V_L - V_C}{V_R}.$$

Impedence triangle:



Power factor $\cos\phi = \frac{R}{Z}$

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

$$\boxed{\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)}$$

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From the impedence triangle, the impedence can be expressed as :

$$Z = R + j(X_L - X_C) \text{ in Rectangular form}$$

$$|Z| = \sqrt{R^2 + (X_L - X_C)^2} \text{ and } \phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$$

and

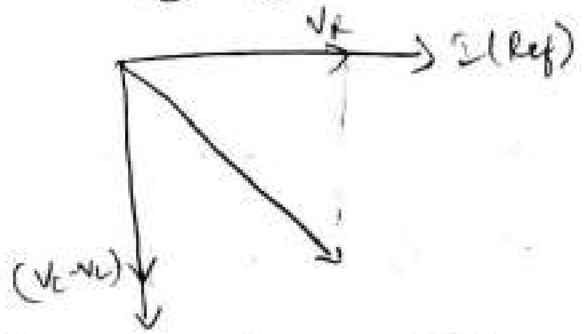
$$|Z| \angle \phi \text{ in polar form.}$$

Case (ii) If $X_C > X_L$

If the capacitive reactance is greater than inductive reactance, voltage across capacitor will be greater than the voltage across inductor.

The circuit is said to be capacitive in nature.

The difference $V_C - V_L$ will be directed towards V_C.



$$V^2 = V_R^2 + (V_C - V_L)^2$$

$$V^2 = (IR)^2 + (IX_C - IX_L)^2$$

$$V^2 = I^2 \left(R^2 + (X_C - X_L)^2\right)$$

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

$$V = I|Z|$$

where $|Z| = \sqrt{R^2 + (X_C - X_L)^2}$ and Z is the impedence of the circuit.

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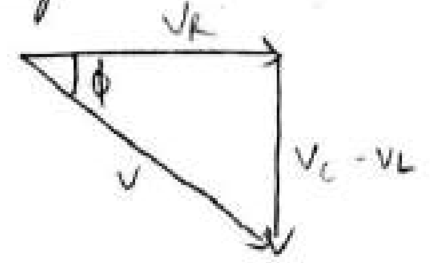
It is the resistance offered by the series LCR circuit

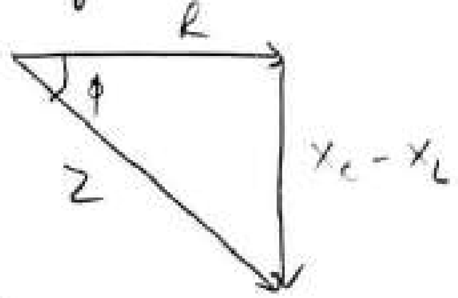
Voltage triangle.



Power factor $\cos\phi = \frac{V_R}{V} \Rightarrow V_R = V\cos\phi$

$$\tan\phi = \frac{V_C - V_L}{V_R}$$

Impedence triangle:



Power factor $\cos\phi = \frac{R}{Z}$.

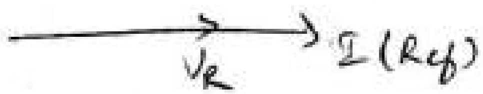
$$\tan\phi = \frac{X_C - X_L}{R} \Rightarrow \boxed{\phi = \tan^{-1}\left(\frac{X_C - X_L}{R}\right)}$$

Case (iii) $X_L = X_C$

$\Rightarrow V_L = V_C$

So V_L and V_C gets cancelled with each other.

$\therefore$ The circuit is said to be pure resistor circuit.



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A resistance of 10Ω is connected in series with a 50mH inductor across a 230V, 50Hz supply. Calculate (i) current flowing in the circuit (ii) phase angle of current (iii) the voltage across resistor and inductor.

Ans) $R = 10\,\Omega$ $L = 50\times10^{-3}\,H$ $V = 230V$ $f = 50Hz$.

(i) $X_L = 2\pi f L = 2\times3.14\times50\times50\times10^{-3}$

$X_L = \underline{15.7\,\Omega}$

$V = I\sqrt{R^2+X_L^2}$

$\Rightarrow 230 = I\sqrt{10^2+(15.7)^2}$

$I = \cancel{\dfrac{230}{\sqrt{10^2+15.7^2}}} \quad \dfrac{230}{10+15.7j} = 12.35\angle-57.5^\circ$

$\boxed{I = 12.35A}$

(ii) phase angle $\boxed{\phi = -57.5^\circ.}$

(iii) $V_R = V\cos\phi = 230\times0.54 = \boxed{124.2V}$

$V_L = V\sin\phi = 230\times0.84 = \boxed{193.2V}$

8Q) A resistance of 10Ω, inductance of 0.5H and capacitance of 10μF are connected in series to the supply of 50V, 50Hz supply. Calculate the voltage across each element and active power.

Ans) $V = 50V$ $R = 10\,\Omega$, $L = 0.5H$, $C = 10\times10^{-6}F$, $f = 50Hz$

$X_L = 2\pi f L = 2\times3.14\times50\times0.5$

$X_L = \underline{157\,\Omega}$

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$$X_C = \frac{1}{2\pi f C} = \frac{1}{2\times3.14\times50\times10\times10^{-6}} = \underline{318.47\,\Omega}.$$

$$I = \frac{50}{\sqrt{10^2+(318.47-157)^2}} = \frac{50}{161.78} = \underline{0.3A}$$

$V_R = 0.3\times10$ $\quad V_L = 0.3\times157$ $\quad V_C = 0.3\times318.47$

$\boxed{V_R = 3V}$ $\quad \boxed{V_L = 47.1V}$ $\quad \boxed{V_C = 95.5\,V}$

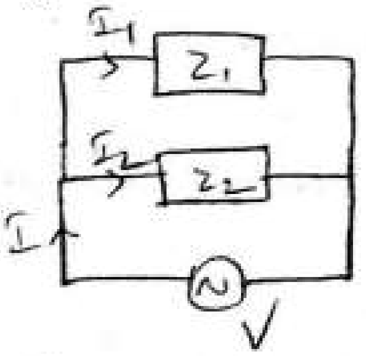
$$\cos\phi = \frac{R}{Z} = \frac{10}{161.77} = 0.062$$

Active Power $P = VI\cos\phi = 50\times0.3\times0.062$

$\boxed{P = 0.93W}$

9Q) The impedences of a parallel circuit are $Z_1 = 6+8j\,\Omega$ and $Z_2 = 8-6j\,\Omega$. If the applied voltage is 120V, find (i) Current and power factor of each branch and (ii) Total current and overall power factor.

Ans) $Z_1 = 6+8j\,\Omega$ $\quad Z_2 = 8-6j\,\Omega$ $\quad V = 120V.$



$$I_1 = \frac{V}{Z_1} = \frac{120}{6+8j} = 12\angle-53.13^\circ$$

$\phi_1 = -53.13^\circ$

$\boxed{I_1 = 12A}$ $\quad \boxed{\cos\phi_1 = 0.6}$

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$I_2 = \frac{V}{Z_2} = \frac{120}{8-6j} = 12 \angle 36.87°$ $\phi_2 = 36.87°$

$\boxed{I_2 = 12A}$ $\boxed{\cos\phi_2 = 0.79}$

Overall impedence $Z = \frac{Z_1 Z_2}{Z_1 + Z_2} = \frac{(6+8j)(8-6j)}{(6+8j+8-6j)}$

$Z = 7.07 \angle 8.13$

Total current $I = \frac{V}{Z} = \frac{120}{7+j} = 16.97 \angle -8.13°$

$\phi = -8.13°$

$\boxed{I = 16.97\,A}$ $\boxed{\cos\phi = 0.99}$

10a) Obtain the resonance condition for series RLC circuit. If elements $R = 8k\Omega$, $L = 20mH$ and $C = 80$[illegible]F are connected in series and circuit is in resonant condition, find resonant frequency.

Ans) $L = 20 \times 10^{-3} H$ $C = 80 \times 10^{-9} F$

Resonant frequency $f_0 = \frac{1}{2\pi\sqrt{LC}}$

$f_0 = \frac{1}{2 \times 3.14 \sqrt{20 \times 10^{-3} \times 80 \times 10^{-9}}}$

$\boxed{f_0 = 3980.89 Hz}$

$f_0 = 3.98 kHz$

$\boxed{f_0 \approx 4 kHz}$

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BEE question bank

Unit 3

Short answer questions:

1. magnetic flux density:

It is defined as the flux for unit area. It is denoted by 'B'.

$B = \phi/A$

Units: weber/m^2 (or)Tesla.

Magnetic field intensity:

Magnetic field intensity or magnetizing force H is defined as the ratio of the magnetic flux density B and the absolute permeability of the medium, μ.

$H = B/\mu$

Units: Henry/meter (or)Newton/ampere^2

2.Types of magnetic materials:

There are three types of magnetic materials they are:

1. Para magnetic.
2. Dia magnetic.
3. Ferro magnetic.

Para magnetic:

Materials which do not freely get attracted by the magnet, $\mu=1$.

Eg: Aluminium

Dia magnetic:

Materials which are repelled by a magnet, $\mu<1$.

Eg: Wood, plastic.

Ferro magnetic:

Materials which are strongly attracted by the magnet, $\mu=100$ to 1000.

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Eg: Iron, Steel.

3. Faradays laws of electromagnetic induction:

Faradays first law:

- Whenever the conductor cuts the magnetic flux an emf will be induced in the coil (conductor).
- For the emf to produce three things are necessary they are:

1.coil

2.flux

3.relative motion between conductor and flux.

