DC circuit

Introduction :-

Q. What is electrical engineering?

Ans. Electrical engineering is a branch of engineering which deals with the expect of electrical energy, its system, componant & devices. Every equipment & componant of an electrical system can be represented by an equivalent electrical network which consist of a very few element such as energy source, resister, capcity & inductors.

★ Electric Current ⇒ It is the rate of flow of charges w.r.t. time.

$$\boxed{I = \frac{dQ}{dt}}$$

★ Electric potential ⇒ It is the amount of work done required to move a unit positive charge b/w two points $\boxed{V = \frac{w}{q}}$ (Unit - Volts)

★ Electro motive force ⇒ It is the force or voltage that drives and electric current to flow in an electric circuit.

Electric power ⇒ It is the rate of doing work per unit time.

★ $$\boxed{P = \frac{w}{t} = VI = I^2R}$$

☆ **Ohm's Law :-** A current flowing through the conductor is directly proposnal to the potential appled across its ends with the physical Condition that is temperture, pressure, Resistance etc. $I \propto V$

$$\boxed{V = IR}$$

Resistance :- It is the properties of the conductor by which it oppose the flow of current.

$$\boxed{R = \frac{\rho l}{A}}$$

Inductance :- It is the properties of the conductor by which change in the current throw it induces a EMF.

$$\boxed{V = L\frac{di}{dt}} \qquad \boxed{L = \frac{\mu N^2 A}{l}}$$

Capacitance :- It is the ability of a conductor to store electric charge

$$\boxed{C = \frac{Q}{V}}$$

Unit - फैरड

Basic circuit elements :-

1.) Active elements ⇒ The circuit elements which supply energy to the circuit is known as Active elements.

eg - Battery, generater, cells etc.

2/ Passive element ⇒ The elements which either disipute or store energy are known as passive.
eg- Register, capaitor etc.

3/ linear element ⇒ The elements whoose output is directly proposnal to the input are said to be linear element.
eg- pure register, inductor, capacitor etc.

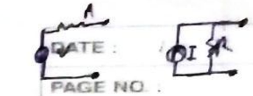
4/ Non linear element ⇒ The elements which are not linear are called non-linear.
eg- ~~Diaod~~ Diode.

5/ Bilateral element ⇒ Elements whoose conduction of current are in both the directi
eg- register, capcitor, inductor.

6/ Unilateral element ⇒ Elements whoose conduction of current is only one direction.
eg- Diaod, ~~trangister~~ transistor etc.

7/ Lumped element ⇒ Elements which are pure and physically seperable
eg- pure register, inductor, capacitor etc.

8/ distributed element ⇒ Distributed element are the elements which are not pur and can not be seperated physically.
eg- transmission line.



* Faredey's first Law ⇒ When ever the conductor cut the magnetic flux line and emf is induced in conductor.

* Faredey's second Law ⇒ The magnetude of induced emf in a conductor is directly proposnal to the rate of change of flux linkage.

* Lenz's Law ⇒ According to this Law and induced emf will give rise to a current whoose magnetic field opposes the change in original magnetic field.

Energy Source :- Energy sources may be some time called as network sources as these sources provide neccessary excitation to an electric network. There are two types of energy source :-

(i) Voltage Source
(ii) Current Source

Further these sources classified as ideal and practical and dependent ~~and~~ independent

1) Ideal Voltage Source :- It is an energy source whoose terminal Voltage is constant and independent of current throught it.

2) Ideal current source :- It is energy source which can supply a constant magnetitude of current irrespective of the voltage across its terminal.

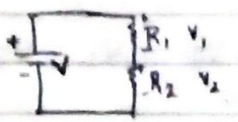
3) Practical Voltage source :- It is can be represented by an ideal voltage in Series with and internal resistance ~~are~~ 'r'. This resistance accounts for the drop in Voltage across its terminals.

4) Practical Current source :- It is can be represented by an ideal current Source in parallel with and internal registance 'r'.

5) dependent energy source :- Dependent energy sources are the voltage and current Source whoose output depends on the voltage or current of ~~sed~~ certain elements of the network in which they are ~~core~~ connected.

* Network Analysis ⇒

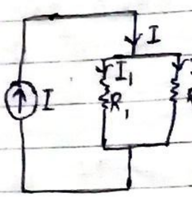
Voltage Divider Rule :-



$$V_1 = \frac{V \times R_1}{R_1 + R_2}$$

$$V_2 = \frac{V \times R_2}{R_1 + R_2}$$

Current Divider Rule :-

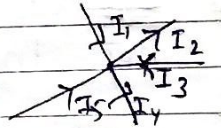


$$I_1 = \frac{I \times R_2}{R_1 + R_2}$$

$$I_2 = \frac{I \times R_1}{R_1 + R_2}$$

kirchoff's Law :-

→ KCL :-

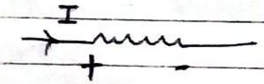


According to this Law in an electric circuit the algebric sum of all the current meeting at a point is equal to zero.

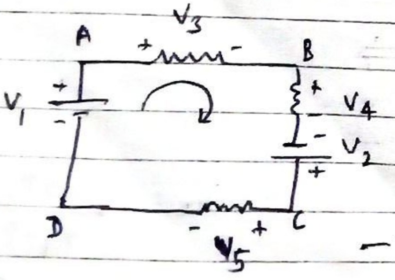
$$I_1 - I_2 + I_3 - I_4 + I_5 = 0$$

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

NOTE →



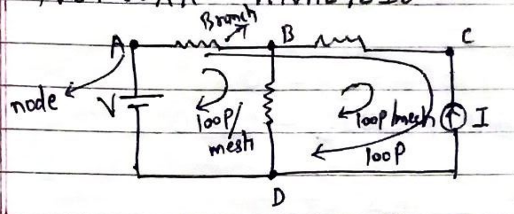
→ KVL :- According to this law the alzebric sum of all the voltages in a closed path is equal to zero.



(-) + → - (droop)
(+) - → + (Rise)

$$-V_3 - V_4 + V_2 - V_5 + V_1 = 0$$

NETWORK ANALYSIS :-



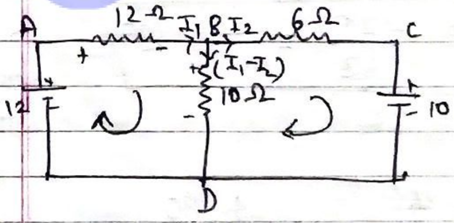
(i) NODE :- A node is the point at which two or more circuit elements are interconnected.

(ii) Branch :- A branch is a ~~that~~ part of a network which lie b/w two points or nodes.

(iii) loop :- A loop in a network is any closed conducting ~~part~~ path through two or more elements of the network.

(iv) mesh :- A mesh is the most elementry form of a loop which can not be further divided.

eg -



Apply KCL at node B
$I_1 = I_2 + I_3$
$I_3 = I_1 - I_2$

Apply KVL in ABDA loop :-

$$12 - I_1 \times 12 - (I_1 - I_2)(10) = 0$$

$$12 - 22I_1 + I_2 \times 10$$

$$10I_2 + 12 = 22I_1$$

$$5I_2 + 6 = 11I_1 \quad — ①$$

Apply KVL in BCDA

$-6\times I_2 - 10 + 10(I_1 - I_2) = 0$

$-6I_2 + 10I_1 - 10I_2 - 10 = 0$

$10I_1 = 10 + 16I_2$

$5I_1 = 5 + 8I_2$ —② $\times 5$

from eqⁿ-① $(5I_2 + 6 = 11I_1)$ $\times 8$

$25I_1 = 25 + 40I_2$

$88I_1 = 48 + 40I_2$

$63I_1 = 23$

$I_1 = \frac{17}{63}$ $\boxed{\frac{23}{63} = I_1}$ $\boxed{I_1 = 0.365}$

in eqⁿ-①

$5I_2 + 6 = \frac{11\times 23}{63} = \frac{253}{63}$

$5I_2 = \frac{253 - 378}{63} = \frac{-125}{63}$

$\frac{23}{253}$

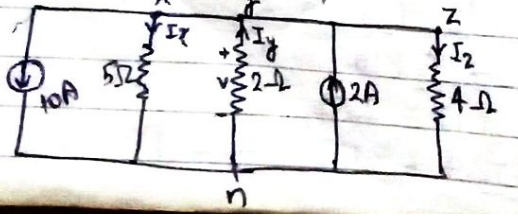
$\boxed{I_2 = \frac{-25}{63} = -0.397}$ (- sign is show that opposite direction

$V_1 = I_1\times 12 = 12\times 0.365 = 4.380$

$V_2 = I_2\times 6 = 2.382$

$V_3 = 10\times(I_1 - I_2) = 10(0.762) = 7.62$

Q.



Apply KCL at node y $\{\because I_y = \frac{-v}{2}$ current out $\}$

$I_y - I_x - 10 + 2 - I_z = 0$

$-I_x + I_y - I_z = 8$

$\frac{-v}{5} - \frac{v}{2} - \frac{v}{4} = 8$

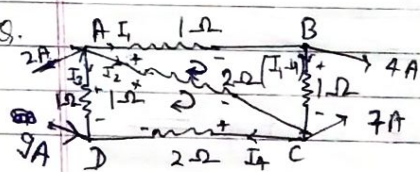
$\frac{-v}{5} - \frac{3v}{4} = \frac{-4v - 15v}{20} = 8 = \frac{-19v}{20} = 8$

$-19v = 160 \Rightarrow v = \frac{-160}{19} = -8.42$

$I_x = \frac{-8.42}{5} = -1.684$

$I_y = -\left(\frac{-8.42}{2}\right) = 4.21$, $I_z = \frac{-8.42}{4} = -2.105$

Q.



Apply KCL at node A

$I_1 + I_2 + I_3 = 2$

$I_3 = 2 - I_1 - I_2$ —①

$I_1 - 4 = I_5$

Apply KCL at node c

$I_2 + I_1 - 4 = 7 + I_4$

$I_4 = I_1 + I_2 - 11$ —②

~~loop~~ Apply KVL in loop ABCA

$-I_1\times 1 - 1\times(I_1 - 4) + 2\times I_2$

$-I_1 - I_1 + 4 + 2I_2$

$2I_2 - 2I_1 + 4 = 0$

$I_1 - I_2 = 2$ —③

loop KVL in loop ACDA

$I_3\times 1 - 2\times I_2 - (I_1 + I_2 - 11)\times 2 = 0$

$I_3 - 2I_1 \quad -2I_1 - 2I_2 + 22$

$I_3 - 4I_1 \quad -2I_2 + 22$

$I_3 + 22 = 4I_1 + 2I_2$

$2 - I_1 - I_2 + 24 = 4I_1 + 2I_2$

$3I_2 + 5I_1 = 26$ ④

$(I_1 = I_2 + 2A)$

$3I_2 + 5I_2 + 10 = 26$

$8I_2 = 16 \Rightarrow \boxed{I_2 = 2A}$

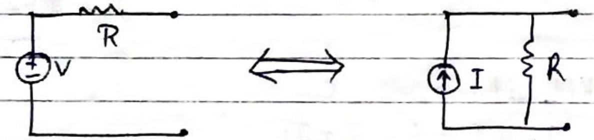
$\boxed{I_1 = 4A}$

$I_3 = 2 - 2 - 4 \Rightarrow \boxed{I_3 = -4A}$

$I_4 = I_1 + I_2 - 11 = \boxed{-5A = I_4}$

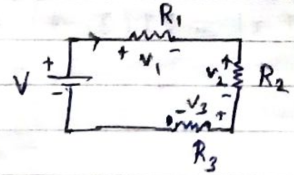
$I_5 = I_1 - 4 = \boxed{0 = I_5}$

Voltage - current source change ⟹



Series Parallel network:-

Series network ⇒



$V = V_1 + V_2 + V_3$

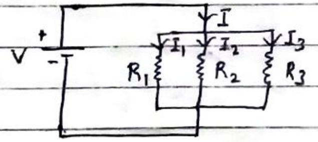
~~$= I\left[\frac{1}{R_1} + \frac{1}{R_2}\right]$~~

$V = I(R_1 + R_2 + R_3) \Rightarrow V = I R_{eq}.$

$\boxed{I = \frac{V}{R_{eq}.}}$

$V_1 = IR_1 = \boxed{\frac{V}{R_{eq}.} \times R_1 = V_1}$. $\boxed{V_2 = \frac{V}{R_{eq}.} \times R_2}$

Parallel network ⇒



$I = I_1 + I_2 + I_3$

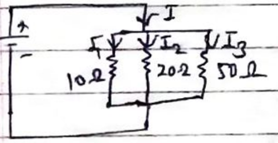
$I = V\left[\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right] \Rightarrow \frac{1}{R_{eq}.} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

$G_{eq}. = G_1 + G_2 + G_3$

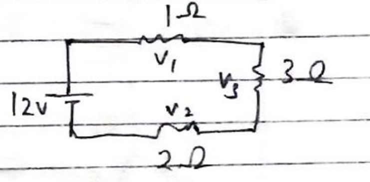
$I_1 = \frac{V}{R_1} = V \times G_1 \Rightarrow \boxed{I_1 = \frac{I}{G_{eq}.} \times G_1}$

$\boxed{I_2 = \frac{I}{G_{eq}.} \times G_2}$ $\boxed{I_3 = \frac{I}{G_{eq}.} \times G_3}$

Q. (i)



(ii)



Ans - (ii) $V_1 = \frac{V}{R_1 + R_2 + R_3} \times R_1 = \frac{12 \times 1}{6} = 2$ Volt

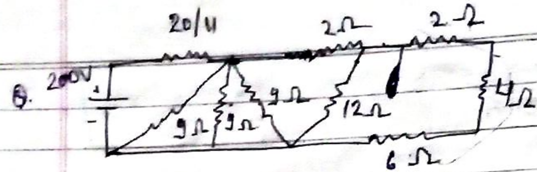
$V_2 = \frac{12}{6} \times 3 = 6$ Volt

$V_3 = \frac{12}{6} \times 2 = 4$ Volt

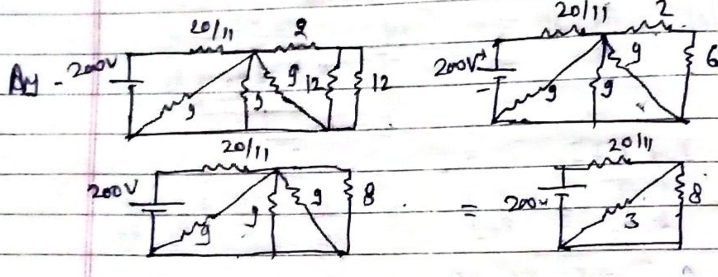
(i) $I_1 = \frac{I \times G_1}{G_{eq}.} = V \times G_1 = 100 \times \frac{1}{10} = 10A$

$I_2 = 100 \times \frac{1}{20} = 5A$, $I_3 = 100 \times \frac{1}{50} = 2A$

Q.



ΔY -



$$\frac{24}{11}+\frac{20}{11}=\frac{\cancel{4}4}{11}=4$$

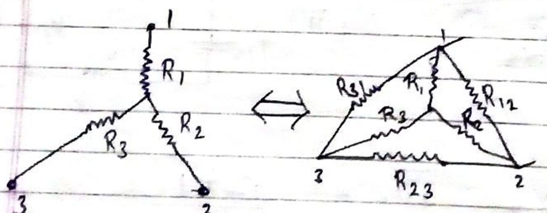
$\frac{1}{3}+\frac{1}{8}=\frac{8+3}{24}=\frac{11}{24}$

$$R_{eq.}=\frac{\cancel{44}}{11}=4\Omega \qquad \boxed{R_{eq.}=4\Omega}$$

$$V=IR=4\times I=200$$

$$\boxed{I=50A}$$

● Star - Delta Transformation :-



Delta-Star :-

$$R_{12}=R_1+R_2$$

$$R_{12}=R_{12}\parallel(R_{23}+R_{31})$$

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

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

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

Adding - ①, ② & ③

$$R_1+R_2+R_3=\frac{R_{12}\cdot R_{23}+R_{23}\cdot R_{31}+R_{31}\cdot R_{12}}{R_{12}+R_{23}+R_{31}} \quad \text{——} ④$$

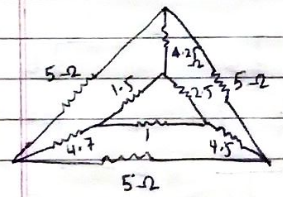
$$\boxed{R_1=\frac{R_{12}\cdot R_{31}}{\Sigma R_{eq.}}}, \quad \boxed{R_2=\frac{R_{12}\cdot R_{23}}{\Sigma R_{eq.}}}, \quad \boxed{R_3=\frac{R_{23}\cdot R_{31}}{\Sigma R_{eq.}}}$$

Star- Delta :-

$$\boxed{R_{12}=R_1+R_2+\frac{R_1R_2}{R_3}} \qquad \boxed{R_{31}=R_1+R_3+\frac{R_1\cdot R_3}{R_2}}$$

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

Q.



