LORDS INSTITUTE OF ENGINEERING &TECHNOLOGY

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QUESTION BANK

BASIC ELECTRICAL ENGINEERING

[U23EE201]

[Common to CSE,CSD]

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Note: A question bank is versatile and flexible FAQs that cover the entire syllabus of a subject. It is used by students and teachers for learning and assessment purposes only.

Basic Electrical Engineering (U23EE201)
UNIT-I – D.C CIRCUITS

SHORT ANSWER QUESTIONS(SAQs)

1. State ohms law. **[BTL-1]**

Ohm's law states that "the current flowing through a conductor is directly proportional to the voltage across its ends at constant temperature."

Mathematically Ohm's law is given as

$$I \,\alpha\, V$$

$$\frac{V}{I} = Constant$$

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

$$\boxed{V=IR}$$

where V is the voltage (in volts),
I is the current (in amperes), and
R is the resistance (in ohms).

2. Write limitations of Ohm's law. **[BTL-2]**

1. It is not applicable for electrolytes, non-linear devices such as diodes, zener diode, voltage regulators etc.
2. It is not applicable for vacuum tube semiconductors gas field tubes and arc lamps.
3. It is not applied to metals which get heated up due to flow of current through it.
4. It is not applied for the appliances like metal rectifies, crystal detectors in which operation depends on direction of current.

3. State Kirchhoff's laws. **[BTL-1]**

Kirchhoff's laws are two types

(i) <u>Kirchhoff's Current Law (KCL) or Point law:-</u>

In any electrical network, "the algebraic sum of currents meeting at a node or junction point is zero". Total current leaving a junction is equal to the total current entering that junction.

$$\boxed{\sum I = 0}$$

Total Incoming currents = Total Outgoing currents

ii) **<u>Kirchhoff's Voltage Law (KVL) or Mesh law: -</u>**

"The algebraic sum of voltages and voltage drops in any closed path in a network is zero."

$$\boxed{\sum(V+IR) = 0}$$

4. State the super position theorem. **BTL-1**

Superposition theorem states that "In any linear network consisting of two are more sources. The response in any element is equal to the algebraic sum of the responses caused by individual sources acting alone, while the other sources are eliminated."

5. State the Thevenin's theorem. **BTL-1**

Thevenin's theorem states that "Any linear network consisting of independent and/or dependent voltage or current sources and resistances can be replaced with an equivalent circuit consisting of a voltage source V_{th} in series with a resistance R_{th}."

6. **Define i)Potential ii)Voltage iii)Specific Resistance iv)conductance BTL-1**

i)Potential: It is the work done in moving a unit positive charge from Infinity distance to a point of reference within electric field.

$$\text{Electric Potential} = \frac{\text{work done}}{\text{Charge}} \text{ volts(V)}$$

ii)Voltage(V): It is the pressure required to drive the current in the circuit. Sometime potential difference is called as voltage. It is denoted by letter V and is measured in volts.

iii)Specific Resistance(ρ): It is the resistance between the opposite faces of a cube of the material. It is measured in ohm meter(Ω-m).

iv)Conductance(G): It is the ability of the substance to conduct electricity. Conductance is the reciprocal of the resistance. It is measured in siemens(S).

$$G = \frac{1}{R}$$

7. **List the different types of voltage and current sources. [BTL-1]**

The Voltage and Current sources are classified as

<u>Independent Sources</u>

1. Independent Voltage Source
   a) Ideal Voltage source.
   b) Practical Voltage source.
2. Independent Current Source
   a) Ideal current source.
   b) Practical current source.

<u>Dependent Sources</u>

1. Voltage Dependent Voltage Source
2. Voltage Dependent Current Source
3. Current Dependent Voltage Source
4. Current Dependent Current Source

8. **Define i)Charge ii)Electric Current iii)Power iv)Network v)Circuit vi)Energy [BTL-1]**

(i) **<u>Charge(Q):</u>** The total deficiency or excess of electrons in an atom is known as charge. It is measured in coulombs(C).

(ii) **<u>Electric Current(I):</u>** Electric current is the time rate of net transfer of charge across a conductor.it is also defined as the flow of electric charges through a conductor .It is measured in amperes (A).

$$\text{Current}, I = \frac{dQ}{dt} \text{ C/S or A}$$

(iii) **Electrical Power(P):** power is the rate of doing work (or)it is the rate at which work is being done in electric circuit. It is measured in watts (W).

$$\text{Electrical Power, } P = V \times I = I^2 R = \frac{V^2}{R} \text{ watts(W)}$$

(iv) **Electrical Energy(W):** Energy is the capacity of doing work (or) electrical energy is the amount of work done in an electrical circuit. It is measured in joules.

Electrical Energy, W=Power x Time = V x I x t Joules(J) or watt-hours

1 unit of electrical energy = I kilo-watt-hour(KWH)

(v) **Network:** A network is an interconnection of various circuit elements or branches.

(vi) **Circuit:** A circuit is a closed path consisting circuit components, through which the current flows.

9. **Define active and passive elements.** **[BTL-1]**

Active Elements: Active elements are components in a circuit that can generate and supply energy to the circuit. Ex: Generators, Battery, Amplifiers.

Passive Elements: Passive elements are components that consume or store energy from the circuit. They don't have the ability to generate energy.
Ex: Resistors, Capacitors, and Inductors.

10. **Define unilateral and bilateral elements.** **[BTL-1]**

Unilateral Element: A unilateral element allows the flow of current in one direction only.
Ex: Diodes, Transistors.

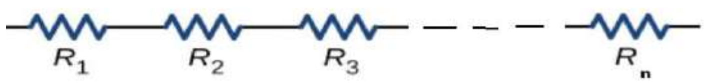
Bilateral Element: A bilateral element allows the flow of electric current in both directions.
Ex: Resistors, Capacitors, and Inductors.

11. **Define linear network and non-linear network.** **[BTL-1]**

Linear Network: A network is said to be linear if all its elements are linear i.e they do not change with voltage or current.

Non-linear Network: A network will be called as non-linear network, even if only one of its elements is non- linear, i.e whose parameter change with voltage or current.

12. **If 'n' number of unequal resistances are connected in series then what is its equivalent resistance?** **[BTL-2]**



Let

$R_1, R_2, R_3,$ ----------- R_n are the resistances connected in series.

The equivalent resistance of the series connected resistances is given by

$$R_{eq} = R_1 + R_2 + R_3 + \text{-------} + R_n$$

13. **Write the characteristics of a parallel Circuit.** **[BTL-2]**

In parallel circuit

i. Voltage across all the resistances is same.
ii. Total current is equal to the sum of the individual currents. $I=I_1+I_2+I_3$
iii. The reciprocal of the equivalent resistance is equal to the sum of the reciprocals of the individual resistances connected in parallel circuit. $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$
iv. The total power consumed by parallel circuit is sum of the individual powers. $P=P_1+P_2+P_3$

14. **Voltage across 5ohm resistor is 10 volts. Find the current and power dissipated in that resistor.** **[BTL-3]**

Resistance of the resistor, $R=5\Omega$

Voltage across the resistor, $V=10V$

Current through the resistor, $I = \frac{V}{R} = \frac{10}{5} = 2A$

Power dissipated, $P = I^2 R = 2^2 \times 5 = 20W$

15. **Give the V-I Relationship for electrical circuits elements R, L & C.** **[BTL-2]**

The V-I relationship for the three basic electrical circuit elements:

<u>Resistor (R):</u> The voltage across a resistor is directly proportional to the current flowing through it.

Voltage across the Resistor, $V = I \times R$.

Current through the Resistor, I=V/R

Inductor (L): The voltage across an inductor is proportional to the rate of change of current.

Voltage across the Inductor, V =$L\ \frac{di}{dt}$,

Current through an inductor, I=$\frac{1}{L}\int V$ dt

Capacitor (C): The current through a capacitor is proportional to the rate of change of voltage.

Current through the Capacitor, I =$C\,\frac{dv}{dt}$

Voltage across the capacitor, V=$\frac{1}{C}\int I\ dt$

BASIC ELECTRICAL ENGINEERING (U23EE201)

UNIT-II – ELECTROMAGNETISM

SHORT ANSWER QUESTIONS(SAQs)

16. State Faraday's laws of electromagnetic induction. BTL-1

i) First Law: It states that "when the magnetic flux linking with the conductor changes, an emf is induced in it" or "whenever a moving conducted cuts the magnetic flux, an emf is induced in the conductor.

ii) Second Law: It states that " The magnitude and EMF induced in a conductor or coil is equal to the rate of change of flux linkages

Induced emf, $e = -N \frac{d\emptyset}{dt}$

where N-number of turns and

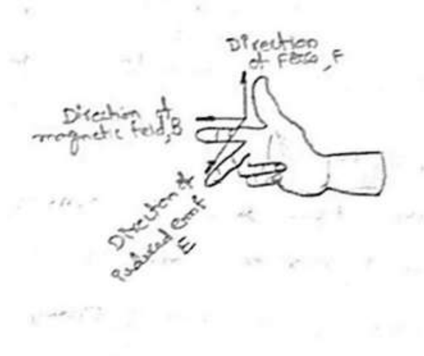
$d\Phi/dt$- rate of change of linking flux

17. What is Lenz's law? BTL-1

The direction of emf induced in a conductor or coil is governed by Lenz's law which states that the direction of induced emf or voltage is such that the current produced by it sets up a magnetic field opposing the very cause which produces it.

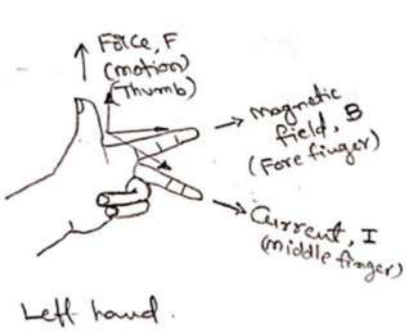
18. What is Fleming's right-hand rule? BTL-1

According to Fleming's right-hand rule if the thumb, forefinger and middle finger of the right hand are held mutually perpendicular to each other, forefinger pointing in the direction of the field and thumb in the direction of motion of conductor then middle finger will point in the direction of the induced emf.



19. What is Fleming's left-hand rule? BTL-1

According to Fleming's left-hand rule if the thumb, forefinger and middle finger of the left hand are held mutually perpendicular to each other, forefinger pointing in the direction of the field and middle finger in the direction of the current then thumb indicates the direction of force acting on conductor.



20. Define Statically induced emf and dynamically induced emf. BTL-1

Statically induced emf is defined as the emf induced in a conductor without the physical movement of conductor. Here, the conductor is stationary and magnetic field is varying.

Dynamically induced emf is defined as the emf induced in a conducted due to its motion in a uniform magnetic field.

21. What is coefficient of self-induction or self-inductance? BTL-1

Coefficient of self-induction or self-inductance(L) is defined as the ability of a coil to induce an emf in it due to change in its own current. It is measured in Henry(H).

22. What is mutual inductance? Give its unit. BTL-1

Mutual inductance may be defined as the ability of one coil or circuit to induce an emf in a nearby coil by induction when the current flowing in the first coil is changed. The action is also reciprocal i.e. the change in current flowing through second coil will also induce an emf in the first coil. The ability of reciprocal induction is measured in terms of the coefficient of mutual induction M. Its unit is Henry.

23. Define coefficient of coupling. BTL-1

When the two coils are placed near each other, all the flux produced by one coil does not link with the other coil, only a certain portion (say, K) of flux produced by one coil link with the other coil, K being less than unity. K is called the coefficient of coupling.

Coefficient of coupling, $K = \frac{M}{\sqrt{L_1 L_2}}$

24. A solenoid has 1,200 turns and carries a current of 2 A. The iron core has a length of 0.4m and cross section of 80 cm, the relative permeability is 1,000, Calculate the self-inductance of the solenoid. BTL-3

Solution:

No.of turns $N = 1200$

Length of iron core, $l = 0.4\text{m}$

Area of cross-section of iron core, $a = 80\ \text{cm}^2 = 0.008\ \text{m}^2$

$\mu_r = 1000$

Time $t = 0.01$ s

Self-inductance of coil, $L = \frac{N^2 a \mu_r \mu_o}{l}$

$= \frac{1200^2 \text{x}\ 0.008\ \text{x}\ 1000\ \text{x} 4\pi \text{x} 10-7}{0.4}$

$= 36.19$ H

25. A coil of 300 turns, wound on a core of non-magnetic material, has an inductance of 10mH. Calculate the average value of emf induced when a current of 5 A is reversed in 8ms. BTL-3

Solution:

No.of turns $N = 300$

Inductance $L = 10\text{mH}$

Rate of change of current, di/dt = [5-(-5)] / 0.008 = 1,250 A/S

Induced emf, e = L (di/dt) = 0.01 x 1,250= 12.5 V Ans.

26. Classify induced emf and give one example. **BTL-2**

Induced emf classified in to two categories.

1. Statically induced emf
   Ex: Transformer
   Statically induced emf further divided in to two types.
   a) Self-induced emf b) Mutually induced emf
2. Dynamically induced emf
   Ex: Stationary field, moving conductor – D.C Generator
   Stationary field, moving magnet - A.C Generator

27. What is self-induced emf and mutually induced emf? **BTL-1**

The emf induced in a coil due to change of its own flux linked with it is known as self-induced emf. The emf induced one coil due to change of current in another coil is known as mutually induced emf.

28. Distinguish between statically and dynamically induced emfs. Give examples of each. **BTL-4**

When flux linking with any coil or circuit changes, an emf is induced in the coil or circuit,called the electromagnetically induced emf.

EMF induced in a coil or circuit by increasing or decreasing magnitude of the linking flux (no relative motion between coil or circuit and magnetic field) is known as statically induced emf.

The emf induced in a conductor or coil due to relative motion between it and the magnetic field, that produces flux, is known as dynamically induced emf. EMF induced in transformer windings are statically induced emf's while emf induced in armature winding of dc and ac generators are dynamically induced emfs.

29. What is the energy stored in magnetic field. Write the expression for energy stored in a magnetic field. **BTL-2**

When a coil is connected to an electric source, the current flowing in the circuit gradually increases from zero to its final value and a magnetic field is established. A portion of electrical energy supplied by the electric source is stored as a magnetic field and remaining is dissipated in the form of heat. The energy stored in the coil will be spent in generating an induced emf or current

Energy stored in a magnetic field, $E = \frac{1}{2} LI^2$

Where L – Self-inductance of the coil.
I – Current flowing through the coil

30 *Calculate the energy stored in a coil having a self-inductance of 0.6 mH, when a current through the coil rises from 0 to 5 A.*

Given data,

Self-inductance of coil, $L = 0.6 \text{ mH} = 0.6 \times 10^{-3}$ H

Current, $I = 5$ A

Energy stored, $E = ?$

Energy stored in a coil, $E = \frac{1}{2} L I^2$ joules

$= \frac{1}{2} \times (0.6 \times 10^{-3}) \times 5^2 =$ **0.0075 joule** (or) **7.5 mJ**

Basic Electrical Engineering (U23EE201)
UNIT-III-A.C CIRCUITS

SHORT ANSWER QUESTIONS(SAQs)

31. Define time period and frequency, phase and phase difference. **BTL-1**

Time Period(T): The time taken by an alternating quantity to complete one cycle is called time period. It's unit is seconds.

Frequency(f) : The number of cycles per second is called the frequency of the alternating quantity. It's unit is Hertz (Hz).

Phase : It is the fraction of the time period of that alternating current that has elapsed since the current last passed through the zero position of reference.

Phase Difference: When two alternating quantities having same frequency attain their zero value at different instants of time, then the quantities are said to have a phase difference. This angle between zero points of two alternating quantities (while becoming negative to positive) is called the angle of phase difference.

32. Define amplitude and peak to peak value. **BTL-1**

Amplitude : - The maximum value attained by alternating quantity during positive or negative half cycle is called its amplitude. it is denoted by V_m & I_m

V_m = Peak value of Voltage

I_m = Peak value of Current

Peak to Peak value: - The amplitude of the ***ac*** quantity from its positive *peak* to its negative peak.

33. Define cycle, Instantaneous value. **BTL-1**

Cycle: - one complete set of positive and negative instantaneous values of an alternating quantity is known as a cycle.

Instantaneous value: - It is a magnitude of an alternating quantity at a particular instant of time.These are indicated by lower case letters

34. Define effective value or R.M.S value. **BTL-1**

The RMS (or) effective value of an alternating current is given by that steady current which when flows through a given resistance for a given time, produces the same amount of heat as when the alternating current is flowing, through the resistance for the same time.

RMS value is the square root of mean of squares of instantaneous values. It is also known as virtual value.

RMS value of sinusoidal current, I_{rms} (or) $I = \frac{Im}{\sqrt{2}} = 0.707\ I_m$

RMS value of sinusoidal current, V_{rms} (or)$V = \frac{Vm}{\sqrt{2}} = 0.707V_m$

35. Define average value. **BTL-1**

The average value of an alternating current is equal to the value of direct current, which transfers across any circuit the same charge as is transferred by that alternating current during a given time. The average value is defined as the average of all the instantaneous values of an alternating quantity, such as current or voltage over one complete cycle .

Average value of sinusoidal current, $I_{av} = \frac{2Im}{\pi} = 0.637\ I_m$

Average value of sinusoidal current, $V_{av} = \frac{2Vm}{\pi} = 0.637\ V_m$

36. Define form factor and peak factor. **BTL-1**

Form factor (K_f): - The form factor of an alternating quantity is defined as the ratio of RMS value to Average Value.

$$\text{Form factor } (K_f) = \frac{\text{RMS value}}{\text{Average value}} = \frac{0.707\ \text{Im}}{0.637\ \text{Im}} = 1.11$$

Peak factor (Kp) :- The Peak factor of an alternating quantity is defined as the ratio of maximum value to RMS value.

$$\text{Peak factor } (K_p) = \frac{Maximum\ value}{RMS\ value} = \frac{\text{Im}}{0.707\ \text{Im}} = 1.414 = \sqrt{2}$$

37. Define Active power and Reactive power. **BTL-1**

Active Power(P): -

It is the power which is actually dissipated in the circuit resistance. It is measured in Watts(W).

$P = I^2R = V\ I\ \text{Cos}\Phi$ watts(w)

Reactive Power(Q):-

It is the power developed in the reactance of the circuit.
It is measured in Volt-Ampere-Reactive (VAR)

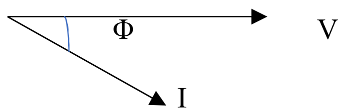
$Q = I^2X = V\ I\ \text{Sin}\Phi$ Volt-Ampere-Reactive (VAR)

38. What do you understand by apparent power and power factor of an AC circuit. **BTL-2**

Apparent Power: - Apparent power is defined as the product of RMS voltage(V) and RMS current(I).
Its unit is Volt-Ampere (VA) or KVA (Kilo-Volt-Ampere)

Power factor: (CosΦ)

I. It is the cosine of the angle between voltage and current. CosΦ



II. It is defined as the ratio of the active power (or real power) to the apparent power in an AC circuit.

$$\text{Cos}\Phi = \frac{Active\ Power}{Apparent\ Power} = \frac{P}{S}$$

III. It is the ratio of resistance to impedance.

$$\text{Cos}\Phi = \frac{Resistance(R)}{Impedance(Z)}$$

Basic Electrical Engineering (U23EE201)
UNIT-I – D.C CIRCUITS
LONG ANSWER QUESTIONS(LAQs)

1. State and explain kirchhoff's laws. **[BTL-2]**

Kirchhoff's laws are useful

a) in determining the equivalent resistance of the complicated circuit and

b) for calculating the current through our voltage across various circuit elements

The two laws are

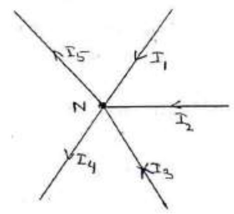
i) Kirchhoff's Current Law (KCL) or Point law

ii) Kirchhoff's Voltage Law (KVL) or Mesh law

1) Kirchhoff's Current Law (KCL) or Point law:-

In any electrical network, "the algebraic sum of currents meeting at a node or junction point is zero". Total current leaving a junction is equal to the total current entering that junction.

$$\boxed{\sum I = 0}$$



I_1, I_2 & I_3 – Incoming currents (Positive)

I_4, I_5 – Out going currents (negative)

$$I_1 + I_2 + I_3 + (-I_4) + (-I_5) = 0$$

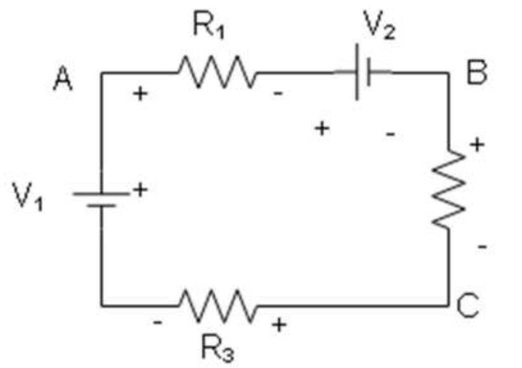
$$I_1 + I_2 + I_3 = I_4 + I_5$$

Total Incoming currents = Total Outgoing currents

ii) Kirchhoff's Voltage Law (KVL) or Mesh law: -

"The algebraic sum of voltages and voltage drops in any closed path in a network is zero."

$$\boxed{\sum(V+IR) = 0}$$



By KVL in loop ABCDA

$-IR_1 - V_2 - IR_2 - IR_3 + V_1 = 0$ **------ KVL Equation**

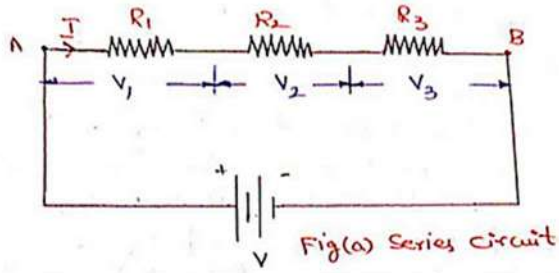
$IR_1 + IR_2 + IR_3 = V_1 - V_2$

$I\,(R_{1+}\text{-}R_{2\,+}\,R_3\,) = V_1 - V_2$

$$I = \frac{V1 - V2}{R1 + R2 + R3}$$

2) Derive expression for equivalent resistance if the resistances are connected in series and in parallel. [BTL-2]

Ans) <u>Equivalent Resistance in Series circuit:</u>



Fig(a) Series circuit

When two or more number of resistors are connected end-to-end, as shown in figure (a), then the resistances are said to be connected in series.

Let R_1, R_2 & R_3 are three resistances connected in series across a voltage source of V. I be the current flowing through all the resistors.

According to Ohm's law

Voltage drop across the resistance R_1, $V_1 = IR_1$,

Voltage drop across the resistance R_2, $V_2 = IR_2$

Voltage drop across the resistance R_3, $V_3 = IR_3$

The applied voltage equal to the sum of the three individual voltage drops.

$$V = V_1 + V_2 + V_3$$

$$V = IR_1 + IR_2 + IR_3$$

$$V = I(R_1 + R_2 + R_3)$$

$$\frac{V}{I} = R_1 + R_2 + R_3$$

Equivalent Resistance, $\mathbf{R_{eq} = R_1 + R_2 + R_3}$

<u>Equivalent Resistance in parallel circuit:</u>

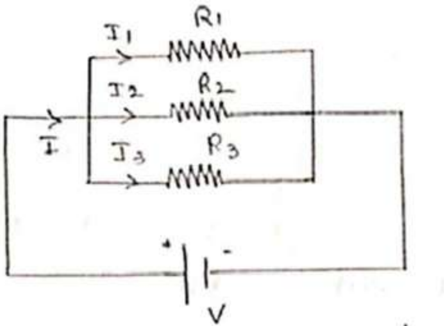


fig : Parallel circuit

Three resistances are joined as shown in figure are said to be connected in parallel across a voltage source of 'V'.

Let R_1, R_2 & R_3 are three resistances connected in parallel across a voltage source of V.

I - the total current

I_1, I_2 & I_3 are the three current flowing through the three resistors R_1, R_2 & R_3 respectively.

Current flowing through the resistor R_1, $I_1 = \frac{V}{R1}$

Current flowing through the resistor R_2, $I_2 = \frac{V}{R2}$

Current flowing through the resistor R_3 , $I_3 = \frac{V}{R3}$

Total current, $I = I_1 + I_2 + I_3$

$$I = \frac{V}{R1} + \frac{V}{R2} + \frac{V}{R2}$$

$$I = V\left[\frac{1}{R1} + \frac{1}{R2} + \frac{1}{R2}\right]$$

$$\frac{I}{V} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R2}$$

$$\frac{\mathbf{1}}{\mathbf{Req}} = \frac{\mathbf{1}}{\boldsymbol{R1}} + \frac{\mathbf{1}}{\boldsymbol{R2}} + \frac{\mathbf{1}}{\boldsymbol{R2}}$$

3) Explain in detail about Active elements. [BTL-2]

A) Active elements are energy sources and are capable of delivering energy to the network or device which are connected across them. These are divided into two types.

1.voltage source.

2.current source.

Energy sources are classified into independent sources and dependent sources.

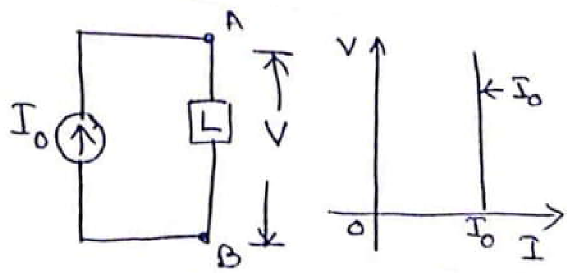
<u>Independent sources:</u>

Independent sources are those which do not depends on any other quantity in the circuit. They are two terminal devices and has a constant value of either voltage or current, irrespective of all circuit conditions.

<u>Independent current source:</u>

i) <u>Ideal Current Source:</u>

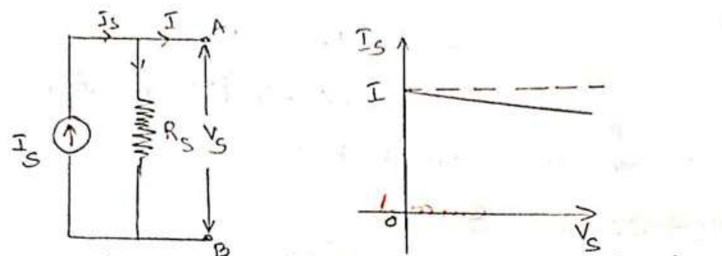
An ideal current source sends the specified current through any load connected across the terminals, irrespective of the voltage across the terminals. This specified current may be AC or DC.



a) Ideal current source b) V-I characteristics

The current is completely independent of the voltage across its terminals. The internal residence of an ideal current source is Infinite.

ii) <u>Practical Current Source:</u>



(a) Practical Current Source (b) V-I characteristics

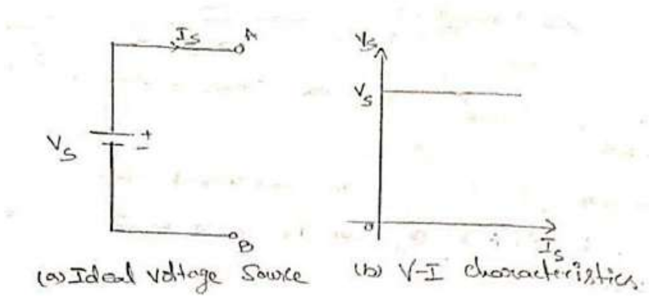
In practical current source, the internal resistance is connected in parallel with the source, as shown in figure (a). In this case, magnitude of current falls as the voltage across its terminals increases Figure (b) shows V-I characteristics.