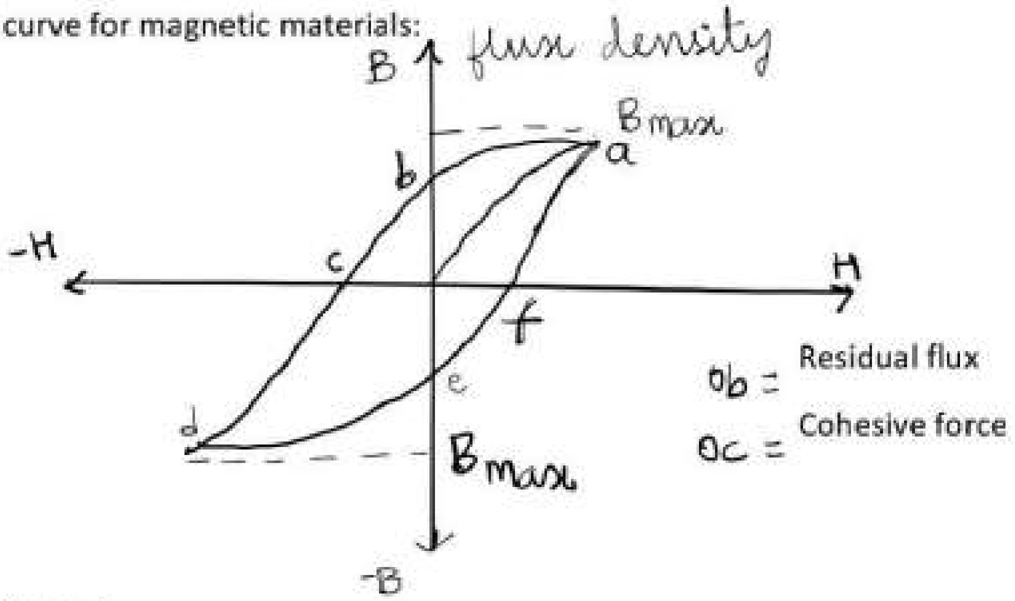
Faradays second law:

Magnitude of the induced emf is equal to the rate of change of flux linkages.

$$e = d\psi/dt.$$

Where $\psi = N\Phi$, Φ=flux per turn, ψ=flux linkages, N=total number of turns.

4.B-H curve for magnetic materials:



5. Self-induction:

It is the ratio of induced electromotive force (EMF) across a coil to the rate of change of current through the coil. We denote self-inductance with L. Its unit is

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Henry(H).

$$E \propto \frac{di}{dt} \Rightarrow E = L\frac{di}{dt}$$

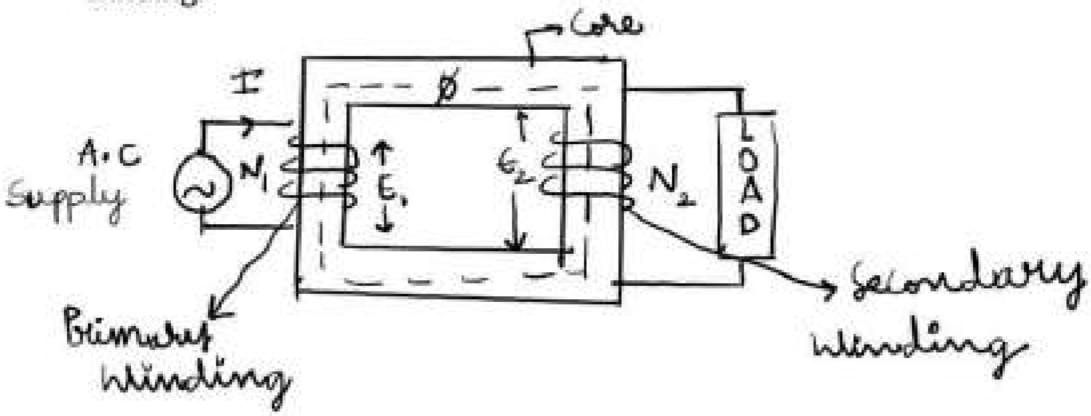
$$\Rightarrow L = \frac{E}{\frac{di}{dt}} = self\ inductance$$

6.Mutual inductance:

According to Faradays laws the change in flux induces an emf in the second coil. This emf is called mutually induced emf and the two coils are said to have mutual inductance.

7.Transformer:

- It is a static device which transfers electrical power from one circuit to another circuit without change in frequency and magnitude of power.
- The transfer of power takes place by changing voltage and current.
- The winding which is connected to the AC supply is called primary winding.
- The winding which is connected to the load is called a secondary winding.



8.Main parts of a transformer:

1. Core.
2. Limb.
3. Yoke.
4. Conservator tank.
5. Breather.

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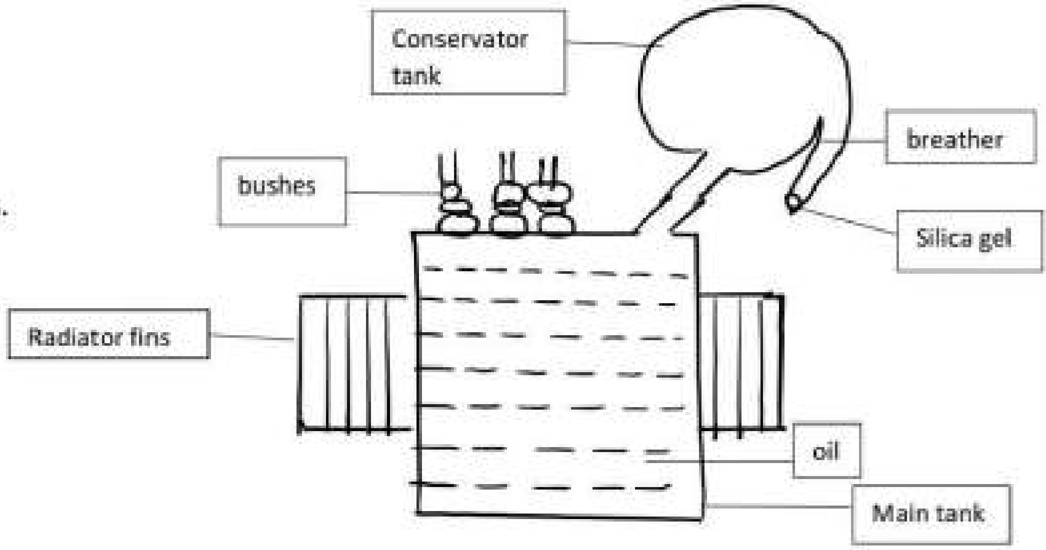
6. Silica gel.
7. Radiator fins.
8. Windings.
9. Bushes.



9. Transformers are rated in kVA because the losses occurring in the transformers are independent of power factor. KVA is the unit of apparent power. It is a combination of real power and reactive power.Φ

10.emf equation of a transformer:

$$E1=4.44f\phi N_1$$

$$E2=4.44f\phi N_2$$

Where E1=RMS value of induced emf in the primary winding.

E2=RMS value of the induced emf in the secondary winding.

N_1=number of primary windings.

N_2=number of secondary windings.

Transformer ratio:

$$E1/E2=N2/N1=K=\text{transformer ratio.}$$

E1>E2 and N1>N2 the transformer is called step down transformer.

E2>E1 and N2>N1 the transformer is called step up transformer.

11.Ideal transformer:

Transformer should satisfy the following conditions then it is an ideal transformer.

1. Permeability of core = ∞.

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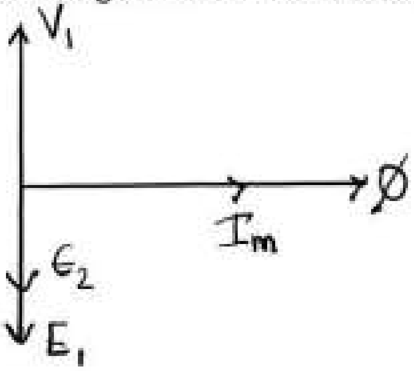
$\mu=\infty$.

2.there should be no leakage flux.

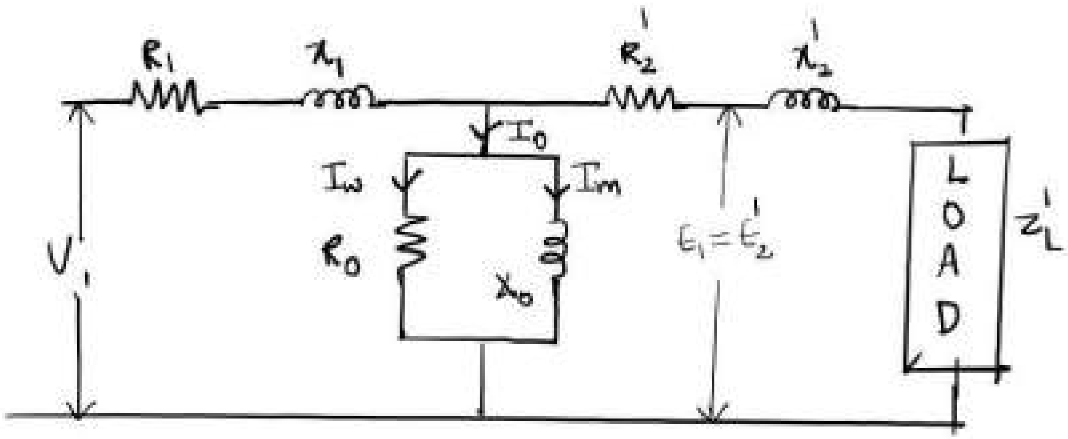
3.losses must be equal to zero.

4.resistance of the winding should be zero.

12.No load phaser diagram of an ideal transformer:



13.Approximate equivalent circuit of transformer referred to the primary side:



14.Regulation:

It is defined as the ratio of change in voltage from no-load to full load with respect to no-load voltage.

$$\text{Regulation Percentage} = \frac{E_{\text{no-load}} - E_{\text{full-load}}}{E_{\text{full-load}}}(100\%)$$

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15.Equations of voltage regulation of a transformer are:

%Regulation=(I2Ro1cosϕ1+I2Xo2sinϕ2)/V2 (or)

%Regulation=(I1Ro1cosϕ1+I1Xo1sinϕ1)/V1

For lagging current and 'minus (-)'in place of 'plus (+)' for leading power factor load.