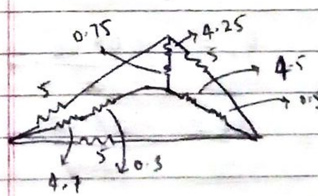
माना $R_{12}=2.5$, $R_{23}=1$, $R_{31}=1.5$

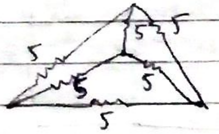
ΔY - $R_1=\frac{R_{12}\cdot R_{31}}{\Sigma R_{eq.}}$

$$R_1=\frac{2.5\times1.5}{\cancel{2.5\times1+1\times1.5}\ 2.5+1.5+1}$$

$$R_1=\frac{2.5\times1.5}{5}=0.75$$

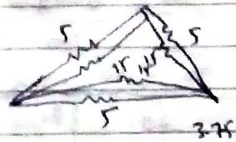
$$R_2=\frac{2.5}{5}=0.5, \quad R_3=\frac{1.5}{5}=\frac{3}{10}=0.3\Omega$$

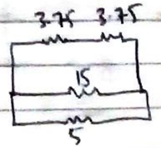




$$R_{12}=5+5+\frac{5\times5}{5}=15$$

$$\frac{1}{R_1}=\frac{1}{5}+\frac{1}{15}=\frac{3+1}{15}=\frac{4}{15} \Rightarrow R_1=\frac{15}{4}=3.75$$



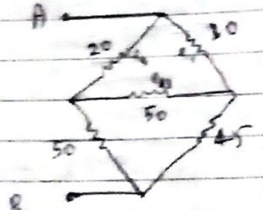


$$\frac{1}{R_{eq.}}=\frac{1}{15}+\frac{1}{5}+\frac{10}{75}=\frac{5+15+10}{75}=\frac{30}{75}$$

1.5°

$R_{eq} = \frac{75}{30} = 2.5\,\Omega$

Q.

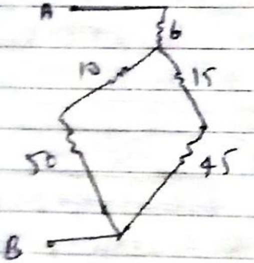


$R_{AB} = ?$

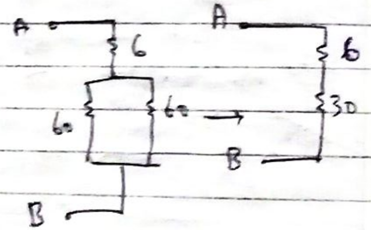
Ans - $R_1 = \frac{30 \times 20}{100} = 6$

$R_2 = \frac{50 \times 30}{100} = 15$

$R_3 = \frac{50 \times 20}{100} = 10$

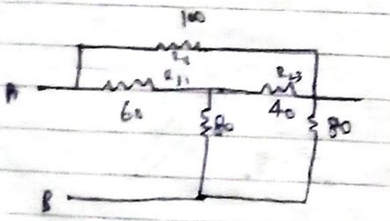


$\rightarrow$



$\boxed{R_{eq} = 36\,\Omega}$

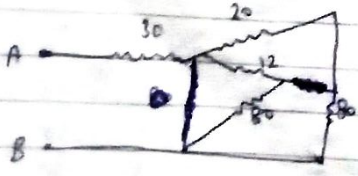
Q.



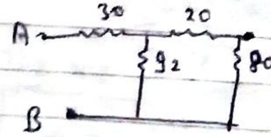
$R_1 = \frac{100 \times 60}{200} = 30$

$R_2 = \frac{40 \times 100}{200} = 20$

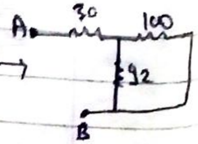
$R_3 = \frac{60 \times 40}{200} = 12$

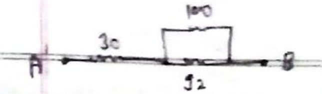


$\rightarrow$



$\rightarrow$

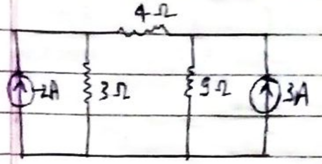




$\rightarrow \frac{1}{92} + \frac{1}{100} = \frac{192}{9200}$ $\frac{575}{12}$

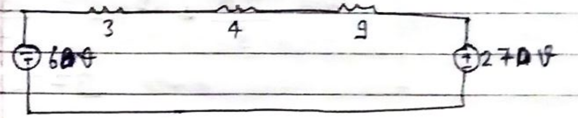
$R_{eq} = 30 + \frac{575}{12} = \frac{360+575}{12} = \frac{935}{12} = 77.9\,\Omega$

Q.



Find current through 4 Ω resistor using source conversion.

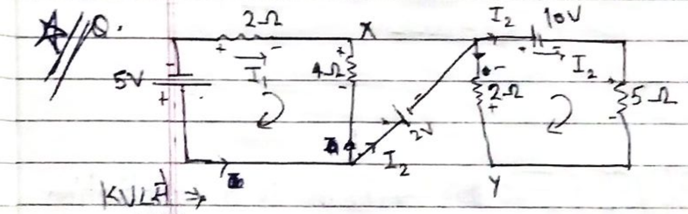
Ans -



$I = \frac{33}{16}$

$I = 2.06$

Q.



find $V_{xy} = ?$

KVL $\Rightarrow$

$-2I_1 - 4I_1 - 5 = 0 \quad \Rightarrow \quad 6I_1 = -5 \Rightarrow I_1 = -5/6$

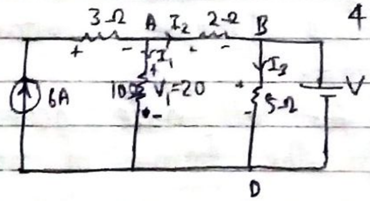
$-10 - 5I_2 - 2I_2 = 0 \quad I_2 = -10/7$

$V_{xy} = 4\times - \left(-\frac{5}{6}\right) - 2 + 2\left(-\frac{10}{7}\right) = \frac{20}{6} - \frac{24}{7} = \frac{140-204}{42} = \frac{-109}{42}$

$= -~~2.59~~ \quad -\frac{64}{42} = -\frac{32}{21} = -1.5$

204
-140
64

Q.



$V_1 = 20, \quad R = 10$

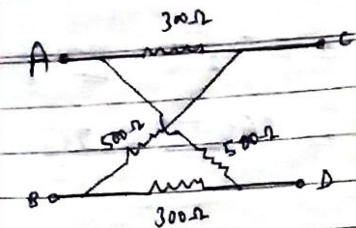
$I_1 = 2A$

$6 = I_1 + I_2 \Rightarrow I_2 = 4A$

$-2I_2 - V_{BD} + 20 = \quad V_{BD} = 20 - 8 \Rightarrow \boxed{V_{BD} = 12V}$

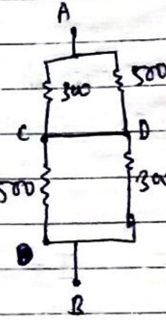
$\boxed{V=12}$

Q.



Case-I when C&D are short.
Case-II when C&D are open.

Ans-
(I)



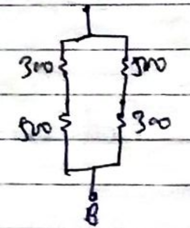
$\frac{1}{R} = \frac{1}{300} + \frac{1}{500} = \frac{800}{1500 \times 100}$

$R = \frac{1500}{8}$

$R = \frac{1500}{8} \times 2 = \frac{1500}{4}$

375Ω

(II)



R=400Ω

NODAL ANALYSIS ⇒ This theorem is a application of KCL and computes all the node voltages.

STEP to solve the circuit using nodal analysis:-

(i) Identify all the nodes in the network and assume one node as a reference node.

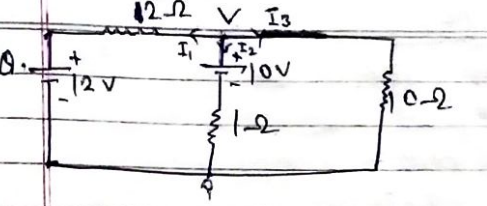
(ii) Assume node voltages at each node accept the reference one/node because voltage of reference node is zero volt.

(iii) Right KCL eqn for all node accept the reference node in the form of node voltage and solve them.

'n' node होने पर eqn (n-1) होगी |

Current high voltage to low voltage

Q.



node A, KCL

$I_1 + I_2 + I_3 = 0$

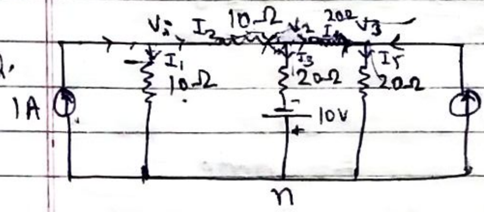
$\frac{V-12}{2} + \frac{V-10}{1} + \frac{V}{10}$

$\frac{5V-60+10V-100+V}{10} = 0$

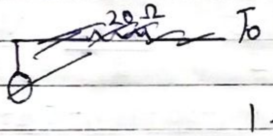
16V = 160

$\boxed{V = 10\,\text{Volt}}$

Q.



Solve⇒



To KCL Rule:- (At node 1)

$1 = I_1 + I_2$

$1 = \frac{V_1}{10} + \frac{V_1 - V_2}{10} = 2V_1 - V_2 = 10$ —①

At node 2

$I_3 + I_4 = I_2$

$\frac{V_2+10}{20} + \frac{V_2-V_3}{20} = \frac{V_1-V_2}{10} \Rightarrow V_2+10+V_2-V_3$

$= 2V_1 - 2V_2$

$4V_2 + 10 = 2V_1 + V_3$

$8V_1 - 40 + 10 = 2V_1 + V_3$

$6V_1 = V_3 + 30$ —②

At node 3

$I_4 + 0.5 = I_5$

$\frac{V_2-V_3}{20} + 0.5 = \frac{V_3}{20}$

$V_2 - V_3 + 10 = V_3$

$V_2 + 10 = 2V_3$ —③

$2V_1 - 10 + 10 = 2V_3$

$\boxed{V_1 = V_3}$

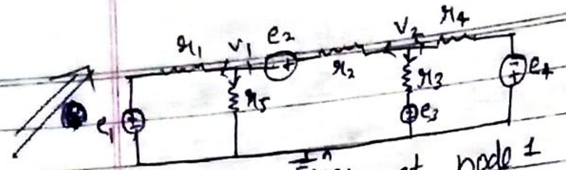
$6V_3 = V_3 + 30$

$\boxed{V_3 = 6}$

$\boxed{V_1 = V_3 = 6\,\text{Volt}}$

$\boxed{V_2 = 2\,\text{Volt}}$

DATE: / /
PAGE NO.:



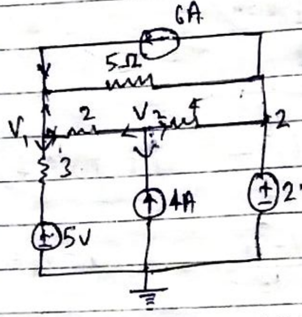
Apply KCL at node 1

$$\frac{V_1-e_1}{r_1}+\frac{V_1}{r_5}+\frac{V_1+e_2-V_2}{r_2}=0$$

At node 2

$$\frac{V_2-e_2-V_1}{r_2}+\frac{V_2-e_3}{r_3}+\frac{V_2+e_4}{r_4}=0$$

Q.



At node 1

$$\frac{V_1-5}{3}+\frac{V_1-V_2}{2}+\frac{V_1-2}{5}=6$$

$$\frac{10V_1-50+15V_1-15V_2+6V_1-12}{30}=6$$

$$31V_1-15V_2=180+50+12$$

$$31V_1-15V_2=242 \quad — ①$$

At node 2

$$\frac{V_2-V_1}{2}+\frac{V_2-2}{4}=4$$

$$\frac{2V_2-2V_1+V_2-2}{4}=4 \Rightarrow 3V_2-2V_1=18 \quad — ②$$

$$V_2=\frac{18+2V_1}{3}$$

$$31V_1-\overset{5}{\cancel{15}}\left(\frac{18+2V_1}{\cancel{3}}\right)=242$$

$$31V_1-90-10V_1=242$$

$$21V_1=332$$

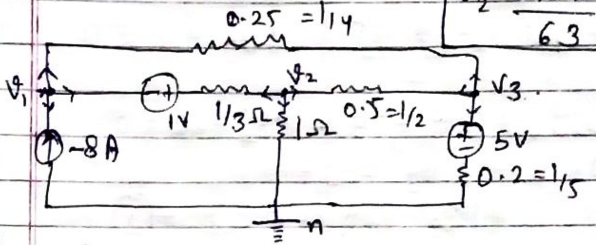
$$\boxed{V_1=\frac{332}{21}}$$ = 15
Vo

DATE: / /
PAGE NO.:

$$3V_2-\frac{664}{21}=18 \Rightarrow 3V_2=18+\frac{664}{21}$$

$$\boxed{V_2=\frac{1042}{63}}=16.5 \text{ Volts}$$

Q.



At node ①

$$\frac{V_1+1-V_2}{1/3}+\frac{V_1-V_3}{1/4}+8=0$$

$$3V_1+3-3V_2+4V_1-4V_3+8=0$$

$$7V_1-3V_2-4V_3+11=0 \quad — ①$$

At node 2 :—

$$\frac{V_2-1-V_1}{1/3}+\frac{V_2}{1}+\frac{V_2-V_3}{1/2} \Rightarrow 3V_2-3V_1-3+V_2+2V_2-V_3=0$$

$$-3V_1+6V_2-2V_3=3$$

$$3V_1+2V_3=6V_2-3 \quad — ②$$

At node ③ :—

$$\frac{V_3-V_1}{1/4}+\frac{V_3-V_2}{1/2}+\frac{V_3-5}{1/5}=0$$

$$4V_3-4V_1+2V_3-2V_2+5V_3=25$$

$$11V_3-4V_1-2V_2=25 \quad — ③$$

$$3V_1+2V_3+3=6V_2$$

$$7V_1-3\left(\frac{3V_1+2V_3+3}{6}\right)-4V_3+11=0$$

$$7V_1-\frac{(3V_1+2V_3+3)}{2}-4V_3+11=0$$

$$14V_1-3V_1-2V_3-3-8V_3+22=0$$

$$11V_1-10V_3=-19 \quad \leftarrow ④$$

DATE : / /
PAGE NO. :

from eqn -③

$11v_3 - 4v_1 - 25 = 2v_2$

$7v_1 - 3\left(\frac{11v_3 - 4v_1 - 25}{2}\right) - 4v_3 + 11 = 0$

$14v_1 - 33v_3 + 12v_1 + 75 - 8v_3 + 22 = 0$

$26v_1 - 41v_3 = -97$

$41v_3 - 26v_1 = 97$ —⑤

$410v_3 - 260v_1 = 970$

(eqn-4) $-410v_3 + 451v_1 = -779$

$191v_1 = 191$

$\boxed{v_1 = 1}$

41
41 3
41
19
7C
779

$v_3 = \frac{-19-11}{-10} = 3$ $\boxed{v_3 = 3}$

$7 - 3v_2 - 12 + 11 = 0$

$\boxed{v_2 = 2}$

* Mesh current method ⇒ This method is based on KVL. In this method instead of assumeing branch current mesh current are assume ~~with~~ ~~do~~ which do not split but complete their path around the mesh.