Current at the terminals, $I = I_s - \frac{V_s}{R_s}$

where $\mathbf{R_s}$ is the internal resistance of the source

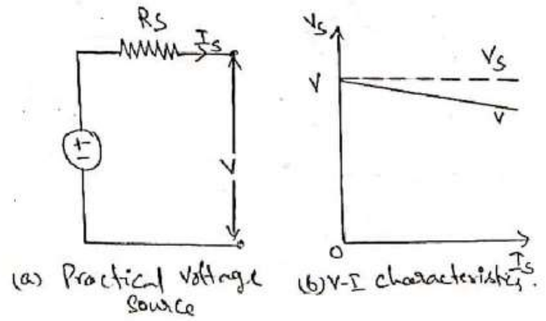
Independent Voltage source:

i) Ideal voltage Source:



In an ideal voltage source. The voltage across the terminals is constant and is independent of the current flowing through its terminals to the load At any time, the value of voltage is constant, irrespective of the current drawn by the load across the terminals A and B. The internal resistance of an ideal voltage source is equal to zero.

ii) Practical Voltage Source:



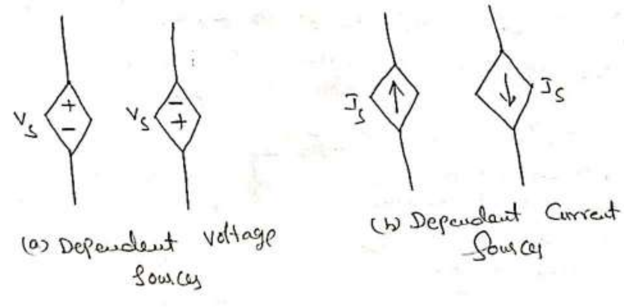
In practical voltage source, the internal resistance is connected in series with the source as shown in figure(a) in practical voltage source,the voltage across the terminals falls as the current through it is increases, as shown in figure(b).

DEPENDENT SOURCES:

Independent sources, the voltage or current associated with the element is depends on either the voltage or current in some other element in the network. These are also known as controlled sources. Diamond shaped symbol is used to represent dependent sources.

There are four types of controlled or dependent sources

a. Voltage controlled voltage source
b. Current controlled voltage source
c. Voltage controlled current source
d. Current controlled current source



4) Explain in detail about passive elements. **[BTL-2]**

A) **Passive Elements:**

Passive elements are those elements which dissipates or stores energy. These are resistors, inductor and capacitors. Resistor dissipates energy, whereas the inductor and capacitor stores energy.

Resistor: Resistance is the property of the resistor due to which it opposes the current through it. Resistor dissipates energy. Resistance is denoted by R. The unit of resistance is ohms (Ω).

R (Ω)

Resistance of a conductor, $R = \rho \frac{l}{a}$ Ω

By Ohm's law, the resistance, $R = \frac{V}{I}$ Ω

V-I Characteristics:

A resistance is linear if it is characterized by the straight line passing through the origin in the V-I plane as shown in figure.

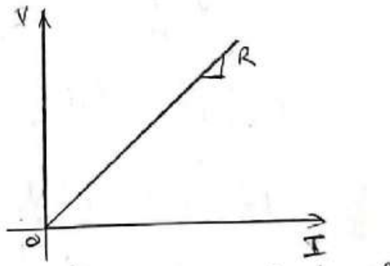


fig: V-I characteristics of Resistance

L

Voltage across the resistor, V = IR

Current through the resistor, $I = \frac{V}{R}$

Power absorbed by resistor, $P = VI = I^2R = V^2/R$ watts

Inductor: Inductor is an energy storing element, which stores energy in the form of electromagnetic field. Inductance is the property of the inducted due to which it opposes the change in current. Inductance is defined as the ratio of magnetic flux to the current.

$L = \frac{\Phi}{I}$ Henry

Unit of inductance is Henry (H)

Voltage across the inductor, $V = L\frac{dI}{dt}$

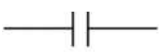
Current through the inductor, $I = \frac{1}{L}\int v\,dt$

Power stored, $P = VI = L\frac{dI}{dt} \times I$

Capacitor:

Capacitor stores energy in the form of electrostatic field. Capacitance is the property of the capacitor due to which it opposes the change in voltage. Capacitance is defined as the electric charge stored per unit potential difference

C



Capacitance, $C = \frac{Q}{V}$ Farad

Unit of capacitance is Farad(F)

Voltage across the capacitor, V = $\frac{1}{C}\int I\,dt$

Current through the capacitor, I = C $\frac{dV}{dt}$

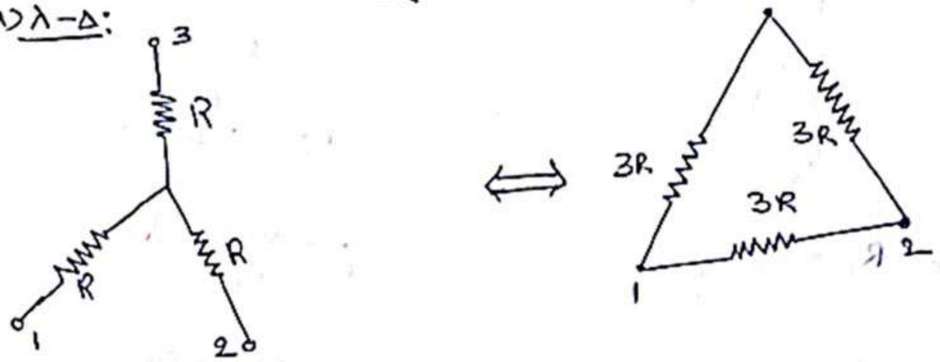
Power stored, P = VI = V x C $\frac{dv}{dt}$

5. Explain the star – Delta transformation technique used for solving electrical networks having equal and un-equal resistances. [BTL-3]

Star - Delta transformation :-

(I) Similar Resistances (Equal resistances)

(a) $\lambda - \Delta$:



$R_\lambda = R\,\Omega$

$R_\Delta = 3 \times R_\lambda = 3R\,\Omega$

$\boxed{R_\Delta = 3\,R_\lambda}$

If three resistances each of R Ω are connected in star, then their equivalent resistances in delta are $\boxed{R_\Delta = 3\,R_\lambda}$

(b) $\Delta - \lambda$:

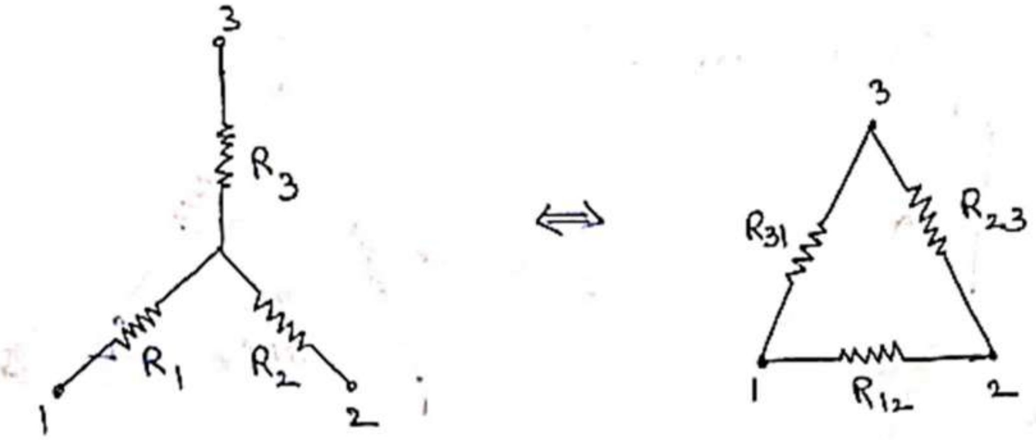
$R_\Delta = R\,\Omega$

$\therefore R_\lambda = \frac{R_\Delta}{3} = \frac{R}{3}\,\Omega$

$\boxed{R_\lambda = \frac{R_\Delta}{3}}$

If three equal resistances each of R Ω are connected in delta, then its equivalent resistance in star is $R_\lambda = \frac{R_\Delta}{3}$

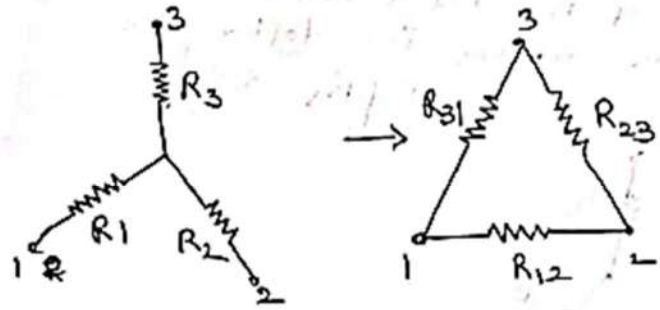
(ii) Un-equal resistances :-

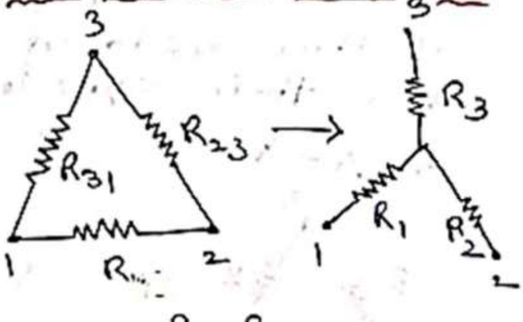


Star (λ) Delta (Δ)

R_1, R_2 & R_3 — Resistances connected in star
R_{12}, R_{23} & R_{31} — Resistances connected in Delta

(a) Star to Delta (λ → Δ) (b) Delta to Star (Δ → λ)





$$R_{12} = R_1 + R_2 + \frac{R_1 R_2}{R_3}$$

$$R_{23} = R_2 + R_3 + \frac{R_2 R_3}{R_1}$$

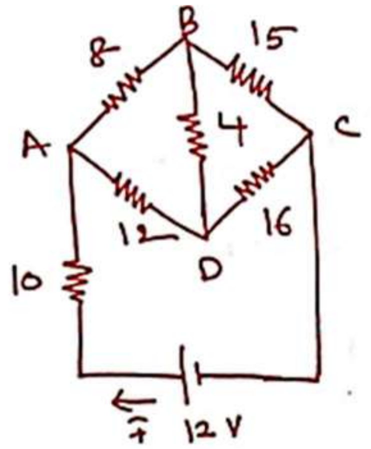
$$R_{31} = R_3 + R_1 + \frac{R_3 R_1}{R_2}$$

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

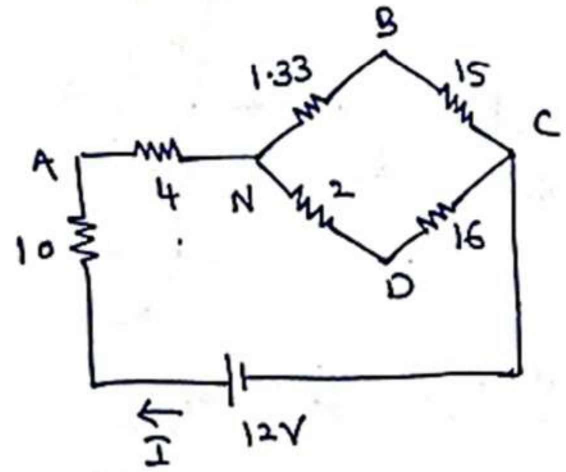
$$R_2 = \frac{R_{12} R_{23}}{R_{12} + R_{23} + R_{31}}$$

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

6. **For the Network shown in figure find the value of battery current I using star /delta transformation.** **[BTL-3]**



Sol:- convert delta ABD to star. The Circuit is



$$R_{AN} = \frac{R_{AB} R_{AD}}{R_{AB}+R_{AD}+R_{BD}} = \frac{8\times12}{8+12+4} = 4$$

$$R_{BN} = \frac{8\times4}{8+12+4} = 1.33$$

$$R_{DN} = \frac{12\times4}{8+12+4} = 2\,\Omega$$

$1.33\,\Omega$ & $15\,\Omega$ in series $= 1.33+15 = 16.33\,\Omega$

$2\,\Omega$ & $16\,\Omega$ in series $= 2+16 = 18\,\Omega$

16.33 & $18\,\Omega$ in Parallel and in Series with $10\,\Omega$ & $4\,\Omega$

$$R_{Eq} = \frac{(16.33)(18)}{16.33+18} + 10 + 4 = 22.56$$

$\therefore$ Battery Current, $I = \frac{V}{R_{Eq}} = \frac{12}{22.56} = 0.532\,A$

7) **State and explain Thevenin's theorem.** **[BTL-2]**

"A two terminal linear bilateral network consisting of independent and/or dependent voltage or current sources and resistances Can be replaced with an equivalent circuit consisting of a voltage source V_{th} in series with a resistance R_{th}."

V_{th} is the open circuit voltage between the terminals of the network and R_{th} is the resistance measured between the terminals of the network, with all energy sources eliminated. This circuit is called Thevenin's equivalent circuit.

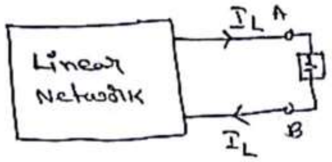


fig (a) Linear Network

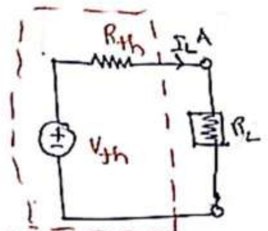


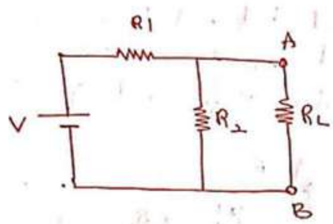
fig (b) Thevenin's equivalent circuit.

Procedure:

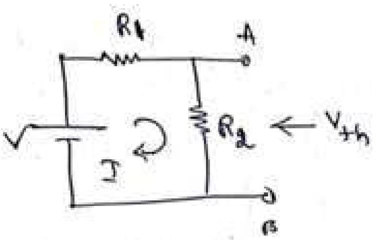
1) Disconnect the load resistance R_L
2) Determine the Thevenin voltage by using network reduction techniques across the open circuit terminals.
3) Determine thevenin resistance by reducing independent sources to zero i.e independent voltage source is short circuitted and independent current source is open circuitted.
4) Draw the voltage source equivalent circuit representation of given network and reconnect the load resistance and calculate the load current.

From fig(b) Load Current, $I_L = \frac{Vth}{Rth+RL}$

Proof: Consider the circuit as shown in figure below. Applying Thevenin's theorem to find load current through R_L



Step 1: Disconnect the load resistance and calculate Thevenin's voltage V_{th}



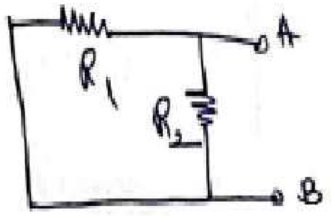
Current, $I = \frac{V}{R1+R2}$

V_{th} is the voltage across the resistance R_2

$V_{th} = I \times R_2 = \frac{V}{R1+R2} \times R_2$

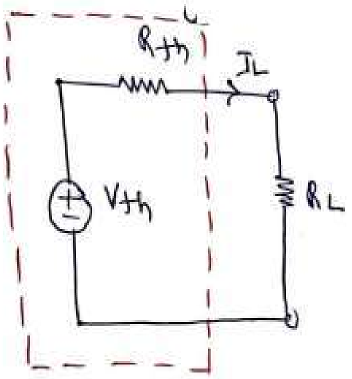
Step 2: Calculate R_{th}

Short circuiting the independent voltage source.



R_1 & R_2 are in parallel, $R_{th} = \frac{R1\ R2}{R1+R2}$

Step 3: Drawing the Thevenin's equivalent circuit, reconnecting the load resistance. R_L and calculating load current.

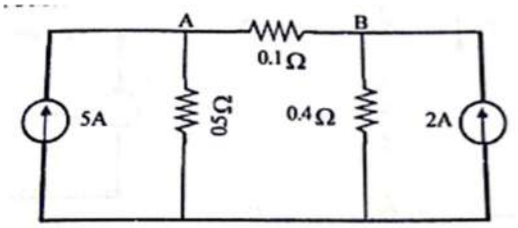


R_{th} and R_L are in series

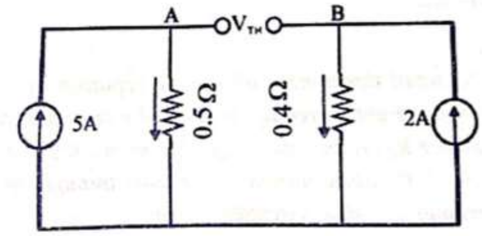
$\therefore R_{eq} = R_{th} + R_L$

$I_L = \frac{V_{th}}{R_{th}+R_L}$ A

8) Find current through 0 .1ohm resistor in the circuit shown below, using Thevenin's theorem. **[BTL-3]**



Ans] Disconnect the load resistance 0.1Ω and calculate Vth.

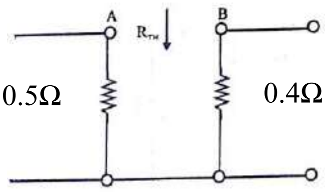


Circuit to find V_{TH}:

Voltage at A, $V_A = 5 \times 0.5 = 2.5$ V
Voltage at A, $V_B = 2 \times 0.4 = 0.8$ V

Thevenin Voltage, $Vth = V_{AB} = V_A - V_B = 2.5 - 0.8 = 1.7V$

Calculating R_{th}: Reducing sources to zero i.e Open circuiting current sources



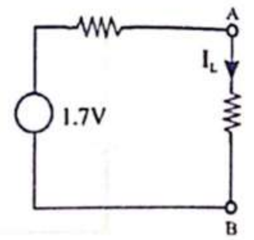
0.5Ω 0.4Ω

0.5Ω and 0.4Ω are in series between the terminals A&B

Thevenin's Resistance, $R_{th} = R_{AB} = 0.5+0.4=0.9\Omega$

Drawing the Thevenin's equivalent circuit, connecting the load resistance 0.1 Ω

0.9Ω



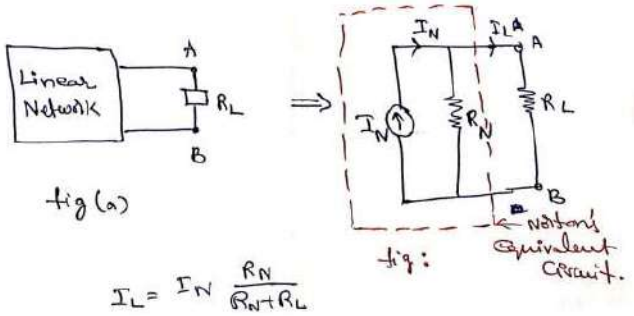
0.1Ω

Current through 0.1 Ω resistance, $I_L = \frac{Vth}{Rth+R} = \frac{1{,}7}{0.9+0.1} = 1.7A$

9) State and explain Norton's theorem. **[BTL-2]**

"Any two terminal linear network consisting of independent and /or dependent voltage or current sources and resistances can be replaced by an equivalent network consisting of a current source I_n parallel with a resistance R_n."

I_n is the short circuit current through the short placed between the terminals and Rn is the resistance measured between the terminals by reducing the energy sources to zero.

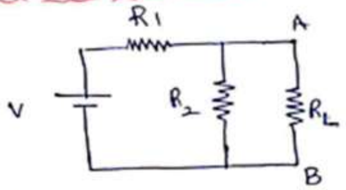


PROCEDURE:

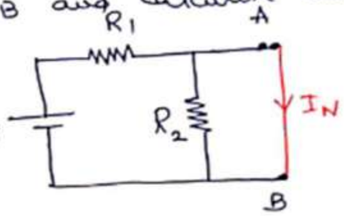
1. Disconnect the load resistance and place a short between the terminals.
2. Determine Norton's current using network analysis techniques.
3. Determines Norton's resistance by reducing independent sources to zero i.e short circuiting independent voltage source and open circuiting dependent current source.
4. Draw Norton's equivalent circuit and reconnect the load resistance and calculate load current.

Proof:

Proof :- Norton's theorem :-

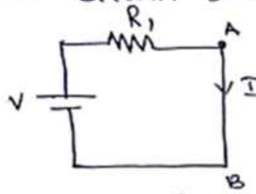


Step-I :- Disconnect the load resistance and place a short between A and B and calculate current I_N.



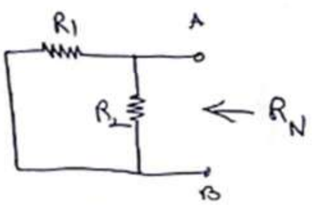
The value of R_2 becomes '0' as it is in parallel with short.

The circuit becomes



Norton's Current, $I_N = \frac{V}{R_1}$

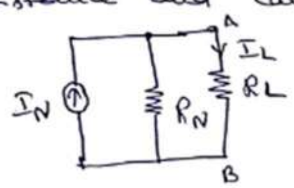
Step-II :- Calculating R_N



R_1 and R_2 are in parallel.

Norton's Resistance, $R_N = \frac{R_1 R_2}{R_1+R_2}$

Step-IV :- Draw Norton's equivalent circuit and reconnect load resistance and calculate I_L.

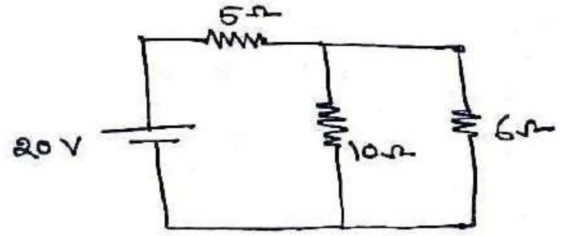


Apply current division rule

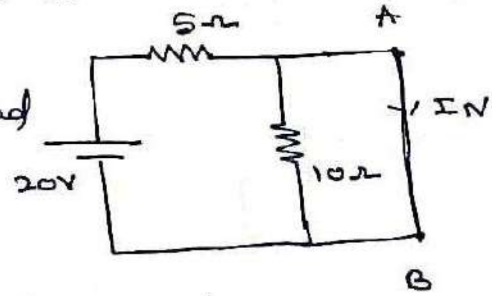
Load current $I_L = I_N \cdot \frac{R_N}{R_N+R_L}$

10) Calculate Current through 6Ω resistor using Norton's theorem.

[BTL-3]

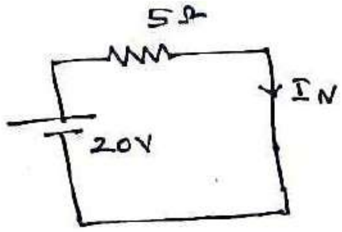


Sol:- Remove load resistance, 6Ω and place a short across terminals, the circuit becomes



Calculating I_N:-

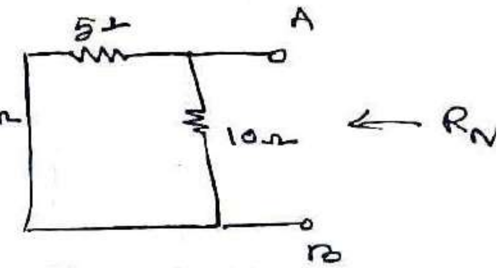
10Ω is in parallel with a short, then 10Ω replaced by short, the circuit will be



Norton's Current

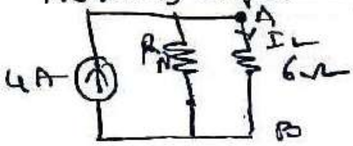
$$I_N = \frac{20}{5} = 4\,A$$

Finding R_N :-



$$R_N = R_{AB} = \frac{10 \times 5}{10+5} = \frac{50}{15} = \underline{3.33\Omega}$$

Norton's equivalent Circuit



$$I_L = I_N \cdot \frac{R_N}{R_N + R_6} = 4 \cdot \frac{3.33}{6+3.33} = \underline{1.43A}$$

11. State and explain Superposition Theorem. [BTL-2]

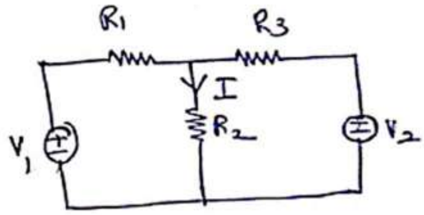
"The Superposition Theorem states that in any linear network, containing two or more sources the response in any element is equal to the algebraic sum of responses caused by individual sources acting alone while the other sources are eliminated. In reducing the sources, independent voltage sources are short circuited and independent current sources are open circuited.

Procedure:

1. Select a single source acting alone. Short the other voltage sources and open the current sources.
2. Find the current through or voltage across the required element due to the source under consideration, using suitable network simplification technique.
3. Repeat the above two steps for all the sources.
4. Add all the individual effects produced by individual sources to obtain the total current in or total voltage across the element.

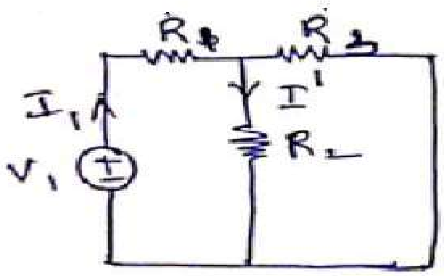
Proof:

Consider the circuit shown below and find current through resistor R_2



Consider one source at a time.

Considering Volte source, V_1 alone and short circuiting the voltage source, V_2, the circuit will be



R_2 and R_3 are in parallel then combination is in series with R_1

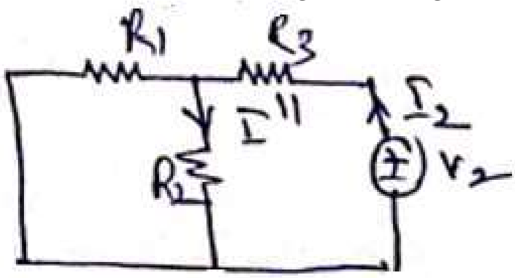
$R_{eq1} = \frac{R2R3}{R2+R3} + R1$

Total Current ,$I_1 = \frac{V1}{Req1}$

Apply current division rule

$I^1 = I_1 \left[\frac{R3}{R2+R3} \right]$

Considering Volte source, V_2 alone and short circuiting the voltage source, V_1, the circuit will be



R_1 and R_2 are in parallel then combination is in series with R_3

$$R_{eq2}=\frac{R1R2}{R1+R2}+R3$$

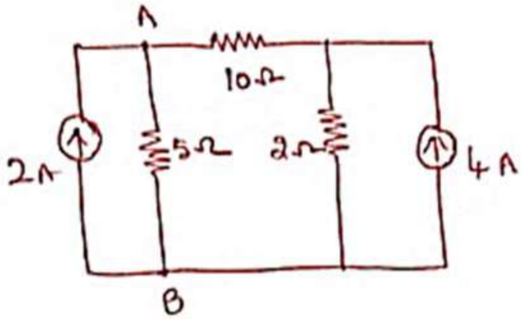
Total Current , $I_2=\frac{V2}{Req2}$

Apply current division rule

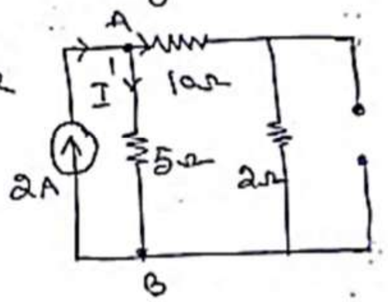
$I^{11} = I_2\left[\frac{R1}{R1+R2}\right]$

Current flowing through resistor R_2 , $I = I^1 + I^{11}$

12. Find voltage across terminals, A and B using superposition theorem. [BTL-3]



Sol :- considering 2A current source alone. eleminating 4A current source by open circuiting it, the ckt becomes.