16.Transformer losses:

There are two types of transformer losses they are:

1.core loss (or) Iron loss:

a. Hysteresis loss.

b. Eddy current loss.

2. Copper loss:

They are also called I^2R loss. These losses occur in transformer windings. Total copper loss in a transformer.

Total Cu loss=$I^2 1R1+I^2 2R2$.

17.Efficiency of a transformer:

- The performance of a transformer is decided by two factors:

1. Efficiency.
2. Regulation.

- In a practical transformer the output power will never be equal to input power.
- The efficiency of a transformer is defined as the ratio of output power to the input power.

%η=output power / input power x100%
=output power / (output power+losses)x100%
=V2I2cosϕ2 / (V2I2cosϕ2+Wi+Wcu)x100%
=KVA Rating / (KVA+Wi+Wcu)x100%

efficiency of a transformer will be maximum when copper loss and iron losses are equal. That is Copper loss = Iron loss.

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18.

At full load:

$$\% \eta = \frac{V_2 I_2 \cos\phi_2}{V_2 I_2 \cos\phi_2 + W_i + W_{cu}} \times 100$$

At half load:

$$\% \eta = \frac{\frac{1}{2} V_2 I_2 \cos\phi_2}{\frac{1}{2} V_2 I_2 \cos\phi_2 + W_i + W_{cu}} \times 100$$

19. In Open Circuit test is used to find the core losses in the transformer. In this test the secondary side of the transformer is left open. Therefore, the current on the primary side is very less. Then the copper losses will be neglected. This test will be conducted on the low voltage (LV) side of the transformer because on LV side the rated voltage is less.

20. Short Circuit test is used to find out copper losses in the transformer. This test will be performed on the high voltage (HV) side of the transformer because on the HV side of the rated current is less then less amount of voltage is required to produce rated current. Therefore, core losses can be neglected.

Long answer questions:

1. B-H characteristics of magnetic materials:
   - The curve drawn between flux density 'B' and magnetisation flux 'H'.
   - The characteristic curve is also called hysteresis loop. When the magnetisation force is equal to zero then all the dipoles in magnetic material will orient in different directions.
   - When the magnetisation force is increased material gets magnetised therefore, flux density will also increase and reaches its saturation point.
   - When the, magnetisation force is decreased flux density will also decrease and it doesn't come to zero. This flux is called residual flux.

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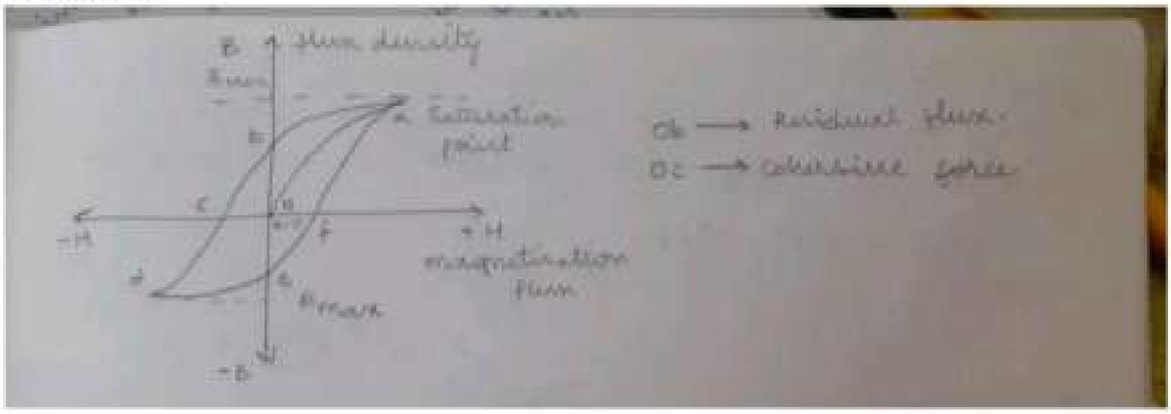
- To make the residual flux zero we have to increase the magnetisation force in negative direction. Therefore, this force is called cohersive force.

B-H curve:



2.

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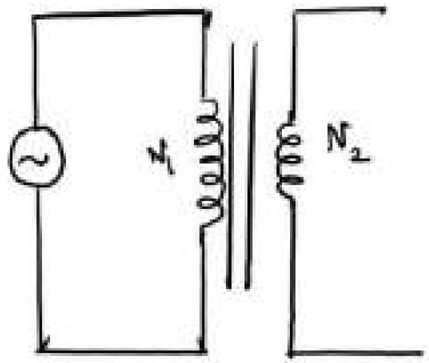
Where $\psi=N\Phi$, Φ=flux per turn, ψ=flux linkages, N=total number of turns.

3.Principle of operation of a single-phase transformer:

Transformer woks on the principle of mutual induction which states that "when the two coils are inductively coupled and if the current in one coil changes then an emf gets induced in the second coil".



N_1= Primary winding

N_2= Secondary winding

4.Types of single-phase transformer:

Based on the constructional of a transformer those are divided into two types:

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1. Core type.
2. Shell type.

Core type:

- It consists of two limbs and two yolks.
- In core type of transformer winding surrounds the core.
- The flux produced in the primary winding will flow through the entire core.
- More amount of winding is used compared to the core.
- These are used for high voltage application.

  Eg: Distribution transformers, power transformer.

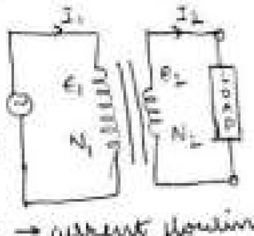
Shell type:

- It consists of three limbs and 2 yolks.
- In shell type transformer core surrounds the winding and both the windings are placed on central limb.
- The flux produced by the primary winding will flow in the central limb and the other limb carries half of the main flux i.e., Φ_2
- Core is more than the windings.
- These are used for low voltage applications.

  Eg: In electronic circuits.

5.

E.M.F equation of a transformer:



E_1 → R.M.S value of Induced emf in primary winding.

E_2 → RMS value of Induced emf in secondary winding.

N_1 → No: of primary windings.

N_2 → NO: of secondary windings.

I_1 → current flowing in primary winding.

I_2 → current flowing secondary windin

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$I \rightarrow AC \quad \phi \rightarrow AC$

Primary winding is excited by purely sinusoidal alternating voltage hence the flux produced is also sinusoidal in nature let $I = I_m \sin\omega t$..

- The nature of the flux depends on nature of current

$\therefore \phi = \phi_m \sin\omega t$ where I_m, ϕ_m are maximum values of current and flux.

Let e_1 = instantaneous value of induced emf in primary winding

e_2 = instantaneous value of induced emf in secondary winding

According to faraday's law the magnitude of induced emf is equal to rate of change of flux linkages

$$\therefore e_1 = \frac{d\psi}{dt} = \frac{d(N_1\phi)}{dt} = N_1\frac{d\phi}{dt} \qquad e_2 = \frac{d\psi}{dt} = \frac{d(N_2\phi)}{dt} = N_2\frac{d\phi}{dt}$$

According to lenz law always the effect opposes the cause

$$\therefore e_1 = -N_1\frac{d\phi}{dt}$$

$$= N_1 \frac{d}{dt}(\phi_m \sin\omega t) = -N_1\phi_m\frac{d}{dt}(\sin\omega t)$$

$$= -N_1\phi_m \cos\omega t \cdot \omega$$

$$= -N_1\phi_m\omega\,[\sin(90 - \omega t)]$$

$$= -N_1\phi_m\omega\,[\sin(-(\omega t - 90°))]$$

$$e_1 = +N_1\phi_m\omega \sin(\omega t - 90°)$$

Ily $e_2 = N_2\phi_m\omega\sin(\omega t - 90°)$

$e_1\,max = N_1\phi_m\omega$, $e_2\,max = N_2\phi_m\omega$

$$e_1 = \frac{N_1\phi_m\omega}{\sqrt{2}} = \frac{N_1\phi(2\pi f)}{\sqrt{2}}$$

$$\boxed{e_1 = 4.44\,f N_1\phi_m}$$

$$\boxed{e_2 = 4.44\,f N_2\phi_m}$$

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6. Transformer losses:

There are two types of transformer losses they are:

1.core loss (or) Iron loss:

a. Hysteresis loss.

b. Eddy current loss.

2. Copper losses:

They are also called I^2R loss. These losses occur in transformer windings. Total copper loss in a transformer.

Total Cu loss=$I^2 1R1+I^2 2R2$.

Core loss (or) iron loss:

Hysteresis loss:

It will occur due to the reversal of magnetisation force. This loss is given by Wn= η(Bmax)fv.

f=frequency.

v=applied voltage.

η= steinmetz constant.

Eddy current loss:

Due to the alternating nature of the flux and emf will be induced in the core because of that emf current will circulate in the core this current is called eddy current and the loss due to eddy currents is called eddy current loss.

$$W_e = K_e f^2 K_f^2 B_m^2 \, watts$$

Bm=maximum flux density.

This loss can be reduced by using laminated core.

7.Ideal transformer at no load condition:

- When the ideal transformer is in no load the secondary current I2=0.