Step to solve current using mesh anaylsis ⇒

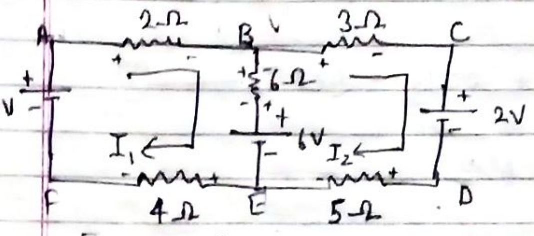
1.) Identify all the mesh and assume mesh current in any direction.

DATE : / /
PAGE NO. :

2.) Write KVL eqn for each mesh and solve it.

Note → This method is not applicable in a mesh containing current source.

Q.



In mesh ABEFA

$-2I_1 - 6I_1 - 6 - 4I_1 + 10 + 6I_2 = 0$

$6I_2 - 12I_1 + 4 = 0$ —— = ~~$3I_2 - 6I_1 = -2$~~ —①

$12I_1 - 6I_2 = 4$ —① ×3

In mesh BCDEB

$-3I_2 - 2 - 5I_2 + 6 - 6I_2 + 6I_1 = 0$

$6I_1 - 14I_2 + 4 = 0$

$3I_1 - 7I_2 = -2$ —② ×4

~~$21I_2 - 42I_1$~~

$9I_2 - 18I_1 = -6$

$-42I_2 + 18I_1 = -12$

$-33I_2 = -18$ $I_2 = \frac{18}{33}$

$12I_1 - 28I_2 = -8$

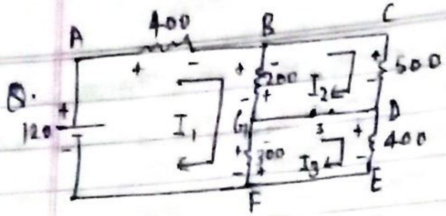
$12I_1 - 6I_2 = 4$

$-22I_2 = -12$ $\boxed{I_2 = \frac{6}{11}}$

$I_1 =$ $\boxed{I_1 = \frac{20}{33}}$

DATE
PAGE NO.

Q.



In mesh ABGFA

$120 - 400I_1 - 200I_1 - 300I_1 + 200I_2 + 300I_3$

$120 + 200I_2 + 300I_3 = 900I_1$ —— ①

In mesh BCDGB

$-500I_2 - 200I_2 + 200I_1$

$200I_1 = 700I_2$

$I_1 = \frac{7}{2}I_2$ —— ②

In mesh GDEFG

$-400I_3 - 300I_3 + 300I_1 = 0$

$3I_1 = 7I_3$

$I_1 = \frac{7}{3}I_3$ —— ③

$I_3 = \frac{3}{2}I_2$ —— ④

$120 + 200I_2 + 300 \times \frac{3}{2}I_2 = 900 \times \frac{7}{2}I_2$

$240 + 400I_2 + 900I_2 = 6300I_2$

$(6300 - 1300)I_2 = 240$

$5000\ I_2 =$ ~~$\frac{6060}{1300} = \frac{4.507}{100} = 4.507$~~

$I_2 = \frac{240}{5000}$

$\boxed{I_2 = 0.048}$

~~$I_1 = \frac{7}{2} \times 4.5 = 7 \times 2.25 = 15.75$~~

$I_1 = \frac{7}{2} \times 0.048$

7×0.024

$\boxed{I_1 = 0.168}$

~~$I_3 = \frac{3}{2} \times 4.5 = 3 \times 2.25 = 6.75$~~

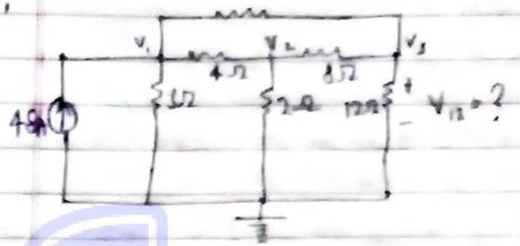
DATE $\frac{72}{-8}$ 64
PAGE NO.

$I_3 = \frac{3}{2} \times 0.048 = 3 \times 0.024 = \boxed{0.072 = I_3}$

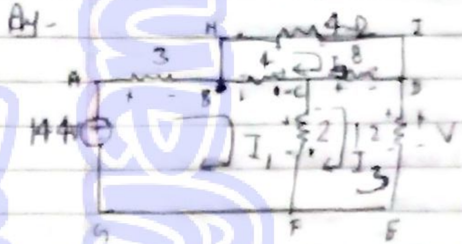
GD of $I_3 - I_2 = -0.048 + 0.072 = 0.024$

Q.

(node+mesh method)



Ay-



In ABCFGA of

$144 - 3I_1 - 4I_1 - 2I_1 + 4I_2 + 2I_3$

$144 + 2I_3 = 9I_1 + 4I_2$ —— ①

In mesh CDEFC

$-2I_3 - 8I_2 - 12I_3 + 2I_1 + 8I_2$

$8I_2 + 2I_1 = 22I_3$ —— ② ~~$= I_1 + 4I_3$~~

In mesh BCDIHB

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

$4I_1 + 8I_3 = 16I_2$ —— ③ $\Rightarrow$ ~~$I_1 + 2I_3 = 4I_2$~~ ③

$2I_1 + 4I_3 = 8I_2$ —— ③ $\Rightarrow$

in eq^n ②

$144 + 4I_3 - I_1 = 9I_1 + 4I_3$ (from eq^n ② + ③)

~~$10I_1 = 144$~~

~~$I_1 = 14.4$~~

(~~$2I_1 = 16I_3 = 8I_2$~~ / 2)

in ② $8I_2 - 4I_2 = 22I_3 + 8I_3$

~~in eq^n ②~~

~~$8I_2 - 4I_2 = 22I_3 + 8I_3$~~

from eq^n ② & ③

$2I_1 + 4I_3 = 22I_3 - 2I_1$

$I_1 = \frac{18}{4} I_3 = \frac{9}{2} I_3$ —④

from eq^n ① & ③

$144 - 9I_1 + 11I_3 - I_1 + 2I_3 = 0$

$144 + 13I_3 = 10I_1$

$144 + 13I_3 = \frac{90}{2} I_3 \Rightarrow 288 = (90-26) I_3$

$\boxed{I_3 = 4.5}$ $I_1 = \frac{9}{2} \times 4.5 = 20.25$ $\boxed{I_1 = 20.25}$

In eq^n ③

$2I_1 + 4I_3 = 8I_2$

$2 \times 20.25 + 4 \times 4.5 = 8I_2$

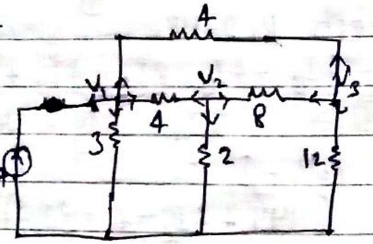
$40.5 + 18 = 8I_2$

$\frac{58.5}{8} = I_2 \Rightarrow \boxed{I_2 = 7.81}$

In 'ED' Branch

$V = I_3 \times R = 4.5 \times 12 = 54$ Volt

node method:-



At node 1

$\frac{V_1 - V_3}{4} + \frac{V_1 - V_2}{4} + \frac{V_1}{3} = 48$

$3V_1 - 3V_3 + 3V_1 - 3V_2 + 4V_1 = 576$

$10V_1 - 3V_2 - 3V_3 = 576$ —①

At node 2

$\frac{V_2 - V_1}{4} + \frac{V_2 - V_3}{8} + \frac{V_2}{2} = 0$

$\frac{2V_2 - 2V_1 + V_2 - V_3 + 4V_2}{8} = 0 \Rightarrow 7V_2 = 2V_1 + V_3$ —②

At node 3

$\frac{V_3}{12} + \frac{V_3 - V_2}{8} + \frac{V_3 - V_1}{4} = 0$

$\frac{2V_3 + 3V_3 - 3V_2 + 6V_3 - 6V_1}{24} = 0 \Rightarrow 11V_3 = 3V_2 + 6V_1$ —③

in eqn ②,③ $21V_2 - 6V_1 = 3V_3$

$3V_2 + 6V_1 = 11V_3$

$\frac{24V_2}{14} = V_3 \Rightarrow \frac{12}{7} V_2 = V_3$

$\Rightarrow V_2 = \frac{7}{12} V_3$

~~$10V_1 - 3V_2 - \frac{36V_2}{7} = 576$~~

~~$70V_1 - 57V_2 = 4032$~~

$10V_1 - \frac{3 \times 7}{12_4} V_3 - 3V_3 = 576$

$40V_1 - 7V_3 - 12V_3 = 2304$

$40V_1 - 19V_3 = 2304$ —④

eq^n ② $\frac{7 \times 7}{12} V_3 = 2V_1 + V_3$

$(49-12) V_3 = 24V_1$

$37V_3 = 24V_1$ $V_1 = \frac{37}{24} V_3$

$\left(\frac{\overset{10\,5}{\cancel{40}} \times 37}{\cancel{24}_3}\right) - 19V_3 = 2304$

$(185 - 57) V_3 = 2304$ $V_3 = \frac{2304}{128}$

31/8/18

Network Theorem

→ Superposition theorem ⇒

In a linear resistor network containing two or more energy sources, the total current in any part of a circuit is equal to the algebraic sum of all the currents produced by each source separatally

Steps for solving superposition theorem ⇒

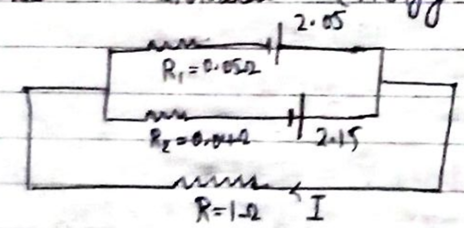
1.) Take any one of the independent voltage or current source. Replace the other energy sources by their internal resistances that is voltage sources become short circuits and current sources become open circuited.

2.) Obtain various branch current.

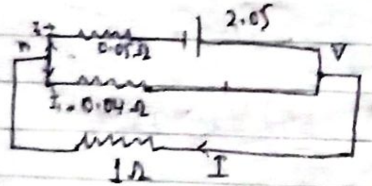
3.) Repeat the about two step for each of the independent energy sources.

4.) At all the currents obtain in each branch for individual energy source.

Q.



Ans.



① $\frac{V-2.05}{0.05} + \frac{V}{0.04} + \frac{V}{1} = 0$

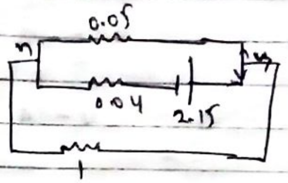
$\frac{820}{880} = \frac{41}{44}$

② $\frac{100(V-2.05)}{5} + \frac{V\times100}{4} + \frac{V}{1}$ ~~$\frac{400V-820+500V}{20}$~~

$920V = 820$

$V = \frac{820}{920} = \frac{41}{46} = 0.891$

~~I=0.0891A~~



$\frac{V}{0.05} + \frac{V}{1} + \frac{V-2.15}{0.04} = 0$

$\frac{100V}{5} + \frac{V}{1} + \frac{100V-215}{4} = 0$

$\frac{400V + 20V + 500V - 1075}{20} = 0$

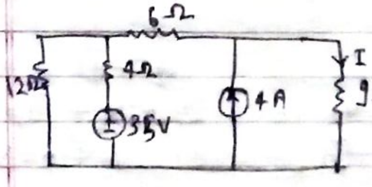
$920V = 1075$

$V = \frac{1075}{920} = 1.16$

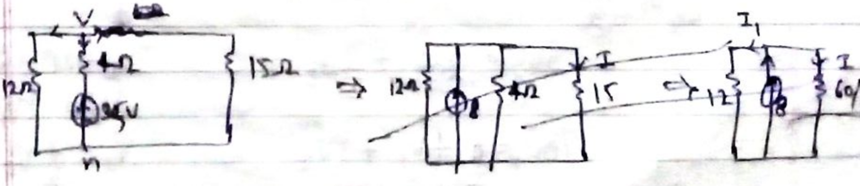
$V_{total} = 0.891 + 1.16 = 2.051$

$I_{total} = 2.051$

Q.



Ans -



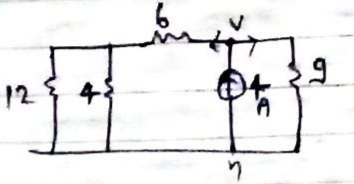
$\frac{V}{12} + \frac{V-32}{4} + \frac{V}{15} = 0$

$\boxed{V=20}$

~~$\frac{5V + 12V - 384 + 4V}{60}$~~ = ~~19V = 384~~

$V = I \times R \Rightarrow \frac{20}{15} = I \Rightarrow I = \frac{4}{3} A$

5/
$\frac{14}{71}$



$V = \frac{\cancel{9}}{\cancel{2}} \times \cancel{4}^{2} = \cancel{18}$

$V = 18$

$\cancel{I}F$

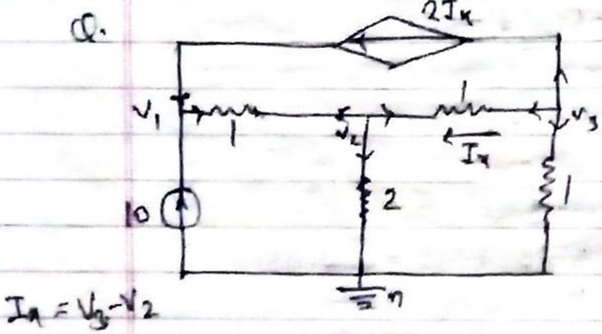
$\frac{v}{9} + \frac{v}{9} = 4 \Rightarrow v = \frac{9}{2} \times 4 = 18$

$I = \frac{v}{R} = \frac{18}{9} = 2$

$I_{tot} = \frac{4}{3} + 2 = 1.3 + 2 = 3.33$

dependent

Q.



$I_x = V_3 - V_2$

$V_3 - V_2 + 2I_x + V_3$

$2V_3 + 2I_x = V_2$

$2V_3 + 2V_3 - 2V_2 = V_2$

$4V_3 = 3V_2$ —③

eqⁿ —②

$5V_2 = 2V_1 + \frac{3}{2}V_2$

$10V_2 = 4V_1 + 3V_2$

$7V_2 = 4V_1$

$\frac{7 \times 8}{4} = V_1$

$V_1 = \frac{56}{4} = 14$

$\boxed{V_1 = 14 Volt}$

$2 \cdot I_x + 10 = V_1 - V_2$ —①

$V_2 - V_1 + \frac{V_2}{2} + V_2 - V_3 = 0$

$5V_2 = 2V_1 + 2V_3$ —②

eqⁿ —①

$2V_3 - 2V_2 + 10 = V_1 - V_2$

$2V_3 + 10 = V_1 + V_2$ —④

$3V_2 + 20 = 2V_1 + 2V_2$

$V_2 = 2V_1 - 20$

$V_2 = \frac{7}{2}V_2 - 20$

$V_2(1 - \frac{7}{2}) = -20$

$V_2(-\frac{5}{2}) = -20$

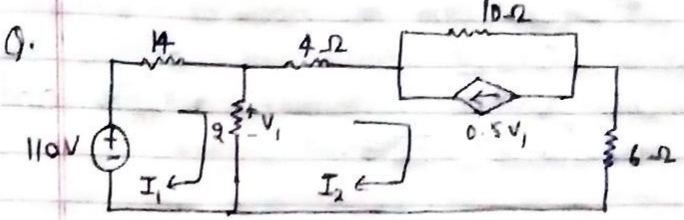
$\boxed{V_2 = 8 Volt}$

$4V_3 = 3 \times 8$

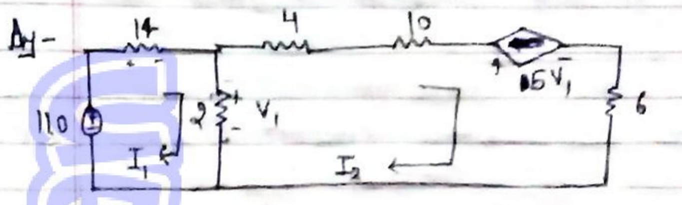
$\boxed{V_3 = 6}$

$I_x = V_3 - V_2 = 6 - 8 = \boxed{-2A = I_x}$

Q.