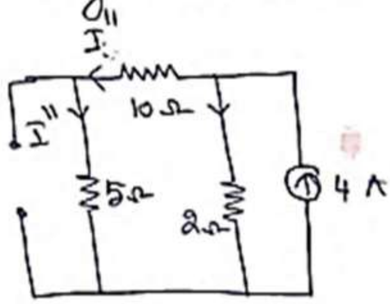


Applying current division rule current through 5Ω resistor

$I^1 = I\cdot\frac{10+2}{10+5+2}$

$I^1 = 2\ \frac{12}{17} = \underline{1.41\ A}$

considering 4A current source alone. eleminating 2A current source by open circuiting it. The circuit will be



Applying current division rule, current through 5Ω resistor

$I'' = 4\times\frac{2}{10+5+2} = \frac{8}{17} = \underline{0.47A}$

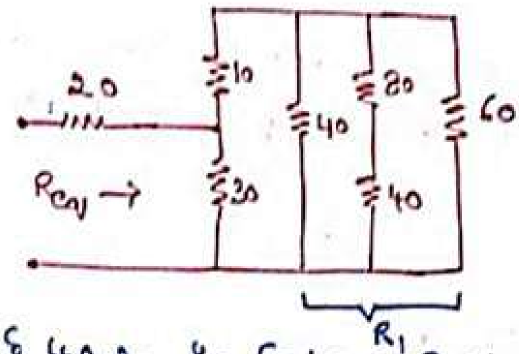
Total current through 5Ω resistor, $I = I^1 + I'' = 1.41 + 0.47$

$= 1.88\ A$

Voltage across the terminals A and B i.e across 5Ω resistor $V = I\times 5 = 1.88\times 5 = \underline{9.4}\ V$

13 Find Req in the resistance network shown below..

[BTL-3]



80Ω & 40Ω in Series $80+40 = 120\Omega$

40Ω, 120Ω & 60Ω in Parallel

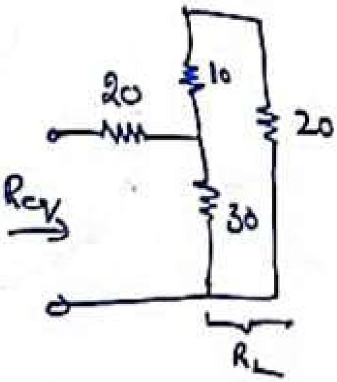
$$\frac{1}{R_1} = \frac{1}{40}+\frac{1}{120}+\frac{1}{60}$$

$$R_1 = \frac{120}{3+1+2} = \frac{120}{6} = 20\,\Omega$$

The Circuit is

10 & 20 in Series and

combination is Parallel with 30Ω

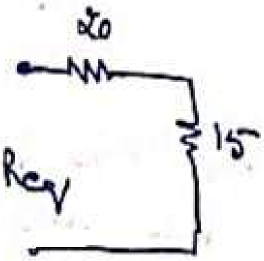


$(10+20) \parallel 30$

$\Rightarrow 30 \parallel 30 \quad \Rightarrow \frac{1}{R_2} = \frac{1}{30}+\frac{1}{30} = \frac{2}{30} \quad \Rightarrow R_2 = \frac{30}{2} = 15\,\Omega$

The Circuit will be

$\therefore$ $R_{eq} = 20+15 = 35\,\Omega$



14 An electric iron is marked 250V, 500W. What current does it take if connected to the correct voltage? What is the hot resistance? If the iron is used for one hour daily for 30 days in a month, what will be the monthly bill at Rs.4.50 per unit?

[BTL-3]

Sol :-

Power rating of iron, $P = 500W$

Voltage rating, $V = 250V$

Current drawn if connected to 250V

$$I = \frac{P}{V} = \frac{500}{250} = 2\,A$$

Hot resistance, $R = \frac{P}{I^2}$ $\quad (\because P = I^2R)$

$$= \frac{500}{2^2} = \frac{500}{4} = 125\,\Omega$$

Working hours of iron/month

t = working hrs/day × 30

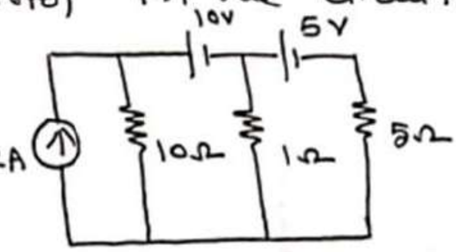
$= 1 \times 30$

$= 30$ hrs.

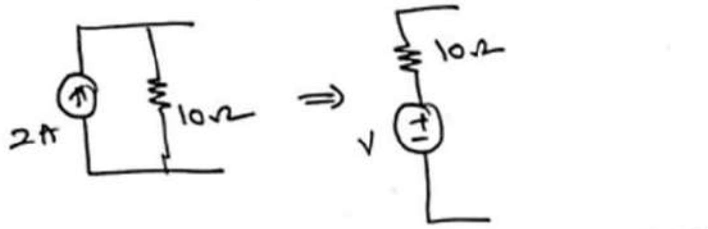
monthly energy consumption $= \frac{P \times t}{1000} = \frac{500 \times 30}{1000} = 15$ KWh

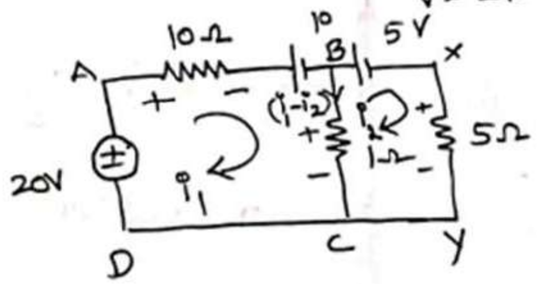
monthly bill = ₹ 4.50 × 15 = ₹ 67.50

15 Find the Current and Power dissipated in the 5Ω resistor in the Circuit shown below. **[BTL-3]**



Sol:- 2A Current Source is transformed to an equivalent voltage source and the circuit becomes





Apply KVL at loop ABCD

$$+20 - 10 i_1 - (i_1 - i_2)1 - 10 = 0$$

$$-11 i_1 + i_2 = -10$$

$$11 i_1 - i_2 = 10 \quad \text{— (1)}$$

Apply KVL in loop bxyc

$$-5 + (i_1 - i_2) - 5 i_2 = 0$$

$$i_1 - 6 i_2 = 5 \quad \text{— (2)}$$

Solving Eq① & ②

$$11 i_1 - i_2 = 10 \quad \times 6$$
$$i_1 - 6 i_2 = 5 \quad \times 1$$

$$66 i_1 - \cancel{6 i_2} = 60$$
$$i_1 - \cancel{6} i_2 = 5$$
$$- \quad + \quad -$$

$$65 i_1 = 55$$
$$i_1 = \frac{55}{65}$$

$$11 i_1 - i_2 = 10$$
$$11 \times \frac{55}{65} - i_2 = 10$$
$$i_2 = -\frac{9}{13} \text{ A}$$

The Current through 5Ω resistor $i_5 = \frac{9}{13}$ A flowing from y to x.

The Power dissipated in 5Ω resistor $= i_2^2 \times 5$

$= \left(\frac{9}{13}\right)^2 \times 5$

$= \underline{2.64}$ W

BASIC ELECTRICAL ENGINEERING (U23EE201)

UNIT-II – ELECTROMAGNETISM

LONG ANSWER QUESTIONS(LAQ's)

16. State and explained Faraday's laws of electromagnetic induction. [BTL-2]

A) First Law:

"It states that when the magnetic flux linking the conductor or coil changes, an emf is induced in it."

(or)

"Whenever a moving conductor cuts the magnetic field or lines of force, an emf is induced in the conductor".

Second Law:

It states that "The magnitude of emf in a conductor or coil is equal to the rate of change of flux linkages".

Induced emf, $e = -N\frac{d\Phi}{dt}$

Explanation of Faraday's laws:

Consider a coil of N torns and flux linking the coil changes from Φ_1 to Φ_2 Weber in time t seconds.

Initial flux linkages $= N\Phi_1$

Final flux linkages $= N\Phi_2$

Change of flux linkages $= N\Phi_2 - N\Phi_1$

Rate of change of flux linkages $= (N\Phi_2 - N\Phi_1) / t = N(\Phi_2 - \Phi_1) / t$

According to Faraday's second law, the magnitude of emf is equal to the rate of change of flux linkages.

emf induced, $e = \frac{\mathbf{N(\Phi2 - \Phi1)}}{\boldsymbol{t}}$

In differential form

emf induced, $e = \frac{\mathbf{d(N\Phi)}}{\boldsymbol{dt}} = \mathbf{N}\frac{\mathbf{d\Phi}}{\boldsymbol{dt}}$

Where $d\Phi$ – Change in flux

dt – Change in time

$N\frac{d\Phi}{dt}$ - Rate of change of flux linkages

EMF induced, $e = \mathbf{-N}\frac{\mathbf{d\Phi}}{\boldsymbol{dt}}$ volts

Negative sign signifies that the induced EMF generates a current tending to oppose the increasing of flux through the coil. This is explained by Lenz's law.

Lenz's law states that 'the direction of induced emf or voltage is such that the current produced by it sets up a magnetic field opposing the very cause which produces it."

17. A coil having 100 turns is links ~~a~~ with a flux of 1mwb. If the direction of this flux is reversed in 0.01 sec, Find the emf induced in the coil.

(Ans) Given data

No. of turns $N = 100$

Initial flux $\phi_1 = 1\,mwb = 1 \times 10^{-3}\,wb$

Final flux $\phi_2 = -1\,mwb = -1 \times 10^{-3}\,wb$

Time $dt = 0.01\,s$

Emf induced $e = ?$

Change in flux $d\phi = \phi_1 - \phi_2 = 1 \times 10^{-3} - (-1 \times 10^{-3})$

$= 2 \times 10^{-3}\,wb$

Emf induced $e = N\dfrac{d\phi}{dt} = 100 \times \dfrac{2 \times 10^{-3}}{0.01} = 20V$

18. A coil consisting of 120 turns is placed in the magnetic field of 0.8mwb. Calculate the average emf induced in the coil, when it is moved in 0.08S from the given field of 0.3 mwb. If the resistance of the coil is 200Ω, find the induced current in the coil.

Ans) Given data

No. of turns, $N = 120$

Initial flux, $\phi_1 = 0.8\,mwb = 0.8 \times 10^{-3}\,wb$

Final flux, $\phi_2 = 0.3\,mwb = 0.3 \times 10^{-3}\,wb$

Time, $dt = 0.08\,sec$

Resistance of the coil, $R = 200\Omega$ $\qquad d\phi = \phi_1 - \phi_2$

Average induced emf, $e = ?$

Induced current, $I = ?$

Average induced emf, $e = N\dfrac{d\phi}{dt} = 120 \times \dfrac{(0.8 \times 10^{-3} - 0.3 \times 10^{-3})}{0.08} = 0.75V$

Induced Current, $I = \dfrac{e}{R} = \dfrac{0.75}{200} = 3.75\,mA$

19. Explain clearly about statically induced emf. [BTL-3]

Whenever the conductor cuts the magnetic field or magnetic field links with the conductor, an EMF is induced in the conductor. This emf is divided into two types.

1) Statically induced emf and
2) Dynamically induced emf

1) Statically induced emf:

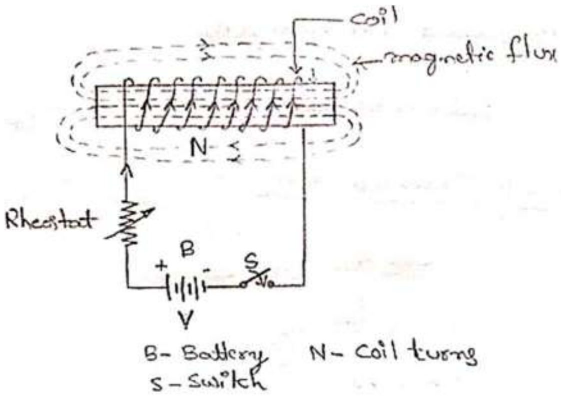
It is the emf induced in a conductor without the physical movement of conductor. Here, the conductor is stationary and magnetic field is varying.

It is further divided in to two types.

a) Self-induced emf and
b) Mutual induced emf

a) Self-induced emf:

The EMF induced in a coil due to change of its own flux linked with it is known as self-induced emf. Consider a coil of N turns, length 'l' m, area of cross section' a' m^2 and of relative permeability μ_r. When a coil carries a current of I A, a magnetic flux of Φ wb is set up around the coil and links with it.



If the current flowing through the coil is changed, the flux produced by it will change, and therefore an emf will be induced.

Self-induced emf, $e = -N\frac{d\Phi}{dt}$ volts ----------------(1)

We know $\Phi = \frac{\text{mmf}}{\text{Reluctance}} = \frac{NI}{l/\mu a}$ ----------------(2)

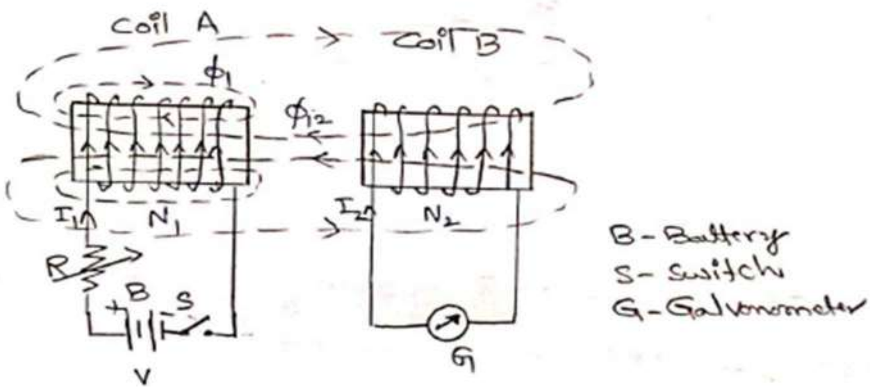
Substituting equation 2 in equation 1

Self-induced emf, $e = -N\frac{d\left[\frac{NI}{l/\mu a}\right]}{dt} = -N\frac{N}{l/\mu a}\frac{dI}{dt} = -\frac{N^2\mu a}{l}\frac{dI}{dt} = -L\frac{dI}{dt}$

Where L is the constant is known as coefficient of self-inductance

b) Mutual induced emf

The emf induced one coil due to change of current in another coil is known as mutually induced emf. Consider two coils, A and B placed close together so that the flux created by one coil completely links with the other coil.



Consider coil A of turns N_1 wound on a core of length l metres, area of cross section 'a' m^2 and relative permeability μ_r. When current of I_1 flows through it, a flux of Φ_1 weber is set up around the coil A, this whole flux linked with coil B having N_2 turns and placed nearby coil A.

Mutually induced emf, e_m = - Rate of change of flux linkages of coil B

= - N_2 x Rate of change of flux in coil A

$$= -N_2 \frac{d\Phi 1}{dt}$$

$$= -N_2 \frac{d[\frac{mmf}{s}]}{dt}$$

$$= -N_2 \frac{d}{dt}\left[\frac{N_1 I_1}{l/\mu a}\right]$$

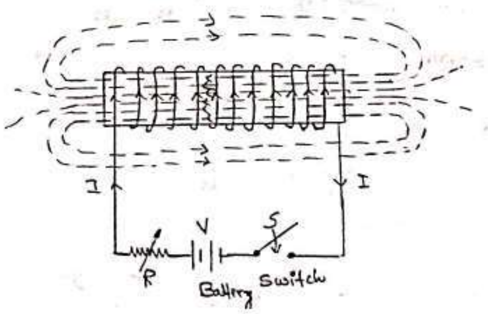
$$= -\left[\frac{N_1 N_2 \mu a}{l}\right]\frac{dI_1}{dt}$$

Mutually induced emf, $e_m = -M\frac{dI_1}{dt}$

Where M is Coefficient of mutual induction or mutual inductance.

20. Explain self-inductance .Derive the expression for self- inductance. BTL-3

Coefficient of self-induction or self-inductance(L) is defined as the ability of a coil to induce an emf in it due to change in its own current. It is measured in Henry(H).



The self-inductance of the coil can be determined in terms of its physical dimentions of the coil.

We know Self-Inductance, $L = \frac{N\Phi}{I}$ H

Flux, $\Phi = \frac{mmf}{Reluctance} = \frac{NI}{S}$

$$L = \frac{N N I}{I S} = \frac{N^2}{S}$$

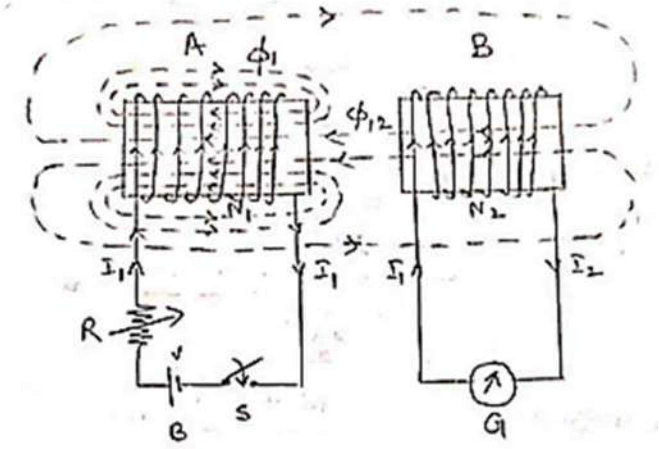
Reluctance, $S = \frac{l}{\mu a} = \frac{l}{\mu_0 \mu_r a}$

$$L = \frac{N^2}{\left(\frac{l}{\mu_0 \mu_r a}\right)} = \frac{N^2 \mu_0 \mu_r a}{l} \text{ H}$$

Self-Inductance, $\boxed{L = \frac{N^2 \mu_0 \mu_r a}{l}}$ H.

21. Explain clearly about mutual inductance. Derive the equation for mutual inductance.
[BTL-3]

Mutual inductance may be defined as the ability of one coil or circuit to induce an emf in a nearby coil by induction when the current flowing in the first coil is changed. The action is also reciprocal i.e the change in current flowing through second coil will also induce an emf in the first coil. The ability of reciprocal induction is measured in terms of the coefficient of mutual induction M.Its unit is Henry.



We know that, Mutual inductance, $M = \frac{N_2 \phi_{12}}{I_1}$

The mutual flux ϕ_{12} is a part of flux ϕ_1. Let K_1 be the part of flux ϕ_1 which is linked with coil-2.

$$\therefore \quad \phi_{12} = K_1 \phi_1$$

$$\therefore \text{ Mutual inductance, } \quad M = \frac{N_2 K_1 \phi_1}{I_1} = \frac{K_1 N_2 \phi_1}{I_1} \quad \text{........ (iii)}$$

The flux ϕ_1 in coil-1 can be expressed as

$$\text{Flux, } \quad \phi_1 = \frac{\text{m.m.f.}}{\text{reluctance}} = \frac{N_1 I_1}{S} \quad \text{........ (iv)}$$

Substituting the value of ϕ_1 from equation (iv) in equation (iii), we get

$$\text{Mutual inductance, } \quad M = \frac{K_1 N_2}{I_1} \times \frac{N_1 I_1}{S} = \frac{K_1 N_1 N_2}{S}$$

Assuming the flux produced by coil 1 completely links with coil 2, then K=1.

$$\therefore \text{ Mutual inductance, } \quad M = \frac{N_1 N_2}{S} = \frac{N_1 N_2}{\frac{l}{\mu_0 \mu_r a}} = \frac{N_1 N_2 \mu_0 \mu_r a}{l}$$

The mutual inductance also calculated using the expression

$$\therefore \text{ Mutual inductance, } \quad M = \frac{N_2 \phi_{12}}{I_1} \text{ Henry}$$

22. Two coils having 100 and 150 turns respectively are wound side by side on a closed iron circuit of section 125 cm^2 and mean length 200 cm. If the permeability of iron is 2,000, calculate (*a*) self-inductance of each coil (*b*) mutual inductance between them (*c*) the emf induced in the second coil if current in first coil changes from 0 to 5 A in 0.02 *s*.

Solution: Area of x-section of iron circuit, $a = 125\ cm^2 = 0.0125\ m^2$

Length of iron circuit, $l = 200\ cm = 2.0\ m$

(*a*) Self-inductance of first coil,

$$L_1 = \frac{N_1^2 \mu_0 \mu_r a}{l} = \frac{(100)^2 \times 4\pi \times 10^{-7} \times 2{,}000 \times 0.0125}{2.0}$$

$= 157.1$ m H Ans.

Self-inductance of second coil,

$$L_2 = \frac{N_2^2 \mu_0 \mu_r a}{l} = \frac{(150)^2 \times 4\pi \times 10^{-7} \times 2{,}000 \times 0.0125}{2.0}$$

$= 353.4$ mH Ans.

(*b*) Mutual inductance between coil,

$$M = \frac{N_1 N_2 \mu_0 \mu_r a}{l}$$

$$= \frac{100 \times 150 \times 4\pi \times 10^{-7} \times 2{,}000 \times 0.0125}{2.0} = 235.6 \text{ mH Ans.}$$

Rate of change of current in first coil,

$$\frac{di_1}{dt} = \frac{5-0}{0.02} = 250 \text{ A/s}$$

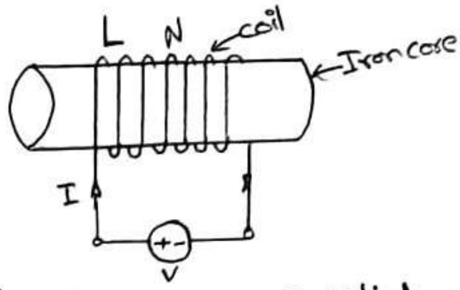
(*c*) EMF induced in second coil,

$$e_2 = M\frac{di_1}{dt} = 235.6 \times 10^{-3} \times 250 = 58.9 \text{ V Ans.}$$

23. Derive expression for energy stored in a magnetic field. **[BTL-3]**

Energy stored in a magnetic field :-

When a coil is connected to an electric source, the current flowing in the circuit gradually increases from zero to its final value, and a magnetic field is established.



A portion of the electrical energy supplied by the electric source is stored as magnetic field and remaining is dissipated in the form of heat. The energy stored in the coil will be spent in generating an induced emf (or) current.

Let L - Inductance of the coil, Henry

i — Current flowing through the coil at any instant, t

The rate of rise of current $= \frac{di}{dt}$

$\therefore$ The emf induced in the coil $\Big\}, \; e = L\frac{di}{dt}$

Power input to the coil, $p = ei = L\frac{di}{dt} \cdot i = Li\frac{di}{dt}$.

at time $t=0$, current is zero and has attained the value of 'I' at $t = T$

$\therefore$ The Energy input to the coil during this time of interval of T seconds is

$$W_e = \int_0^T p\,dt = \int_0^I Li\frac{di}{dt}\,dt$$

$$= \int_0^I Li\,di = L\left[\frac{i^2}{2}\right]_0^I$$

Energy stored, $\boxed{W_e = \frac{1}{2}LI^2}$ Joules.

24 . *An inductor with 10Ω resistance and 200 mH inductance is connected to 24 V d.c supply. Calculate energy stored in the inductance.*

BTL-3

Given data,

Resistance,	$R = 10\ \Omega$
Inductance,	$L = 200\ mH = 200 \times 10^{-3}\ H = 0.2\ H$
Voltage,	$V = 24\ V$
Energy stored,	$E = ?$

Solution :

Current through the inductor, $I = \frac{V}{R} = \frac{24}{10} = 2.4\ A$

Energy stored, $E = \frac{1}{2}LI^2 = \frac{1}{2} \times 0.2 \times 2.4^2 = \mathbf{0.576\ Joule}$

25 . **The inductance of a coil is 0.15 H. The coil has 100 turns. Find the following :**

(i) Total magnetic flux through the coil when the current is 4 A.

(ii) Energy stored in the magnetic field.

(iii) Voltage induced in the coil, when current is reduced to zero in 0.01 second.

BTL-3

Solution : (i) Total magnetic flux through the coil,

$$\Phi = \frac{LI}{N} = \frac{0.15}{100} \times 4 = 6\ mWb\ Ans.$$

(ii) Energy stored in the magnetic field

$$= \frac{1}{2}\ LI^2 = \frac{1}{2} \times 0.15 \times (4)^2 = 1.2\ J\ Ans.$$

Rate of fall of current,

$$\frac{di}{dt} = \frac{4}{0.01} = 400\ A/s$$

(iii) Voltage induced in the coil,

$$e = L\ \frac{di}{dt} = 0.15 \times 400 = 60\ V\ Ans.$$

26. Derive the expression for coefficient of coupling in terms of mutual and self-inductance.

[BTL-3]

When two coils are placed near each other, all the flux produced by one coil does not link with another coil. Only a certain portion, say **K** of the flux produced by one coil links with another coil. **K** is called the coefficient of coupling.

Flux created in Coil A due to a current of I_1 , $\Phi_1 = \frac{N_1 I_1}{l/\mu_0 \mu_r a}$ wb

Flux linking with coil B, $\Phi_2 = K \Phi_1$

$$\Phi_2 = K \frac{N_1 I_1}{l/\mu_0 \mu_r a} \text{ wb}$$

Coefficient of mutual inductance, $M = \frac{N_2 \Phi_2}{I_1} = \frac{K N_1 N_2 I_1}{[l/\mu_0 \mu_r a] I_1} = \frac{K N_1 N_2}{[l/\mu_0 \mu_r a]}$ ----------(1)

Self- inductance of Coil A, $L_1 = \frac{N_1 \Phi_1}{I_1} = \frac{N_1^2}{[l/\mu_0 \mu_r a]}$ -----------------------------------(2)

Self- inductance of Coil A, $L_2 = \frac{N_2 \Phi_2}{I_2} = \frac{N_2^2}{[l/\mu_0 \mu_r a]}$ -----------------------------------(3)

Multiplying equations 2&3 and taking square root on both sides, we get

$$\sqrt{L_1 L_2} = \frac{N_1 N_2}{[l/\mu_0 \mu_r a]} \quad \text{---(4)}$$

Comparing equations 1 & 4, we get

$$M = K \sqrt{L_1 L_2}$$

Coefficient of coupling, $\boxed{K = \frac{M}{\sqrt{L_1 L_2}}}$

The value of K is always less than 1

If

K=1 – Both the coils are tightly coupled

K=0 – No coupling between two coils.

27. Example 9.31. Two coils A of 1,200 turns and B of 800 turns lie near each other so that 60 per cent of the flux produced in one links the other. It is found that a current of 5 A in A produces a flux of 0.25 mWb while the same current in B produces a flux of 0.15 mWb. Determine the mutual inductance and coefficient of coupling between the coils.

BTL-3

Solution: Number of turns on coil A, $N_1 = 1{,}200$

Number of turns on coil B, $N_2 = 800$

Flux per ampere of current in coil A,

$$\frac{\Phi_1}{i_1} = \frac{0.25 \times 10^{-3}}{5} = 0.05 \times 10^{-3} \text{ Wb}$$

Self-inductance of coil A,

$$L_1 = N_1 \frac{\Phi_1}{i_1} = 1{,}200 \times 0.05 \times 10^{-3} = 0.06 \text{ H}$$

Flux per ampere of current in coil B,

$$\frac{\Phi_2}{i_2} = \frac{0.15 \times 10^{-3}}{5} = 0.03 \times 10^{-3} \text{ Wb}$$

Self-inductance of coil B,

$$L_2 = N_2 \frac{\Phi_2}{i_2} = 800 \times 0.03 \times 10^{-3} = 0.024 \text{ H}$$

Flux linking coil B per ampere of current in coil A,

$$\frac{\Phi_2}{i_1} = \frac{0.25 \times 10^{-3}}{5} \times 0.6 = 0.03 \times 10^{-3} \text{ Wb}$$

Mutual inductance between the coils,

$$M = N_2 \frac{\Phi_2}{i_1} = 800 \times 0.03 \times 10^{-3} = 0.024 \text{ H} \textbf{ Ans.}$$

Coefficient of coupling,

$$K = \frac{M}{\sqrt{L_1 L_2}} = \frac{0.024}{\sqrt{0.06 \times 0.024}} = 0.6325 \textbf{ Ans.}$$

28. Explain indetail about Dynamically induced emf. **[BTL-2]**

Dynamically induced emf:-

By moving a conductor in a uniform magnetic field, an emf is induced in the conductor. This emf is known as dynamically induced emf.