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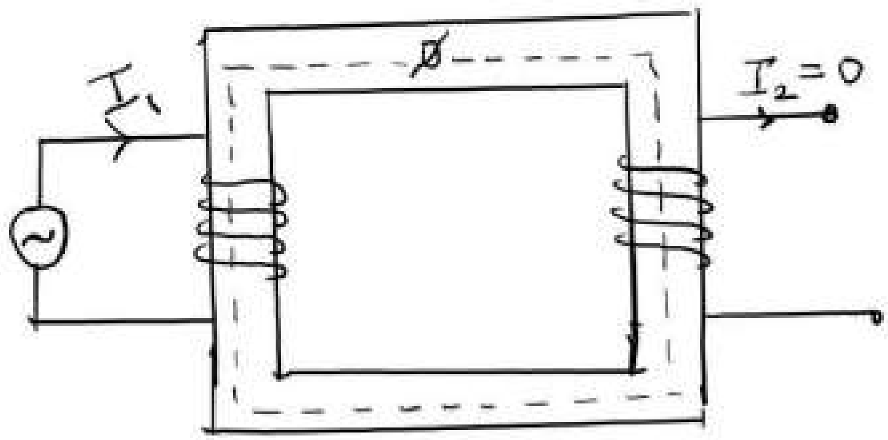
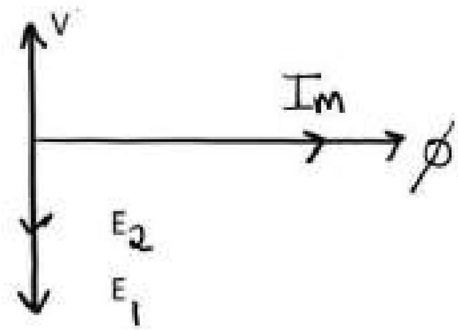
- The primary cross a current I1 which is just necessary to produce the flux in the core. As this flux is magnetising component of current (Im).
- There are no losses in a transformer and there is no winding resistance. Therefore, the transformer windings are purely inductive in nature then magnetising current (Im) lags V1 by an angle 90°.
- As the flux links with both the windings and produces emfs e1and e2.
- According to lenz's law e1 and e2 should oppose V1.



Phasor diagram :



8.Practical transformer on load:

- In a practical transformer magnetic core causes iron losses and primary winding resistance causes copper losses (small amount).

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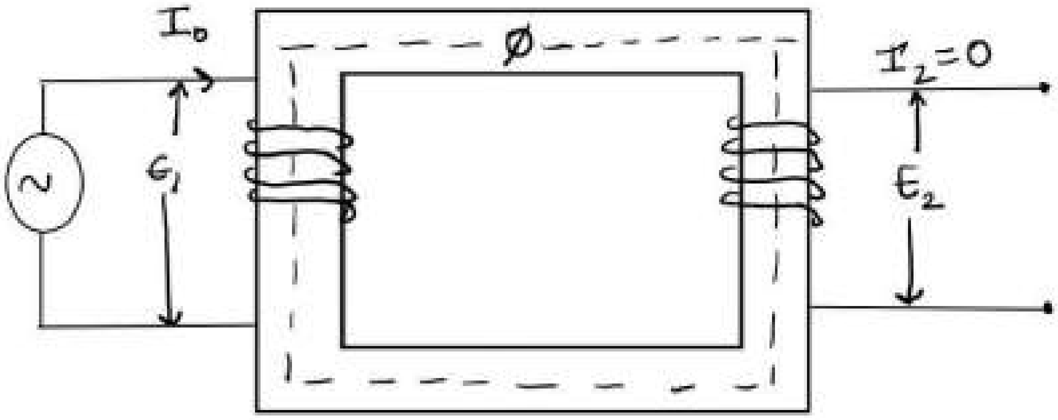
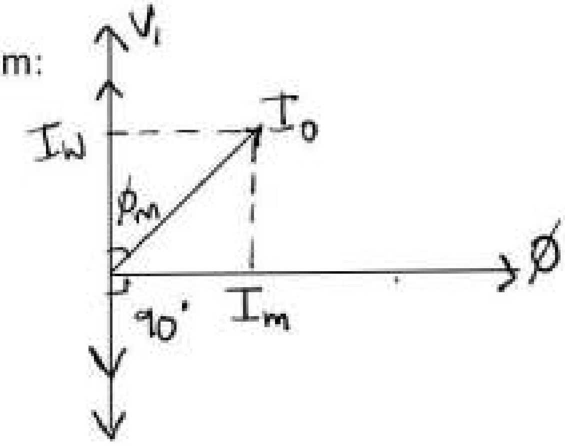
- Thus, the primary current under no-load condition has to supply iron losses and a small amount of primary copper losses. This current is denoted as Io.
- The no load current Io is divided into two components:
  1.The current which is used to produced flux on the core is called magnetising component of current.
  2.The current which is used to produce iron losses in the core is called core loss component of current or working component of current i.e., Iw.



Phasor diagram:



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4. ~~given~~

9. Given that:

$E_1/E_2 = 2200/250^{V}$

$f = 50\,Hz$

$A = 36$ Sq. cm

$B_{max} = 0.6\ wb/m^2$

$N_1 = ?$

$N_2 = ?$

we know $E_1 = 4.44 f N_1 \phi$ and $E_2 = 4.44 f N_2 \phi$

$\Rightarrow N_1 = \dfrac{E_1}{4.44 f \phi}$ and $N_2 = \dfrac{E_2}{4.44 f \phi}$

we know $B = \dfrac{\phi}{A}$

$\phi = BA = 0.6 \times 36 \times 10^{-4} = 21.6 \times 10^{-4}$

$N_1 = \dfrac{2200}{4.44 \times 50 \times 21.6 \times 10^{-4}} = 4587.9$

$N_2 = \dfrac{250}{4.44 \times 50 \times 21.6 \times 10^{-4}} = 521.3$

10. Given that

$KVA = 8 =$ [illegible]

$E_1 = 400V,\ E_2 = 120V$

$f = 50\,Hz$

Power factor $= \cos\phi = 0.8$

$\Rightarrow \sin\phi = 0.6$

Efficiency $= \eta = \dfrac{KVA\ rating}{KVA + W_i + W_{cu}} \times 100\%$

$I_{sc} = 20A,\ V_{sc} = 9.5V,\ W_{sc} = 110W$

$I_0 = 4A,\ V_0 = 120V,\ W_0 = 75W$

$\%\ \text{Regulation} = \dfrac{I_2 R_{02} \cos\phi_2 + I_2 X_{02} \sin\phi_2}{E_2}$

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$W_{sc} = I_{sc}^2 \, R_{O_2}$

$$R_{O_2} = \frac{W_{sc}}{I_{sc}^2} = \frac{110}{(20)^2} = \frac{11\cancel{0}}{20 \times 2\cancel{0}} = 0.275\ \Omega$$

$$Z_{O_2} = \frac{V_{sc}}{I_{sc}} = \frac{9.5}{20} = 0.475\ A$$

$$X_{O_2} = \sqrt{Z_{O}^2 - R_{O_2}^2} = \sqrt{\left(\frac{19}{40}\right)^2 - \left(\frac{11}{40}\right)^2} = \frac{\sqrt{15}}{10} = 0.38$$

$$\%\ \text{Regulation} = \frac{(20 \times 0.275 \times 0.8) + (20 \times 0.38 \times 0.6)}{120} \times 100$$

$$= \frac{4.4 + 4.56}{120} \times 100 = \frac{8.96}{120} \times 100$$

$$= 7.46$$

$$\text{efficiency} = \%\ \eta = \frac{8 \times 10^3}{8 \times 10^3 + 75 + 110} \times 100$$

$$= 97.7$$

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UNIT - 4

SHORT - ANSWER QUESTIONS :

1. What is Fleming's right hand rule?

When the right hand three fingers (thumb, forefinger and middle finger) are placed ~~in~~with perpendicular with each other, then fore finger indicates direction of magnetic flux, middle finger indicates direction of induced current and thumb indicates direction of force.

2. List the main parts of D.C machine

The main parts of DC machine are

1) Field system - i, pole core
   ii, pole shoe
   iii, Field winding
   iv, yoke
2) Armature system - i, armature core
   ii, armature winding

3. What are the functions of yoke in DC machine?

functions of yoke in DC machine are

1. It supports entire machine giving mechanical support
2. It provides return path for the flux
3. It acts as a protecting cover for entire machine

4. What are the functions of pole core and pole shoe in D.C machines?

polecore :- It accomodates field winding and provides low reluctance to the flux

pole shoe : It is used to distributes the flux uniformly

5. What are the functions of commutator in D.C machines?

Function of commutator is to convert AC to DC

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6 What is flemings left hand rule?
When the left hand 3 fingers (thumb, middle and fore finger) are placed perpendicular with each other then fore finger represents direction of magnetic field, middle finger indicates direction of induced current and thumb indicates direction of force

7 What is an electric motor? state its principle of working.
Electric motor: It is a machine that converts electrical energy into mechanical energy
principle of working: Whenever the current carrying conductor is placed in a magnetic field, it experiences a mechanical force and direction of force is given by flemings left hand rule

8 Define back emf. Write the significance of back e.m.f in D.C motor
Back emf: When motor starts rotating, it cuts magnetic flux and emf will be induced in the armature called back emf.
Significance: Back emf makes dc motor self regulating machine. During starting, back emf is zero and large current flows through motor. As motor picks up speed, back emf opposes, and limit current to safe value. i.e, it makes motor to draw as much armature current as is just sufficient to develop torque required by the load

9. List the types of D.C motors.
There are three types of motors
1. shunt motor
2. series motor
3. compound motor

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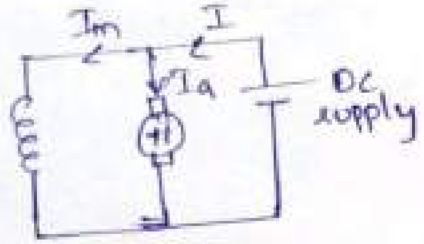
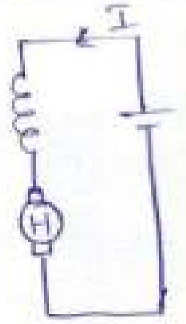
i, shunt motor

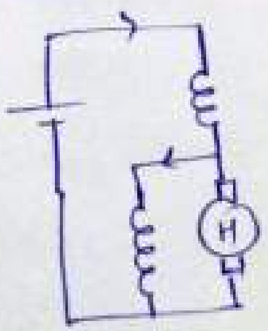


ii, series motor

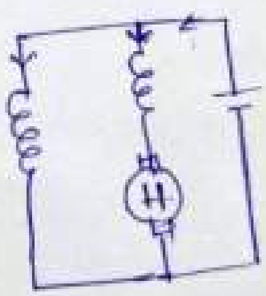


iii, component motor

a) short shunt



b) long shunt



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10. Write the Torque, voltage equations of DC motor

Torque equation = $\frac{0.159\phi ZPI_a}{A}$ N-m

Voltage equation ⇒ $V = I_aR_a + E_b$

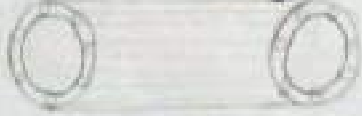
11. A three phase Induction motor does not run at synchronous speed why?