Ans -



$V_1 = (I_1 - I_2) \times 2$

$110 - 14I_1 - 2I_1 + 2I_2 = 0$

$110 - 16I_1 + 2I_2 = 0$ —①

$-2I_2 - 14I_2 - 6I_2 + 2I_1 - 5V_1 = 0$

$\cancel{5V_1 =}\ 2I_1 - 22I_2 - 5(I_1 - I_2) \times 2$

$2I_1 - 22I_2 - 10I_1 + 10I_2$

$-8I_1 - 12I_2 = 0$

$-12I_2 = 8I_1$

$-3I_2 = 2I_1$

eqⁿ —①

$110 + 24I_2 + 2I_2 = 0$

$26I_2 = -110$

$I_2 = \frac{-55}{13} = -4.23$

$-3(-4.23) = 2I_1$

$I_1 = \frac{12.69}{2} = 6.34$

$I_1 = 6.34$

$V_1 = 6.34 + 4.23$

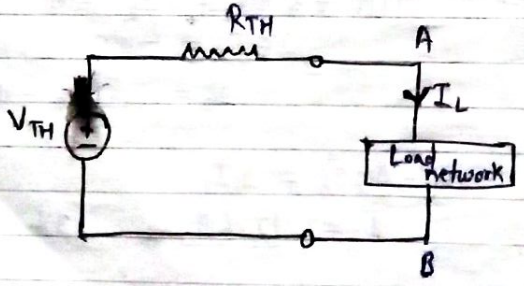
10.57×2

$\boxed{V_1 = 21.149}$

Thevenin Theorem:— Any linear resistive network with current & voltage sources can be replaced by an equivalent circuit containing of a single independent voltage source ~~V_{TH}~~ V_{TH} and series resistance R_{TH}.

Step for solveing thevenin theorem⟶

1.) Open the load resistor
2.) Calculate the open circuit voltage or thevenin Voltage that is V_{TH}.
3.) Replace the sources by their internal resistances i.e. current source become open circuited and voltage become a short circuited.
4.) Calculate the thevenin resistance i.e. R_{TH}
5.) Now re-draw the circuit with majored value of V_{TH} & R_{TH} and connect the load resistor. This is the equivalent thevenin circuit.
6.) Find the total ~~circu~~ current I_L flowing through the load resistor.

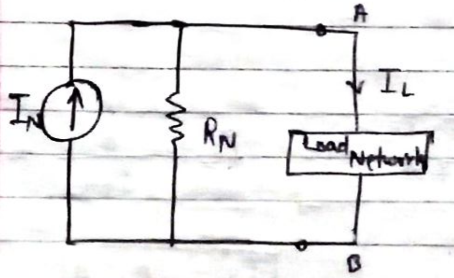


$$\boxed{I_L = \frac{V_{TH}}{R_{TH}+R}}$$

Norton's theorem⟹ Any linear resistive network with current and voltage sources can be replqred by an equivalent circuit containing of a single independent current source I_N and a parallel resistence R_N.

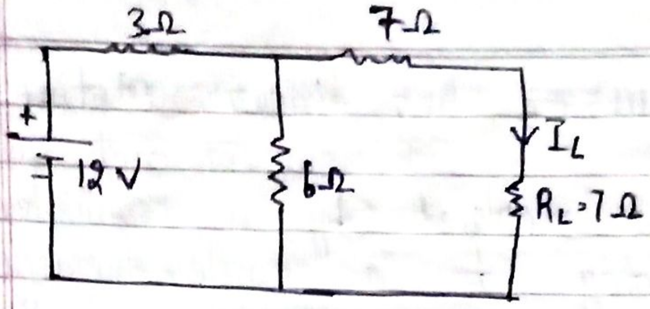
Step for solveing Noston's theorem ⟶

1.) Short the load resistor.
2.) Calculate the norton's current i.e I_N
3.) Replace the source by their internal resistance i.e. current source becomes open circuited and voltage source become short circuited.
4.) Calculate the norton's resistance. i.e. R_N
5.) Now re-draw the ciruit with majored value of I_N & R_N and connect the load resistor. This is the equivalent norton's circuit
6.) Find out the total load current flowing through the load resistor.



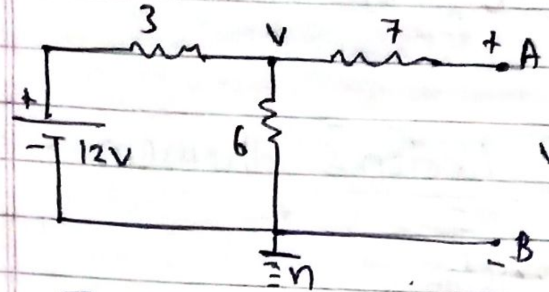
$$\boxed{I_L = \frac{I_N * R_N}{R_N + R_L}}$$

Q.



find $I_L = ?$ using thevenin theorem

Ay -



$V_{TH} = ?$

By nodal ~~theorem~~:—

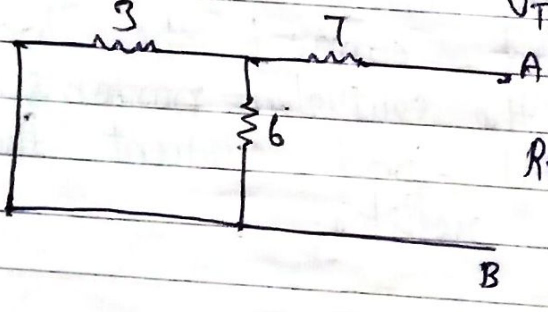
$$\frac{V-12}{3} + \frac{V}{6} = 0$$

$$\frac{2V-24+V}{6} =$$

$3V = 24$

$V = 8$ Volt

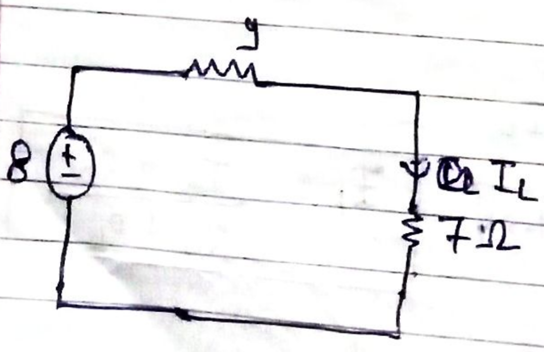
$V_{TH} = 8$ Volt



$R_{TH} = ?$

$R_{TH} = 2+7$

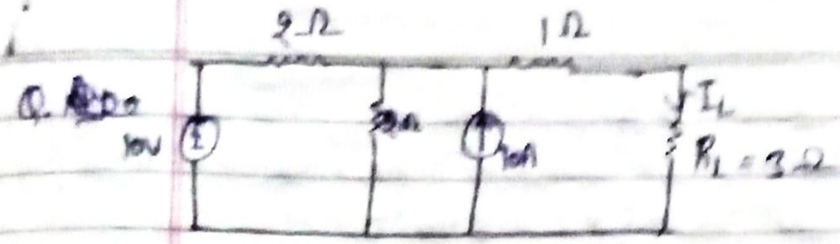
$R_{TH} = 9\ \Omega$



$$I_L = \frac{8}{9+7} = \frac{8}{16} = \frac{1}{2}$$

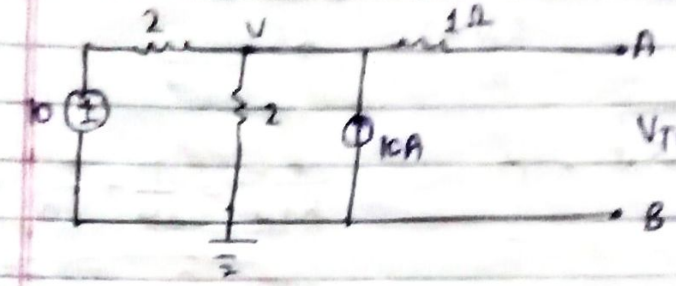
$$\boxed{I_L = 0.5A}$$

Q.



find $I_L = ?$

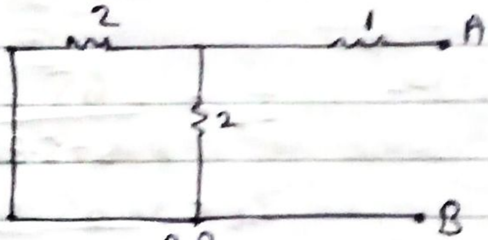
Ay -



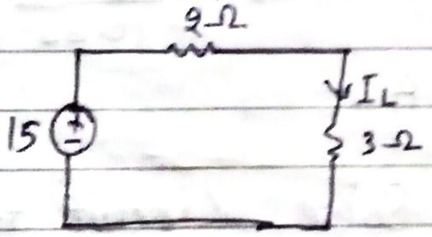
$V_{TH} = ?$

$$\frac{V-10}{2} + \frac{V}{2} = 10$$

$2V = 30$ → $V = 15$ Volt $V_{TH} = 15V$

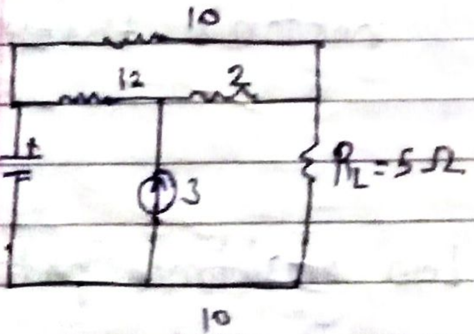


$R_{TH} = 2Ω$



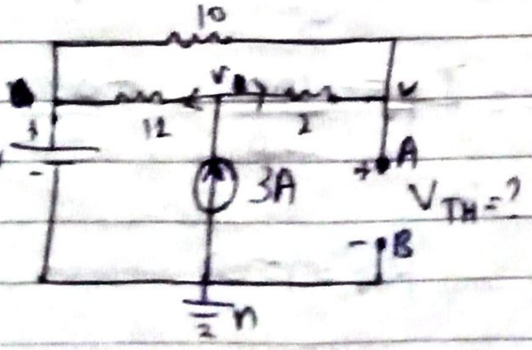
$$I_L = \frac{15}{2+3} = 3\text{ A}$$

Q.



find $I_L = ?$

Ay -



$V_{TH} = ?$

$$\frac{V-50}{12} + \frac{V-50}{12} = 3$$

$2V = 36 + 100$

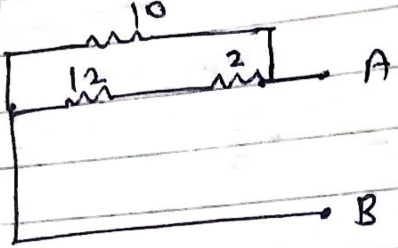
$V = \frac{136}{2} = 68$ Volt

2 | 7, 7, 10
5 | 7, 5
7

$I = \frac{68-80}{12} = \frac{18}{12} = 1.5A$

$V' = 1.5 \times 2 = 3$ Volt

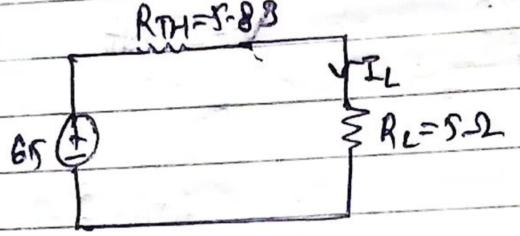
$V_{TH} = V - V' = 68 - 3 = 65$



$\frac{1}{R_{TH}} = \frac{1}{14} + \frac{1}{10} = \frac{5+7}{70}$

$R_{TH} = \frac{70}{12} = 5.83$

$R_{TH} = 5.83\,\Omega$



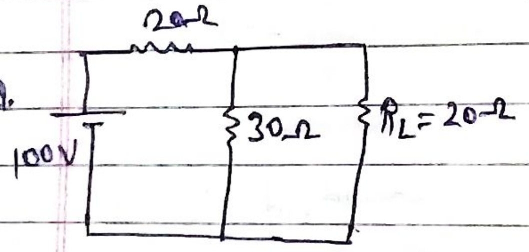
$I_L = \frac{65}{5+5.83}$

$I_L = \frac{65}{10.83} = \frac{6500}{1083}$

$I_L = 6A$

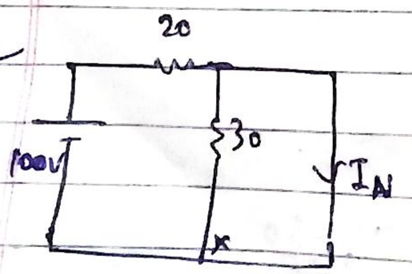
VR
VR=

Q.



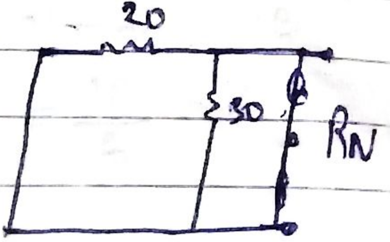
Solve circuit to norton's theorem

Ans



(Low resistance path follow)

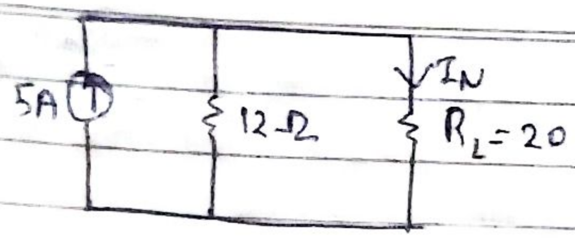
$I_N = \frac{100}{20} = 5A$



$R_N = 12\,\Omega$

$\frac{60}{5} = 12$

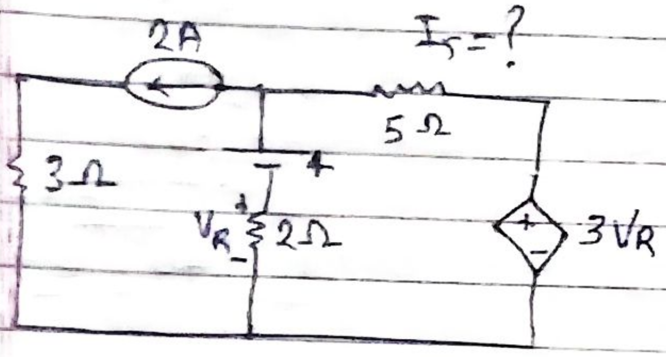
$\frac{1}{20} + \frac{1}{30} = \frac{3+2}{6}$



$$I_L = \frac{5 \times 12}{12+20} = \frac{60}{32} = \frac{30}{16}$$

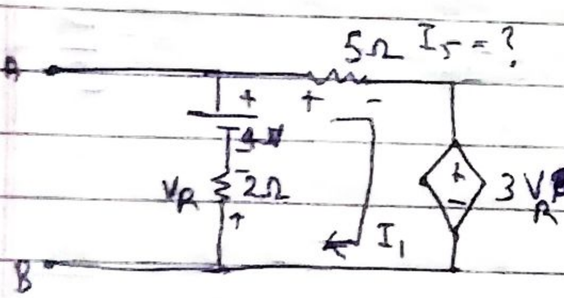
$$= \frac{15}{8} = 1.8$$
$$= 1.875A$$

Q.



find out at
5 Ω Resistance
Using superposition theorem

Ay –



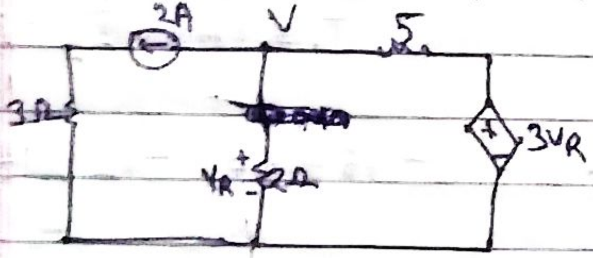
By Mesh :–

$$-5I_1 - 3V_R - 2I_1 + 4 = 0$$

~~$V_R = 2I_1$~~

$V_R = -2I_1$

$$-5I_1 + 6I_1 - 2I_1 + 4 = 0$$
$$I_1 = 4A$$



$$2 + \frac{V}{2} + \frac{V - 3V_R}{5} = 0$$

$$2 + \frac{V_R}{2} + \frac{V_R - 3V_R}{5} = 0$$

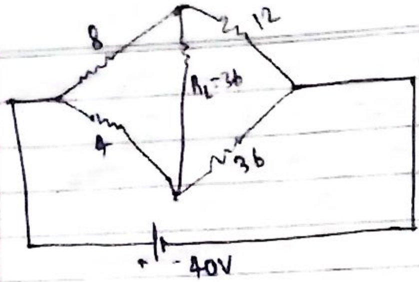
∴ $V = V_R$

$$\frac{20 + 5V_R - 4V_R}{10} = 0$$

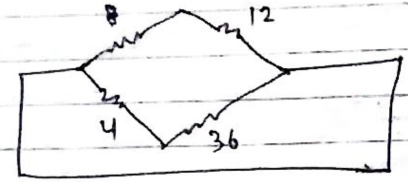
$V_R = -20$ Volt

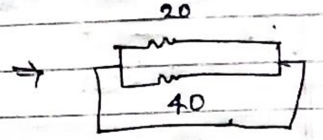
$$I_2 = \frac{V - 3V_R}{5} = \frac{-2V_R}{5} = \frac{-2(-20)}{5} = 8\ A$$

$$I = 8 + 4 \Rightarrow \boxed{12A = I_{total}}$$

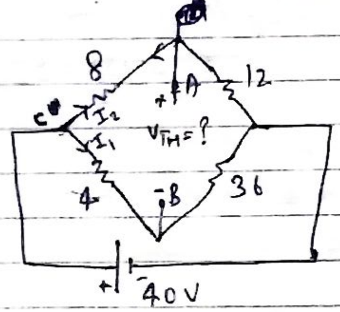
Q. 

find $I_L = ?$ using Thevenin theorem?