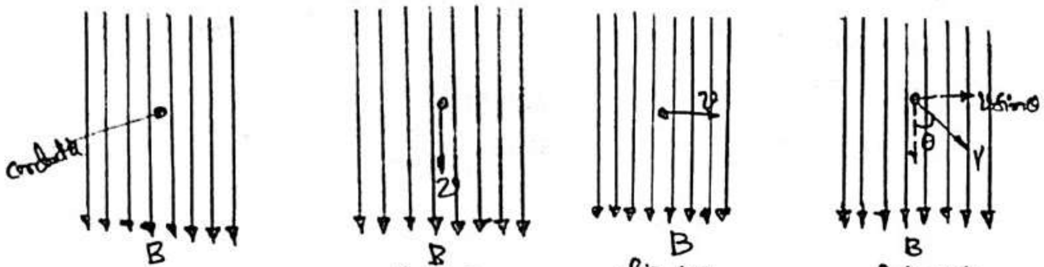


fig (a) fig (b) fig (C) fig (D)

Consider a conductor of length l meters placed in a uniform magnetic field of flux density, B T. as shown in fig (a).

This conductor is moved with velocity v m/s in the direction of the field, as shown in fig (b). in this case no flux is cut by the conductor, therefore no emf is induced in the conductor.

If the conductor be moved with velocity v m/s in the direction perpendecular to its length and perpendecular to the direction of magnetic field as shown in fig.(C), the flux is cut by the conductor, therefore, emf is induced in the conductor.

Area swept per second by the conductor $= l \times v$ m²/s

Flux cut per second = Flux density × area swept per second

$= Blv$

Rate of change of flux, $\frac{d\phi}{dt}$ = Flux cut per second

$= Blv$ wb/s

Induced emf, $e = \frac{d\phi}{dt} = Blv$ volts.

If the conductor is moved with velocity, V m/s in a direction perpendicular to its own length and at an angle θ to the direction of magnetic field as shown in fig (d), the magnitude of emf induced is proportional to the velocity in a direction perpendicular to the direction of the magnetic field and is given by

Induced emf, $\boxed{e = Blv \sin\theta}$

The direction of induced emf is given by Fleming's Right hand rule.

29. A conductor of active length 30 cm carries a current of 100 A and lies at right angles to a magnetic field of strength 0.4 Wb/m^2. Calculate the force in newtons exerted on it.

If the force causes the conductor to move at a velocity of 10 m/s, calculate (*i*) the emf induced in it and (*ii*) the power in watts developed by it. **BTL-3**

Solution: Length of conductor, l = 30 cm = 0.3 m

Current flowing through conductor, I = 100 A

Field strength, B = 0.4 Wb/m^2

Force exerted on the conductor,

$F = B\,I\,l = 0.4 \times 100 \times 0.3 = 12$ N **Ans.**

Conductor velocity, v = 10 m/s

Induced emf, $e = B\,l\,v = 0.4 \times 0.3 \times 10 = 1.2$ V **Ans.**

Power developed, $P = F \times v = 12 \times 10 = 120$ watts **Ans.**

30. **A coil having an inductance of 60 mH is carrying a current of 90 A. Calculate the self-induced emf in the coil, when the current is (i) reduced to zero in 0.03 second (ii) reversed in 0.03 second.**

BTL-3

Solution: Coil inductance, L = 60 mH = 0.06 H

When the current is reduced to zero in 0.03 s

$$\text{Rate of change of current, } \frac{di}{dt} = \frac{90-0}{0.03} = 3{,}000 \text{ A/s}$$

$$\text{Self-induced emf, } e = L\frac{di}{dt} = 0.06 \times 3{,}000 = 180 \text{ V} \quad \textbf{Ans.}$$

When the current is reversed in 0.03 second,

$$\text{Rate of change of current, } \frac{di}{dt} = \frac{90-(-90)}{0.03} = 6{,}000 \text{ A/s}$$

$$\text{Self induced emf, } e = L\frac{di}{dt} = 0.06 \times 6{,}000 = 360 \text{ V} \quad \textbf{Ans.}$$

Basic Electrical Engineering (U23EE201)

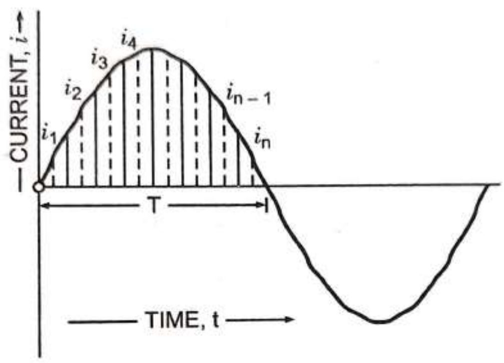
UNIT-III- A.C CIRCUITS

LONG ANSWER QUESTIONS(LAQs)

31. Derive the expression for RMS value and average value of sinusoidal current. BTL-3

RMS Value of sinusoidal current:

The RMS (or) effective value of an alternating current is given by that steady current which when flows through a given resistance for a given time, produces the same amount of heat as when the alternating current is flowing, through the resistance for the same time.



The mean of the squares of the instantaneous values of current over complete cycle is

$$= \int_0^{2\pi} \frac{i^2}{(2\pi - 0)}\, d\theta$$

The root of this current is the RMS current, $I_{rms} = \sqrt{\int_0^{2\pi} \frac{i^2}{(2\pi-0)}\, d\theta}$

The instantaneous current, $I = I_m \, \text{Sin}\theta$

RMS current, $I_{rms} = I = \sqrt{\int_0^{2\pi} \frac{(\mathbf{Im\ Sin\theta})^2}{(2\pi)}\, d\theta}$

$$= \frac{I_m}{\sqrt{2\pi}} \sqrt{\int_0^{2\pi} (\text{Sin}\theta)^2\, d\theta}$$

$$= \frac{I_m}{\sqrt{2\pi}} \sqrt{\int_0^{2\pi} \frac{1 - cos2\theta}{2}\, d\theta}$$

$$= \frac{I_m}{\sqrt{4\pi}} \sqrt{\left(\theta - \frac{sin2\theta}{2}\right)_0^{2\pi}}$$

$= \frac{I_m}{\sqrt{4\pi}} \sqrt{2\pi}$

$$\boxed{\text{RMS Current, } I = \frac{I_m}{\sqrt{2}} = 0.707\ I_m}$$

Average Value of sinusoidal current:

The average value of an alternating current is equal to the value of direct current, which transfers across any circuit the same charge as is transferred by that alternating current during a given time.

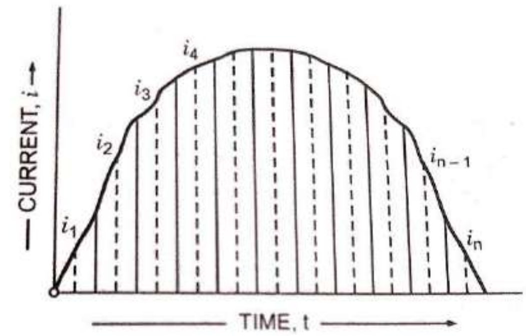


Fig. 11.6

The average value of sinusoidal current, $I_{av} = \int_0^{\pi} \frac{i}{(\pi-0)}\, d\theta$

$I = I_m \sin\theta$

$I_{av} = \frac{1}{\pi}\int_0^{\pi} Im \sin\theta\ d\theta$

$I_{av} = \frac{I_m}{\pi}\int_0^{\pi} \sin\theta\ d\theta$

$I_{av} = \frac{I_m}{\pi}(-\cos\theta)_0^{\pi}$

$I_{av} = \frac{I_m}{\pi}\ 2$

$I_{av} = \frac{2I_m}{\pi}$

$I_{av} = \frac{I_m}{\pi/2} = 0.637\ I_m$

$$\boxed{\text{Average Current, } I_{av} = \frac{I_m}{\pi/2} = 0.637\ I_m}$$

32.

An alternating voltage is v = 100 sin 100t. Find (*i*) Amplitude (*ii*) Time period and frequency (*iii*) Angul **BTL-3**
(*iv*) Form factor (*v*) Peak factor.

Solution: Instantaneous value of alternating voltage is given by expression

$$v = 100 \sin 100\, t$$

(*i*) Amplitude of alternating voltage is given by the coefficient of the sine of the time angle, so

Amplitude of given wave = V_{max} = 100 V **Ans.**

(*ii*) Frequency is given by coefficient of time, t divided by 2π

$$\therefore \text{ Frequency}, f = \frac{100}{2\pi} = 15.9 \text{ Hz} \quad \textbf{Ans.}$$

$$\text{Time period, T} = \frac{1}{f} = \frac{1}{15.9}$$

$$= 0.063 \text{ second or } 63 \text{ ms} \quad \textbf{Ans.}$$

$$(iii) \text{ Angular velocity, } \omega = 2\pi f = 2\pi \times 15.9$$

$$= 100 \text{ radians/second} \quad \textbf{Ans.}$$

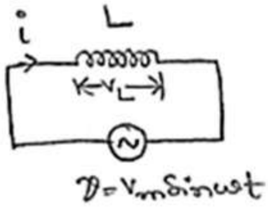
$$\text{RMS value, } V_{rms} = \frac{V_{max}}{\sqrt{2}} = \frac{100}{\sqrt{2}} = 70.71 \text{ V}$$

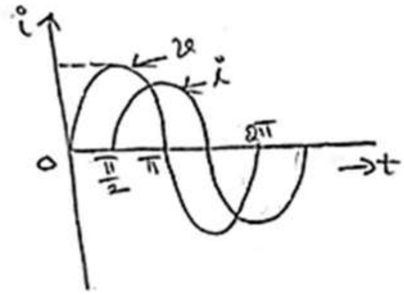
$$\text{Average value } V_{av} = 0.637\, V_{max} = 0.637 \times 100 = 63.7 \text{ V}$$

$$(iv) \text{ Form factor, } K_f = \frac{V_{rms}}{V_{av}} = \frac{70.71}{63.7} = 1.11 \quad \textbf{Ans.}$$

$$(v) \text{ Peak factor, } K_p = \frac{V_{max}}{V_{rms}} = \frac{100}{70.71} = 1.4142 \quad \textbf{Ans.}$$

33. Obtain expression for the current through the pure inductor. If voltage across it is $v=V_m \sin \omega t$. **BTL-3**





Let $v = V_m \sin \omega t$ is the voltage applied.

Pure inductance is one that has no resistance and hence no I^2R loss. Whenever an alternating voltage is applied to a pure inductor, a back emf is produced due to the self-inductance of the coil. The back emf at every step opposes the rise or fall of current through the coil. The applied voltage has to overcome this self-induced emf only.

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

$$V_L = v = L\frac{di}{dt}$$

$$i = \frac{1}{L}\int v\, dt$$

$$i = \frac{1}{L}\int V_m \sin \omega t\; dt$$

$$i = \frac{V_m}{L}\int \sin \omega t\; dt$$

$$i = \frac{V_m}{L}\left[\frac{-\cos \omega t}{\omega}\right]$$

$$i = \frac{V_m}{\omega L}\sin\left(\omega t - \frac{\pi}{2}\right)$$

$$i = \frac{V_m}{X_L}\sin\left(\omega t - \frac{\pi}{2}\right)$$

Where $X_L = \omega L = 2\pi f L$

$X_L \, \alpha \, f$

$$i = I_m \sin\left(\omega t - \frac{\pi}{2}\right)$$

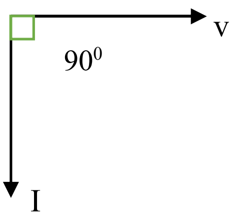
Applied Voltage, $v = V_m \sin \omega t$

Current through pure inductor, $i = I_m \sin\left(\omega t - \frac{\pi}{2}\right)$

Phase difference Φ between v and i is 90^0 or $\frac{\pi}{2}$ and the current lags behind the applied voltage.

$$\Phi = 90^0 \text{ or } \frac{\pi}{2} \text{ lagging}$$

Power factor, $\cos \Phi = \cos 90 = 0$ lagging



34. Prove that average power consumption in pure capacitor is zero when ac voltage is applied.

BTL-3

Pure Capacitor:

In pure capacitive circuit

$$v = V_m \sin \omega t = V_m \sin\theta$$

$$i = I_m \text{Sin}\left(\omega t + \frac{\pi}{2}\right) = I_m \text{Sin}\left(\theta + \frac{\pi}{2}\right)$$

Instantaneous power, p = v x i

$$= V_m \sin\theta \text{ x } I_m \text{Sin}\left(\theta + \frac{\pi}{2}\right)$$

The average power for one full cycle

$$P = \frac{1}{2\pi}\int_0^{2\pi} v * i \, d\theta$$

$$= \frac{1}{2\pi}\int_0^{2\pi} \text{Vm} \sin\theta \text{ x Im Sin}\left(\theta + \frac{\pi}{2}\right) d\theta$$

$$= \frac{1}{2\pi}\int_0^{2\pi} \text{Vm} \sin\theta \text{ x Im Cos}\theta \, d\theta$$

$$= \frac{\text{Vm Im}}{2\pi}\int_0^{2\pi} \frac{\sin 2\theta}{2} d\theta$$

$$= \frac{\text{Vm Im}}{2\pi}\left[-\frac{\cos 2\theta}{4}\right]_0^{2\pi}$$

$$P = \frac{\text{Vm Im}}{2\pi}\left[-\frac{\cos 2(2\pi)}{4} - \left(-\frac{\cos 2(0)}{4}\right)\right] = 0$$

"The average power consumption in pure capacitor is zero when ac voltage is applied"

35. **A load having impedance of $1 + j\,1\ \Omega$ is connected to an ac voltage represented as $v = 20\sqrt{2}\cos(\omega t + 10°)$ volt.** **BTL-3**

(i) Find the current in load, expressed in the form of $i = I_m \sin(\omega t + \phi)$ A.

(ii) Find real power consumed by the load.

Solution: Load impedance, $\mathbf{Z} = (1 + j1)\ \Omega = \sqrt{2}\angle 45°\ \Omega$

Maximum value of applied voltage, $V_{max} = 20\sqrt{2}$ V

RMS value of applied voltage, $V_{rms} = \dfrac{V_{max}}{\sqrt{2}} = \dfrac{20\sqrt{2}}{\sqrt{2}} = 20$ V

Phase angle of applied voltage,

$$\phi = 100° \quad \because \cos(\omega t + 10°) = \sin(\omega t + 90° + 10°)$$

So applied voltage,

$$\mathbf{V} = 20\angle 100°\ \text{V}$$

Load current, $\mathbf{I} = \dfrac{\mathbf{V}}{\mathbf{Z}} = \dfrac{20\angle 100°}{\sqrt{2}\angle 45°} = 10\sqrt{2}\angle 55°$ A

Peak value of load current,

$$I_{max} = \sqrt{2} \times 10\sqrt{2} = 20\ \text{A}$$

and equation for load current is given as

$$i = I_{max}\sin(\omega t + \phi) = 20\sin(\omega t + 55°)\ \textbf{Ans.}$$

36. An alternating voltage has the equation v=141.4 Sin 377t. Find the values of i) RMS voltage b) frequency c) instantaneous voltage when t=3 msec. **BTL-3**

Ans. We know alternating voltage, $v = V_m \sin\omega t$ ---------------------- (1)

Given $v = 141.4 \sin 377t$ -----------------(2)

Comparing equations 1&2

$$V_m = 141.4\ \text{V}$$

$$\omega = 377\ \text{r/s}$$

(a) RMS voltage , $V = \dfrac{V_m}{\sqrt{2}} = \dfrac{141.4}{1.414} = 100$ V

(b) Frequency,f = ?

$$\omega = 2\pi f = 377$$

$$f = \frac{\omega}{2\pi} = \frac{377}{2\pi} = 60\ \text{Hz}$$

(c) $v = 141.4 \sin 377t$ at t = 3s

$$v = 141.4 \sin 377(3) = 109.88\ \text{V}$$

37. . A capacitor of 100 μF is connected across a 200 V, 50 Hz single-phase supply. Calculate (*i*) the reactance of the capacitor (*ii*) rms value of the current and (*iii*) maximum current. **BTL-3**

Solution: Capacitance, $C = 100\ \mu F = 1 \times 10^{-4} F$

Supply voltage, $V = 200\ V$

Supply frequency, $f = 50\ Hz$

(*i*) Reactance of capacitor, $X_C = \dfrac{1}{2\pi f C}$

$$= \frac{1}{2\pi \times 50 \times 1 \times 10^{-4}} = 31.83\ \Omega$$

(*ii*) RMS value of current, $I = \dfrac{V\,(\text{rms value})}{X_C} = \dfrac{200}{31.83} = 6.283\ A$

(*iii*) Maximum value of current,

$$I_{max} = \sqrt{2} \times I_{rms} = \sqrt{2} \times 6.283$$

$$= 8.886\ A\ \textbf{Ans.}$$

Basic Electrical Engineering (U23EE101)

UNIT-III- Part-2

SHORT ANSWER QUESTIONS(SAQs)

1. **What are the advantages of 3 phase circuits over single phase Circuits?**

   There are several advantages of three-phase electrical systems over single-phase systems.

   1. It is more efficient.
   2. It uses less material for a given capacity.
   3. It costs less than single phase systems.
   4. Output of a three-phase machine is greater than the single-phase machine.
   5. Three phase motors have less vibrations compared to single phase motors.
   6. Maintenance cost also less compared to single phase system.
   7. Power capacity for a three-phase system is more compared to single phase system.

2. **Give the relation between line and phase values of voltages and currents in star and Delta connected of 3-phase system.**

   Star Connection:

   Line Voltage = √3 x Phase Voltage

   $V_L = \sqrt{3} x V_{ph}$

   Line Current = Phase Current

   $I_L = I_{ph}$

   Delta Connection:

   Line Voltage = Phase Voltage

   $V_L = V_{ph}$

   Line Current = √3xPhase Current

   $I_L = \sqrt{3}\ I_{ph}$

3. **An alternating circuit takes a power of 10 kW at a power factor of 0.8 lagging find i)Apparent power ii) Reactive power.**

   Given data:

   Active (real) power (P) = 10 kW=$10x10^3$ watts

   Power factor (PF), CosΦ = 0.8 lagging

$$\text{Apprent Power, S} = \frac{\text{Active Power(P)}}{\text{PF(Cos}\Phi)} = \frac{10X1000}{0.8} = 12.5\text{KVA}$$

   From power triangle we Know

$$S^2 = P^2 + Q^2$$

$$\text{Reactive Power, } Q = \sqrt{S^2 - P^2}$$

$$= \sqrt{(12.5)^2 - (10)^2}$$

$$Q = 6.25\ \text{KVAR}$$

4. **Why the inductors are usually iron cored?**

   Inductors are made of iron core because large value of flux densities can be produced in iron cores and so, inductances of large values can be produced. Air-cored inductors become too much bulky to provide an inductance of a required value.

5. **In an RLC circuit on what factors depends whether the phase angle between voltage V and current I is lagging or leading?**

Phase angle in R-L-C circuit is given by $\Phi = \mathrm{Tan}^{-1}\frac{X}{R} = \mathrm{Tan}^{-1}\ \frac{XL-Xc}{R}$

i.e the phase angle between the voltage V and current I will depend upon whether the inductive reactance is greater or smaller than the capacitor reactance. When X_L exceeds X_C voltage V will lead current I and when X_c exceeds X_L applied voltage V will lag behind the current I.

6. **What is the phase relationship between the supply voltage and current flow through a pure resistor circuit, pure inductive circuit and a pure capacitive circuit?**

Pure Resistive Circuit: In pure resistive circuit, both supply voltage and current are in phase with each other. Hence phase angle between voltage and current, $\Phi=0^0$

Pure Inductive Circuit: In pure inductive circuit current lags behind the supply voltage by 90^0 or $\frac{\pi}{2}$ radians i.e $\Phi=90^0$ or $\frac{\pi}{2}$ lagging

Pure capacitive Circuit: In pure capacitive circuit current leads behind the supply voltage by 90^0 or $\frac{\pi}{2}$ radians i.e $\Phi=90^0$ or $\frac{\pi}{2}$ leading

7. **What is the effect of frequency on inductive reactance and capacitor reactance?**

Inductive reactance of an inductor increases proportionally with the increase in supply frequency i.e indictive reactance is directly proportional to frequency.

$$X_L = 2\ \pi\ f\ L$$

$$\mathbf{X_L\ \alpha\ f}$$

Capacitive reactance of a given capacitor decreases with the increase in supply frequency i.e , capacitive reactance is inversely proportional to the supply frequency.

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

$$\mathbf{X_C\ \alpha\ \frac{1}{f}}$$

Basic Electrical Engineering (U23EE101)
UNIT-IV
D.C MACHINES & TRANSFORMERS
SHORT ANSWER QUESTIONS(SAQs)

8. On what principle does the generator operate?

he dc generator operates on the principle of production of dynamically induced emf. whenever flux is cut by the conductor, dynamically induced emf is produced in it, according to the Faraday's laws of electromagnetic induction.

9. What is the function of armature in a dc generator?

The function of armature is to rotate the conductor in uniform magnetic field and provide a path of very low reluctance to the magnetic flux. It holds the conductors in slots.

10. What are the various parts of DC machine and mention the type of material used for each part?

The various parts of DC machine are

Sl.No	Name of the part	Material used
1	Magnetic frame (or)Yoke	Small Machine-Cast Iron Large Machines – Cast Steel (or) Rolled steel
2	Pole Core	Cast iron (or) cast steel of solid piece
3	Pole Shoe	Laminated steels
4	Field Coils	Copper wires
5	Armature Core	Silicon steel or CRGO steel laminations
6	Armature Windings	Copper wires
7	Commutator	Hard drawn copper (or) drop forged copper
8	Brushes	Carbon (or) Graphite

11. Is there any fundamental difference between a DC generator and a DC motor.

So far as construction is concerned, there is no basic difference between a DC generator and a DC motor. In fact, the same machine could be used either as a generator or a motor. Each consists of magnetic poles, rotating armature, a commutator, brushes and brush holders, etc. However, a dc generator converts mechanical energy into electrical energy, but a dc motor converts electrical energy into mechanical energy.

12. Mention the applications of various types of D.C Generators.

Separately excited D.C Generator:

i. These are generally used in Ward-Leonard method of speed control

ii. These are also used wear quick and requisite response to control is important.

Self-Excited D.C Generator:

D.C Shunt Generator: These are used in

i. Battery charging

ii. Power supplies

D.C Series Generator: These are used for

i. Series arc lighting.

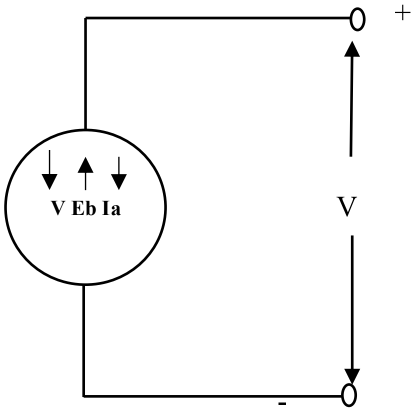
ii. As a series booster
iii. Series incandescent lighting

D.C Compound Generator:

i. Railway circuits
ii. Elevators
iii. Incandescent lighting.
iv. Industrial Motors

13. Why is the generated emf in the motor armature called counter emf or back emf?

When the motor armature rotates, the conductor also rotates, and hence cut the flux and an emf is induced in conductors. The direction of this emf is opposite to the applied voltage. Hence, it is called back emf (or) counter emf.



The presence of back EMM makes the DC motor as a self-regulating machine. It makes the motor to draw as much armature current as is just sufficient to develop the torque required by the load.

The armature Current, $I_a = \frac{V - Eb}{Ra}$

Where are Ra is the armature circuit resistance

Back EMF depends on the other factors, armature speed. If the speed is high, E_b is large, hence armature current is small. If the speed is less ,then Back EMF is less. Hence, armature current is more to develop more torque. So back emf acts like a governor. That is, it makes a motor self-regulating so that it draws as much current as is just necessary.

14. Write the applications of various types of DC Motors.

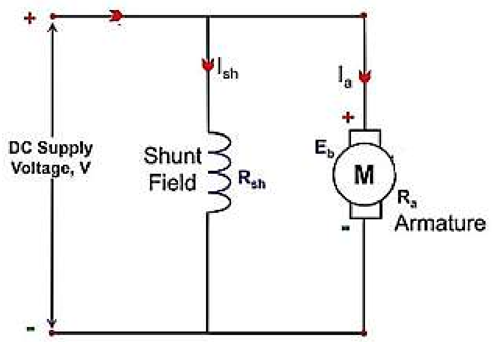
Applications of various types of DC Motors are

- **<u>Separately excited D.C Motor:</u>** These are used in
  a. paper machines
  b. In steel rolling mills
  c. Diesel electric propulsion of ships etc.
- **<u>D.C Shunt Motor</u>:** These are used in
  a. Laths, common line driving
  b. Machine tools
  c. Drills and bearing mills
  d. Shapers, blowers reciprocating pumps
  e. Spinning machines, weaving machines etc
- **<u>D.C Series Motor:</u>** These are used in
  a. Hoists, cranes and conveyors
  b. Electric locomotives, Trolly cars
  c. Air compressors,
  d. Vacuum cleaners, hair dryers, sewing machines
  e. Rapid transit systems.

➢ **D.C Compound Motor:** These are used in

a. Heavy planers
b. Elevators, conveyors
c. Rolling mills
d. Printing presses
e. Air compressors
f. Shears and punching machines

15. Give the voltage equation of a DC motor with neat diagram.



DC Shunt Motor

Let V - Applied Voltage
E_b - Back EMF
Ra - Armature Resistance.
Ia - Armature Current

Since the back emf acts in opposite to the applied voltage across the terminals of the circuit is V-E_b. Therefore, the armature current, I_a is given by

$$I_a = \frac{V - Eb}{Ra}$$

$$\boxed{V = E_b - I_a R_a}$$

This is known as voltage equation of a DC motor

16. List the various losses in a transformer.

Various losses occurring in a transformer are

1. Core losses (or) Iron losses
   a. Hysteresis Loss
   b. Eddy Current loss
2. Copper loss (or) Ohmic loss
3. Stray loss.
4. Dielectric loss.

17. Explain why transformer rating is in KVA.

The rating of a transformer is expressed in kilo-volt- ampere (KVA) rather than in kilowatt (KW). This is due to the fact that rated transformer output is limited by heating, and hence, by the losses in the transformer. The losses depend on transformer voltage and current, and not on the phase angle between voltage and current, i.e it is independent of load power factor. Hence, transformer rated in KVA, not in KW.

18. Define efficiency of the transformer and write the equation of the transformer to find efficiency at any load.

Ans.

The efficiency of the transformer defined as the ratio of the output power to the input power.

$$\text{Efficiency of the transformer, } \eta = \frac{\text{Output Power}}{\text{Input Power}}$$

$$= \frac{\text{Output Power}}{\text{Output Power+Total Losses}}$$

$$= \frac{\text{Output Power}}{\text{Output Power+Iron loss+Copper loss}}$$

$$= \frac{\text{Output Power}}{\text{Output Power}+W_i+\text{Wcu}}$$

$$= \frac{V_2 I_2 COS\Phi_2}{V_2 I_2 COS\Phi_2 + W_i + \text{Wcu}}$$

$$\text{Efficiency of the transformer, } \eta = \frac{V_2 I_2 COS\Phi_2}{V_2 I_2 COS\Phi_2 + W_i + I_2^2 R_{02}}$$

$$\text{**Efficiency of the transformer at any load} = \frac{x{*}KVA * COS\ \Phi{*}10^3}{x{*}KVA * COS\ \Phi{*}10^3 + W_i + x^2 Wcu} \text{ x100}$$

Where x – load on transformer

19. What is the difference between an ideal and practical transformer?

An ideal transformer is an imaginary transformer that has no winding resistance, no magnetic leakage and no iron losses and zero reluctance. While a practical transformer is an actual transformer, which operates at a particular frequency and has winding resistance, magnetic leakage, iron losses, copper losses and magnetic reluctance.