If rotor speed becomes equal to synchronous speed then no flux linkage will be in rotor conductors as there will be no relative ~~mot~~ speed between rotating magnetic field and rotor and the rotor speed starts decreasing. so to maintain relative speed between stator and rotor it should always runs less than synchronous speed

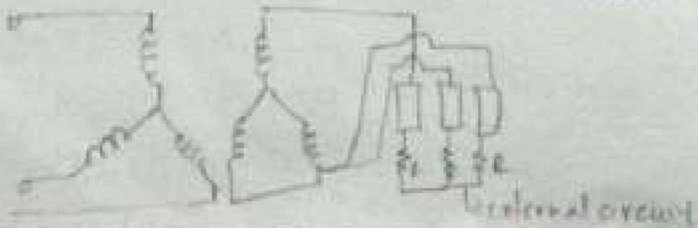
12. Write about types of rotors in three phase Induction motor

Two types of rotors

1. Squirrel cage induction motor : This rotor is cylindrical, made up of silicon steel lamination and consists of aluminium bars called rotor conductors placed in slots. These bars are permanently short circuited at each end with end ring



2. slip ring rotor : It will be in form of star-delta rotor and made up of silicon steel laminations.
   - → Armature conductors are placed in rotor and rotor is connected to external circuit through slip rings



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13 Define synchronous speed and slip?

Synchronous speed: The speed of rotating magnetic field in stator of motor is called synchronous speed

$$N_s = \frac{120f}{P}$$

slip: it is defined as difference between synchronous speed and rotor speed as a fraction of synchronous speed

$$S = \frac{N_s - N_r}{N_s}$$

14 Write the torque equation of three phase induction motor

$$T = \frac{60}{2\pi N_s} \times \frac{SE_2^2 R_2}{R_2^2 + (SX_2)^2}$$

where S = slip of induction motor

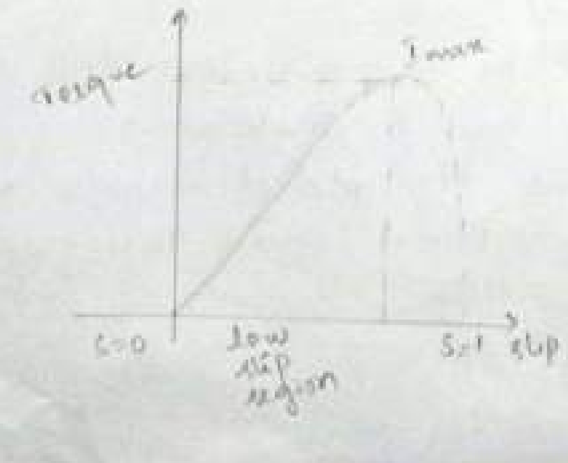
N_s = synchronous speed

R_2 = Rotor Resistance

X_2 = Rotor reactance

E_2 = Induced emf of rotor

15 Draw the torque slip characteristics of three phase induction motor



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16 Write the working principle of single phase induction motor

A single phase induction motor consists of single phase winding which is mounted on stator of motor and cage winding is placed on rotor. A pulsating magnetic field is produced, when the stator winding of the 1-ϕ induction motor is energised by 1-ϕ supply

17 Why single phase induction motors are not self-start induction motor?

When 1-ϕ supply is given to stator winding, it does not produce rotating magnetic field as it consists of only one winding. In positive half cycle, it produces positive torque and in negative half cycle, it produces negative torque. Average Torque becomes zero with this reason, single 1-ϕ induction motor initially oscillates and finally reaches to steady state (0 rpm). So Induction motor cannot run with single stator winding arrangement and it is not self starting machine

18 What is the function of capacitor in 1-ϕ induction motor?

A single phase induction motor cannot produce a rotating torque. So in order to start the motor by increasing the starting torque, capacitor is used

19 Why starting torque of a capacitor start induction motor is high?

In capacitor start induction motor there are two windings - main winding and auxillary. Since the torque produced by these windings depends upon angle difference which is almost 90°. Hence it produces high starting torque.

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20 Write the applications of capacitor start Induction motor.

Applications:

1) It is used in refregerators and air conditioners

2) It is used in pumps and compressors

3) These motors are used for loads of higher inertia where frequent starting is required.

4) These are used for conveyors and machine tools

LONG ANSWER QUESTIONS.

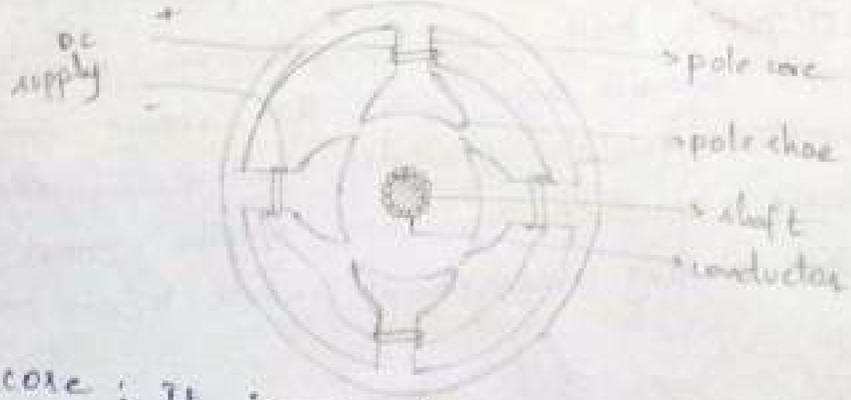
1. With neat diagram explain the construction of DC machine

Construction of DC machine :-

DC machine consists of two main parts

1. Field system 2. Armature system

1. Field system:



i) Pole core: It is made up of cast iron and cast steel for larger machines

→ It is used to accomodate field winding

→ It provides low reluctance to the flux

ii) pole shoe: It is used to distribute the flux uniformly. It is also made up of cast iron or cast steel.

iii) Field winding: It is used to produce flux. It is made up of copper windings

iv) yoke: It is made up of iron or steel

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→ It supports entire machine and give mechanical support
→ It provides return path for the flux
→ It acts as a protecting cover for entire machine.

3 Armature system:
It consists of i) armature core and
ii) armature winding.

i) Armature core: It is made up of silicon steel and it is laminated to reduce eddy current loss
→ It is used to accomodate armature winding.
These windings are placed in armature slots and this armature ~~winden~~ core is cylindrical in shape
ii) Armature winding: It is made up of copper.

2. Explain the principle and operation of DC motor
DC motor: It is a machine which converts electrical energy into mechanical energy
principle of operation:- whenever the current carrying conductor placed in a magnetic field it experiences mechanical force and direction of force is given by flemings left hand rule.
Flemings left hand rule:
when the left hand 3 fingers (thumb, middle and fore

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finger) are placed perpendicular with each other, then fore finger represents direction of magnetic field, middle finger indicates direction of induced current and thumb indicates direction of force.

3. Derive the expression for the armature torque of a DC motor.

Input for DC motor is electric power and output is mechanical power.

Mechanical power $= T \times \omega$

$= T \times 2\pi f$

$= T \times 2\pi N/60$

$= 2\pi N T/60$

Electrical power $= E_b \times I_a$.

$\Rightarrow E_b \times I_a = \frac{2\pi N T}{60}$

$\Rightarrow T = \frac{E_b I_a 60}{2\pi N}$

$\Rightarrow \tau = \frac{\phi Z N P}{60 A} \times \frac{I_a 60}{2\pi N}$

$= \frac{1}{2\pi A} \times \phi Z P \times I_a$

$$\boxed{\tau = \frac{0.159 \phi Z P I_a}{A} \quad N\text{-}m}$$

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4 With neat diagram explain the construction of three phase induction motor

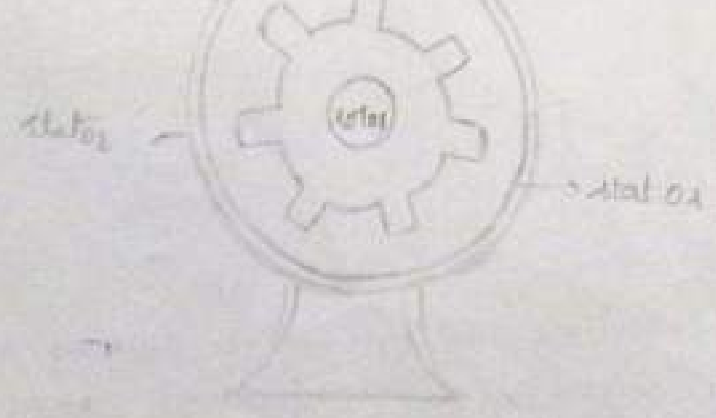
3-ϕ Induction motor consists of two main parts
i) stator
2) rotor

1 Stator : stator consists of i) stator core
ii) stator winding
iii) yoke.

i) stator core : It accomodates stator winding and made up of iron/steel and it is laminated core. It consists of slots and field winding is placed in those slots.

ii) stator winding: stator winding bounded in the form of Δ or Y whenever 3-ϕ supply is given to the windings, it produces magnetic flux, i.e, rotating magnetic field

iii) yoke: It is made up of iron/steel
→ It acts like protecting cover for entire machine and it also gives mechanical support to the motor



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2. Rotor : There are two types of rotors

i) squirrel cage induction motor

→ Rotor is made up of silicon steel lamination

→ Rotor core is cylindrical in shape and has slots

→ rotor consists of aluminium bars called rotor conductors and these are placed in slots.