Ans - 



$\frac{1}{R_H} = \frac{1}{20} + \frac{1}{40} = \frac{2+1}{40} =$ $R_H = \frac{40}{3}\ \Omega$



$I = \frac{V}{R} = \frac{40}{40/3} = 3A$

$I = 3A$

$I_1 = 1A,\ I_2 = 2A$

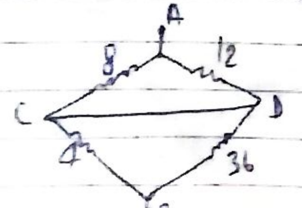
$I_1 = 3 \times \frac{20}{60} = 1$

$I_2 = 3 \times \frac{40}{60} = 2$

$V_{TH} = V_{AC} + V_{BC} = -16 + 4 = -12$ Volt

$I_L = \frac{V_{TH}}{R_{TH} + R_L} = \frac{-12}{\frac{40}{3} + 36} = \frac{-12 \times 3}{40 + 108}$

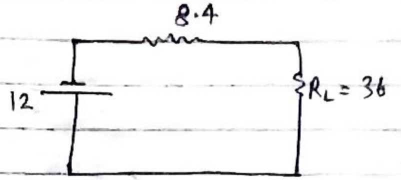
$I_L = \frac{-36}{148} = \frac{-18}{74} = \frac{-9}{37}$



$\frac{1}{8} + \frac{1}{12} =$ $\frac{1}{4}\left(\frac{1}{2} + \frac{1}{3}\right) = \frac{1}{4}\left(\frac{5}{6}\right.$

$\frac{1}{4}\left(1 + \frac{1}{9}\right) = \frac{105}{4 \times 9} = \frac{18}{5} + \frac{24}{5}$

$R_{TH} = \frac{18 + 24}{5} = \frac{42}{5} = 8.4\ \Omega$



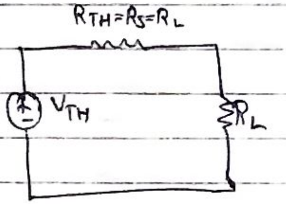
$I_L = \frac{-12}{8.4 + 36}$

$I_L = -+\frac{12}{\cancel{44.4}\ 12}$

$I_L = \frac{+120}{444} = \frac{+60}{222} = \frac{+30}{111}$

Maximum Power Transfer Theorem :—

$\boxed{R_S = R_L}$



$I_L = \frac{V}{R_S + R_L}$

Power transfer.

$P_L = I_L^2 R_L$

$P_L = \frac{V^2}{(R_S + R_L)^2} \times R_L$

$P_L = \frac{V^2}{R_S^2 + R_L^2 + 2R_SR_L} \times R_L$

$P_L = \frac{V^2}{\left(\frac{R_S^2}{R_L} + R_L + 2R_S\right)}$

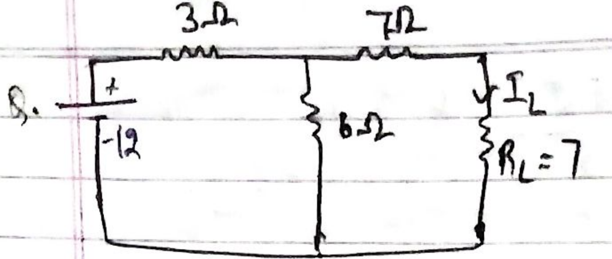
for max. Power transfer

$P_{max.} = \frac{dP_L}{dR_L} = 0$

$-\frac{R_S^2}{R_L^2} + 1 = 0$

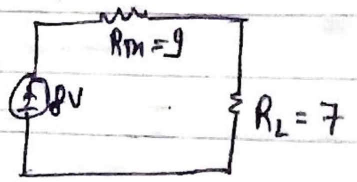
$\boxed{R_S = R_L}$

→ The max. power transfer theorem is used to determine the condition underwhich max. power can be transfered from a source network to load. According to this theorem max. power will be transfered from a source network to a load. If the load resistance R_L ~~is~~ equal to the equivalent resistance R_S of the source network i.e. $\boxed{R_S = R_L}$



$V_{TH} = 8$

$R_{TH} = 9$



$$I_L = \frac{V_{TH}}{(2R_S)}$$

$$P = I_L^2 R$$

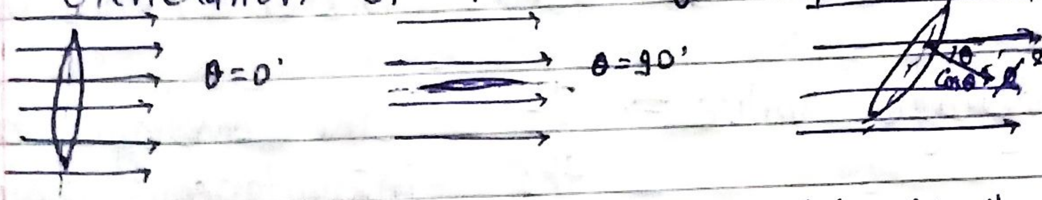
$$P = \frac{V^2}{4R^2} \times R = \frac{8 \times 8}{4 \times 9} = \frac{64}{36} \frac{2}{18}$$

$$P = \frac{16}{9} = 1.77$$

Unit - 2
AC Circuits

Generation of AC Voltage or EMF ⇒

$\theta = \omega t$



$\theta = \omega t$

$$e = \frac{-d(N\phi)}{dt} = N\frac{d(-\phi\cos\omega t)}{dt} = \omega N\phi\sin\omega t$$

$$e = N\phi\omega\sin\omega t$$

$$\boxed{e = E_{max}\sin\omega t}$$

According to the fardey's Law of electro-magnetic induction when a moveing conductor is placed in a magnetic field emf is generated. It is important to note that max. of flux is linked with the conductor when the plane of the conductor is ⊥ to the flux lines. And it is zero when the plane of the coil is in parallel. At any other angle say θ the flux linked with the conductor is equal to the component of ∅ which is ⊥ to the coil.

1.) Alternating Quantity
2.) Waveform 3.) Cycle 4.) Time period
5.) frequency 6.) Phase angle 7.) Phase difference
8.) Instantaneous Value 9.) Average Value 10.) peak value

1.) Alternating Quantity ⇒ It is the Quantity which changes periodially in magnetude and indirection w.r.t. time.

2/ Instantaneous Value ⇒ The Value of alternating quantity at any perticular instant t is called instantaneous Value.

3/ Average Value ⇒ It is the average of all the instantaneous value over one complete cycle.

4/ Time period ⇒ Time taken by an alternating quantity to complete one cycle is called time period and it is denoted by 'T'.

5/ Frequency → The number of cycles are completed first, second by an alternating quantity is called 'Frequency' and denoted by 'f'.

6/ Peak Value ⇒ It is the maximum magnetude of an alternating quantity.

7/ Wave form ⇒ The curve obtained by the plotting instantaneous values w.r.t. time is called 'wave form.

8/ Cycle → One complete set of positive and negative values of an alternating wave is called cycle.

9/ Phase angle ⇒ It is the angle of an AC wave at t=0

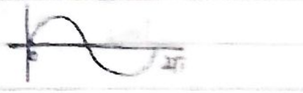
10/ Phase difference ⇒ It is the angular difference b/w the Phase angle of the two waves.

Average Value and RMS Value ⇒

Average value :- It is the average of all the instantaneous value of an alternative quantity over one complete cycle.

$$I_{av} = \frac{\text{Area under full cycle}}{\text{length of one cycle}}$$

$$\boxed{I_{av} = \frac{1}{2\pi}\int_{0}^{2\pi} i\,dt}$$



Note:- In case of periodic alternative quantity that is one whoose two half cycles are same wheather it is synosoildal or non-synosoidal. The average value over come a complete cycle is zero.

RMS Value:- It is the square root of mean of square instantaneous value.
The RMS Value of an alternating quantity is given by that steady voltage or current which when flow through a resistor of an known resistance for a given periodic time

produces the same amount of heat. when the alternating current or voltage is applyed to the same resistor for the same period of time.

$$I_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} i^2(t).dt}$$

Foam vector(kf) ⇒ It is the ratio of effective value or rms value to the average value.

$$\boxed{kf = \frac{I_{rms}}{I_{av}}}$$

Note:- for synesoidal wave kf = 1.11
For square wave kf = 1
For triangular wave kf = 1.547

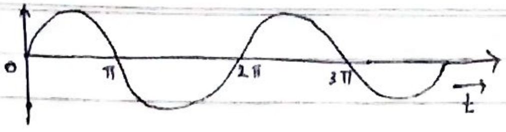
Peak vector (kp) ⇒ It is the ratio of max. value to the RMS value.

$$\boxed{kp = \frac{I_{max}}{I_{rms}}}$$

Note:- For sin wave kp = 1.414
for square wave kp = 1
For triangular wave kp = 1.732

Q. Find out average value, RMS value, Foam value and Peak value for sin wave.

Ans -



$$I_{av.} = \frac{1}{\pi}\int_0^{\pi} i\,dt = \frac{1}{\pi}\int_0^{\pi} I_{max}\,Sin\,t.dt$$

$$= \frac{I_{max}}{\pi}[-Cost]_0^{\pi} = \frac{I_{max}}{\pi}[-Cos\,\pi + Cos\,0]$$

$$\boxed{I_{av.} = \frac{2I_{max.}}{\pi}}$$

$$I^2_{rms} = \frac{1}{2\pi}\int_0^{2\pi} I^2_{max}\,Sin^2t\,dt$$

$$I^2_{rms} = \frac{I^2_{max}\times 2}{2\pi}\int_0^{\pi}\frac{(1-Cos2t)}{2}.dt$$

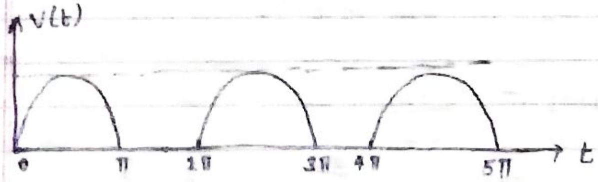
$$I^2_{rms} = \frac{I^2_{max}}{2\pi}\left[t - \frac{Sin2t}{2}\right]_0^{\pi} = \frac{I^2_{max}}{2\pi}(\pi)$$

$$\boxed{I_{rms} = \frac{I_{max}}{\sqrt{2}}}$$

$$kf = \frac{I_{rms}}{I_{av}} = \frac{I_{max}}{\sqrt{2}} \times \frac{\pi}{2I_{max}} = \frac{\pi}{2\sqrt{2}} \frac{3.14}{2.82} = 1.11$$

$$kp = \frac{I_{max}}{I_{rms}} = \frac{I_{max}}{I_{max}}\times\sqrt{2} = \sqrt{2} = 1.414$$

Q.



$$V(t) = \begin{cases} Vm\,Sint & 0 \text{ to } \pi \\ 0 & \pi \text{ to } 2\pi \end{cases}$$

Ans -

$$V_{av} = \frac{1}{2\pi}\int_0^{2\pi} V(t).dt = \frac{1}{2\pi}\left[\int_0^{\pi} Vm\,Sint.dt + \int_{\pi}^{2\pi} 0.dt\right.$$

$$V_{av} = \frac{Vm}{2\pi}[-Cost]_0^{\pi} = \frac{Vm}{\pi}$$

$$V_{rms} = \sqrt{\frac{1}{2\pi} \int_0^{2\pi} V^2 . dt}$$

$$V_{rms} = \sqrt{\frac{1}{2\pi} \left[\int_0^{\pi} V_m^2 \sin^2 t \, dt + 0 \right]}$$

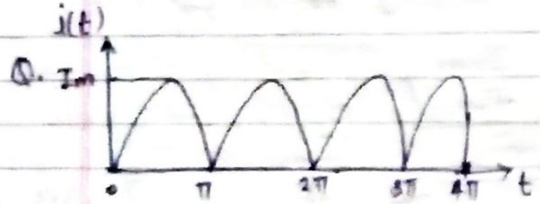
$$V_{rms}^2 = \frac{1}{2\pi} \quad V_m^2 \quad \int_0^{\pi} \left(\frac{1 - \cos 2t}{2} \right) . dt$$

$$V_{rms}^2 = \frac{V_m^2}{4\pi} \quad (\pi - 0) = \frac{V_m^2}{4}$$

$$\boxed{V_{rms} = \frac{V_m}{2}}$$

$$k_f = \frac{V_{rms}}{V_{av}} = \frac{V_m}{2} \times \frac{\pi}{V_m} = \frac{3.14}{2} = 1.57$$

$$k_p = \frac{V_{max.}}{V_{rms}} = \frac{V_m}{V_m} \times 2 = 2$$

Q. 

$$I_{av} = \frac{1}{\pi} \int_0^{\pi} I_m \sin t . dt$$

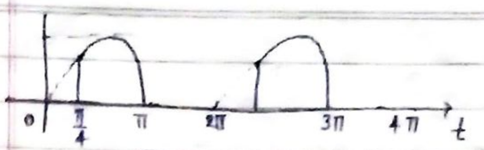
$$I_{av} = \frac{I_m}{\pi} \left[-\cos t \right]_0^{\pi} = \frac{2 I_m}{\pi} \quad \text{Ay}$$

$$I_{rms}^2 = \frac{1}{\pi} \int_0^{\pi} I_m^2 \sin^2 t . dt$$

$$I_{rms} = \frac{I_0}{\sqrt{2}}$$

$$k_f = \frac{I_{rms}}{I_{av}} = \frac{\frac{I_0}{\sqrt{2}}}{\frac{2I_0}{\pi}} = \frac{\pi}{2\sqrt{2}} \quad \text{Ay}$$

$$k_p = \frac{I_{max.}}{I_{rms}} = \frac{I_m}{\frac{I_m}{\sqrt{2}}} = \sqrt{2} \quad \text{Ay}$$

Q. 

$$i(t) = \begin{cases} 0 , & 0 \text{ to } \pi/4 \\ 100 \sin t , & \pi/4 \text{ to } \pi \\ 0 , & \pi \text{ to } 2\pi \end{cases}$$

Ay - $$I_{av} = \frac{1}{2\pi} \left[\int_0^{\pi/4} 0 + \int_{\pi/4}^{\pi} 100 \sin t . dt + \int_{\pi}^{2\pi} 0 \right]$$

$$I_{av} = \frac{1}{2\pi} \left[-100 \left[\cos t \right]_{\pi/4}^{\pi} \right]$$

$$I_{av} = \frac{-100}{2\pi} \left(-1 - \frac{1}{\sqrt{2}} \right) = \frac{50}{\pi} \times \frac{\sqrt{2}+1}{\sqrt{2}}$$

$$I_{av} = \frac{50}{3.14} \times \frac{2.41}{1.41} = \frac{120.50}{4.4274} = 27.17$$

$$I_{rms}^2 = \frac{(100)^2}{2\pi} \left[\int_{\pi/4}^{\pi} \sin^2 t . dt + 0 \right]$$

$$I_{rms}^2 = \frac{50 \times 100}{\pi} \left[\int_{\pi/4}^{\pi} \frac{1 - \cos 2t}{2} . dt \right]$$

$$= \frac{5000}{\pi \times 2} \left[t - \frac{\sin 2t}{2} \right]_{\pi/4}^{\pi}$$

$$= \frac{5000}{2 \times \pi} \left(\frac{3\pi}{4} - \left(0 - \frac{1}{2} \right) \right)$$