20. What is turns ratio and transformation ratio in a transformer?

Turns Ratio: It is the ratio of number of turns in the secondary winding to the number of turns in the primary winding

$$\text{Turns Ratio} = \frac{N_2}{N_1} = K$$

Transformation Ratio:

a) **Voltage Transformation Ratio:**

The ratio of secondary induced emf to the primary induced emf is known as voltage transformation ratio.

$$\text{Voltage Transformation Ratio, } K = \frac{E_2}{E_1}$$

For an ideal Transformer $V_1 = E_1$ and $V_2 = E_2$

$$\frac{V_2}{V_1} = \frac{E_2}{E_1} = \frac{4.44\ f\ \emptyset_m N_2}{4.44\ f\ \emptyset_m N_1} = K$$

$$\frac{V_2}{V_1} = \frac{E_2}{E_1} = \frac{N_2}{N_1} = K$$

b) Current Transformation Ratio:

The ratio of primary winding current to the secondary winding current is known as current transformation ratio.

For an ideal transformer,

input power = output power.

$$V_1 I_1 = V_2 I_2$$

$$\frac{I_1}{I_2} = \frac{V_1}{V_2}$$

$$\frac{V_2}{V_1} = \frac{E_2}{E_1} = \frac{N_2}{N_1} = \frac{I_1}{I_2} = K$$

21. On what factors does the Hysteresis loss and Eddy current loss depends.

Hysteresis loss depends upon the type of material, volume of the material, frequency of reversal of magnetic field and maximum value of flux density in the core of the material. Since from no-load to full load the flux linking with the core and supply frequency remains constant, hysteresis loss is assumed to be remain constant.

Eddy current loss depends on the maximum value of flux density of the core and supply frequency for a given core (i.e nature of the magnetic material, volume of the core and thickness of the laminations remaining unchanged) Since from no-load to full load, the flux linking with the core and supply frequency remain constant, the eddy current loss remains constant.

22. What do you know about the no-load current of a transformer?

The current drawn by primary winding of a transformer on no-load is called the no load current or exciting current. It is very small in magnitude in comparison to the full load current, i.e 2 to 5% of the full load current. It has two components, energy component to meet the iron losses in addition to the small amount of copper losses occur in the primary winding and magnetizing component relatively large to create the alternate flux in the core

Basic Electrical Engineering (U23EE101)

UNIT-V

A.C MACHINES

SHORT ANSWER QUESTIONS(SAQs)

23. Explain what is rotating magnetic field.

Ans: A rotating magnetic field is that, which is constant in magnitude, but whose axis of direction rotates in space as field system of a dc machine. When a three-phase winding is energized by a 3- phase supply, a rotating magnetic field is developed that tends the rotor of the machine to move in the direction of rotation. Energy transfer occurs due to such rotating magnetic field. The operation of ac rotating machines is based on the production of rotating magnetic field .

24. Write the advantages and disadvantages of 3-Φ induction motors.

Advantages:

1. It has very simple and ragged construction.
2. Its cost is low and it is very reliable.
3. It has high efficiency in normal conditions, no brushes are needed. Hence frictional losses are reduced.
4. It has a reasonably good power factor.
5. It requires less maintenance.
6. It starts up from rest and needs no extra starting motor and has not to be required. Its starting arrangement is simple, especially for squirrel cage type motors.

Dis-advantages:

1. Its speed cannot be varied without sacrificing some of its efficiency.
2. Just like a DC shunt motor, its speed decreases with increase in load.
3. It's starting Torque is somewhat inferior to that of DC shunt motor.

25. Define Slip and slip speed?

Slip: The difference between the synchronous speed N_S of the starter rotating field and the actual rotor speed N is called **slip**. It is usually represented as a percentage of the synchronous speed, i.e.

% Slip, % $S = \frac{Ns - N}{Ns} \times 100$

Per unit slip, $S = \frac{Ns - N}{Ns}$

Rotor speed (motor speed), N=Ns (1 - S)

Slip Speed:

The difference between synchronous speed and the actual speed is known as slip speed.

Slip speed = Ns - N

26. What is the frequency of rotor current or e.m.f

In the rotor is stationary, the frequency of rotor current (e.m.f) is same as the supply frequency. But when the rotor starts revolving, then the frequency depends upon the relative speed or on slip speed. The frequency of rotor current $\mathbf{f_r}$ can be expressed as

$$Ns - N = \frac{120\, f_r}{P} \quad \text{and} \quad Ns = 120\frac{f}{P}$$

$$\frac{fr}{f} = \frac{Ns - N}{Ns} = s$$

Frequency of rotor currents, $\mathbf{f_r = S\, f}$

The rotor current and stater current each produce a sinusoidally distributed magnetic field of constant magnitude and constant space speed of (N+SNs) =Ns. These two fields, superimpose on each other and give rise to the actually existing rotating field.

27. List the applications of capacitor start single phase induction motor.

These motors are used for heavy loads where frequent start required.

1. These motors are used for pumps and compressors.
2. They are also used for conveyors and some machine tools.

28. Why single-phase induction motors are not self-starting.

When single phase supply is given to stator winding of a single-phase induction motor, it produces flux., which is alternating in nature It is not synchronously revolving flux, as the case of three phase induction motor. Now, an alternating or fluctuating flux acting on the stationary squirrel case rotor cannot produce rotation. That is why a single-phase induction motor is not self-starting.

29. Name some of the starting methods of single-phase induction motors.

Single face induction motors make use of the principle of phase split for the purpose of Starting. Split-Phase motors are of the following types.

i. Split phase motor or Resistance start motors.
ii. Capacitor start motors.
iii. Single valve capacitor motor.
iv. Capacitor -start capacitor run motor.
v. Shaded pole motor(inductance split-phase)

30. Explain why a capacity is connected in one of the windings of single-phase induction motor.

Single phase induction motors are not self- starting. Single phase induction motor can be made self-starting by using the principle of phase splitting. The capacitor used in single-phase capacitor motor to cause phase splitting. By using the capacitor of suitable value in starting or auxiliary winding, the starting winding current at standstill can be made to lead the main winding current by 90^o.

31. Explain the choice of synchronous generator on the basis of the generating station.

Synchronous generators are of two types (1) salient-pole type (2) Cylindrical type.

The salient-pole synchronous generator is characterized by small core length and large diameter. These are very suitable for slow speed hydro-generators.

A cylindrical rotor synchronous generator is characterized by long core length and small diameter. These are suitable for high speeds. These are employed in steam generating situations.

32. Write the advantages of stationary armature and revolving field system in case of synchronous machine.

In an alternator the armature is stationary and field system is rotating. The stationary armature has following advantages.

1. It is easier to insulate stationary armature winding for very high voltage.
2. The output current can be collected easily from fixed terminals on the stator to the load.
3. Only two slip-rings are required for dc supply to excite the field winding on the rotor.
4. The armature windings can be more easily braced to prevent any deformation.
5. Rotating field winding is comparatively light and can run with high speeds.
6. It requires less maintenance and less damage to the winding.
7. The armature can have a large number of conductors, hence emf induced will be more.

33. What is double revolving field theory and cross field theory?

Double revolving field theory: As per this theory, the pulsating field created by single phase stator winding can be decomposed into two rotating fields. These two fields rotate in opposite directions.

Cross field theory: As per this theory, the flux is resolved into two components, one acting along starter winding axis and the other at right angles to it.

34. What is a split-phase motor?

This is a single-phase induction motor equipped with an auxiliary winding, also called as the starting winding, connected in parallel with the main winding on stator and differing from it in both phase and space. The starting winding is usually opened by a centrifugally operated device known as centrifugal switch when the motor attains a predetermined speed.

35. Mention the applications of squirrel cage and wound rotor induction motors.

Squirrel cage Induction motor: Squirrel-cage induction motors are suitable for constant speed industrial drives of small power where, speed control is not required, and where starting torque requirements are of medium or low values as for printing machinery, flour mills, saw mills, pumps, prime movers for small generators and other shaft drives of small power.

wound rotor induction motors: Wound rotor induction motor is used for loads requiring severe starting conditions or far loads requiring speed controls such as for driving line shafts, lifts, pumps, generators, winding machines, cranes, hoists, elevators, compressors, small electrical excavators, printing machines, strokers, large ventilating fans, crushers etc.

36. What is shaded pole motor? And write its applications

Shaded pole motor is a salient pole split-phase type induction motor provided with one or more auxiliary short circuited stator windings displaced in magnetic position from the main winding.

Because of their poor starting torque, low power factor and poor efficiency such motors are only suitable for low power applications such as for toys, small fans, electric clocks, hair dryers ,sliding projectors, humidifiers photocopying machines, vending machines, advertising displays, etc.

37. Mention the various types of capacitor single phase induction motors used?

Various types of capacitors single phase induction motor are

I. Capacitor start single phase induction motor
II. Capacitor start capacitor run single phase induction motor.
III. Permanent capacitor single phase induction motor.
IV. Two-value capacitor motor.

Basic Electrical Engineering (U23EE101)
UNIT-III – PART-2
LONG ANSWER QUESTIONS(LAQs)\

38. Derive and explain the concept of voltage and current in R-L series circuit with help of phasor diagram.

Consider an ac circuit consisting of resistance of RΩ and inductance of L Henries connected in series, as shown in figure(a).

Let the current flowing through the circuit be of I amperes.

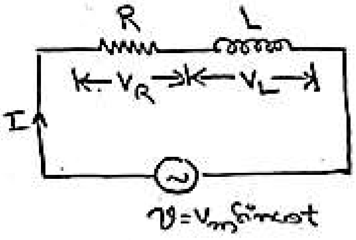


fig (a)

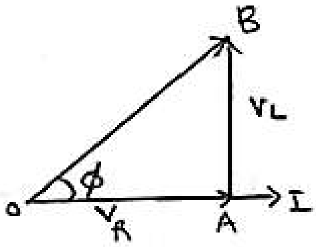


fig (b)

A pure resistance R and pure inductor L are shown connected in series in fig(a)

let V = rms value of applied voltage

I = rms value of resultant current

$V_R = IR$ — voltage drop across 'R'

$V_L = I X_L$ — voltage drop across 'L'

Applied voltage is vector sum of V_R and V_L shown in fig(b)

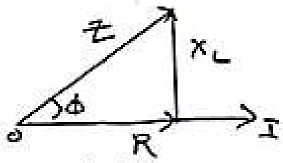
$$V^2 = V_R^2 + V_L^2$$

$$V = \sqrt{V_R^2 + V_L^2}$$

$$= \sqrt{(IR)^2 + (IX_L)^2}$$

$$= I\left[\sqrt{R^2 + X_L^2}\right)$$

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



fig(c)

$Z = \sqrt{R^2 + X_L^2}$ — Impedance of the Circuit (ohms)

from fig(c) $Z^2 = R^2 + X_L^2$

Magnitude, $Z = \sqrt{R^2 + X_L^2}$

$$\tan\phi = \frac{V_L}{V_R} = \frac{iX_L}{iR} = \frac{\omega L}{R} = \frac{X_L}{R}, \quad \phi = \tan^{-1}\left(\frac{X_L}{R}\right)$$

Current lags applied voltage by an angle 'ϕ'

$0 < \phi < 90°$ lagging

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

Current $I = I_m \sin(\omega t - \phi)$

where $I_m = \frac{V_m}{Z}$

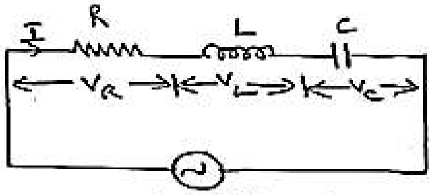
Power factor $1 > \cos\phi > 0$ lagging.

*In R-L series circuit current, I lags behind the voltage, V

39. Derive an expression for impedance, current and phase angle for R-L-C series circuit with phasor diagram.

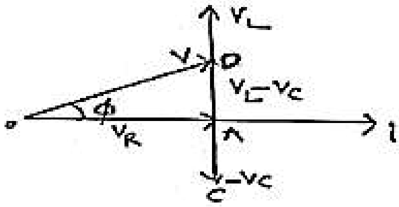
Ans: Consider an ac circuit consisting of resistance of RΩ, inductance of L, henry and capacitance of C farads connected in series, as shown in figure(a).

Let the current flowing through the circuit be of I amperes.



$v = V_m \sin\omega t$

fig(a)



Let Fig (a) shows a RLC series circuit.

Let $v = V_m \sin\omega t$, V = applied voltage rms

I = Current rms

$V_R = IR$ — voltage drop across 'R'

$V_L = IX_L$ — voltage drop across 'L'

$V_C = IX_C$ — voltage drop across 'C'

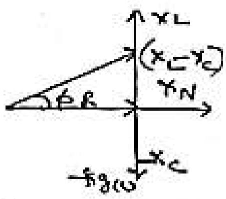
From fig (b) $OD = \sqrt{OA^2 + AD^2}$

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

$$= \sqrt{(IR)^2 + (IX_L - IX_C)^2}$$

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

$$= I\sqrt{R^2 + X_N^2}$$



Net Reactance, $X_N = X_L - X_C$ (or) $X_C - X_L = X_L \sim X_C$

$$I = \frac{V}{\sqrt{R^2 + X_N^2}} = \frac{V}{Z}$$

Z — Impedance of the circuit $= \sqrt{R^2 + X_N^2}$

$Z = R \pm jX_N$

From fig (c)

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

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

$0 < \phi < 1$ lag (or) lead

$1 > \cos\phi > 0$ lag (or) lead

$v = V_m \sin\omega t$

$I = I_m \sin(\omega t \pm \phi)$ '−' → lagging

'+' → leading

The phase angle between the applied voltage, V and current, I will depend upon whether the inductive reactance is greater or smaller than the capacitor reactance. When X_L exceeds X_C then current lags the applied voltage and when X_C exceeds X_L current leads the applied voltage.

40 **A load having impedance of $1 + j\,1\ \Omega$ is connected to an ac voltage represented as $v = 20\sqrt{2}\cos(\omega t + 10°)$ volt.**

(i) Find the current in load, expressed in the form of $i = I_m \sin(\omega t + \phi)$ A.

(ii) Find real power consumed by the load.

Solution: Load impedance, $\mathbf{Z} = (1 + j1)\ \Omega = \sqrt{2}\angle 45°\ \Omega$

Maximum value of applied voltage, $V_{max} = 20\sqrt{2}$ V

RMS value of applied voltage, $V_{rms} = \dfrac{V_{max}}{\sqrt{2}} = \dfrac{20\sqrt{2}}{\sqrt{2}} = 20$ V

Phase angle of applied voltage,

$$\phi = 100° \quad \because \cos(\omega t + 10°) = \sin(\omega t + 90° + 10°)$$

So applied voltage,

$$\mathbf{V} = 20\angle 100°\ \text{V}$$

$$\text{Load current, } \mathbf{I} = \frac{\mathbf{V}}{\mathbf{Z}} = \frac{20\angle 100°}{\sqrt{2}\angle 45°} = 10\sqrt{2}\ \angle 55°\ \text{A}$$

Peak value of load current,

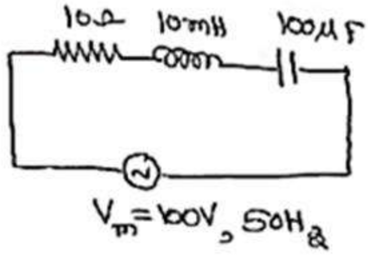
$$I_{max} = \sqrt{2} \times 10\sqrt{2} = 20\ \text{A}$$

and equation for load current is given as

$$i = I_{max}\sin(\omega t + \phi) = 20\sin(\omega t + 55°)\ \textbf{Ans.}$$

41 A Series Circuit consisting of a 10Ω resistor, a 100 μF Capacitance and 10mH inductance is driven by a 50Hz, A.C voltage Source of maximum value 100V. Calculate the equivalent impedance, current in the circuit, the Power factor and Power dissipated in the Circuit.

Sol:-



Data given

Resistance, $R = 10\Omega$

Inductance, $L = 10 \times 10^{-3} H$

Capacitance, $C = 100 \times 10^{-6} F$

Frequency, $f = 50\ Hz$

maximum voltage, $V_m = 100V$

Rms value of voltage, $V = \frac{V_m}{\sqrt{2}} = \frac{100}{1.414} = 70.72\ V$

Impedance, $Z = \sqrt{R^2 + X_N^2}$

X_N – Net reactance $= X_L \sim X_C$

Inductive reactance, $X_L = 2\pi f L = 2 \times \pi \times 50 \times 10 \times 10^{-3}$

$= 3.141\ \Omega$

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

$= \frac{1}{2 \times \pi \times 50 \times 100 \times 10^{-6}}$ = 31.83 ohms

$\therefore$ Impedance, $Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{10^2 + (3.141 - 31.83)^2}$

= 30.38 ohms

current in the circuit, $I = \frac{V}{Z} = \frac{70.72}{30.38}$ = 2.328 A

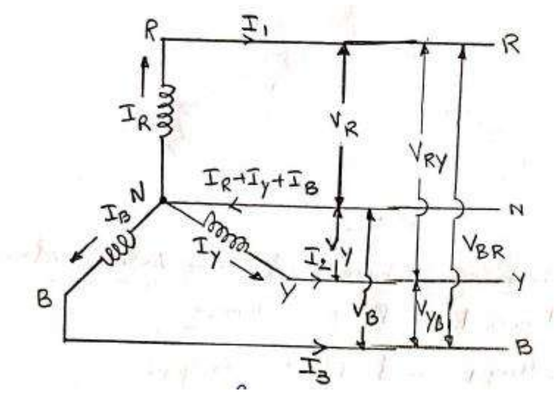
Power factor, $\cos\phi = \frac{R}{Z}$ = 10/30.38 = 0.329 leading

Power dissipated, $P = VI\cos\phi$ =

= 70.72 x 2.328 x 0.329 = 54.16W

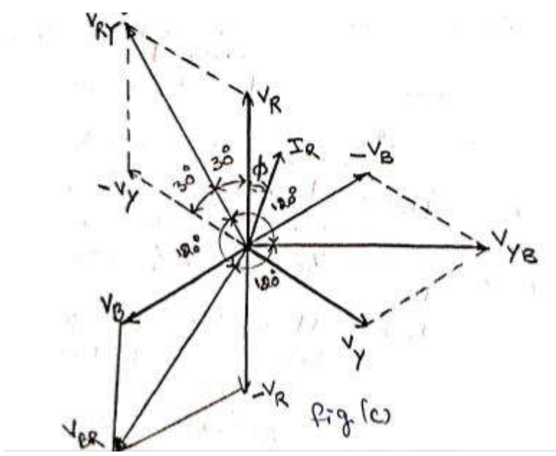
42.Derive the relation between line and phase quantities of voltages and currents for a balanced three phase star connected system.

In this method, the similar ends, that is, start end of three coils or finish end are joined together. The joining point N is known as star point or neutral point.



Relation between phase and line values of voltages and currents In a balanced three phase system:

a) **Line voltages and phase voltages**



The potential difference between line 1 and two is $V_{RY} = V_R - V_Y$

$V_{RY} = V_R + (-V_Y)$

V_{RY} is found by compounding V_R and V_Y reversed. The angle between V_R and V_Y reversed is 60^O.

$$V_{RY} = 2\ V_{Ph} \text{Cos}\left(\frac{60}{2}\right)$$

$$= 2\ V_{Ph} \text{Cos}\ 30$$

$$= 2\ V_{Ph} \frac{\sqrt{3}}{2}$$

$$V_L = \sqrt{3}\ V_{ph}$$

Similarly $V_{YB} = V_Y - V_B = V_Y + (-V_B) = V_L = \sqrt{3}\ V_{ph}$

$V_{BR} = V_B - V_R = V_B + (-V_R) = V_L = \sqrt{3}\ V_{ph}$

Hence, in star connection Line Voltage = √3 x Phase Voltage.

$$\boxed{\mathbf{V_L = \sqrt{3}\ V_{ph}}}$$

b) Line Currents and Phase Currents:

From figure it is seen that each line is in series with its phase winding. Hence the line current in each line is same as the current in each phase winding to which the line is connected.

Current in line 1 = I_R

Current in line 2 = I_Y

Current in line 3 = I_B

$I_R = I_Y = I_B = I_{Ph}$

Line Current I_L = Phase Current I_{Ph}

$$\boxed{I_L = I_{Ph}}$$

43. Derive the relation between line and phase quantities of voltages and currents for a balanced three phase delta connected system.

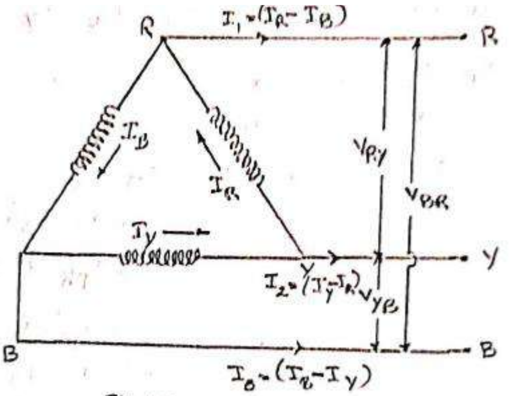


Fig (a)

<u>Relation between phase and line values of voltages and currents In a balanced three phase system:</u>

a) <u>Line currents and phase currents:</u>

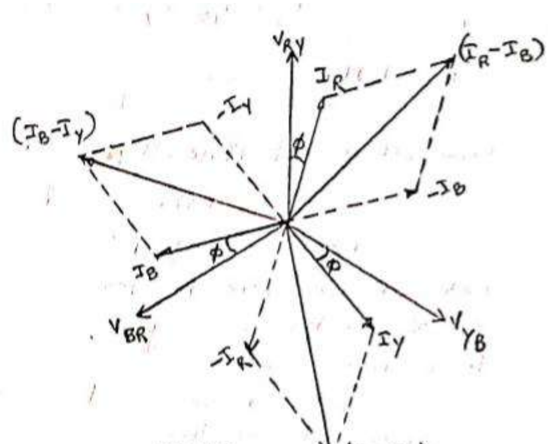


Fig (b)

From Figure(a), It will be seen that current in each line is the vector sum of the two phase currents flowing through that line.

Current in line 1, $I_1 = I_R - I_B$

Current in line 2, $I_2 = I_Y - I_R$

Current in line 3, $I_3 = I_B - I_Y$

$I_R = I_Y = I_B = I_{Ph}$

$$I_1 = I_2 = I_3 = I_L$$

Current in line 1, $I_1 = I_R - I_B$

$= I_R + (-I_B)$

$= 2\, I_{Ph} \cos\left(\frac{60}{2}\right)$

$= 2\, I_{Ph} \cos 30$

$= 2\, I_{Ph} \frac{\sqrt{3}}{2}$

$I_1 = \sqrt{3}\, I_{Ph}$

Similarly, $I_2 = I_Y - I_R = \sqrt{3}\, I_{Ph}$

$I_3 = I_B - I_Y = \sqrt{3}\, I_{Ph}$

In Delta connection **Line Current = √3 x Phase Current**

$$\boxed{\mathbf{I_L = \sqrt{3}\, I_{Ph}}}$$

b) <u>Line voltages and phase voltages:</u>

In Delta connection, only one winding present between any pair of terminals. Hence voltage between any pair of terminals equal to the phase voltage of the winding connected between the two lines considered.

Voltage between line 1 and line 2 is V_{RY}

Voltage between line 2 and line 3 is V_{YB}

Voltage between line 3 and line 1 is V_{BR}

$V_{RY} = V_{YB} = V_{BR} = V_L$

Hence, in delta connection Line Voltage = Phase Voltage.

$$\boxed{\mathbf{V_L = V_{ph}}}$$

44 **If load draws a current of 10 A at 0.8 pf lagging when connected to 100 V supply, calculate the value of real, reactive and apparent powers. Also find out the resistance of the load.**

Solution: Supply voltage, $V = 100$ V

$$\text{Current, } I = 10 \text{ A}$$

$$\text{Power factor, } \cos\phi = 0.8 \text{ (lagging)}$$

$$\text{Phase angle, } \phi = \cos^{-1} 0.8 = 36.87° \text{ (lagging)}$$

$$\text{Real power, } P = VI\cos\phi = 100 \times 10 \times 0.8 = 800 \text{ W } \textbf{Ans.}$$

$$\text{Reactive power, } Q = VI\sin\phi = 100 \times 10 \sin(-36.87°)$$

$$= 100 \times 10 \times 0.6$$

$$= 600 \text{ VAR (lagging) } \textbf{Ans.}$$

$$\text{Apparent power, } S = \sqrt{P^2 + Q^2} = \sqrt{800^2 + 600^2}$$

$$= 1{,}000 \text{ VA } \textbf{Ans.}$$

$$\text{Load impedance, } Z = \frac{V}{I} = \frac{100}{10} = 10\ \Omega$$

$$\text{Resistance of load, } R = Z\cos\phi = 10 \times 0.8 = 8\ \Omega \quad \textbf{Ans.}$$

45 **Three impedances each of $(3 - j4)$ ohms are connected in delta to a 230 V, 3-phase, 50 Hz balanced supply. Calculate the line and phase currents in delta-connected load and power delivered to the load.**

Solution: Phase voltage, V_P = Line voltage, $V_L = 230$ V

$$\text{Impedance in each phase, } Z_P = \sqrt{3^2 + (-4)^2} = 5\ \Omega$$

$$\text{Phase currents, } I_P = \frac{V_P}{Z_P} = \frac{230}{5} = 46 \text{ A} \quad \textbf{Ans.}$$

$$\text{Line currents, } I_L = \sqrt{3}\, I_P = \sqrt{3} \times 46 = 79.67 \text{ A } \textbf{Ans.}$$

$$\text{Power factor, } \cos\phi = \frac{R}{Z} = \frac{3}{5} = 0.6$$

$$\text{Power delivered to load, } P = \sqrt{3} \times V_L \times I_L \cos\phi$$

$$= \sqrt{3} \times 230 \times 79.67 \times 0.6$$

$$= 19{,}044 \text{ W or } 19.044 \text{ kW } \textbf{Ans.}$$

Alternatively power delivered to load,

$$P = 3 I_P^2 R_P$$

$$= 3 \times 46^2 \times 3$$

$$= 19{,}044 \text{ W or } 19.044 \text{ kW } \textbf{Ans.}$$

46. a) What is 3-phase system? What are the advantages of three phase system over single-phase system?

b) Explain about Phase sequence.

Ans (a) <u>3-Phase System:</u> A three phase system consists of three ac voltages and three currents. The voltage induced in the three windings are 120 degrees apart in time phase. In three phase system, there are three independent alternating windings which are displaced from one another by 120 electrical degrees apart.

The electrical displacement = $\frac{\text{360 electrical degrees}}{\text{Number of phases}} = \frac{360}{n}$

For three phase system the electrical displacement = $\frac{360}{3} = 120^{o}$

A supply system is said to be symmetrical when several voltages of the same frequency have equal magnitude are displaced from one another by equal time angle.

A 3-phase supply system is balanced when the three phase voltages are equal in magnitude and phase angle between the three phases is equal to 120^{o}.

A 3-phase supply will be unbalanced when either of the three phase voltages are unequal in magnitude, or the phase angle between the three phases is not equal to 120 degrees.

<u>Advantages:</u>

The various advantages of three phase system are

1) It is more efficient.
2) It uses less material for a given capacity.
3) It's cost less than single phase operators.
4) Output of a three-phase machine is greater than the single-phase apparatus.
5) Three phase motors have less vibrations compared to single phase motors.
6) Polyphase system is more capable and reliable than single phase system.

(b) Phase Sequence:

"Phase sequence is the order in which the three phases attain their maximum values." It means that emf of phase 'b' lags behind that of 'a' by 120^{0}. Similarly, the emf of phase 'c' lags behind that of 'b' by 120 degrees, or that of 'a' by 240 degrees. It is called the phase order or phase sequence i.e . a $\longrightarrow$ b $\longrightarrow$ c

The rotation of the field is reversed, then the phase sequence becomes. a $\longrightarrow$ c $\longrightarrow$ b

A three-phase system has only two possible phase sequences, such as a, b, c and a, c, b .

The three phases may be numbered as 1,2,3 (or) they may be given three colours R,Y,B.

The three colours commonly used are Red, Yellow & Blue.