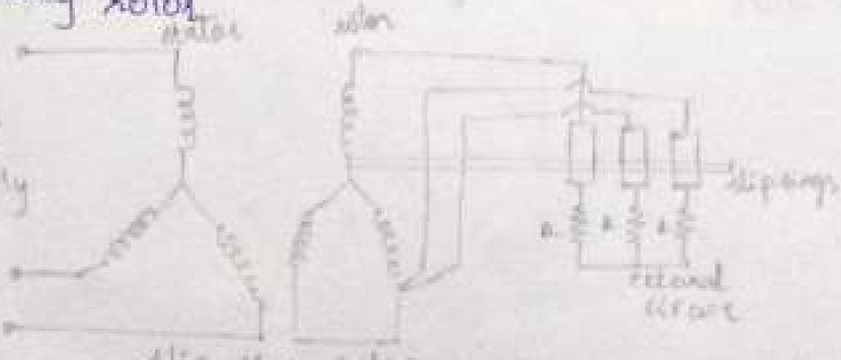
→ These bars are permanently short circuited at each end with the help of copper ring called as end ring

→ These end rings provide good mechanical strength to the rotor

→ The entire structure of a rotor looks like a cage so that rotor is also called squirrel cage rotor

→ There is no need of commutator and brushes in the rotor so it is easy to maintain. The rotor has slots and these slots are not arranged parallel to shaft but are skewed.

ii) slip ring rotor



slip ring rotor

slip ring rotor winding will be in the form of star/delta. Rotor is made up of silicon steel laminations and these armature conductors are placed in slots of the rotor and thus rotor is connected to external circuit through slip rings.

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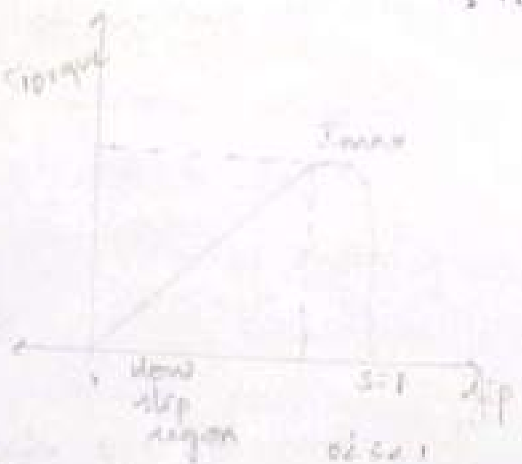
6. Explain the Torque slip characteristics of three phase induction motor.

Torque equation of 3-ϕ Induction motor $= \frac{60}{2\pi N_s} \cdot \frac{SE_2^2 R_2}{R_2^2 + (SX_2)^2}$

From this equation, $T \propto \frac{SE_2^2 R_2}{R_2^2 + (SX_2)^2}$



For low slip region:

slip values are less therefore neglect $(SX_2)^2$ term in above equation

$$T \propto \frac{SE_2^2 R_2}{R_2^2}$$

$$T \propto \frac{S}{R_2} \Rightarrow T \propto S$$

In high slip region:

$$(SX_2)^2 >> R_2$$

So, neglect R_2^2 term

$$\Rightarrow T \propto \frac{SE_2^2 R_2}{(SX_2)^2}$$

$$\Rightarrow T \propto \frac{SR_2}{S^2 X_2^2}$$

$$\Rightarrow T \propto \frac{R_2}{SX_2^2}$$

$$\Rightarrow T \propto \frac{1}{S}$$

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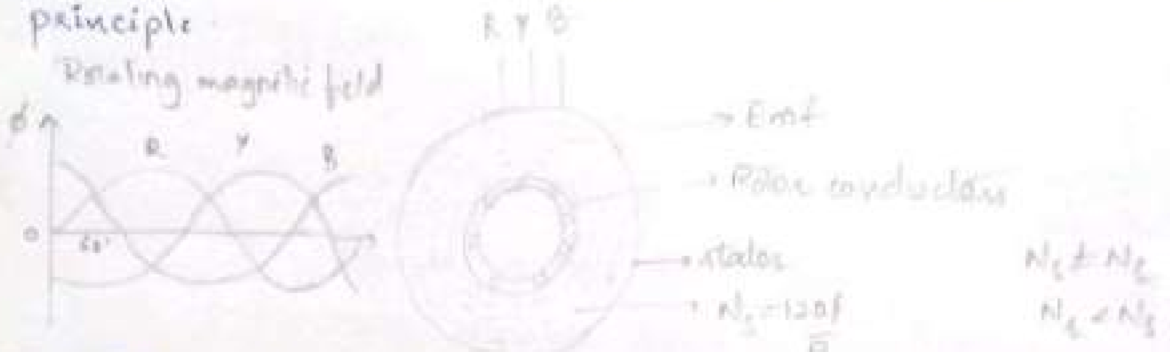
5. Explain the principle and working of a three phase induction motor.

Induction motor works on faraday's laws of electromagnetic induction i.e, induction motor works on the principle of mutual induction which is similar to transformer working principle.



→ When a 3-ϕ supply given to 3-ϕ winding of stator then rotating magnetic field in the air gap between rotor and stator. The speed of the rotating magnetic field is given by synchronous speed $N_s = \frac{120f}{P}$.

→ These rotating magnetic field links with the stationary rotor conductors then relative motion between rotating magnetic field and rotor and emf induced in the rotor conductors according to faraday's laws

→ As rotor conductors bars are short circuited on both sides by end rings then rotor forms a closed loop therefore induced emf circulates current in rotor known as rotor current

→ This rotor current produces magnetic field and interacts with stator magnetic field

→ according to lorentz force law, the interaction of these two magnetic field produces torque then rotor starts rotating with the speed of N_r

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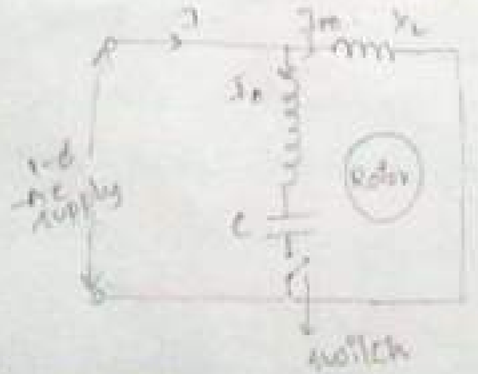
Rotor tries to catch the speed of rmf i.e, N_s, when the rotor achieves synchronous speed, then there will be no relative speed between stator and rotor. Then emf becomes zero in the rotor. Then there will be no current in rotor conductors. Due to this speed of rotor starts decreasing

- To maintain relative speed between stator and rotor, the rotor should always runs less than synchronous speed.

7. Explain the working principle of capacitor start single phase induction motor

In capacitor start induction motor there are 2 windings. Those are

1) Main winding. - connected across auxillary winding
2) Auxillary winding - connected to series with capacitor and centrifugal switch.



When single phase supply is given to the stator it passes through two windings. let Im = current in main winding, Ia = current in auxillary winding.

Main winding has high reactance and less resistance therefore Im lags the voltage

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Auxiliary winding has less reactance and more resistance and this current is also passing through capacitor, then $x_C > x_L$

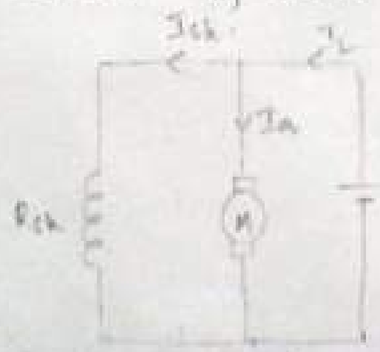
Therefore, I_A leads voltage.

These two currents produce flux and there will be phase difference between these two. Then the resultant flux interacts with the rotor flux and produces torque.

Once the Induction motor gets 70% of the rated speed the centrifugal switch will open. Then the stator consists of main winding only.

Due to Inertia of motor, the motor will continuously rotate.

8) A 230 volts dc shunt motor takes 51A at full load. Resistances of armature and field windings are 0.1Ω and 230Ω respectively. Determine i) field current ii) Armature current iii) back emf.



Given $I_L = 51A$

$R_a = 0.1\Omega$

$R_{sh} = 230\Omega$

~~i) Field current ii) Arm~~

i) Field current $(I_{sh}) = \frac{V_{dc}}{R_{sh}} = \frac{230V}{230\Omega} = 1A$

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ii) We know that $I_L = I_a + I_{sh}$

Armature current $(I_a) = I_L - I_{sh}$

$= 51 - 1$

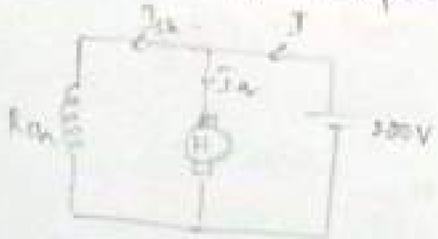
$= 50A$

iii) Back emf $(E_b) = V - I_a R_a$

$= 230 - 50 \times 0.1\Omega$

$= 225V$

9. A 200V, 4pole, lap wound DC shunt motor has 800 conductors on its armature. The resistance of the armature winding is 0.5Ω and that of shunt field winding is 200Ω. The motor takes a current of 21A, the flux/pole is 30mWb. Find the speed and the torque developed in the motor.