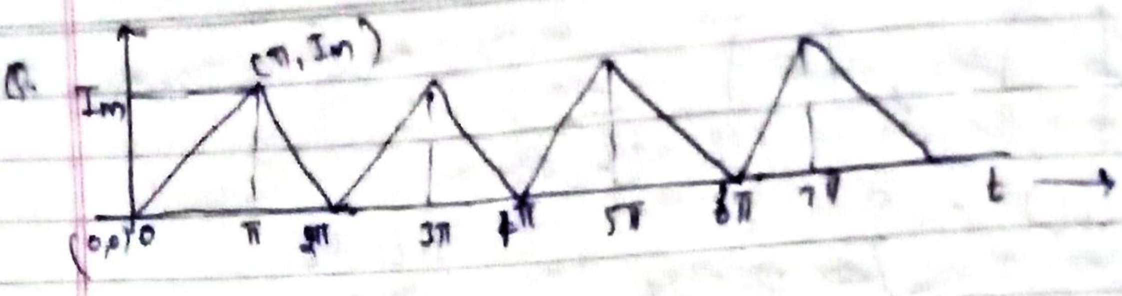
$$I_{rms}^2 = \frac{5000 \times 3}{8} + \frac{5000}{4 \times \pi} = 5000 \left(\frac{3}{8} + \frac{100}{1256} \right)$$

$$5000 \times (0.3$$

$$= \frac{5000 \times 571}{1256} = \frac{2855000}{1256} = 2273.08$$

$$I_{rms} = \sqrt{2273.08} = 47.6$$

Q.



$$I_{av} = \frac{\frac{1}{2} \times \pi \times I_m}{\pi} = \frac{I_m}{2}$$

$$y = mx + c$$

$$i(t) = \frac{y_2 - y_1}{x_2 - x_1} \times t + 0$$

$$i(t) = \frac{I_m}{\pi} \times t$$

$$I_{av.} = \frac{1}{\pi} \int_0^{\pi} \frac{I_m}{\pi} \cdot t \cdot dt$$

$$I_{av.} = \frac{1}{2\pi} \times \frac{I_m}{\pi} \times \frac{\pi^2}{2} = \frac{I_m}{2} \qquad \boxed{I_{av} = \frac{I_m}{2}}$$

$$I_{rms}^2 = \frac{1}{2\pi} \int_0^{2\pi} \frac{I_m^2}{\pi^2} \times t^2 \cdot dt$$

$$\cancel{\frac{1}{\pi} \times \frac{I_m^2}{\pi^2} \times \frac{8\pi^3}{2 \times 3}} = \cancel{\frac{1}{2\pi} \times \frac{I_m^2}{\pi^2} \times \frac{8\pi^3}{3}}$$

$$\cancel{I_{rms} = \frac{I_m}{\sqrt{6}}} = \cancel{0.25 I_m}$$

$$\cancel{I_{rms} = \frac{2}{\sqrt{3}} I_m} \qquad \cancel{\boxed{\frac{2 I_m}{\sqrt{3}} = I_{rms}}}$$

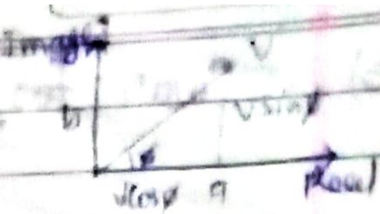
$$\cancel{I_{rms}^2 = \frac{1}{\pi}}$$

$$I_{rms}^2 = \frac{1}{\pi} \int_0^{\pi} \frac{I_m^2}{\pi^2} t^2 \cdot dt$$

$$I_{rms}^2 = \frac{1}{\pi^3} \times I_m^2 \left(\frac{\pi^3}{3}\right) = \frac{I_m^2}{3}$$

$$\boxed{I_{rms} = \frac{I_m}{\sqrt{3}}}$$

Representation of Phasor :—



(i) Regtangular form :—

$\boxed{V = a + jb}$

Magnitude , $v = \sqrt{a^2+b^2}$

phase angle $\emptyset = \tan^{-1}\left(\frac{b}{a}\right)$

(ii) Triangular form :—

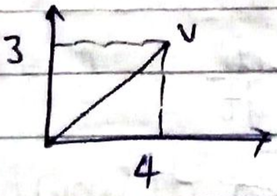
$a = V\cos\emptyset$

$b = V\sin\emptyset$

$$\boxed{V = \underset{\substack{\downarrow \\ \text{magnitude}}}{V}[\cos\emptyset + j\sin\emptyset]}$$

(iii) Polar form :—

$$V = \underset{\substack{\downarrow \\ \text{magnitude}}}{V}\angle\emptyset$$

Q. 

$a = 4$, $b = 3$

magnitude $v = \sqrt{a^2+b^2} = \sqrt{4^2+3^2} = 5$

Rectangular form $\boxed{V = 4 + j3}$

$\emptyset = \tan^{-1}\left(\frac{3}{4}\right) = 37^\circ$ $\cos\emptyset = \frac{4}{5}$, $\sin\emptyset = \frac{3}{5}$

(ii) Triangular form

$V = 5\left[\frac{4}{5} + j\frac{3}{5}\right] = 5[\cos\emptyset + j\sin\emptyset]$

$V = 5[\cos 37^\circ + j\sin 37^\circ]$

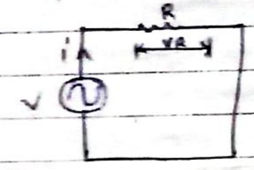
(iii) Polar form

$\boxed{V = 5\angle 37^\circ}$ $V = 5\angle 37^\circ$

$V = 5\tan^{-1}\left(\frac{3}{4}\right)$

Analysis of AC circuit ⟹

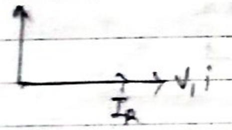
1) Purely Resistance circuit :—

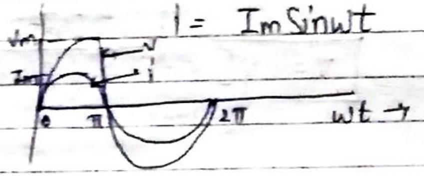


$V = V_m \sin\omega t$

$i = \frac{V}{R} = \frac{V_m \sin\omega t}{R}$

$i = I_m \sin\omega t$

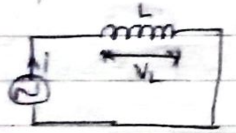




Active power $P = VI\cos\phi$

$\boxed{P = VI}$

(ii) Purely inductive circuit :—

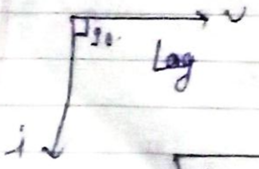


$e = -L\frac{di}{dt}$ $(i = I_m \sin\omega t$

$\boxed{V = -e}$

$e = -L I_m \frac{d(\sin\omega t)}{dt}$

$V = L I_m \omega \cos\omega t = V_m \sin(\omega t + \pi/2)$



$V_m = L I_m \omega = \omega L I_m$

$V_m = X_L I_m$

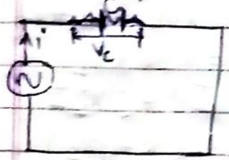
$\boxed{X_L = \frac{V_m}{I_m}}$

$\boxed{X_L = \omega L = 2\pi f L}$

$P = VI\cos\phi = VI\cos 90^\circ$

$\boxed{P = 0}$

(iii) Purely capacitor circuit :—

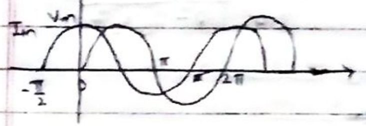


$i = c\frac{dv}{dt}$

where $V = V_m \sin\omega t$

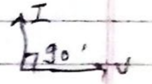
$i = c\frac{d(V_m \sin\omega t)}{dt}$

$i = cV_m\omega\cos\omega t = I_m\cos\omega t = I_m \sin(\omega t + \pi/2)$



$I_m = \omega C V_m$

$\frac{1}{\omega c} = \frac{V_m}{I_m} = X_c$



$\boxed{X_c = \frac{V_m}{I_m}}$ $\boxed{X_c = \frac{1}{C\omega} = \frac{1}{2\pi f c}}$

$\boxed{P = 0}$

Q. $V = 75\sin(200\pi t - 0.25)$ find (i) amplitude and rms value (ii) Time & frequency (iii) Phase angle ϕ

A- (i) 75 , $V_{rms} = \frac{75}{\sqrt{2}}$

(ii) $2\pi f = 200\pi$

$\boxed{f = 100Hz}$

$T = \frac{1}{100}$ ⟹ $\boxed{0.01 sec = T}$

(iii) $0.25 \times \frac{180}{\pi} = \frac{1}{4} \times \frac{180}{\pi} = \frac{45}{\pi} = \frac{4500^\circ}{314}$

$= 14.33^\circ$ Ans

π = 180°

R-L series circuit :—

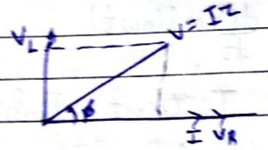
Apply KVL in the loop.

$V = V_R + V_L$

$V = IR + jX_L I$

$V = I(R + jX_L)$

$V = IZ$

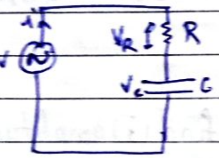


$Z = R + jX_L$

$Z = \sqrt{R^2 + (jX_L)^2}$

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

R-C Series circuit:—



$V = V_R + V_C$

$V = IR - jIX \times \frac{1}{C\omega}$

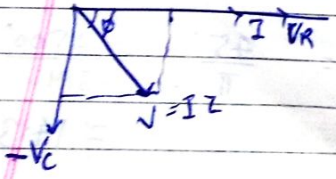
$V = I\left(R - j\frac{1}{C\omega}\right)$

$V = IZ$

$Z = R - j\frac{1}{wC}$

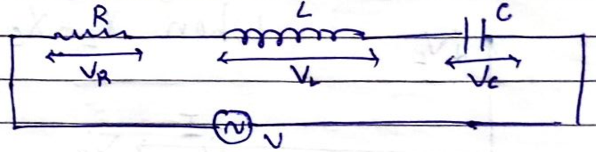
$Z = \sqrt{R^2 + \left(\frac{j}{wC}\right)^2}$

$\phi = \tan^{-1}\left(\frac{1}{wCR}\right)$



$\cos\phi = \frac{V_R}{V}$

Series RLC circuit ⇒



Appling KVL

$V = V_R + V_L + V_C$

$V = IR + jIX_L - jIX_C$

$V = I(R + jX_L - jX_C)$

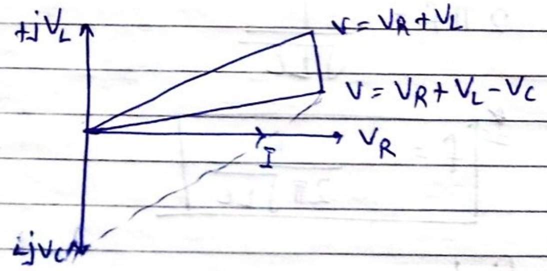
$V = IZ$

$Z = R + jX_L - jX_C$

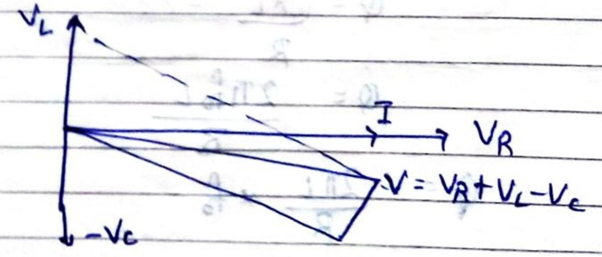
$Z = \sqrt{R^2 + (X_L - X_C)^2}$

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

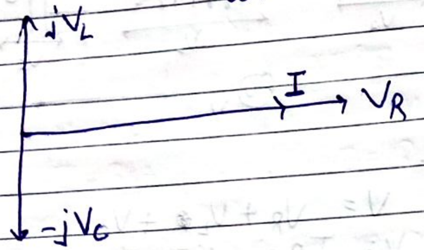
Case - I when $X_L > X_C$



Case - II when $X_C > X_L$



Case - III when $X_L = X_C$



At resonance

$$X_L = X_C$$

$$\omega L = \frac{1}{\omega C}$$

$$\omega^2 = \frac{1}{LC}$$

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

$$2\pi f = \frac{1}{\sqrt{LC}}$$

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

Q factor

$$Q = \frac{X_L}{R}$$

$$Q = \frac{2\pi f_0 L}{R}$$

$$Q = \frac{2\pi L}{R} \times f_0$$

$$Q = \frac{\cancel{2\pi} L}{R} \times \frac{1}{\cancel{2\pi}\sqrt{LC}}$$

$$Q = \frac{1}{R}\sqrt{\frac{L^2}{LC}}$$

$$\boxed{Q = \frac{1}{R}\sqrt{\frac{L}{C}}}$$

DATE : / /

PAGE NO. :

FORMULA

$V_R = IR$, $V_c = jIX_c$, $V_L = jIX_L$, $I = \frac{V\angle 0^\circ}{Z\angle\phi}$,

$X_L = 2\pi fL$, $X_C = \frac{1}{2\pi fC}$, $V = \sqrt{V_R^2 + (V_L - V_C)^2}$

$V_R = \sqrt{V_R^2 + V_C^2}$

$Z = R + jX_L$, $Z = R - jX_C$, $Z = R + j(X_L - X_C)$

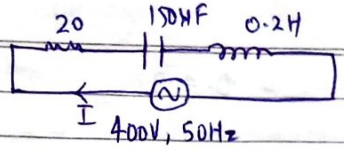
$\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$, $\phi = \tan^{-1}\frac{X_L}{R}$

$\phi = \tan^{-1}\frac{X_C}{R}$, $P = VI\cos\phi$, $Q = VI\sin\phi$

DATE : / /

PAGE NO. :

Q.



Find $Z = ?$, $I = ?$, V_R, V_L, V_C
$\cos\phi$, P & Q

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

~~$Z = \sqrt{(0.2 - 0.00015)^2}$~~

$X_L = 2\pi fL = 2 \times \pi \times 50 \times 0.2 = 20\pi = 62.8$

$X_C = \frac{1}{2\pi fC} = \frac{10^6 \times 10^2}{2 \times 3.14 \times 50 \times 150} = \frac{10^6}{314 \times 0150}$

$X_C = \frac{1000000}{4710} = \frac{100000}{471} = 21.23$

$Z = R + j(X_L - X_C)$

$Z = 20 + j(62.8 - 21.2) = 61.6$

$Z = \sqrt{400 + 1730.56} = \sqrt{2130.56}$

$Z = 46.15$

$\phi = \frac{\tan^{-1}(62.8 - 21.2)}{20} = \frac{61.6}{20} = \tan^{-1}(3.08)$

$\phi = 64.32^\circ = $ ~~$\angle 1.18$~~

$I = \frac{V\angle 0^\circ}{Z\angle\phi} = \frac{400}{46.15 \times \cancel{64.3}\ 1.12} = \frac{400}{59.68}$

$= 7.7$

$I = \frac{400\angle 0^\circ}{46.15\angle 64.3^\circ} = 8.66\angle 64.3^\circ$
$8.66\angle -64.3^\circ$

$V_R = I \times R = $ ~~$173.2\angle 64.3^\circ$~~ $173.2\angle -64.3^\circ$

$V_L = jI \times X_L = (8.66\angle -64.3^\circ)(62.8$

$= 543.8\angle -64.3^\circ = 544\angle 25.6^\circ$

$V_C = I \times X_C = -j(8.66\angle -64.3^\circ)(21.23) = $ ~~$183.8\angle -64.3^\circ$~~

$= 183.8\angle -154.3$

$\cos\phi = \cos(-64.3^\circ) = 0.43$

Real Active

$P = VI\cos\phi$

$P = 400 \times 8.66 \cancel{\angle -64.3} \times 0.43$

$P = 1489.5 \cancel{\angle -64.3^\circ}$ Watt

Reactive

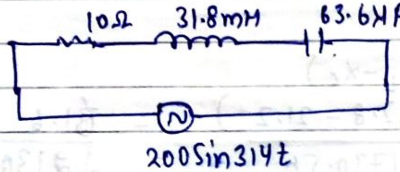
$Q = VI\sin\phi$

$Q = 400 \times 8.66 \cancel{\angle -64.3^\circ} \times (-0.9)$

$Q = -3117.6 \cancel{\angle -64.3^\circ}$ Var

Total power ⓢ Unit = KVA

Q.