The possible phase sequencies are R,Y,B and R,B,Y.

The phase sequencies are R,Y,B is taken as positive and R,B,Y is taken as negative.

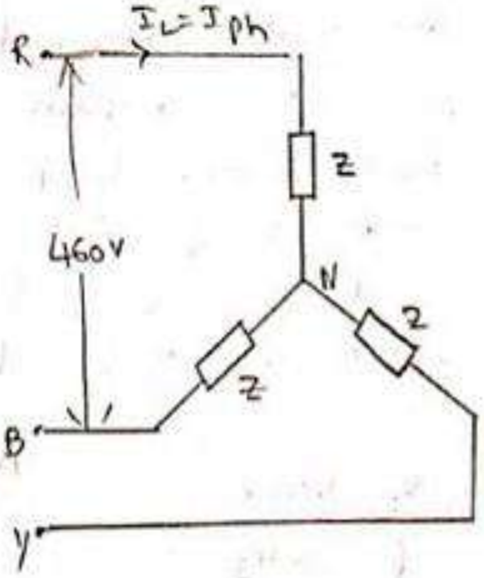
47. Three star connected inductors take 8 kw at a power factor of 0.8 when connected across a 460V,3-phase,3 wire supply. Find the circuit constants of the load per phase.

Sol)

Power taken by load, $P = 8\,KW$

P.f of the load, $\cos\phi = 0.8$

$V_L = 460V$



$P = \sqrt{3}\, V_L I_L \cos\phi$

$8000 = \sqrt{3} \times 460 \times I_L \times 0.8$

$$I_L = \frac{8000}{\sqrt{3} \times 460 \times 0.8}$$

$= 12.55\,A$

$I_{ph} = I_L = 12.55A$

$$V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{460}{\sqrt{3}} = 265V$$

Circuit constant are R_{ph} & X_{ph}

$\therefore R_{ph} = Z_{ph} \cos\phi$, $X_{ph} = Z_{ph} \sin\phi$

$$Z_{ph} = \frac{V_{ph}}{I_{ph}} = \frac{265}{12.55} = 21.1\,\Omega \quad ; \quad \phi = \cos^{-1}(0.8) = 36.86$$

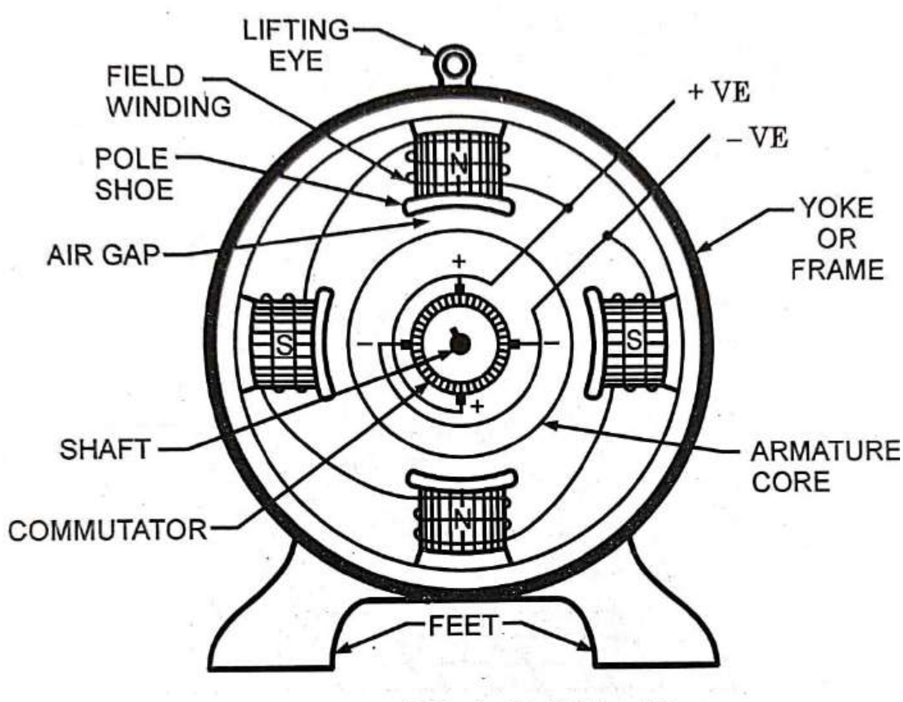
$\therefore R_{ph} = Z_{ph} \cos\phi = 21.1\,(0.8) = 16.9\,\Omega$

$X_{ph} = Z_{ph} \sin\phi = 21.1\,(0.6) = 12.66\,\Omega$

Basic Electrical Engineering (U23EE101)
UNIT-IV - D.C MACHINES & TRANSFORMERS
D.C MACHINES
LONG ANSWER QUESTIONS(LAQs)

48. Explain in detail the of a DC Generator.

Construction:



4-Pole DC Machine

Various parts of D.C machine are

i. Magnetic frame or yoke
ii. Pole core and pole shoe
iii. Field coils
iv. Armature core and armature windings
v. Commutator
vi. Brushes
vii. Bearings

i. Magnetic frame or yoke:

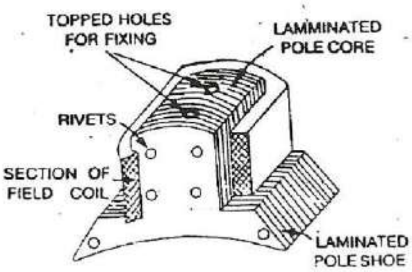
The outer frame or yoke sources to purpose (i) It provides mechanical support for the poles and acts as a protecting cover for the whole Machine and (ii) It carries magnetic flux produced by the poles. It is made of unlaminated ferromagnetic material, such as cast iron or cast steel.

For small machines, it is made of cast iron, but for larger machines, it is made of cast steel or rolled steel. Yoke possesses sufficient mechanical strength and have high permeability.

ii. Pole core and pole shoe:

Field magnets consists of pole cores and pole shoes. Pole shoe serves two purposes (i) They spread out the flux in the air gap and reduces the reluctance of the magnetic path and (ii) They support field coils.

Pole core is made of cast iron or cast steel of solid piece, whereas pole shoe is laminated and fastened to the pole. Pole shoes are laminated annealed steel of thickness 1mm to 0.25 mm.



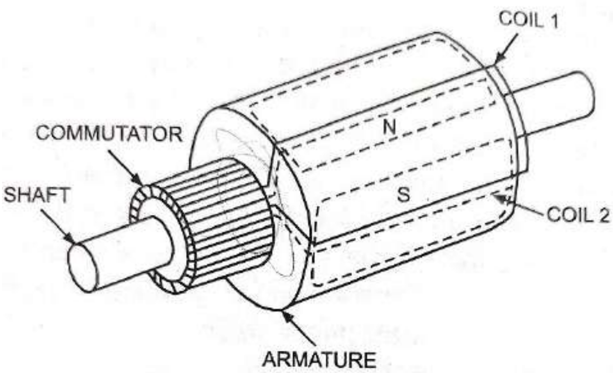
iii. **Field coils:**

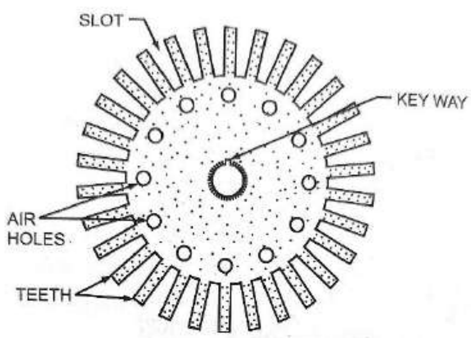
These are consisting of copper wire or strips are farmer wound. These are placed over the core. when current is passed through these coils, they electro magnetize the poles which produce the necessary flux that is cut by the revolving armature conductors.

iv. **Armature Core and Armature windings:**

Armature Core:

It houses the armature conductors or coils and causes them to rotate and hence cut the magnetic flux of field magnets. It provides a very low reluctance path for flux through armature from N-pole to S-pole. It is cylindrical or drum shaped is built up of sheet steel laminations of 0.5 mm thickness. The outer periphery of the armature slotted to carry armature conductors. The laminations are insulated from one another so as to decrease eddy current losses.





Armature Lamination

Armature Windings:

These are former-wound, these are first wound in the form of flat rectangular coils and are then pulled into their proper shape in a coil puller. Various conductors of the coils are insulated from each other. The conductors are placed in the armature slots which are lines with insulating material.

v. **Commutator:**

The function of commutator is to facilitate collection of current from the armature conductors. It works as mechanical rectifier i.e converts alternating emf generated in the armature into the direct emf at the brush terminals. The commutator is a group of wedge-shaped copper segments insulated from each other by thin mica sheets. In motors, it works as inverter. The commutator segments made of hard-drawn or drop-forged copper. The number of segments is equal to the number of armature coils.

vi. **Brushes:**

These collect current from commutator. These are usually made of carbon or graphite. These brushes are housed in the brush holders. A pigtail mounted on the top of the brush, conveys current from the brushes to holders.

vii. **Bearings:**

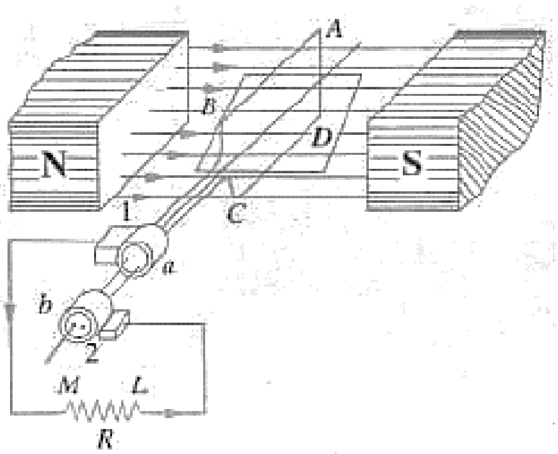
Ball bearings are generally employed, for heavy duty machines roller bearings are employed.

49. Explain the working principle of a DC Generator.

Working Principle of D.C Generator:

An electrical generator is a machine which converts mechanical energy into electrical energy. The energy conversion is based on the principle of production of dynamically induced emf. Whenever a conductor curves the magnetic clicks dynamically induced emf is produced in it according to Faraday's loss of electromagnetic induction.

The basic parts of an electrical generator are magnetic field, conductor and relative motion of conductors with respect to magnetic field.



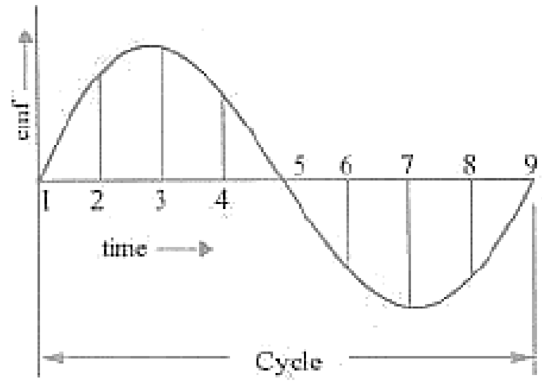
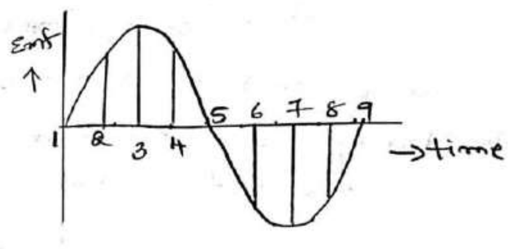


Fig (a): Simple Loop Generator **Fig(b):EMF induced in armature**

Fig (a)shows a Single-turn copper coil ABCD rotating about it's own axis in magnetic field provided by either permanent magnet or electromagnet. The two ends of the coil are joined to the two slip rings a and b, which are insulated from each other and from the shaft .Two copper are carbon brushes are used to collect the current induced in the coil and to carry it to the external load resistance, R. Assuming coil rotating in clock-wise direction, As the coil rotates the flux linked with it changes. Hence, an emf is induced in it, which is proportional to rate of change of flux linkages (e=N$\frac{d\emptyset}{dt}$).
At Position 1(starting position) coil is at right angles to the lines of flux, then flux linked with the coil is maximum but rate of change of flux linkages is minimum. It is because the coil sides, AB and CD, do not cut the flux, rather they move parallel to them. Hence, there is no emf induced in the coil. As the coil continues rotating further, the rate of change of flux linkages and induced emf increases till position 3 is reached, where θ= 90°

At Position 3 the coil plane is horizontal i.e parallel to the lines of flux. The flux linked with the coil is minimum, but rate of change of flux linkages is maximum. Hence, EMF induced in the coil is maximum.

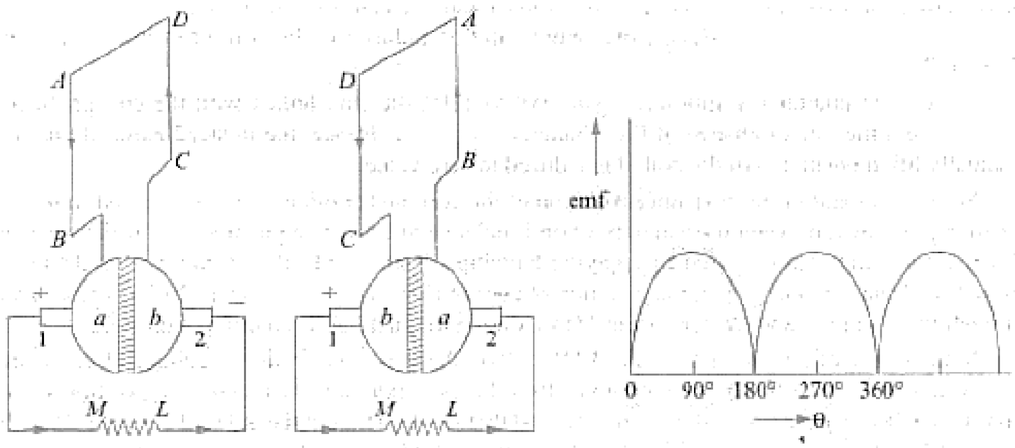


In the next quarter revolution i.e from 90° to 180°. The flux linked with the coil gradually increases, but rate of change of flux linkage is decreases. Hence the induced emf decreases gradually till in position 5 of the coil, it is reduced to zero.

In the next half revolution i.e from 180ºto 360º. The variation in the magnitude of the emf are similar to those in the first half revolution. At position 7 its value is maximum and minimum when in position 1.

The direction of induced EMF is found by applying Fleming's right hand rule. During the first half revolution, the direction of current is ABMLCD. The current through load resistance flows from M to L. During the second half cycle, the direction of current is DCLMBA. The current through the load resistance flows from L to M.

The current reverses its direction after every half cycle .Such current is known as alternating current(AC),For making the flow of current unidirectional in the external circuit, the slip rings are replaced by split rings. These are made up of conducting cylinder, which is cut into two half segments, insulated from each other by thin sheet of mica.



The coil ends are joined to these segments. In the first half revolution current flows along ABMNLCD i.e, the brush number 1 in contact with segment a acts as positive end and b acts as negative end.

In the next half revolution, the direction of induced current in the coil reversed, but at the same time, the position of the segments a and b have also reversed with the result that brush number 1 comes in touch with b segment, which is positive, hence current in the load resistance again flows from M to L Hence, alternating current becomes unidirectional current in the external circuit.

50. Derive the EMF equation of a DC Generator.

According to Faraday's laws of electromagnetic induction, emf will be induced in the armature conductors when the armature is rotated so as to cut a magnetic flux.

If Φ= Flux per pole in webers,

P = Total number of generator poles

Z = Total number of armature conductors

= No.of Slots x No.of conductors /slot

N = Speed of the armature in rpm

A = No.of parallel paths in armature

E = Total emf generated

Generator e.m.f generated / conductor = e.m.f generated in any one parallel paths i.e E

The average EMF generated per conductor, e= $\frac{d(n\Phi)}{dt} = \frac{d\Phi}{dt}$ volts (n=1)

Flux cut/conductor in one revolution, $d\Phi = \Phi P$ Wb

Number of revolutions / second = $\frac{N}{60}$

Time for one revolution, dt = $\frac{60}{N}$ second

Hence According to Faraday's laws of electromagnetic induction, EMF generated / conductor = $\frac{d\Phi}{dt} = \frac{\Phi PN}{60}$ volts

Number of armature conductors per parallel paths = $\frac{Z}{A}$

Total generated emf per path, E = $\frac{\Phi PN}{60} \times \frac{Z}{A}$

EMF generated in D.C Generator $\boxed{\mathbf{E = \frac{\Phi ZN}{60} X \frac{P}{A} \quad Volts}}$

Where A=P for Simplex Lap winding

A=2 for Simplex Wave winding

51. Classify the DC generators according to the method of excitation with neat circuit diagrams.

Ans. Generators are classified according to the way in which their fields are excited. DC generators are classified into two main categories.

1.Separately- excite generators

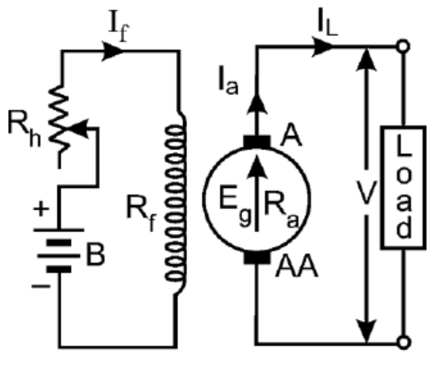
2.Self-excited generator.

Self-excited generators are further divided into three types depending on the way in which the field windings are connected to their armature.

i. Shunt Generators
ii. Series Generators
iii. Compound Generators
   a) Compound generators are divided into short-generators and long shunt-generators.
   b) Compound generators are further divided into differentially compound generator and Cumulatively-compound generators

1. Separately- excite D.C Generator:

In this type field magnets are energized from an independent external source of d.c source, such as battery.



E_g = Generated EMF
V = Terminal Voltage
I_a = Armature Current
I_L = Load current
I_f = Field current
R_a = Armature Resistance
R_f = Field winding Resistance

The circuit diagram illustrated in the above figure. In this case Current flowing through the armature I_a and load I_L is same i.e $I_a = I_L$

The terminal voltage, $V = E_g - I_a R_a$

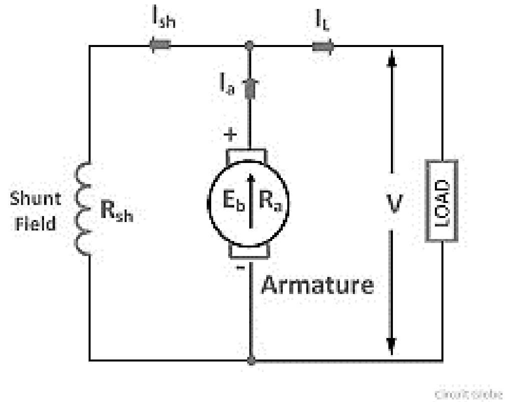
Power developed, $P_g = E_g I_a$

Power delivered to load, $P_L = VI_L$

Self-excited generator:

In this type, the field magnets are energized by the current produced by the generators themselves.

D.C Shunt Generator:



In this type, the field windings are connected across or in parallel with the armature conductors. The voltage across the armature terminals and field windings is same. The field winding consists of a large number of turns of fine wire so as to provide large resistance. The field current is much less than the armature current sometimes as low as 5%.

I_{sh} - Shunt field Current

E_g - Generated EMF

V - Terminal Voltage

I_a - Armature Current

I_L - Load current

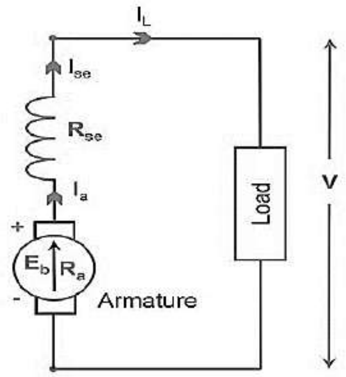
R_a - Armature Resistance

R_{sh}- Shunt field winding Resistance

BCD - Brush contact Drop

i. $I_a = I_{sh} + I_L$
ii. $I_{sh} = \frac{V}{R_{sh}}$
iii. $E_g = V + I_a R_a + BCD$
iv. Power developed, $P_g = E_g I_a$
v. Power delivered to load, $P_L = VI_L$

D.C Series Generator:



Series Generator

In this type the field windings are joined in series with armature conductors. They carry full- load current. Field winding consists of few turns of thick wire. The cross-sectional area of the wire used for the field coils is large enough to carry the armature current.

I_{se} = Series field current

R_{se} = Series winding Resistance

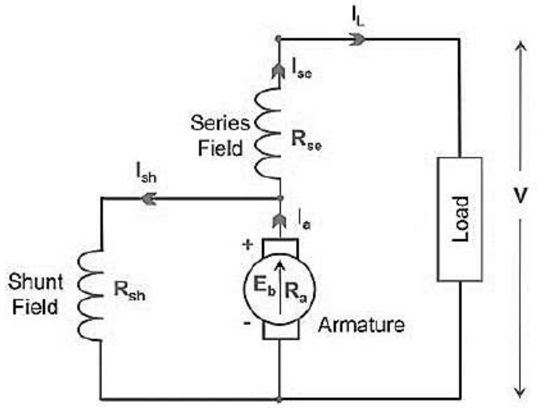
i. $I_a = I_{se} = I_L$
ii. $E_g = V + I_a R_a + I_{se} R_{se} + BCD = V + I_a (R_a + R_{se}) + BCD$
iii. Power developed, $P_g = E_g I_a$
iv. Power delivered to load, $P_L = VI_L$

D.C Compound Generator:

In compound generators, there are two field windings. one is the series field winding and another is the shunt field winding. Compound generators may be connected either short shunt or long shunt. In compound generators, the Shunt field is stronger than series field. When series field is aids the Shunt field generator is said to be commutatively compound generator. If the series field opposes the shunt field, the generator is said to be differentially compounded generator.

Short-Shunt Compound Generator:

This type the shunt field winding is connected in parallel with the armature alone.



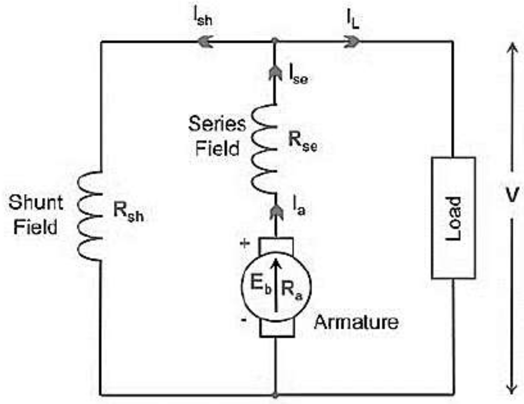
Short Shunt Compound DC Generator

$I_{se} = I_L$

i. $I_a = I_{sh} + I_L$
ii. $E_g = V + I_a R_a + I_{se} R_{se} + BCD$
iii. Power developed, $P_g = E_g I_a$
iv. Power delivered to load, $P_L = VI_L$

Long-Shunt Compound Generator:

In long shunt DC compound generators, the shunt field winding is connected in parallel with both the armature and series field winding.



Long Shunt Compound DC Generator

$I_{sh} = \frac{V}{R_{sh}}$

i. $I_a = I_{sh} + I_L$

ii. $E_g = V + I_a R_a + I_{se} R_{se} + BCD = V + I_a (R_a + R_{se}) + BCD$

iii. Power developed, $P_g = E_g I_a$

iv. Power delivered to load, $P_L = VI_L$

52. A lap-connected 8-pole generator has 500 armature conductors and useful flux per pole of 0.07 Wb. Determine the induced emf when it runs at 1000 rpm.

Ans. No.of poles, P = 8

No.of armature conductor, Z = 500

Flux per pole, Φ = 0.07 wb

Speed ,N = 1000 rpm

Lap connected generator

No.of armature parallel paths, A = P = 8

EMF induced in the generator, $E = \frac{\Phi ZN}{60} \times \frac{P}{A}$ Volts

$$= \frac{0.07 * 500 * 1000}{60} \times \frac{8}{8} = 583.33 \text{ volts}$$

53.Explain the working principle of a DC Motor.

Working Principle:

DC motor converts electrical energy (DC) into mechanical energy. Input to the DC motor is electrical and output is mechanical rotation. Its action is based on the principle that when a current carrying conductor is placed in a magnetic field, it experiences a mechanical force. The direction of this force is given by Fleming's left-hand rule. Constructionally , there is no difference between a DC generator and a DC motor. Magnitude of this force is given by

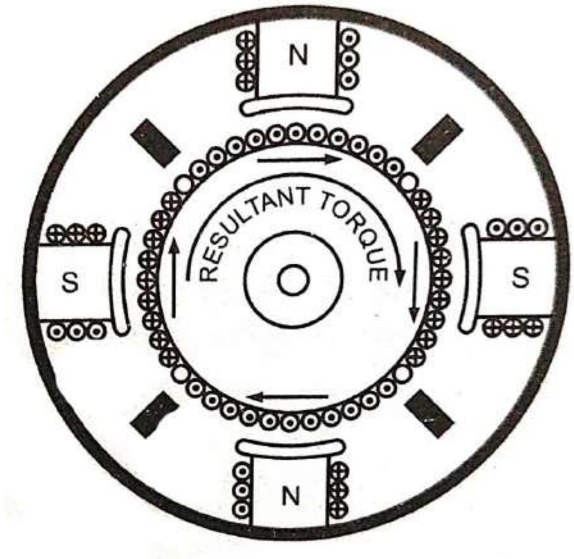
Force , F = BIL Sinθ newtons

where

B- Flux density , tesla
I - Current in conductor, A
L- Length of the conductor in magnetic field, m
θ - Angle between magnetic field and conductor

When the motor is connected to DC supply mains, a direct current passes through the brushes and commutator to the armature winding. While it passes through the commutator, it is converted into ac so that the group of conductors under successive field poles carries current in the opposite direction as shown in figure. Also, the direction of current in the individual conductors reverses as they pass away from the influence of one pole to the next.

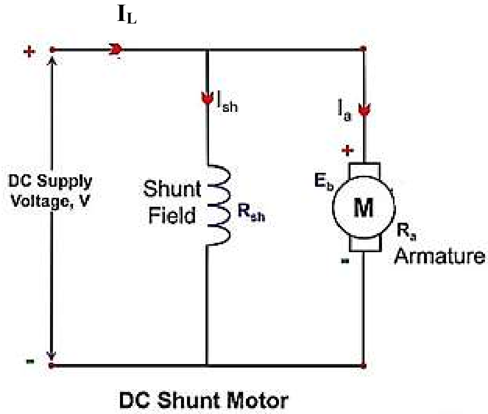
In fig (a), a 4-pole DC motor is shown. when the field and armature currents are connected across DC supply mains, the currents in armature conductors are outwards under the N-Poles(dots) and inwards under the S-Poles(crosses). By applying Fleming's left-hand rule, the direction of force on each conductor can be determined. It is observed that each conductor experiences a force which tends to rotate the motor armature in clockwise direction. These forces collectively produce driving torque.



Fig(a)

54. A 4-pole DC Shunt Motor working on 220 V dc supply takes a line current of 3A at no load. Determine the back emf when the motor takes a line current of 50 A. Assume armature and field resistances as 0.2 ohm and 400 ohm respectively.

Ans.