Given $I = 21A$

$\phi = 30\,mwb$

Armature resistance $R_a = 0.5\Omega$

$R_{sh} = 200\Omega$

No of poles $= P = 4$

A = No of parallel paths = 4 (In Lap wounding, A = P)

Total No of conductors = Z = 800

$I_{sh} = \frac{V}{R_{sh}} = \frac{200}{200} = 1A$

$I_a = I - I_{sh} = 21 - 1$

$= 20A$

We know that $E_b = V - I_a R_a$

$= 200V - 20(0.5)$

$= 190V$

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we know that $E_b = \frac{Z\phi NP}{60A}$

$$N = \frac{E_b \times 60A}{Z\phi P}$$

$$= \frac{190 \times 60 \times 4}{800 \times 30 \times 10^{-3} \times 4}$$

$$= \frac{19 \times 10^5}{10^3 \times 4}$$

$$= 4.75 \times 10^2 \text{ rpm}$$

$$= 475 \text{ rpm}$$

10 A 4-pole, 3-phase induction motor fed from 50Hz supply and has a rotor speed of 1425 rpm calculate i) synchronous speed and ii) % slip.

Given that $P = 4$

$f = 50\,Hz$

Rotor speed $N_r = 1425$ rpm

i) synchronous speed $= N_s = \frac{120f}{P}$

$$= \frac{120 \times 50Hz}{4}$$

$$= 1500 \text{ rpm}$$

ii) % slip $= \frac{N_s - N_r}{N_s} = \frac{1500 - 1425}{1500} \times 100$

$$= \frac{75}{1500} \times 100$$

$$= 5\%$$

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SAQ:

1. AC generator is called alternator because it converts mechanical energy into alternating electric energy which is in sine wave form.

2. Alternator is called synchronous generator because it runs at a constant speed known as synchronous speed (N_s)

3. Armature winding is stationary in an alternator for obtaining large ~~currents of~~ outputs in easier way and also for free maintenance.

4. There are two types of rotors in 3-ϕ alternator:
(i) Salient pole
(ii) Cylindrical.

5. A 3-ϕ synchronous machine will always run at synchronous speed to get a constant frequency of 50Hz.

6. $$f = \frac{PN_s}{120}$$

7. $$E = 4.44 K_c K_d \phi f T$$

8. The stator core of alternator is laminated to reduce eddy current losses.

9. Pole pitch is the angular distance between central line of 1 pole to the central line of other.

10. Pitch factor is the ratio of voltage generated in short pitch coil to voltage generated in full pitch coil.

Coil span factor is the distance between two sides of a coil.

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11. Distribution factor is the phasor sum of the voltages generated in the coil to Arithmetic sum of voltages generated in the coil.

12. $$K_d = \frac{\sin(m\beta/2)}{m \sin(\beta/2)}$$

13. $$K_c = \cos(\alpha/2)$$

14. A fuse is a protective device which protects electrical equipment by breaking the circuit when there is a short circuit.

15. A circuit breaker is a device used to protect appliances from getting damaged due to overload current by performing switching operations under normal as well as abnormal conditions.

16. A battery consists of a cathode, anode and an electrolyte.

17. There are two types of batteries:

(i) Primary batteries:

AA, AAA batteries.

(ii) Secondary batteries:

NiCd, NiMH, Li ion batteries.

18. Advantages of Lithium ion battery

(i) Light weight

(ii) Very low self-discharge rate.

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19.

Fuse	Circuit breaker.
- It works on the electrical and thermal properties of the conducting materials	- It works on electro-magnetism & switching principle.
- It can be used only once	- They can be used a number of times.
- It does not given any status indication	- It gives an indication of the status.
- Cost of fuse is low	- Cost of the circuit breaker is high.

20. Battery back up is the provision of power to a system when the primary source of power is unavailable.

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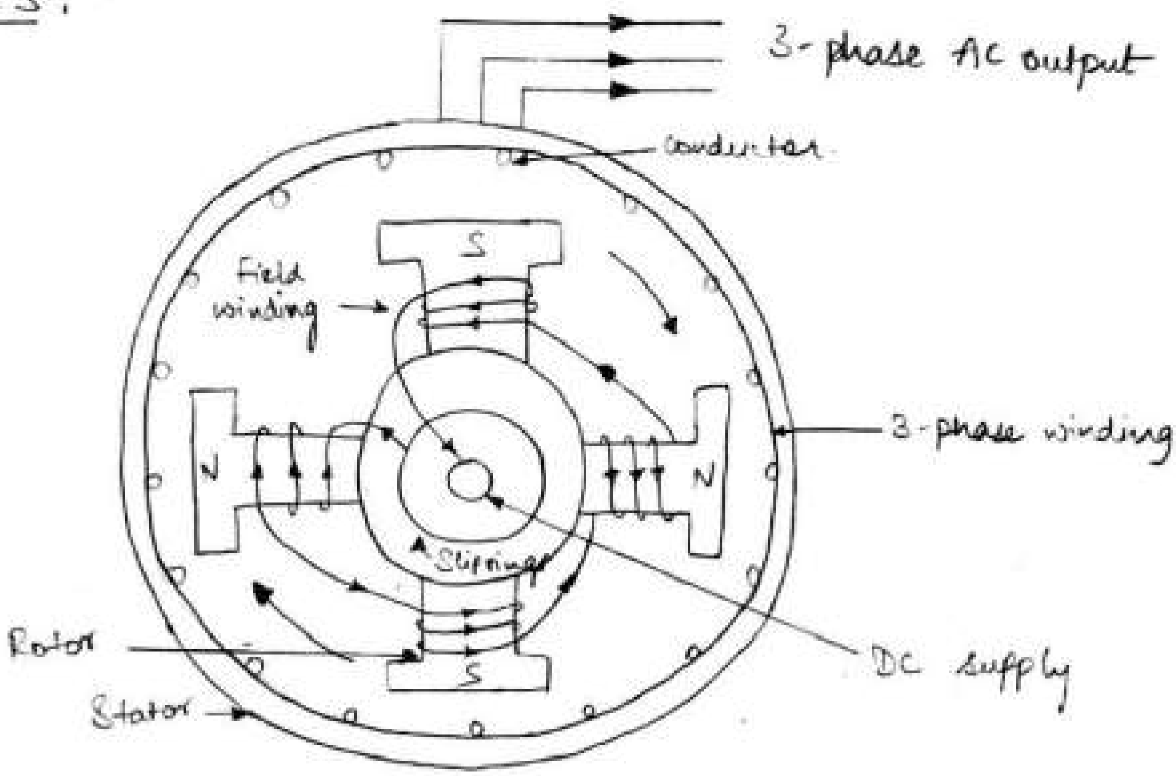
LAQ's:

1.



An AC generator consists of two main parts:
(i) Stator
(ii) Rotor

Stator:

It is the stationary component on which armature winding is wound. Armature winding carries load current. The stator is a stack of laminated steel assembled to form a cylindrical structure. Slots for housing stator winding (armature winding) are cut along the periphery of the stator.

Rotor.

It is the rotating component of the AC Generator which is also made up of laminated steel. DC field winding is wound on the rotor to create magnetic poles. There are two designs for rotor:

a) Salient Pole Rotor :

It is used in low and medium speed alternators. It consists of a large number of projected poles (salient poles) bolted on a magnetic wheel. These poles are also laminated to minimize the losses.

b) Cylindrical rotor:

It is used in high speed alternators, especially turbo alternators. It consists of a smooth and solid steel cylinder having slots along its outer periphery. Field windings are placed in these slots. They are cylindrical in shape having parallel slots on it to place rotor windings. It is made up of solid steel.

2. The basic working principle of AC generator is based on Faraday's laws of electromagnetic induction. According to it, whenever a conductor moves in a magnetic field, EMF gets induced across the conductor. If a closed path is provided to the conductor, induced emf causes current to flow in the circuit. Depending on the direction of rotation of the coil, the direction of induced current can be given by Fleming's right hand rule.

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The direction of current changes after half of the time period, which means that we get an alternating current.

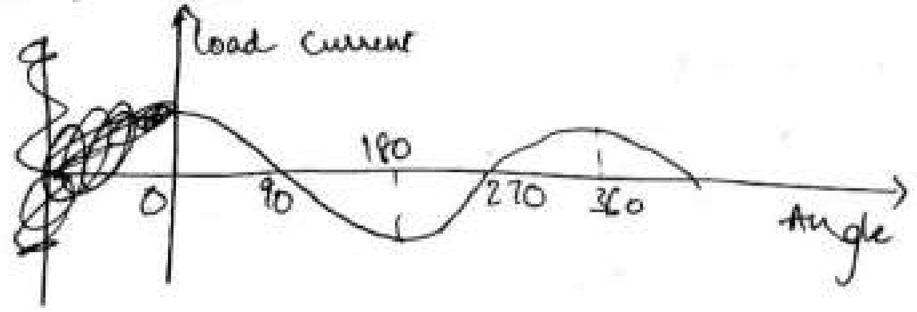
At an instant
When the rotor field axis and armature winding axis coincide, flux linkage is maximum and hence maximum emf is induced. Therefore, maximum current will flow through the load.

At an instant
When the rotor axis and armature winding axis are perpendicular to each other (After rotor is rotated by 90°), no emf will be induced in the stator because there will not be any mutual coupling between the two. Hence, no current will flow through the load.

A further rotation of rotor by 90° causes stator axis and rotor axis to coincide again. Hence flux linkage will again be maximum & maximum current will flow through the load.

But the current will reverse its direction because the direction of ~~flux~~ flux linkage is reversed.

The analysis for further rotor rotation can be done in the same manner.



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Thus, AC generator is converting mechanical energy into alternating electrical energy.