$X_L = L\omega = 31.8 \times 10^{-3} \times 314 = 9.98 \simeq 10\Omega$

$X_C = \frac{1}{C\omega} = \frac{10^6}{63.6 \times 314} = 50\Omega$

$Z = \sqrt{(10)^2 + (10-50)^2} = 10\sqrt{17} = 41.23\Omega$

$\phi = \tan^{-1}\left(\frac{-40}{10}\right) = -75.96^\circ = -76^\circ$

$I = \frac{V\angle 0}{Z\angle\phi} = \frac{200}{41.23 \angle -76^\circ}$

$I = 4.85 \angle 76^\circ$ Amp

$\cos\phi = \cos(76^\circ) = 0.24$

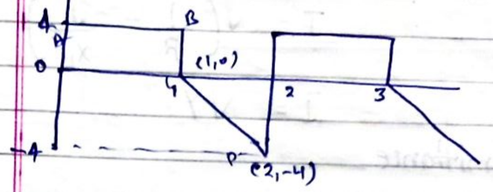
$P = VI\cos\phi = 200 \times 4.85 \times 0.24$

$P = 234.66$ watt

$Q = VI\sin\phi = 200 \times 4.85 \times 0.97$

$= 941.19$ VAR

Q.



y = v   x = t

AB → v = 4

CD → $v - 0 = \frac{-4-0}{2-1}(t-1)$

$v = -4t + 4$

$V_{avg.} = \frac{1}{2}\left[\int_0^1 4.dt + \int_1^2 (-4t+4).dt\right] = \frac{1}{2}\left[(4t)_0^1 + (-2t^2+4t)_1^2\right]$

$V_{avg.} = \frac{1}{2}\left[(4-0) + (-8+8) + (-4+2)\right] = 1$ volt

$V_{rms}^2 = \frac{1}{2}\left[16\int_0^1 dt + 16\int_1^2 (t^2+1-2t).dt\right]$

$V_{rms}^2 = 8\left[[t]_0^1 + \left[\frac{t^3}{3} + t - t^2\right]_1^2\right]$

$V_{rms}^2 = 8\left[(1-0) + \left(\frac{8}{3} + 2 - 4\right) - \left(\frac{1}{3} + 1 - 1\right)\right]$

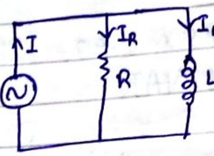
$V_{rms}^2 = 8\left[1 + \frac{8}{3} - 2 - \frac{1}{3}\right]$

$V_{rms}^2 = \frac{32}{3}$ Volt

$V_{rms} = \sqrt{10.67}$

$\boxed{V_{rms} = 3.2 \text{ Volt}}$

Parallel RL circuit :→



Apply KCL

$I = I_R + I_L$

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

$I = V\left(\frac{1}{R} - \frac{j}{X_L}\right)$

$I = VY$

where Y is admittance

$Z = \frac{1}{Y}$ impedence

$Y = \frac{1}{R} - \frac{j}{X_L}$

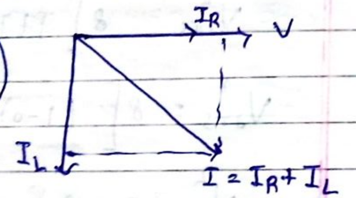
$\boxed{Y = \underbrace{G}_{\text{Conductance}} + j\underbrace{B}_{}}$ → Susceptance

Conductance

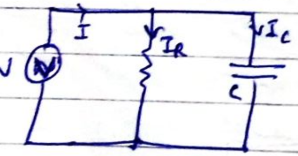
$G = \frac{1}{R}$

$B = \frac{-1}{\omega L}$

$\phi = \tan^{-1}\left(\frac{B}{G}\right)$



Parallel RC circuit :→



$I = I_R - I_C$

$I = \frac{V}{R} - \frac{\phi V}{jX_C}$

$I = \frac{V}{R} + j\frac{V}{X_C}$

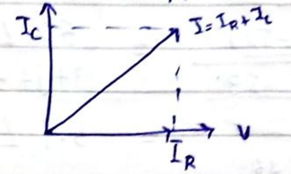
$I = V\left(\frac{1}{R} + \frac{j}{X_C}\right)$

$I = VY$

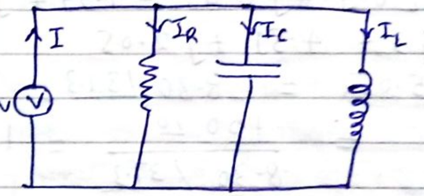
$Y = \frac{1}{R} + \frac{j}{X_C}$

$Y = \frac{1}{R} + jC\omega = G + jB$

$\phi = \tan^{-1}\left(\frac{B}{G}\right)$



Parallel RLC circuit :→



Apply KCL

$I = I_R - I_C + I_L$

$I = \frac{V}{R} - \frac{V}{jX_C} + \frac{V}{jX_L}$

$I = V\left(\frac{1}{R} + \frac{j}{X_C} - \frac{j}{X_L}\right)$

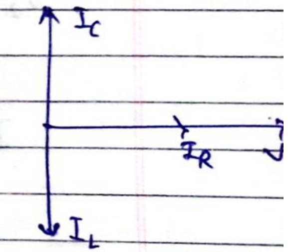
$I = V\left(\frac{1}{R} + j\omega C - \frac{j}{\omega L}\right)$

$I = VY$

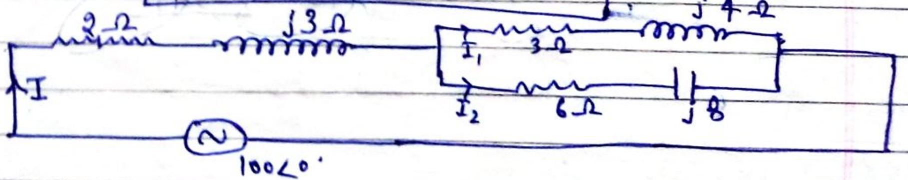
$Y = \frac{1}{R} + j\omega C - \frac{j}{\omega L}$

$Y = G + j(Y_C - Y_L)$

$\boxed{\phi = \tan^{-1}\left(\frac{Y_C - Y_L}{G}\right)}$



Q.



Calculate ⓘ V_1 & V_2 (ii) I_1 & I_2

DATE : / /
PAGE NO. :

Ay - $v_1 = IZ_1$ $\quad I = \frac{V\angle 0°}{Z\angle\theta}$, $Z_{23} = \frac{Z_2 \times Z_3}{Z_2 + Z_3}$

$Z_1 = 2 + j3 = 3.6 \angle 56.3°$

$Z_2 = 3 + j4 = 5 \angle 53.1°$

$Z_3 = 6 - j8 = 10 \angle -53.1°$

$Z_{23} = \frac{5\angle 53.1° \times 10\angle -53.1°}{5\angle 53° + 10\angle -53°} = \frac{50\angle 0°}{3+j4+6-j8}$

$Z_{23} = \frac{50\angle 0°}{9-j4} = \frac{50\angle 0°}{9.84\angle -23.96} = 5.1 \angle 23.9°$

$Z_{23} = 5.1\angle 24° = 5.1\,[\cos 24° + j\sin 24°]$

$Z_{23} = 5.1\,[0.9 + j0.4] = 4.59 + j2.05$

$Z = Z_1 + Z_{23} = 2 + j3 + 4.59 + j2.05$

$Z = 6.59 + j5.05 = 8.30\angle 37.3$

$I = \frac{V\angle 0°}{Z\angle\theta} = \frac{100\angle 0°}{8.30\angle 37.3} = 12\angle -37.3°$

$v_1 = IZ_1 = 12\angle -37.3° \times 3.6\angle 56.3$

$v_1 = 43.2\angle 19$

$v_2 = IZ_2 = 12\angle -37.3° \times 5.1\angle 23.9$

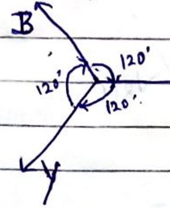
$v_2 = 61.2\angle -13.4$

$I_1 = \frac{v_2}{Z_2} = \cancel{43.2\angle 19}\ \frac{61.2\angle -13.4}{5\angle 53.1} = 12.2\angle 66.5$

$I_2 = \frac{v_2}{Z_3} = \frac{61.2\angle -13.4}{10\angle -53.1} = 6.12\angle 39.7$

DATE : / /
PAGE NO. :

Generation of 3 phase EMF :-



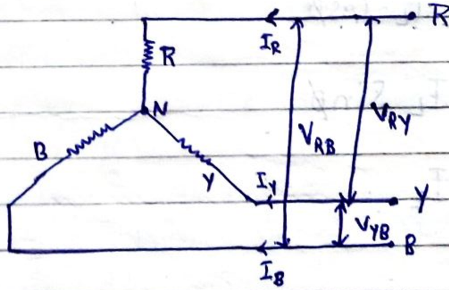
$e_R = E_m \sin\omega t$

$e_Y = E_m \sin(\omega t - 120°)$

$e_B = E_m \sin(\omega t - 240°)$

* **Phase sequence :-** It is the order in which the voltages in the 3 phase attains their maximum +ve value.

* **Star connection :-** In star connection the similar ends either start or finish of 3 widings are connected to a comman point called "nutrual point". And the 3 line conductors are run from the remaining three terminals called line conductor. The current flowing in through each phase is called phase current I_P. and the current flowing through each conductor is called line current I_L.

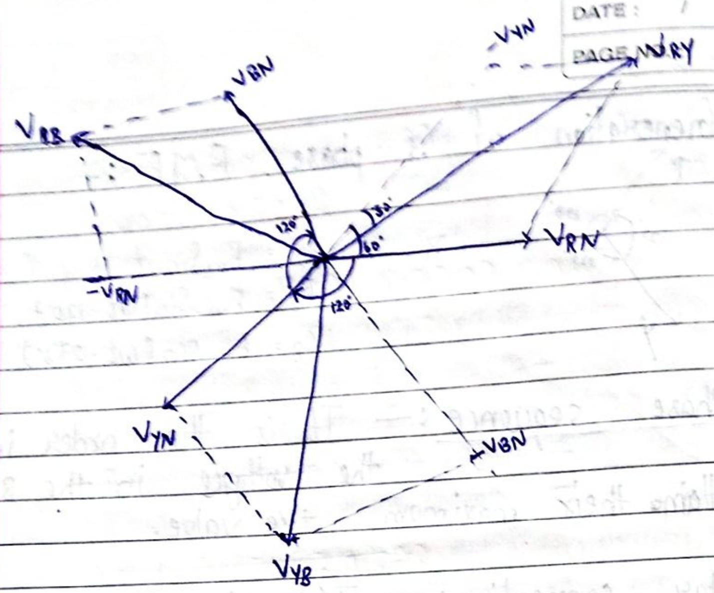


$I_{RN} = I_{BN} = I_{YN} = I_P$

$I_R = I_B = I_Y = I_L$

$V_{RN} = V_{BN} = V_{YN} = V_P$

$V_{RY} = V_{YB} = V_{RB} = V_L$



$V_{RY} = V_{RN} - V_{YN}$

$V_{RY}^2 = |V_{RN}|^2 + |V_{YN}|^2 + 2|V_{RN}||-V_{YN}|\cos 60^\circ$

$V_L^2 = V_p^2 + V_p^2 + 2V_p^2 \times \frac{1}{2}$

$V_L^2 = 3V_p^2$

$\boxed{V_L = \sqrt{3}V_p}$ $\boxed{I_L = I_p}$

$P = 3V_p I_p \cos\phi$

$P = \sqrt{3} \times \sqrt{3}V_p I_p \cos\phi$

$P = \sqrt{3} V_L I_L \cos\phi$.

$Q = \sqrt{3} V_L I_L \sin\phi$.

$S = \sqrt{3} V_L I_L$

Q. A 3 phase star connected generator have a terminal voltage of ~~415~~ 415 volt & deliver a full load current of 200 Amp at 0.8 power fector laging. find
(i) Voltage per phase (ii) ful load current per phase
(iii) KVA rating (iv) Real power deliver
(V) load impedance (प्रतिबाधा)(Ω)

Ans (i) ~~$V_p = 415$ Volt~~ (ii) $I_L = I_p = 200$ Amp

$V_p = \frac{415}{\sqrt{3}}$ = ~~244.11~~ ~~240~~ 239.6

(iii) $S = \sqrt{3} V_L I_L = \sqrt{3} \times 415 \times 200 = 143580$
143.580 kV

(iv) $P = \sqrt{3} \times 415 \times 200 \times 0.8$ = ~~112880~~
115.08 kV

(V) $Z = \frac{1}{Y} = \frac{V_p}{I_p\angle\phi} = \frac{239.6}{200\angle -36.8^\circ}$ = ~~12.0~~

$\cos^{-1}(0.8)$ (Lagging) $= -36.8^\circ$

$Z = 1.19 \angle +36.8^\circ$

Q. A balanced star connected load of 8+j6 ohm per phase is connected to a 3 phase 400 volt supply find the line currents, power vector, real power deliver and KVA rating?

Ans - $I_p = \frac{400}{\sqrt{3} \times 10} = \frac{40A}{\sqrt{3}\angle 36.8} = 23.09\angle 36.8^\circ$ $Z = \sqrt{64+36} = 10$ $V_p = 230.9$ Volt

$V_L = 400$

$\phi = \tan^{-1}(\frac{3}{4}) = 36.8^\circ$

$P = \sqrt{3} V_p I_L \cos\phi$

$P = \sqrt{3} \times 400 \times 23.09 \times \frac{4}{5}$

power ~~vector~~ factor

$\phi = 36.8^\circ$

$\cos\phi = 0.8$

$I_p = 23.09 \angle -36.8^\circ$

$V_p = 230.9$

real power $P = \sqrt{3} \times 400 \times 23.09 \times 0.8$

$P = 12797.77$ Watt

$P = 12.79$ KWatt

$\cancel{Q = \sqrt{3} \times 400 \times 23.09 \times \frac{3}{5}}$

$\cancel{Q = -9.59 \text{ KVAR}}$

$\cancel{Z = \frac{V}{I\angle 36.8^\circ} = \frac{230.9}{23.09\angle 36.8^\circ} = 10\angle -36.8^\circ}$

$S = \sqrt{3} \times 400 \times 23.09 = 16.08$ KVA

$V_R = 230.9 \angle 0^\circ$

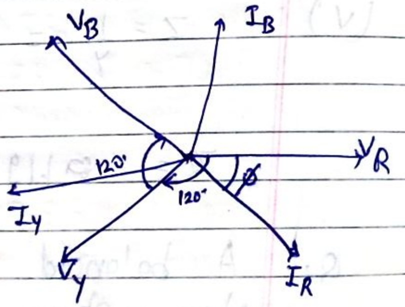
$V_Y = 230.9 \angle -120^\circ$

$V_B = 230.9 \angle -240^\circ$

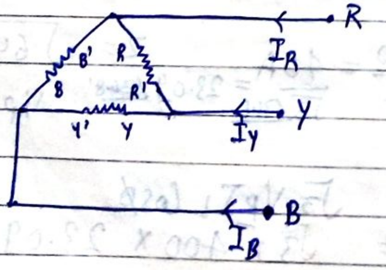
$I_R = 23.1 \angle 36.86^\circ$

$I_Y = 23.1 \angle -156.86^\circ$

$I_B = 23.1 \angle -276.86^\circ$

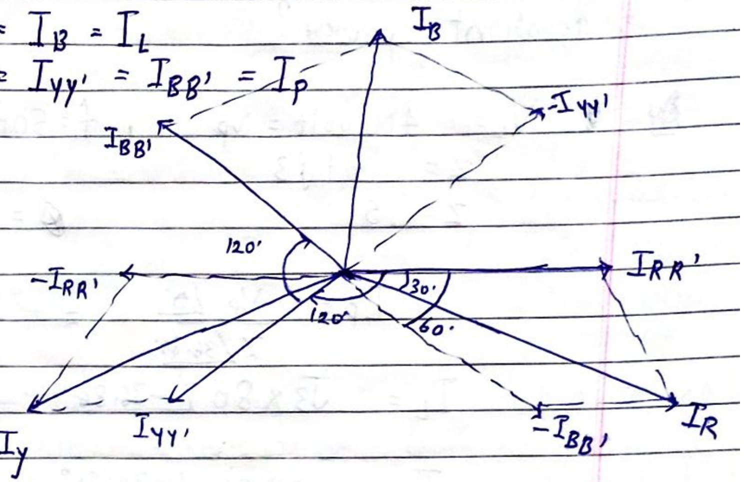


Delta connection :



$I_R = I_Y = I_B = I_L$

$I_{RR'} = I_{YY'} = I_{BB'} = I_p$



$I_R = I_{RR'} - I_{BB'}$

$|I_R|^2 = |I_{RR'}|^2 + |I_{BB'}|^2 + 2|I_{RR'}||-I_{BB'}|\cos 60^\circ$

$I_L^2 = I_p^2 + I_p^2 + 2 \times \frac{1}{2} \times I_p^2$

$I_L^2 = 3I_p^2$

$\boxed{I_L = \sqrt{3} I_p}$

$\boxed{V_L = V_p}$

Power :-

$P = 3V_p I_p \cos\theta = \sqrt{3} \times \sqrt{3} I_p V_p \cos\theta$

$P = \sqrt{3} I_L V_L \cos\theta$

$\boxed{P = \sqrt{3} V_L I_L \cos\theta}$

$\boxed{S = \sqrt{3} V_L I_L}$

$\boxed{Q = \sqrt{3} V_L I_L \sin\theta}$

Q. 3 Coil of equal impedences of $4+j3\,\Omega$ are connected in Delta across 400 Volt, 50Hz Supply. Find the phase current of each coil, Line current, active, reactive &

apparant power ?