No. of poles, P = 4

Applied voltage, V = 220V

Shunt field resistance, $R_{sh} = 400\Omega$

Armature Resistance, $R_a = 0.2\ \Omega$

Shunt field current, $I_{sh} = \frac{V}{R_{sh}} = \frac{220}{400} = 0.55A$

No-load line Current, $I_{Lo} = 3A$

No-load armature current , $I_{ao} = I_{Lo} - I_{sh} = 3 - 0.55\ 2.45$ A

No-load back emf ,$E_{bo} = V - I_{ao} R_a$

$= 220 - 2.45 \times 0.2 = 219.51$ V

When loaded:

Line Current, $I_L = 50A$

Armature current , $I_a = I_L - I_{sh} = 50 - 0.55 = 49.45$ A

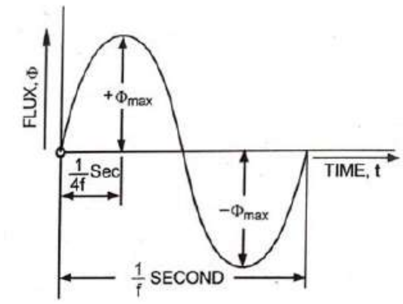
Back emf, $E_b = V - I_a R_a = 220 - 49.45 \times 0.2 = 210.11$ V

TRANSFORMERS

LONG ANSWER QUESTIONS(LAQs)

55. Derive the EMF equation of transformer.

Ans:



Sinusoidal Variation of Flux With Time

Let N_1 = No. of turns in primary

N_2 = No. of turns in secondary

Φ_m= Maximum flux in core in webers

$= B_m \times A$

f = Frequency of a.c. input in Hz

As shown in fig flux increases from its zero value to maximum value Φ_m in one quarter of the cycle i.e in 1/4f second.

Average rate of change of flux $= \frac{\emptyset_m}{1/4f}$

$= 4f\Phi_m$ wb\s or volt

Rate of change of flux per turn means induced e.m.f in volts.

Average e.m.f/turn = 4f Φ_m volt

If flux Φ_m varies sinusoidally, then r.m.s value of induced e.m.f is obtained by multiplying the average value with form factor.

Form factor $= \frac{\text{RMS value}}{\text{Average value}} = 1.11$

R.M.S value of e.m.f /turn = $1.11 \times 4f\Phi_m = 4.44\, f\, \Phi_m$ volt

RMS value of the induced e.m.f in the whole of primary winding

= induced e.m.f/turn X No. of Primary turns

$E_1 = 4.44\ f\ \Phi_m N_1 = 4.44\ f\ B_m\ A\ N_1$ volts --------------------(1)

RMS value of the induced e.m.f in the whole of secondary winding

= induced e.m.f/turn X No. of secondary turns

$E_2 = 4.44\ f\ \Phi_m N_2 = 4.44\ f\ B_m\ A\ N_2$ volts -------------------(2)

Equations (1) & (2) are known as emf equations of transformer primary and secondary.

56 The emf per turn of a single-phase 10 kVA, 2200/220 V, 50 Hz transformer is 10 V. Calculate (i) the number of primary and secondary turns, (ii) the net cross-sectional area of core for a maximum flux density of 1.5 T.

Solution:

EMF per turn = 10 V

Primary induced emf, $E_1 = V_1 = 2{,}200$ V

Secondary induced emf, $E_2 = V_2 = 220$ V

Supply frequency, $f = 50$ Hz

Maximum flux density, $B_{max} = 1.5$ T

(*i*) Number of primary turns,

$$N_1 = \frac{E_1}{\text{EMF per turn}} = \frac{2{,}200}{10} = 220 \text{ **Ans.**}$$

Number of secondary turns,

$$N_2 = \frac{E_2}{\text{EMF per turn}} = \frac{220}{10} = 22 \text{ **Ans.**}$$

Maximum value of flux,

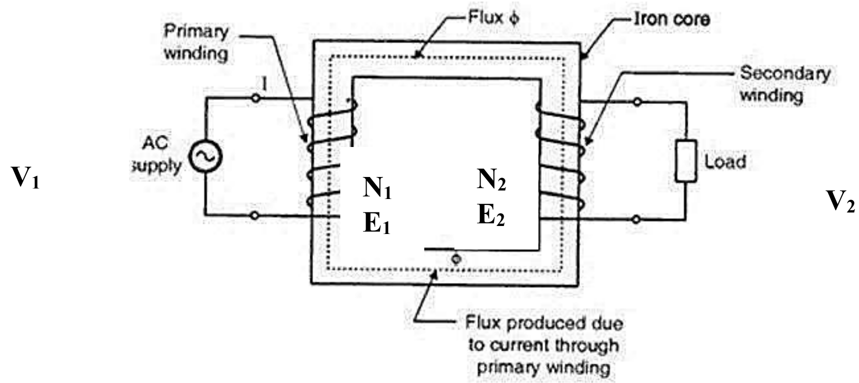
$$\Phi_{max} = \frac{\text{EMF per turn}}{4.44 f} = \frac{10}{4.44 \times 50} = 0.045 \text{ Wb}$$

(*ii*) Net cross-sectional area of core,

$$a = \frac{\Phi_{max}}{B_{max}} = \frac{0.045}{1.5} = 0.03 \text{ m}^2 \quad \textbf{Ans.}$$

57. Explain the construction and working principle of a Transformer?

Ans: **Construction of Transformer:**



A transformer consists of a silicon steel magnetic core and two windings placed on it. The two windings are insulated from each other and from the core. The core is built up of thin silicon steel laminations to provide a path of low reluctance to the magnetic flux. The winding connected to the supply mains is called primary winding and the winding connected to the load circuit is called secondary winding. Also, the winding connected to the higher voltage circuit is called high voltage winding (H.V), while the winding connected to the lower voltage circuit is called low voltage (L.V) winding. The primary and secondary windings of a transformer are not electrically connected, but are coupled magnetically.

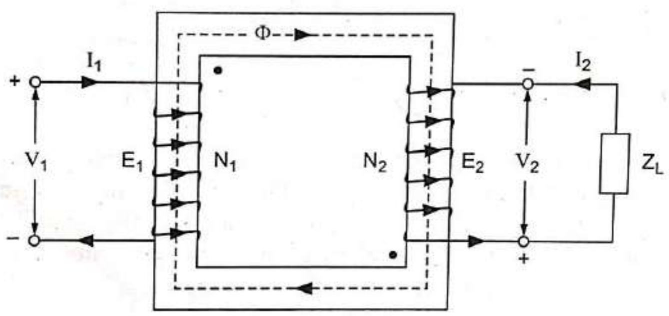
In a transformer, the electrical energy transfer from one electrical circuit to another electrical circuit takes place without the use of moving parts. Therefore, out of all the electrical machines, the transformer has highest possible energy and it requires negligible amount of maintenance and supervision.

Working (or) Operating Principle of Transformer:

Transformer is an ac machine the transfers electrical energy from one electrical circuit to another electrical circuit through the medium of magnetic field and without change in the frequency. The transfer of energy takes place by the principle of electromagnetic induction. The physical basis of a transformer is mutual induction between two circuits linked by a common magnetic field. It changes voltage and current levels simultaneously. Transformer is an electromagnetic energy conversion device.

When primary winding connected to an AC supply source of voltage, V_1 and frequency f Hz, a current of I_1 will flows through it. This current produces an alternating flux in the core which varies with time. This flux first links with primary winding, hence produces self-induced emf E_1 in the primary winding, which opposes the applied voltage.

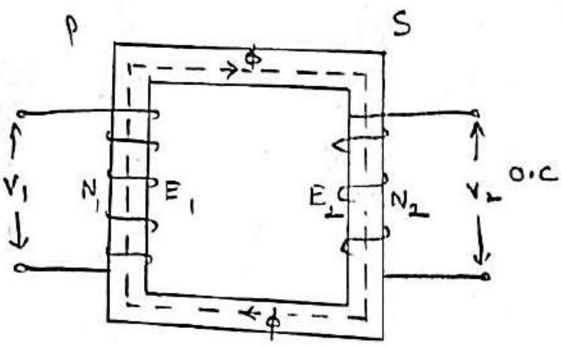
This flux Φ passes through the magnetic core and links with the secondary winding, and induces an emf called mutually induced emf E_2 in the secondary winding. The emf in the secondary winding will able to circulate the current I_2 in the load circuit. The frequency of induced emf in the secondary winding is same as that of the supply frequency.

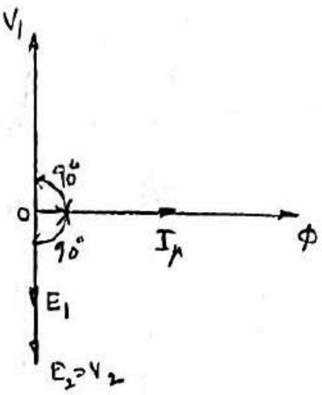


Ideal Iron-Core Transformer

58. Explain in detail about the Ideal and Practical Transformer and draw its phasor diagrams.

IDEAL TRANSFORMER:





Fig(a) Ideal Transformer **Fig(b) Phasor (or) Vector diagram**

An ideal transformer is one which has no losses i.e

(i) No winding resistance i.e the primary and secondary windings have zero resistance.

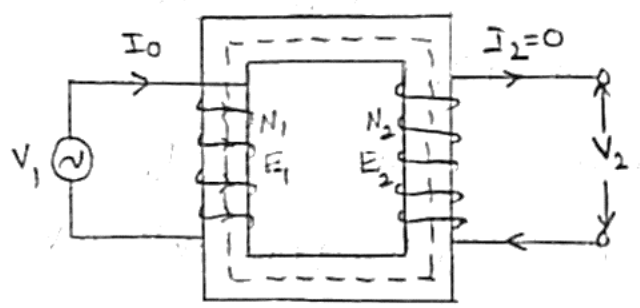
(ii) No magnetic leakage i.e all the flux set up by the primary winding links the secondary winding

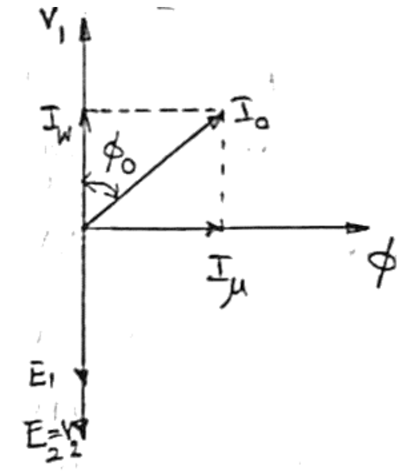
(iii) No iron losses i.e hysteresis and Eddy current losses in the transformer core is zero.

(iv) The core has constant permeability

Consider an ideal transformer as shown in fig(a) whose secondary is opened and primary is connected to a.c supply voltage, V_1. In an ideal transformer, the primary draws the magnetizing current($I\mu$) only. The function of this current is to magnetize the core. The magnetizing current lags the applied voltage by 90^O. This magnetizing current is produces an alternating flux Φ, which is proportional to the current as shown in fig(b).
The emfs induced in primary and secondary (E_1 & E_2) lagging the flux by 90^o and in phase opposition to the applied voltage V_1.

PRACTICAL TRANSFORMER: (Transformer on no-load)





Fig(a) Practical Transformer

Fig(b) Phasor Diagram(or)Vector diagram

Consider a practical transformer whose secondary is open-circuited i.e $I_2 = 0$ and primary is connected to a.c supply as shown in fig(a).This condition is said to be no-load condition. In an actual transformer there is iron loss in the core and copper loss in the windings (both primary and secondary). On no-load primary draws a small amount of current I_o, this current is known as no-load current. No- load current lags the applied voltage by an angle less than 90^0 as shown in fig(b).
The primary no load current Io has to supply

i. the iron loss in the core and
ii. a very small amount of copper losses in the primary winding.

No-load primary current consists of two components,

1. Active or watt-full component of current, $I\omega$
2. Magnetizing component of current, $I\mu$

Active component of current, $I\omega$ is in-phase with applied voltage, V_1. It mainly supplies iron losses and small amount of primary copper losses. This component produces changing flux in the iron core of the transformer. It is also known as iron loss component.

Active component of current, $I\omega = I_0 \cos \Phi_0$

No-load Power factor, $\cos \Phi_0 = \frac{I_\omega}{I_0}$

Magnetizing component of current, $I\mu$ lagging behind the applied voltage by 90 degrees. It is in phase with flux. Its function is to sustain the alternating flux in the core, and is also known as watt less component.

Magnetizing component of current, $I\mu = I_0 \sin \Phi_0$

No-load current, $Io = \sqrt{I_\omega^2 + I_\mu^2}$

No-load input power, $P_0 = V_1 I_0 \cos \Phi_0$

59. A 3300/220 V,30KVA,1Φ transformer takes a no=load current of 1.5A,when the L.V winding is open. The iron loss component of current is 0.4 A ,Find (i) Power factor of no-load current (ii) magnetizing component of current (iii) No-load input power.

Ans.

KVA Rating of transformer, = 30 KVA

No-load Current, $I_o = 1.5A$

Iron loss component of current, $I_\omega = 0.4$ A

No-load primary voltage, $V_o = 3300$ V

(i) Power factor of no-load current Cos Φo = ?

We know $I_\omega = I_o \cos \Phi_o$

Power factor of no=load current, $\cos \Phi_o = \frac{I_\mu}{I_O} = \frac{0.4}{1.5} = 0.266$ lagging

No-load p.f angle, $\Phi_o = \cos^{-1}(0.266) = 74.57^o$

(ii) Magnetizing component of current , I_μ = ?

$I_\mu = I_o \sin \Phi_o$

$= 1.5 \times \sin(74.57) = 1.446$ A

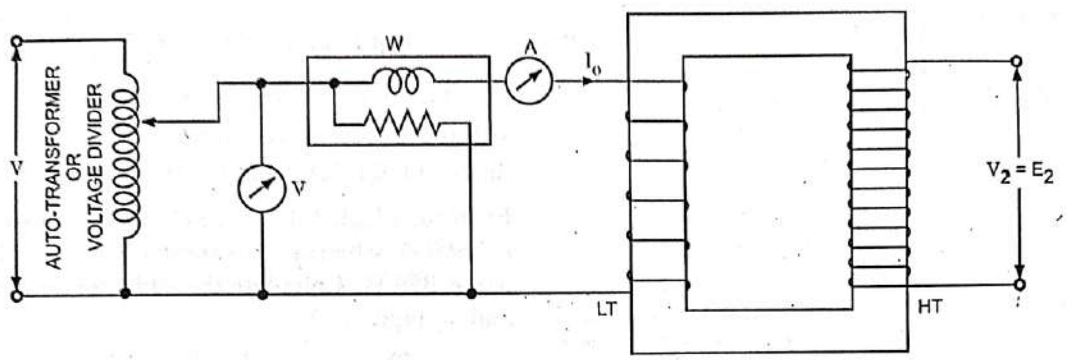
(iii) No-load input power $P_o = V_o\ I_o \cos \Phi_o$ W

$= 3300 \times 1.5 \times 0.266$

$= 1316.7$ W

60. Explain in detail OC & SC test of transformer.

Open Circuit Test:



Circuit Diagram For Open-Circuit Test

The purpose of this test is to determine the core loss (iron loss) and no-load current, which is helpful in finding exiting circuit parameters. In this test usually high voltage(hv) winding is left to open and low voltage (lv) winding is connected to the supply of normal voltage and frequency. When normal voltage is applied to the primary, normal flux will be setup in the core hence normal iron losses will occurs which are recorded by wattmeter. Ammeter measures no-load current Io. Copper loss is negligibly small in primary winding and nill in secondary winding.

No-load current is usually 2 to 10% of rated load current.

Input power on no-load, $W_o = V_1 I_o \cos \Phi_o$ = Iron loss(W_i)

Where I_o - No-load current

V_1 - Applied voltage to primary

$\cos \Phi_o$- No-load power factor

Power factor on no-load, $\cos \Phi_o = \frac{W_o}{V_1 I_0}$

Active or watt-full component of current, $I\omega = I_o \cos \Phi_o$

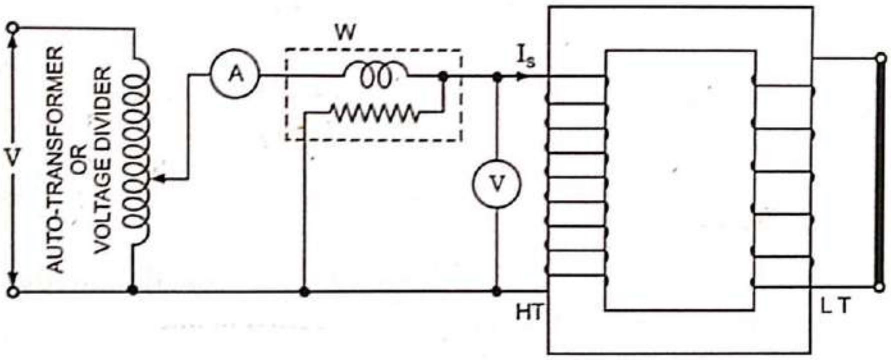
Magnetizing component of current, $I\mu = I_o \sin \Phi_o$

No-load Current, $I_o = \sqrt{I_\omega^2 + I_\mu^2}$

Exciting circuit resistance, $R_0 = \frac{V_1}{I_\omega}$

Exciting circuit reactance, $X_0 = \frac{V_1}{I_\mu}$

Short-Circuit Test:



Circuit Diagram For Short-Circuit Test

The purpose of this test is to determine full-load copper losses and equivalent resistance and equivalent reactance of the transformer. This loss is used in calculating the efficiency of the transformer. Usually, low voltage(lv) winding is solidly short circuited by thick conductor (or through an ammeter, which may serve the additional purpose of indicating the rated load current). high-voltage (hv) winding is connected to the supply of normal voltage and frequency.

Low voltage of 5 to 8% of rated value is sufficient to circulate the rated current in both primary and secondary windings. Flux linking with the core is very small, and therefore iron losses are so small and can be neglected Thus, the power input gives total copper loss at rated load. .
Wattmeter measures full-load copper loss of whole transformer.

W_{sc} - Full-load copper loss
I_{sc} - Short-circuit current
V_{sc} – Primary applied voltage

$W_{sc} = I_{SC}^2 R_{01}$

$Z_{01} = \frac{V_{SC}}{I_{SC}}$

Equivalent resistance, $R_{01} = \frac{W_{SC}}{I_{SC}^2}$

Equivalent reactance, $X_{01} = \sqrt{Z_{01}^2 + R_{01}^2}$

61. What are the various losses occurred in the transformer? Explain them in detail.

Ans. Various losses occur in transformer are

i. Core losses or iron losses
ii. Copper losses are ohmic losses
iii. Stray losses
iv. Dielectric losses

(i) Core losses or iron losses:

This loss occurring in iron core of the transformer. It consists of two components hysteresis loss and eddy current loss.

a) Hysteresis loss (W_h):

This loss is due to the reversal of magnetization of armature core. For each cycle of alternating flux, hysteresis loop is obtained due to the reversal of magnetization, some energy is lost in the form of heat in the transformer. This loss is known as hysteresis loss (W_h).

The hysteresis loss depends upon the volume and grade of iron, maximum value of flux density (B_{max}) and frequency(f) of the flux reversal. This loss is given by

$$\mathbf{W_h = K_h B_{max}^{1.6}\, f\, V} \quad \text{watts}$$

where K_h - Steinmetz hysteresis coefficient

B_{max} - Maximum flux density

f - Frequency of magnetic reversals

V- Volume of the core

t - Thickness of laminations

Hysteresis loss can be minimized by using such a material which has low hysteresis coefficient Generally Special Silicon Steels are used to minimize the hysteresis loss. It depends on both applied voltage and frequency.

b) Eddy Current loss (W_e):

If the magnetic circuit is made up of iron, and if the flux in the circuit is variable, currents will be induced by induction in the core circuit itself. All such currents are known as eddy currents. Eddy currents result in a loss of power with consecutive heating of the material.
The eddy current loss is given by

$$\mathbf{W_e = k_e B_{max}^{2}\, f^2 V^2 t^2} \quad \text{watts}$$

where K_e - Eddy current constant

B_{max} - Maximum flux density

f - Frequency of magnetic reversals

V- Volume of the core

t - Thickness of laminations

In order to reduce eddy current loss to a small value, the core Is beat up of thin laminations. These laminations are insulated from each other by the coating of varnish. eddy current loss depends on voltage only.

Total Iron losses ,$W_i = W_h + W_e = K_h B_{max}^{1.6}\, f\, V + k_e B_{max}^{2}\, f^2 V^2 t^2$

*** Iron losses can be minimized by using silicon steel core in the form of thin laminations.

(ii)Copper loss or Ohmic loss(W_{cu}):

Copper loss occurs in transformer windings due to its winding resistances.

Copper loss in primary winding = $I_1^2 R_1$

Copper loss in secondary winding = $I_2^2 R_2$

Total copper losses, Pcu = $I_1^2 R_1 + I_2^2 R_2$

$= I_1^2 R_{01}$ (or) $I_2^2 R_{02}$

These losses are called variable losses because current flowing through the windings vary with respect to the load. Copper loss proportional to the square of the current. These losses also known as ohmic losses.

(iii) Stary losses:

The losses that occur in the transformer due to the leakage of magnetic flux are called stray losses. Since percentage of stray losses is very small when compared to the iron and copper losses, hence they can be neglected.

(iv) Dielectric losses:

The losses that occur in the insulating material of the transformer are called dielectric losses. This loss affects the efficiency of the transformer. These losses can be eliminated as its percentage is very small compared to the iron and copper losses.

62. Derive the condition for maximum efficiency occurred in transformer.

Transformer Efficiency, $\eta = \frac{V_2 I_2 COS\Phi_2}{V_2 I_2 COS\Phi_2 + w_i + I_2^2 R_{02}}$

Differentiate the efficiency with respect to I_2 and equate to zero

$$\frac{d\eta}{dI_2} = 0$$

$$\frac{d}{dI_2}\left[\frac{V_2 I_2 COS\Phi_2}{V_2 I_2 COS\Phi_2 + w_i + I_2^2 R_{02}}\right] = 0$$

$$[V_2 I_2 COS\Phi_2 + w_i + I_2^2 R_{02}] \text{ x } V_2 COS\Phi_2 - V_2 I_2 COS\Phi_2 \text{ x } [V_2 COS\Phi_2 + 2 I_2 R_{02}] = 0$$

Divide throughout by $V_2 COS\Phi_2$, we get

$$V_2 I_2 COS\Phi_2 + w_i + I_2^2 R_{02} - I_2 \text{ x } [V_2 COS\Phi_2 + 2 I_2 R_{02}] = 0$$

$$V_2 I_2 \cancel{COS}\Phi_2 + w_i + I_2^2 R_{02} - V_2 I_2 \cancel{COS}\Phi_2 + 2 I_2^2 R_{02} = 0$$

$$w_i - I_2^2 R_{02} = 0$$

$$I_2^2 R_{02} = w_i$$

$$W_{cu} = W_i$$

$$\boxed{\textbf{Copper loss = Iron loss}}$$

$$\boxed{\textbf{Variable loss = Constant loss}}$$

The efficiency of the transformer will be maximum when copper losses are equal to iron losses.

*The current corresponding to maximum efficiency, $I_2 = \sqrt{\frac{W_i}{R_{02}}}$

* The load corresponding to maximum efficiency = F.L.KVA * $\sqrt{\frac{\text{Iron loss}}{\text{FL copper loss}}}$

63. A transformer is rated at 100KVA. At full load its copper loss is 1200W & its iron losses is 960W.Calculate (i) the efficiency at full load, UPF (ii) efficiency at half load, 0.8 p.f (iii) the efficiency at 75% full load, 0.7 p.f lag (iv) load KVA at which maximum efficiency occurs.

Ans:

Rating of the transformer(KVA)= 100 KVA

Copper loss at full-load ,W_{cu} = 1200 W

Iron loss W_i = 960 W

(i) The efficiency at full load and UPF = ?

Power factor, CosΦ = 1

$$\text{Efficiency of the transformer at full-load} = \frac{\text{KVA} * \text{COS } \Phi * 10^3}{\text{KVA} * \text{COS } \Phi * 10^3 + W_i + Wcu} \text{ x100}$$

$$= \frac{100 * 1 * 10^3}{100 * 1 * 10^3 + 960 + 1200} \text{ x 100}$$

= 97.88%

(ii) Efficiency at half load, 0.8 p.f

$$\text{Efficiency of the transformer at any load} = \frac{x * \text{KVA} * \text{COS } \Phi * 10^3}{x * \text{KVA} * \text{COS } \Phi * 10^3 + W_i + x^2 Wcu} \text{ x100}$$

Load on transformer , x = half-load = ½ = 0.5

Load power factor, CosΦ = 0.8

$$\text{Efficiency of the transformer at half-load} = \frac{x * \text{KVA} * \text{COS } \Phi * 10^3}{x * \text{KVA} * \text{COS } \Phi * 10^3 + W_i + x^2 Wcu} \text{ x100}$$

$$= \frac{0.5 * 100 * 0.8 * 10^3}{0.5 * 100 * 0.8 * 10^3 + 960 + 0.5^2 * 1200} \text{ x 100}$$

= 96.94%

(iii) The efficiency at 75% full load, 0.7 p.f lag

$$\text{Efficiency of the transformer at any load} = \frac{x * \text{KVA} * \text{COS } \Phi * 10^3}{x * \text{KVA} * \text{COS } \Phi * 10^3 + W_i + x^2 Wcu} \text{ x100}$$

Load on transformer , x = 75% load = 0.75

Load power factor, CosΦ = 0.7 lag

$$\text{Efficiency of the transformer at 75\% load} = \frac{x * \text{KVA} * \text{COS } \Phi * 10^3}{x * \text{KVA} * \text{COS } \Phi * 10^3 + W_i + x^2 Wcu} \text{ x100}$$

$$= \frac{0.75 * 100 * 0.7 * 10^3}{0.75 * 100 * 0.7 * 10^3 + 960 + 0.75^2 * 1200} \text{ x 100}$$

= 96.97%

(iv) load KVA at which maximum efficiency occurs.

$$\text{The load corresponding to maximum efficiency} = \text{F.L.KVA} * \sqrt{\frac{\text{Iron loss}}{\text{FL copper loss}}}$$

$$= 100 * \sqrt{\frac{960}{1200}}$$

= 89.44 KVA

64 *A 100 KVA transformer has iron loss of 1000 W and full load copper loss of 1500 W. If the power factor of the load is 0.8 lagging, calculate (i) full-load efficiency (ii) the load KVA corresponding to maximum efficiency (iii) the maximum efficiency.*

Given data :

$KVA = 100\ KVA$; $W_i = 1000\ W$ $W_{cu} = 1500\ W$

$p.f, \cos\phi_2 = 0.8$ *lagg* $\eta_{F.L}, \eta_{max}$, *load KVA corresponding to max* $\eta = ?$

Solution :

(i) Total full-laod losses

= Iron loss + Full-load copper loss

= $1000 + 1500 = 2500\ W = 2.5\ KW$

Full-load output = $KVA \times p.f = 100 \times 0.8 = 80\ KW$

Full-load input = full load output + total full load losses = $80 + 2.5 = 82.5\ KW$

Full-load efficiency, $\eta_{F.L} = \dfrac{Output}{Input} \times 100 = \dfrac{80}{82.5} \times 100 = \mathbf{96.96\ \%}$

(ii) Load KVA corresponding to maximum efficiency

$$= \text{Full-load } KVA \times \sqrt{\frac{iron\ loss}{full - load\, copper\ loss}}$$

$$= 100 \times \sqrt{\frac{1000}{1500}} = \mathbf{81.65\ KVA}$$

(iii) Maximum efficiency occurs when copper losses are equal to iron losses.

For maximum efficiency, copper losses = Iron losses = $1000W$

Output corresponding to maximum efficiency = $81.65 \times 0.8 = 65.32\ KW$

$\therefore$ Total losses = Iron losses + Copper losses = $1000 + 1000 = 2000\ W = 2\ KW$

Input = Output + Total losses = $65.32 + 2 = 67.32\ KW$

Maximum efficiency,

$$\eta_{max} = \frac{Output}{Input} \times 100 = \frac{65.32}{67.32} \times 100 = \mathbf{97.03\ \%}$$

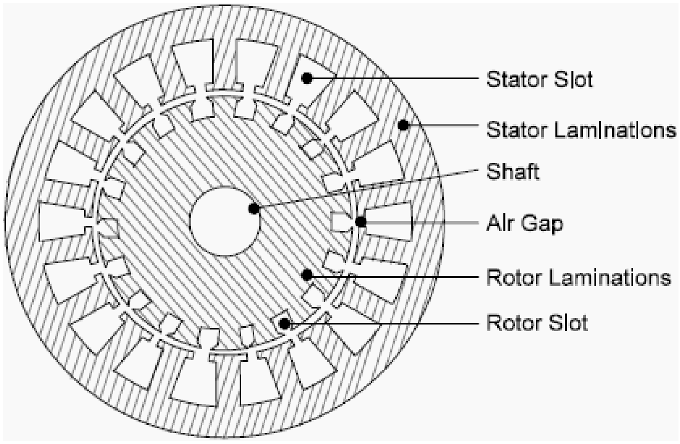
65. Write the differences between core time transformer and shell type transformer.