3. let ϕ be the flux per pole.

let N be the rotor speed in rpm.

for one revolution, rotor takes $\frac{60}{N}$ seconds.

let Z be the number of armature conductors

$$Z = 2T$$

where T is the number of turns.

let P be the number of poles.

let K_f be the form factor $[K_f = 1.11]$.

The average emf induced in a stator conductor:

$$e = \frac{d\phi}{dt} = \frac{P\phi}{(60/N)} = \frac{P\phi N}{60}$$

The synchronous speed $N = \frac{120f}{P}$.

$$\Rightarrow e = \frac{\cancel{P}\phi}{\cancel{60}} \times \frac{\cancel{120}^{2} f}{\cancel{P}} = 2\phi f.$$

If the total number of conductors are Z, then average induced emf:

$$e = 2\phi Z f.$$

We know that:

$$K_f = \frac{V_{rms}}{V_{avg}} \Rightarrow V_{rms} = K_f \times V_{avg}.$$

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$\Rightarrow E = K_f \times e$

$E = 1.11 \times 2 \phi Z f$

$E = 2.22 \phi Z f$

$E = 2.22 \phi (2T) f$

$E = 4.44 \phi T f$

Alternator stator winding is a 3-ϕ winding.
∴ This winding will be of distributed type.
So, the induced emf in an alternator will be reduced by two factors:

(i) Coil span factor (K_c) / Pitch factor

(ii) Distribution factor / winding factor (K_d)

∴ The alternator emf equation becomes:

$$\boxed{E = 4.44 K_c K_d \phi f T}$$

$$\boxed{E = 4 K_f K_c K_d \phi f T}$$

4. $P = 4$ 3-ϕ Slots $= 48$ $\alpha = 150°$ $K_c = ?$ $K_d = ?$

$K_c = \cos\left(\frac{\alpha}{2}\right)$

$K_c = \cos 75$

$K_c = \underline{0.25}$

$K_d = \dfrac{\sin\left(\frac{m\beta}{2}\right)}{m \sin\left(\frac{\beta}{2}\right)}$

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$$m = \frac{slots}{pole \times phase} = \frac{\cancel{48}^{4}}{\cancel{4 \times 3}} = 4$$

$$\beta = \frac{180}{n} = 180 \times \frac{pole}{slots} = \cancel{180}^{15} \times \frac{\cancel{4}}{\cancel{48}_{12}} = 15^\circ$$

$$K_d = \frac{\sin \frac{4 \times 15}{2}}{4 \times \sin \frac{15}{2}} = \frac{\sin 30}{4 \times \sin 7.5}$$

$$K_d = \underline{\underline{0.96}}.$$

5. 3-ϕ $P = 10$ $N_s = 600 rpm$ slots $= 120$

Total number of conductors $= 8 \times 120 = 960$.

$\phi = 56 \times 10^{-3} wb$ $E_{ph} = ?$ $E_{line} = ?$

$K_c = \cos\left(\frac{\alpha}{2}\right)$

Given, it is a full pitch coil

$\Rightarrow$ $K_c = \cos 0 = \underline{1}$.

$$K_d = \frac{\sin \frac{m\beta}{2}}{m \sin \frac{\beta}{2}}$$

$$m = \frac{slots}{pole \times phase} = \frac{\cancel{120}^{4}}{\cancel{3 \times 10}} = 4$$

$$\beta = \frac{180}{n} = 180 \times \frac{pole}{slots} = \cancel{180}^{15} \times \frac{\cancel{10}}{\cancel{120}} = 15$$

$$K_d = \frac{\sin 30}{4 \times \sin 7.5} = 0.957$$

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$$N_s = \frac{120f}{P} \Rightarrow f = \frac{N_s P}{2} = \frac{\cancel{600}^{5} \times 10}{\cancel{120}} = 50\,Hz.$$

$E_{ph} = 4.44 \times K_c \times K_d \phi f T$

$$= 4.44 \times 1 \times \overset{0.957}{\cancel{1}} \times 56 \times 10^{-3} \times 50 \times T$$

$$T = \frac{Z}{2} = \frac{\cancel{960}^{480}}{\cancel{2}} = 480$$

$$\Rightarrow E_{ph} = 4.44 \times \overset{0.957}{\cancel{1}} \times 56 \times 10^{-3} \times 50 \times 480$$

$$E_{ph} = 571.0.76$$

$$E_{line} = \sqrt{3} \times 5668.992 = \underline{9891.03}$$

6. $$K_d = \frac{\sin \frac{m\beta}{2}}{m \sin \frac{\beta}{2}} \qquad m = \frac{\text{slots}}{\text{pole} \times \text{phase}} = \frac{\cancel{36}^{3}}{\cancel{4 \times 3}} = 3.$$

$$\beta = \frac{180}{n} = 180 \times \frac{\text{pole}}{\text{slots}} = 180 \times \frac{4}{\cancel{36}_{9}} = 20.$$

$$K_d = \frac{\sin \frac{60}{2}}{3 \sin 10} = \frac{\sin 30}{3 \sin 10} = 0.96$$

7. $3\text{-}\phi$ $f = 50\,Hz$ $P = 20$ Slots $= 180$

Total no. of conductors $= 4 \times 180 = 720$

$\phi = 0.05$ $\alpha = 160^\circ$

$$K_c = \cos\frac{\alpha}{2} = \cos 80 = 0.173$$

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$$K_d = \frac{\sin\left(\frac{m\beta}{2}\right)}{m \sin\left(\frac{\beta}{2}\right)}$$

$$m = \frac{\text{slots}}{\text{pole} \times \text{phase}} = \frac{\cancel{180}^{3}}{\cancel{20 \times 3}} = 3$$

$$\beta = \frac{180}{n} = 180 \times \frac{\text{pole}}{\text{slots}} = \cancel{180} \times \frac{20}{\cancel{180}} = 20.$$

$$K_d = \frac{\sin\left(\frac{3(20)}{2}\right)}{3 \sin 10} = \frac{\sin 30}{3 \sin 10} = 0.96$$

$$E = 4.44\, K_c K_d \phi f T$$

$$E = 4.44 \times 0.173 \times 0.96 \times 50 \times T$$

$$T = \frac{Z}{2} = \frac{720}{2} = 360.$$

$$E = 4.44 \times 0.173 \times 0.96 \times 50 \times 360 \times 0.05$$

$$E = 663.65\,V$$

8. Batteries are the most common power source from basic handheld devices to large scale industrial applications.

There are two types of batteries:

(i) Primary batteries:

These batteries are meant for single use. Once these batteries are used they cannot be recharged as the devices are easily reversible and active materials may not return to their original forms.

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Some of the examples for the disposable batteries are the normal AA, AAA batteries which we use in wall clocks, television remote etc. Other name for these batteries is disposable batteries.

(ii) <u>Secondary batteries</u>:

They are also called rechargeable batteries. These can be used and recharged simultaneously. They are usually assembled with active materials in the discharged state. They are recharged by applying electric current, which reverses the chemical reactions that occur during discharge.

Chargers are devices which supply the required current. Some examples for these rechargeable batteries are the batteries used in mobile phones, MP3 players etc.

There are 3 types of rechargeable batteries:

(a) Nickel cadmium batteries.

(b) Nickel metal hydride batteries

(c) Lithium ion batteries.

<u>Nickel cadmium batteries</u>:

The active components of a rechargeable NiCd battery in the charged state consists of NiOH in the positive electrode and Cd in the negative electrode. For the electrolyte, KOH is normally used. Due to their low internal resistance and very

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good current conducting properties, Nicd batteries can supply extremely high currents and can be recharged rapidly.

Nicd cells generally offer a long service life thereby ensuring a high degree of economy.

b) Nickel metal hydride batteries:

The active components of a rechargeable NiMH battery in the charged state consists of NiOH in the positive electrode and a hydrogen storing metal alloy (MH) in the ~~metal~~ negative electrode as well as a potassium hydroxide (KOH) electrolyte.

Compared to rechargeable Nicd batteries, NiMH batteries have a higher energy density per volume and weight

c) Lithium ion batteries:

In these batteries the anode and cathode materials serve as a host for the Lithium ion (Li^+). Lithium ions move from the anode to the cathode during discharge. The ions reverse direction during charging. An electrolyte composed of an organic solvent and dissolved lithium salt provides the media for lithium ion transport.

They are used in Mobile phones, laptops, Digital Camera.

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9. Advantages:

(i) Cell reaction is reversible

(ii) Have long shelf life.

(iii) They can be used as energy storage devices

(iv) They have a low self-discharge rate.

Disadvantages:

(i) The deposits inside the electrolyte overtime will inhibit the flow of charge. This increases the internal resistance of the battery and the cell's capacity to deliver current gradually decreases

(ii) High charging & high temperature may lead to capacity loss.

10. Q20 (SAQ)
+

Backup batteries range from small single cells to large battery room facilities.

Applications:

(i) Aircraft emergency batteries:

Backup batteries in aircraft keep essential instruments and devices running in the event of an engine power failure. Each aircraft has enough power in the backup batteries to facilitate a safe landing.

(ii) Computer:

Modern personal computer motherboards have a backup battery to run the real-time clock circuit and retain configuration memory while

(8)

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the system is turned off. Backup batteries are used in uninterruptible power supplies(UPS) and provide power to the computers they supply for a variable period after a power failure.

(iii) Telephony:
A local backup battery unit is necessary in some telephony and combined telephony/data applications. In such networks there are active units on the telephone exchange side and on the user side, but nodes between them are all passive in the meaning of electrical power usage.

(iv) Hospitals:
Power failure in a hospital would result in life-threatening conditions for patients. Patients undergoing surgery or on life support are reliant on a consistent power supply. Backup generators or batteries supply power to critical equipment until main power can be restored.

(v) Power stations:
Power failure in a power station that produces electricity would result in a blackout situation that would cause irreparable damage to equipment such as the turbine-generator. A bank of large station backup batteries are used to power UPS as well as emergency oil pumps while normal power is being restored to the power station.

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