S.No.	Core-type Transformer	Shell-type Transformer
1.	In this type core is surrounded by the winding	In this type winding is surrounded by the core
2.	Cylindrical type winding is used	Sandwiched type winding is used
3.	The core has two limbs or legs and the two legs are equal in size	The core has three limbs or legs and the size of central leg is twice the outer legs.
4.	Magnetic flux has only the magnetic path	Magnetic flux has two magnetic paths
5.	Used for high voltage, high power levels	Used for low voltage, low power levels
6.	Average length of core is more	Average length of core is less
7.	Cross-section of core is less, hence more turns are required	Cross-section of core is more, so less turns are required
8.	The half of L.V. and H.V. windings are wound on both limbs	The L.V. and H.V. windings are wound on central limb
9.	The shape of core laminations are rectangular 'L' type	The shape of core laminations are 'E' type
10.	Because most of the portion of winding is visible hence it is easy to insulate and repair	Most of the winding is enclosed by the core hence difficult to insulate and repair

Basic Electrical Engineering (U23EE101)
UNIT-V A.C MACHINES
LONG ANSWER QUESTIONS(LAQs)

66. Describe the constructional features of 3 phase induction motor with suitable diagrams.
Ans. Construction of 3 phase induction motor :-

An induction motor consists of two main parts.
a) Stator and
b) Rotor



a) Stator:

Stator of the induction motor is stationary. It is a hollow cylindrical structure made of sheet steel laminations having slots on inner periphery. The insulated conductors are placed in the stator slots and are suitably connected to form a balance for 3 Phase Star or Delta connected circuits. The 3- phase stator Winding is wound for a definite number of Poles as per the requirement of speed. Greater the number of poles, lesser the speed and vice-versa. When 3-phase supply is given to the starter winding, a rotating magnetic field of constant magnitude is produced. This rotating magnetic flux induces an EMF in the rotor by mutual induction principle.

b) Rotor :

It is the rotating part of the motor. There are 2 types of constructions for the rotor of an induction motor.

1. Squirrel-cage rotor and
2. Phase wound or Wound rotor.

Squirrel-cage Rotor:

This rotor consists of a cylindrical laminated core with parallel slots for carrying the rotor conductors, which consists of heavy bars of copper, aluminium or alloys. One bar is placed in each slot. The rotor bars are brazed or welded or bolted to two heavy and stout short circuited by end rings. As the rotor bars are permanently short circuited on themselves, hence it is not possible to add any external resistance in series with a rotor circuit for starting purpose.

The rotor slots are not made parallel to the rotor shaft axis, they are skewed at a certain angle to reduce magnetic noise during working, to produce a more uniform torque and to prevent possible magnetic locking. This magnetic locking is known as cogging of the rotor with the starter.

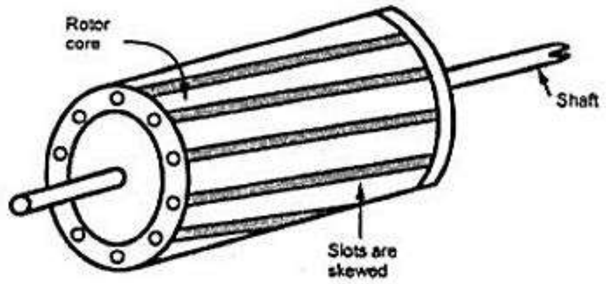
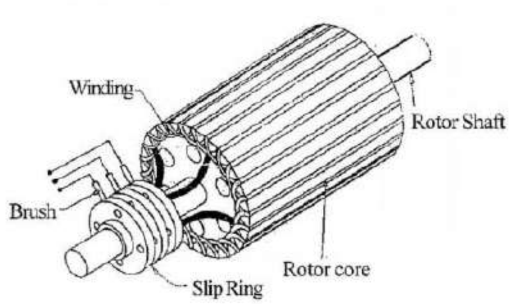


Fig Squirrel Cage Rotor

Fig: Squirrel-cage Rotor:

Phase wound or Wound rotor:

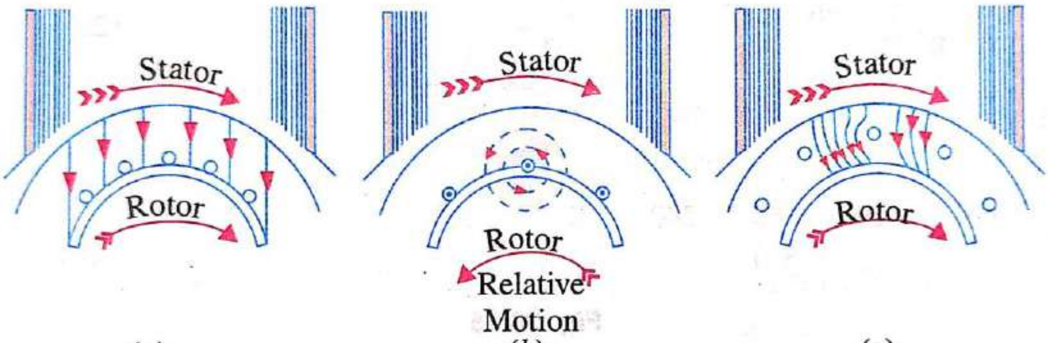
It consists of a laminated cylindrical core having slots on the outer periphery and is provided with 3 phase distributed winding in the insulated rotor slots similar to stator winding. The rotor is wound for as many poles as the number of stator poles and is always wound for 3- phase, even the stator is wound for two-phase. The three phases are starred internally, the other three winding terminals are brought out and connected to three insulated slip rings mounted on the same shaft with brushes resting on them. These brushes are connected to a 3-phase star connected rheostat. This arrangement makes it possible to add external resistance to each phase of the rotor circuit during the starting period for increasing starting torque. Under normal conditions the slip rings are automatically short circuited by means of a metal collar which is pushed along the shaft and connects all slip rings together. This rotor is short circuited on itself like squirrel-cage rotor. The brushes are lifted automatically to reduce friction ,wear and tear.



67. EXPLAIN THE WORKING PRINCIPLE OF 3-PHASE INDUCTION MOTOR

When 3- phase stator winding is fed from 3 phase supply ,a rotating magnetic field of constant magnitude rotating at synchronous speed is produced. This rotating flux passes through the air gap and cuts the stationary rotor conductors, an EMF is induced in the rotor conductors according to Faraday's laws of electromagnetic induction. The frequency of induced emf is same as the supply frequency. Its magnitude is proportional to the relative speed between the flux and rotor conductors, and its direction is given by Fleming's right-hand rule. Since the rotor conductor form a closed circuit, rotor current is produced whose direction is given by Lenz's law, is such as to oppose the very cause producing it. In this case, the cause which produces the rotor current is the relative velocity between the rotating flux of the stator and stationary rotor conductors. Hence To reduce the relative speed the rotor starts running in the same direction as that of the flux and tries to catch up with the rotating flux, but it never dose.

The working principle or torque developed in the rotor can also be explained as below.



(a) (b) (c)

Let us assume that the stator field is rotating in clockwise direction as shown in Figure a. Consider the instant when the rotor is stationary, the relative motion of the rotor with respect to the stator is anticlockwise. By applying Fleming's right-hand rule, the direction of induced EMF in the rotor is found to be towards the observer or outwards. Hence. The direction of the rotor flux is anticlockwise as shown in figure (b). Now by combining the two fields, the flux strengthens on left and weakens on the right of the rotor conductors. The property of magnetic lines, is to travel in straight line. Due to this property, the flux tries to travel in straight lines pushing the rotor conductors towards right i.e clockwise or by applying Fleming's. Left hand rule, the rotor conductors experience a force in clockwise direction. Hence, the rotor is set in to rotation in the same direction as that of the stator rotating flux shown in fig(c).

68. Write the differances between Squirrel cage and Slip ring induction motors.

S.No.	Squirrel cage Induction motor	Wound or slipring Induction motor
1.	Rotor consists of bars which are shorted at both ends by end rings.	Rotor consists of 3 φ winding similar to the stator winding.
2.	Construction is very simple	Construction is complicated.
3.	External resistance cannot be added in the rotor circuit hence starting torque is less.	External resistance can be added in the rotor circuit hence high starting torque can be achieved.
4.	Most commonly used	Used for special purpose.
5.	Its cost is less	It is costly
6.	Mechanically robust, rugged and maintenance free	Requires maintenance
7.	Speed control by rotor resistance is not possible.	Speed control by rotor resistance is possible.
8.	Rotor copper losses are less hence efficiency is high	Efficiency is less

69. Explain the construction and principle of operation of synchronous generator(Alternator).

Ans: **<u>Construction of Synchronous generator:</u>**

A synchronous generator essentially consists of

i. Stator (armature)

ii. Rotor (field system) and

iii. Exciter

<u>i. Stator (armature):</u>

Stator consists of stator frame and stator core.

<u>Stator frame:</u>

Stater frame is used for holding the armature stampings and windings in position. The frames are fabricated from mild steel plates welded together in such a way as to form a frame having a box type section.

<u>Stator Core:</u>

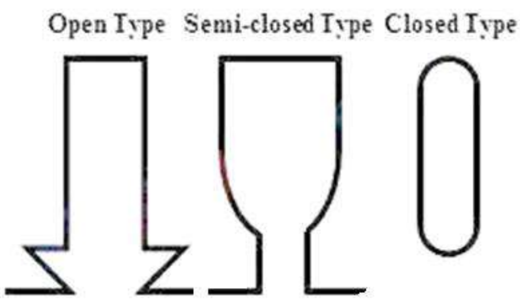
The stator core is supported by stator frame and is built up of laminations of special magnetic iron or silicon steel. The core is laminated to minimize eddy currents .The starter core having slots on its inner periphery to accumulate armature conductors. The laminations are stamped out in complete rings for smaller machines or in segments for larger machines. The laminations are insulated from each other and have spaces between them for allowing the cooling air to pass through.

The slots provided on the inner periphery of the stator are of three types.

i. Open type or wide-open slots

ii. Semi-closed type slots and

iii. Totally closed type slots



The open type slots are more commonly used because the coils can be easily inserted or removed in case of repair.

<u>ii) Rotor (field system):</u>

Rotor is the rotating part of an alternator. The rotor having number of alternating N and S poles fixed to its outer rim. The magnetic poles carry a field winding which is supplied with direct current through two slip rings by a separate dc source .The Rotor are of two types.

a) salient pole type

b) Non-salient pole type(or) smooth cylindrical type.

Salient pole type Rotor:

In this type, the polls are projected out from the rotor surface. The projected poles are mounted on large circular steel frame as shown in figure.

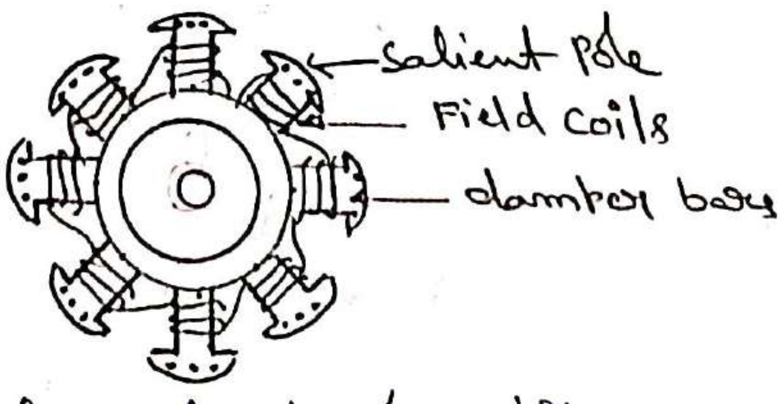
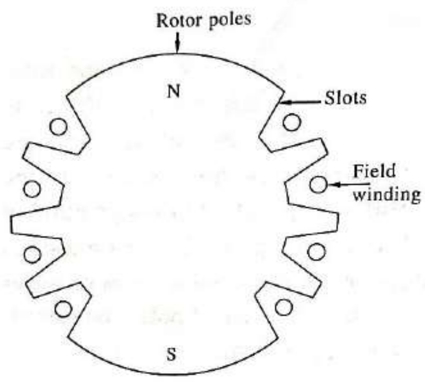


fig. Salient pole rotor

The field winding is placed around the poles. The field poles windings are connected in series and are excited by DC supply. The steel frame is fixed to the shaft of the alternator. It has large diameter and short axial length It has large number of poles(6 to 40). These are used in low and medium speed (120 to 400 rpm)alternators. These are employed with hydraulic turbines and diesel engines.

Non-salient pole type(or) smooth cylindrical type Rotor:

This rotor consists of a smooth, solid steel cylinder. The slots are made on the outer periphery, as shown in figure. The field windings are placed in these slots and excited by dc source through slip rings. These Rotors have less diameter and large axial lengths. It has a smaller number of poles, either two or four. Hence the speed is high (1500 to 3000 rpm). These are employed with steam turbines. These are much balanced and smooth in operation.



Non-salient or smooth cylindrical type rotor

iii) Exciter:

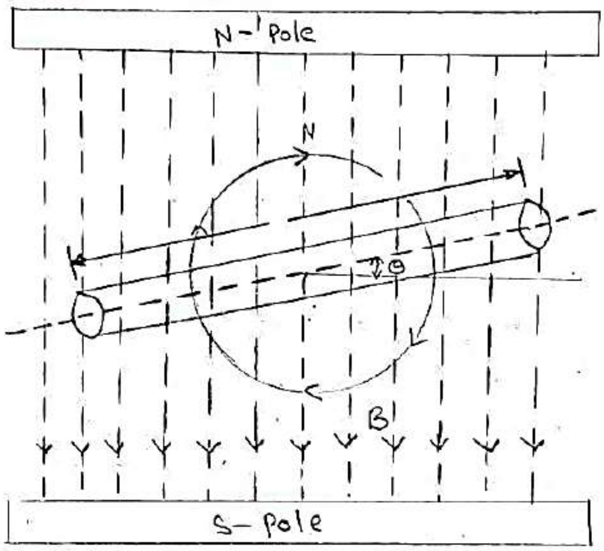
To excite the field winding of an alternator, an exciter is used. It can be a d.c shunt generator or a d.c compound generator. Exciter is mounted on the same shaft of the alternator. The exciting current is supplied to the alternator through two slip rings and brushes. The slip rings are metal rings completely placed on the shaft of the machine, but insulated from it. A brush rides on each slip ring.

The positive end of dc supply is connected to one brush and negative end is connected to another brush.

Principle of operation(working principle) of synchronous generator(Alternator):

An alternator is a machine which converts mechanical energy into a.c electrical energy. The working principle of alternator is based on the principle of faraday's law of electromagnetic induction. According to Faraday's laws, whenever a conductor cuts the magnetic flux, an emf is induced in the conductor. This induced emf is directly proportional to the rate of change of flux linkages and number of turns. The direction of this emf can be found by Fleming's right-hand rule.

Consider a conductor of length 'l' m placed in a uniform field of flux density B wb/m^2 is moved with a velocity of V m/s at an angle of θ to the direction of the magnetic field, as shown in figure.



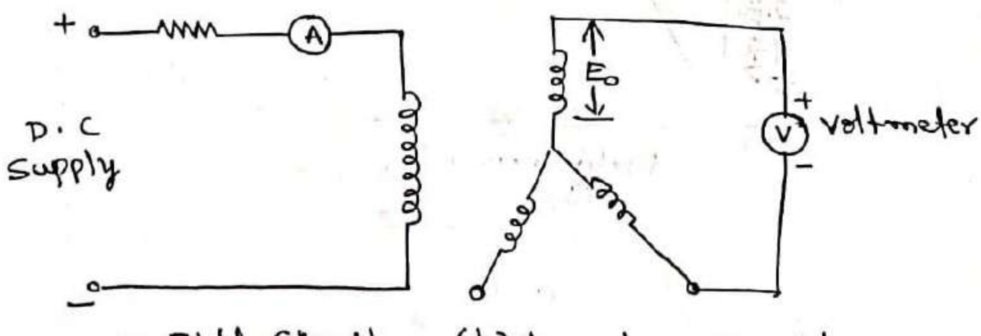
70. Explain OC and SC test conducted on synchronous generator.

To find the regulation of an alternator ,armature resistance, open circuit characteristics, short circuit characteristics are required. These can be obtained by conducting the following test on the alternator .

1. Armature resistance test
2. Open-circuit test or no-load test.
3. Short circuit test.

Open-circuit test or no-load test:

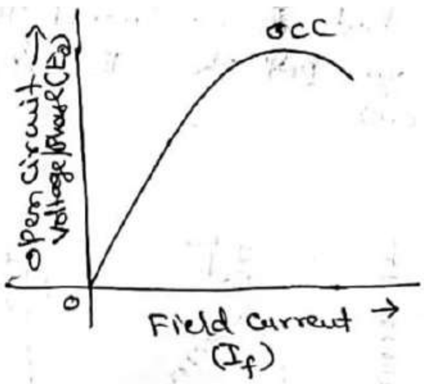
This test is conducted to determine open-circuit voltage(Eo) per phase from open circuit characteristics. The field winding is connected to a d.c source in series with field rheostat and an ammeter.



(a) Field Circuit (b) Armature Circuit

The alternator is run on no-load at a rated speed. The field current I_f is gradually increased in steps from zero by adjusting the field rheostat until the voltage between any pair of armature terminals is above rated emf and corresponding voltmeter readings are noted.

The voltmeter indicates a no-load line voltage. A curve can be obtained between the no-load voltage per phase, Eo and field current I_f as shown in figure below and is known as open circuit characteristics.



Short-Circuit test (SC test):

This test is conducted to determine the short circuit current per phase. I_{SC} from short circuit characteristics .All three phases are shorted and one ammeter is connected in any one of the three phases. The alternator is run at rated speed. The field current I_f is gradually increased in steps from zero by adjusting the field rheostat until short circuit current is about twice the full-load current .

The readings of two ammeters are noted. The ammeter A_2 reads the short-circuit current per phase. A curve is obtained between the short circuit current per phase I_{sc} and field current I_f as shown in figure (b) and is known as short-circuit characteristics .

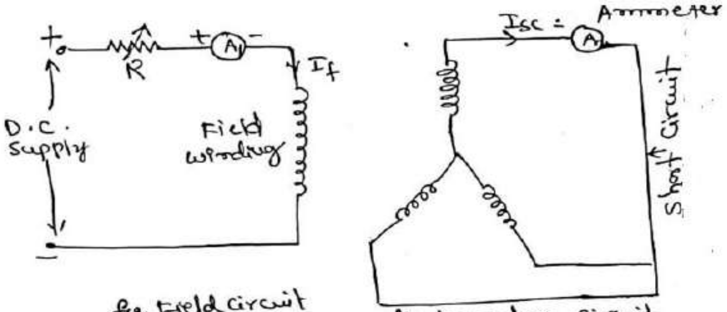


fig. Field circuit fig. Armature Circuit

(a) Connection diagram

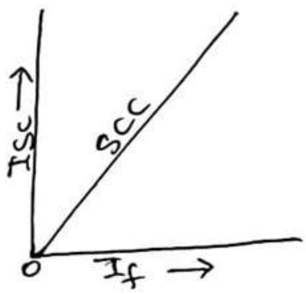


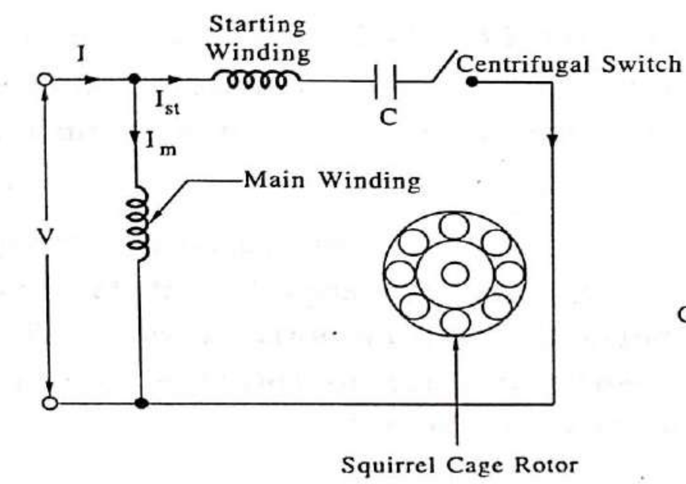
fig (b)

71. Write the differences between salient pole type rotor and non-salient pole type rotor (smooth-cylindrical type rotor)

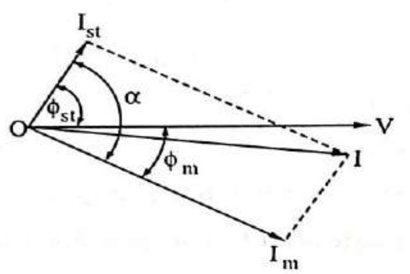
Sl.No	Salient pole rotor	Non-salient pole rotor(Cylindrical type rotor)
1	The rotor consists of a laminated poles projected from the surface	The rotor consists of a smooth, solid steel cylinder
2	It has large diameter and short axial length	It has small diameter and long axial length
3	It has large number of poles	It has lesser number of poles
4	The speed of the Rotor is less(120-400 rpm)	The speed of the rotor is high(1500 – 3000rpm)
5	These are suitable for low and medium speed alternators[Hydraulic turbines]	These are suitable for high-speed alternators [steam turbines]
6	The alternators with salient pole rotors have vertical or horizontal configuration	The alternators with smooth cylindrical rotors have horizontal configuration.

72. Explain the construction and principle of operation of single-phase capacitor start induction motor.

In this motor the rotor is of squirrel cage type and the stator consists of single-phase winding. The stator is slotted and single-phase winding is placed. A centrifugal switch is connected in series with the starting winding. The main and auxiliary or starting windings are space displaced by 90^o. The necessary phase difference between starting or auxiliary winding current(I_S) and main winding current (I_m) is produced by connecting a capacitor in series with starting winding, as shown in fig(a).



(a) Schematic Representation



(b) Pha. or Diagram

The current drawn by the main winding lacks the voltage by Φ_m while current drawn by the starting winding leads the voltage by Φ_{st} . The phase difference between I_m and I_{st} is large, which is almost 80^o as shown in fig(b). Thus, the motor develops very high starting torque.

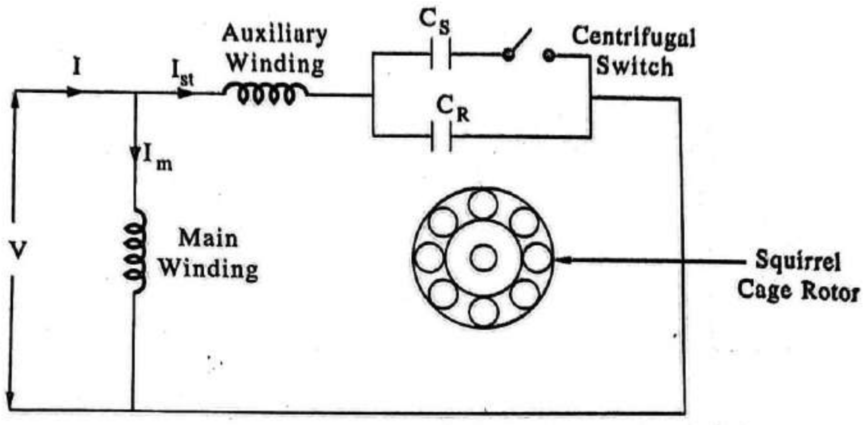
Both the capacitor and starting winding are automatically disconnected by centrifugal switch when the motor has reached 75% of synchronous speed. The capacitor is in the circuit only during the starting. The capacitor used in this type is an electrolytic type. The capacitor value can be selected as per the requirement of starting torque. The starting torque can be as high as 350 to 400 percent of full load torque.

The direction of rotation of this motor can be changed by interchanging the connections of either the main winding or auxiliary winding terminals.

These motors are used where high starting torque is required such as in compressors, pumps, air conditioners, conveyors etc.

73. Describe the construction & working of capacitor start capacitor run induction motor & list out is applications.

In this motor the rotor is of squirrel cage type and the stator consists of single-phase winding. The stator is slotted and single-phase winding is placed. A centrifugal switch is connected in series with the capacitor Cs. The main and auxiliary or starting windings are space displaced by 90^o. To increase the starting torque two capacitors are used in auxiliary winding. One capacitor is used for starting, and other is used for running as shown in fig(a). The necessary phase difference between starting or auxiliary winding current(I_S) and main winding current (I_m) is produced by connecting capacitors in series with starting(or) auxiliary winding, as shown in fig(a).



(a) Schematic Representation

Both capacitors C_S and C_R are in circuit during starting. After the motor picks up 75% of synchronous speed the centrifugal switch disconnects the starting capacitor(C_S). The auxiliary winding and running capacitor (C_R) remain in the circuit during running condition. Also, the capacitor C_s is larger in value and is of electrolytic type, permits high starting torque. The capacitor C_R is small in value and is of oil type. This motor is expensive than a capacitor-start motor. However, it provides the best performance .

These have ability to start heavy loads and are extremely quiet in operation .These are used in compressors, conveyors, pumps and other high torque loads.

74. Write the applications of various types of single-phase induction motors.

Ans. Applications of various types of single-phase induction motors are given below

Split phase motor or Resistance start motors:

These are used for low inertia loads, continuous operating loads and applications requiring moderate starting torques such as driving washing machines, fans, blowers, centrifugal pumps, domestic refrigerators, duplicating machines, office appliances, food processing machines, woodworking tools, grinders, oil burners, etc

Capacitor start motors:

They are widely used for heavy-duty general-purpose applications like refrigerator units, air-conditioners, compressors, jet pumps, sump pumps, centrifugal pumps, compressors, conveyors, fans, blowers ,farm and home workshop tools, oil burners etc

Capacitor -start capacitor run motor:

These motors are used for heavy loads where frequent start required. These motors are used for pumps, compressors, conveyors, refrigerators , machine tools and fire-strokers.

Single valve capacitor motor:

These motors are used where required starting torque is low, such as air moving equipment i.e fans, blowers, voltage regulators and also oil burners wear quiet operation is particularly desirable.

Shaded pole motor:

Because of poor starting torque, low power factor and poor efficiency, such motors are only suitable for low power applications such as for toys, small fans, electric clocks, hairdryers, time phonographs, slide projectors, humidifiers, small business machines such as photocopying machines, vending machines, advertising displays and other similar applications

75 *: A 4-pole, 3-phase induction motor operates from a 50 Hz supply system. If the machine runs at 3 percent slip on f.l, determine (a) the rotor speed (b) the frequency of the rotor currents and (c) the frequency of the rotor current at standstill.*

Solution :

Given Data :

$P = 4$	(a) $N_r = ?$
$f = 50$ H	(b) $f_r = ?$
$S = 3\% = 0.03$	(c) $f_2 = ?$

$$N_s = \frac{120\,f}{P} = \frac{120 \times 50}{4} = 1500 \text{ r.p.m.}$$

(a) $$S = \frac{N_s - N_r}{N_s}$$

$$0.03 = \frac{1500 - N_r}{1500}$$

$\therefore \quad N_r = 1500\,(1 - 0.03)$

$= \mathbf{1{,}455\ r.p.m.}$ **Ans.**

(b) $f_r = Sf = 0.03 \times 50$

$= \mathbf{1.5\ Hz.}$ **Ans.**

(c) $f_2 = Sf = 1 \times 50 = \mathbf{50\ Hz.}$ **Ans.** ($\because$ at standstill $S = 1$)

***************************ALL THE BEST ***************************

THE END