Ay- $V_L = 400\text{ volt} = V_p$, $f = 50Hz$

$Z = 4 + j3$ $\qquad \phi = \tan^{-1}\left(\frac{3}{4}\right) = 36.86°$

$Z = 5$

$$I_p = \frac{V_p \angle 0^\circ}{Z \angle 36.86'} = \frac{400}{5 \angle 36.86'} = 80 \angle -36.86°$$

$$I_L = \sqrt{3} \times 80 \angle -36.86°$$

$$I_L = 138.56 \angle -36.86°$$

$$P = \sqrt{3}\, V_L I_L \cos\theta$$

$$P = \sqrt{3} \times 400 \times 138.56 \times 0.8$$

$$P = 76.81 \text{ KWatt}$$

$$Q = \sqrt{3} \times 400 \times 138.56 \times \sin(-36.86°)$$

$$Q = -\sqrt{3} \times 400 \times 138.56 \times 0.59$$

$$Q = -57.60 \text{ KVAR}$$

$$S = \sqrt{3} \times 400 \times 138.56$$

$$S = 96 \text{ KVA}$$

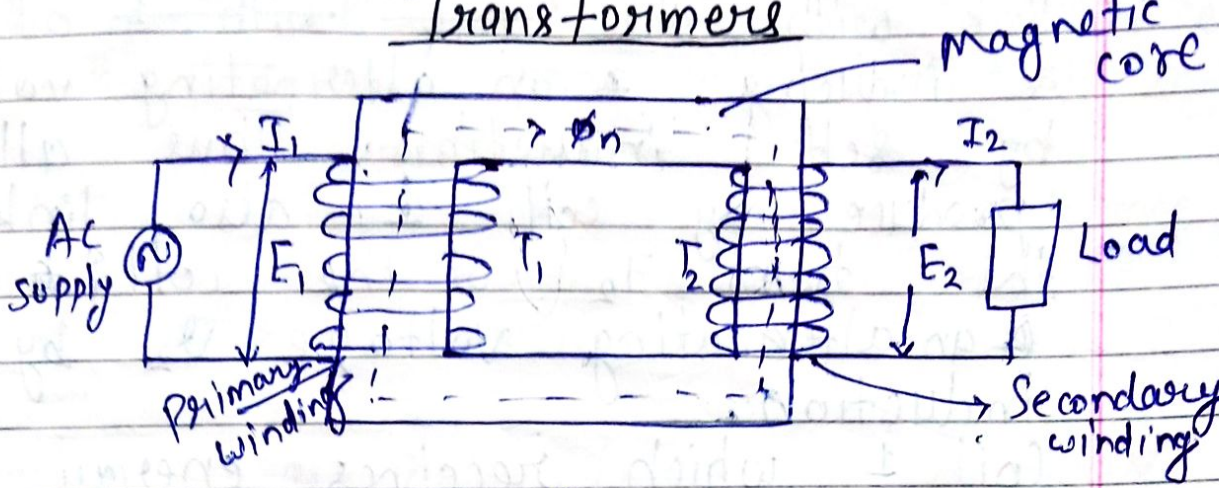
$$I_{RR'} = 80 \angle -36.86°$$

$$I_{YY'} = 80 \angle -156.86°$$

$$I_{BB'} = 80 \angle -276.86°$$

27/2

Transformers



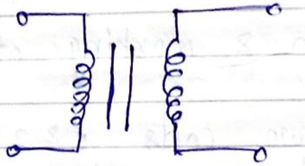
Transformer ⇒ A transformer is a statics device which consists of ~~tovo~~ two or more stationary electric circuit interlinked by a comman magnetic circuit for the purpose of transferring electric energy b/w them. The transfer of energy from one circuit to another takesplace without a change in the frequency.

Construction & working of transformer ⇒

Consider two coils 1 & 2 wound (घुमाया हुआ) ~~oven~~ on a simple magnetic circuit as shown in the figure about. These two coils are insulated (आवरणयुक्त) from each other and there is no electrical connection b/w them. Let T_1 & T_2 be the no. of turn in coils 1 & 2. Now when a source of alternating voltage V_1 is applied to the coil 1 and alternating current I_1 flows in it. This alternating current producing and alternating flux ϕ_n in the magnetic circuit This alternating flux

turn ~~turn~~ ~~with~~ 1 of coil 1
link with the & inducing ~~a~~ an alternating voltage v_1 by self induction. Thus all the flux produce by coil 1 also links with the turn T_2 of the coll 2 and induces ~~a~~ an alternating voltage v_2 by mutual induction.

Coil 1 which receives energy from the source of AC supply is called the "primary widing" or simply the primary. Coil 2 which is connected to the load and deliver energy to the load is called the "secondary widing" or simply the secondary. Thus electric energy is transfer from coil 1 to 2 by a comman magnetic circuit.



Ideal transformer ⟹

An Ideal transformer is an imaginary transformer which has the ~~flo~~ following properties :-

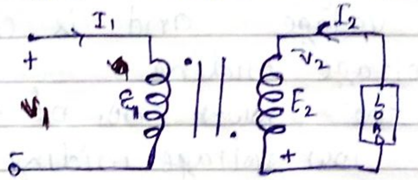
1) Its primary widing & secondary widing resistances are negligible.

2) The core has infinite permiability. (पारगम्यता)

3) Its leakage flux and leakage inductance are zero. So the entire flux is confind to the core and links with both the widings.

4) Their are no losses due to resistance, ~~histo~~ Hysteresis and eddy currents. So the efficiency is 100%.

Note- Practical Transformer has non of these properties inpite of fact that its operation is closed to the ideal transformer.



★★ EMF Equation of transformer ⟹

Let at any instant, the flux ϕ is.

$$\phi = \phi_m \sin\omega t$$

The instantaneous emf is

$$e = -T\frac{d\phi}{dt}$$

$$e = -T\frac{d(\phi_m \sin\omega t)}{dt} = -T\phi_m\omega \cos\omega t$$

$$e = T\phi_m\omega \sin(\omega t - \frac{\pi}{2})$$

$$e = E_m \sin(\omega t - \frac{\pi}{2})$$

For Sin wave $E_{rms} = \frac{E_m}{\sqrt{2}} = \frac{T\phi_m\omega}{\sqrt{2}}$

$$E_{rms} = \frac{T\phi_m \times 2\pi f}{\sqrt{2}}$$

~~E~~ $\boxed{E = 4.44\, T \phi_m f}$

$E_1 = 4.44\, T_1 \phi_m f$

$E_2 = 4.44\, \phi_m f\, T_2$

$B_m = \frac{\phi_m}{A}$

$\boxed{\frac{E}{f} = 4.44\, \phi_m T = \text{Constant}}$

Note:- The widing with higher no. of turns will have a high voltage and is called "the high voltage widing".
The widing with the lower no. of turns is called the low voltage widing.

Stepup transformer :- A transformer in which the output voltage is greater than its input voltage is called a "stepup transformer".

Stepdown transformer :- A transformer in which the output voltage is less than its input voltage is called a "stepdown transformer."

Note:- A transformer may receive energy at 1 voltage and deliver it at the same voltage such a transformer is called **one to one transformer**.
For a one to one transformer

$\boxed{E_1 = E_2}$ & $\boxed{T_1 = T_2}$

Voltage ratio & Turns ratio :-

$E_1 = 4.44\, \phi_m f\, T_1$

$E_2 = 4.44\, \phi_m f\, T_2$

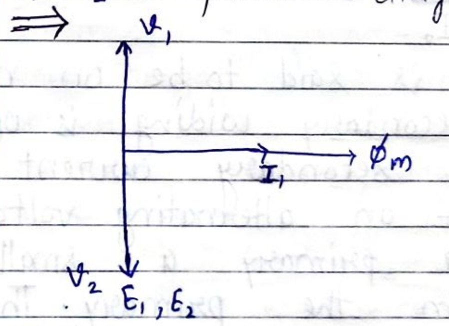
$\boxed{\frac{E_1}{E_2} = \frac{T_1}{T_2} = a = \text{Transformation ratio}}$

$mmf = I_1 T_1 = I_2 T_2$

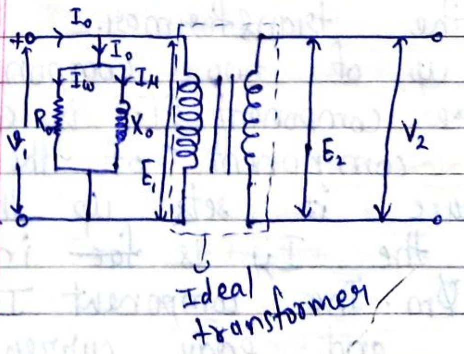
$\frac{I_1}{I_2} = \frac{T_2}{T_1}$

$\boxed{\frac{E_1}{E_2} = \frac{T_1}{T_2} = \frac{I_2}{I_1}}$

No-Load phasor diagram of Ideal transformer ⟹



Transformer on NO-Load ⟹



So form the equivalent ckt (circuit),

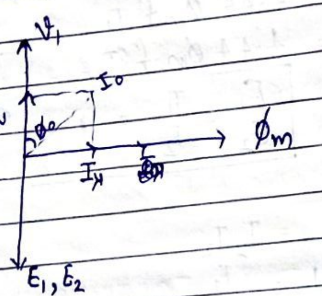
$V_1 = R_0 I_w$

$V_1 = R_0 I_M$

$\boxed{I_0 = I_M + I_w}$

DATE : / /
PAGE NO. :

where Io is the no-load current
I_μ = Reactive compainent of the no load current
I_w = Active component of the no load current



$$I_w = I_0 \cancel{\sin}\,\phi_0$$
$$I_\mu = I_0 \sin\phi_0$$

$$I_0 = I_w + I_\mu$$
$$I_0 = \sqrt{I_w^2 + I_\mu^2}$$

$P = V_1 I_0 \cos\phi$ (active power)
$Q = V_1 I_0 \sin\phi$ (Reactive power)

$$\cos\phi_0 = \frac{I_w}{I_0}$$

A transformer is said to be on no-load when the secondary widing is open circuited. So the secondary current become zero. When ~~In~~ an alternating voltage V_1 is applied to the primary a small current I_0 flows in the primary. This current I_0 is called the no-load current of the transformer.
It is made up of two componants I_μ & I_w. The component I_μ is called the reactive component of the no-load current because it sets up the flux in core. So the I_μ is ~~fac~~ in the face with ϕ_m. The component I_w supply the hysteresis and eddy current losses

DATE : / /
PAGE NO. :

in the core and known as active component ~~of~~ of the no-load current. It is in faces ~~with~~ with the applied ~~to~~ voltage V_1.

For a no-load transformer E_1 & E_2 are induced by the same flux by so they will be in face with each other and lags behind ϕ by 90°. According to Lenz Law E_1 is equal & opposite to V_1. I_μ is in face with ϕ_m and I_w is in face with V_1. The Phaser sum of I_μ & I_w is I_0. $\cos\phi_0$ is the power factor on no load and ~~to~~ ϕ_0 is the phase angle on no load.

Q. Find the active & reactive component of no load current and no-load current of a 440/220 volt ~~watt~~ singal phase transformer. is the input power to the high voltage widing is 80 W. The low voltage widing is cap open & power factor of the no-load current is 0.3 Laging

Ay –
$P_0 = V_1 I_0 \cos\phi$
$\cos\phi_0 = 0.3$, $V_1 = 440V$

$$\frac{^{2}\cancel{440}}{22\cancel{0}} = 80 \times I_0 \times 0.3$$

$$\frac{\cancel{2 \times 10}}{\cancel{80 \times 3}} = \frac{\cancel{2}}{\cancel{24}} = I_0 \Rightarrow \cancel{I_0 = \frac{1}{12} = 0.083A}$$

$$\cancel{I_w = I_0 \cos\phi = 0.083 \times 0.3 = 0.249}$$

$P_0 = V_1 I_0 \cos\phi$
$80 = 440 \times I_0 \times 0.3$

$$I_0 = \frac{8 \times 10}{44 \times 3} = \frac{80}{132} = \frac{20}{33} = 0.60$$

$$\boxed{I_0 = 0.60A}$$

$I_w = I_0 \cos\phi = 0.60 \times 0.3 = 0.18A$ $\boxed{I_w = 0.18A}$

$\sqrt{(I_0)^2 - (I_w)^2} = I_\mu$

$\sqrt{0.36 - 0.032} = I_\mu$

$\cancel{I_\mu = 0.2}$

$\sqrt{0.328}$

$\boxed{I_\mu \doteq 0.578A}$

$$\begin{array}{r} 0.360 \\ 0.032 \\ \hline 0.328 \end{array}$$

Equivalent circuit of a transformer :-

Referred value ⇒

$R_2 \rightarrow R_2'$

$I_2^{2'} R_2' = I_2^2 R_2$

$R_2' = \frac{I_2^2}{I_2^{2'}} R_2 = \left(\frac{I_2}{I_2'}\right)^2 R_2$

$R_2' = \left(\frac{I_1}{I_2}\right)^2 R_2$

$\boxed{R_2' = a^2 R_2}$

$\boxed{X_2' = a^2 X_2}$

$\boxed{Z_2' = a^2 Z_2}$

Let Re_1, Xe_1 and Ze_1 be the effective resistance reactance & Impedence of the whole transformer referred to the primary

$Re_1 = R_1 + R_2'$

$\boxed{Re_1 = R_1 + a^2 R_2}$ —①

$\boxed{Xe_1 = X_1 + a^2 X_2}$

$Ze_1 = Z_1 + Z_2'$

$\boxed{Ze_1 = Z_1 + a^2 Z_2}$

$Ze_1 = \sqrt{Re_1^2 + Xe_1^2} = Re_1 + jXe_1$

Equivalent values referred to the secondary ⇒

Let Re_2, Xe_2 & Ze_2 be the effective resistance reactance & impedence of the whole transformer referred to the secondary.

$\left\{ \begin{array}{l} I_1^2 R_1 = I_1^{2'} R_1' \\ R_1' = \left(\frac{I_2}{I_1}\right)^2 R_1 = \frac{R_1}{a^2} \end{array} \right\}$

$Re_2 = R_2 + R_1'$

$\boxed{Re_2 = R_2 + \frac{R_1}{a^2}}$ —②

$\boxed{Xe_2 = X_2 + \frac{X_1}{a^2}}$

$\boxed{Ze_2 = Z_2 + \frac{Z_1}{a^2}}$

$Ze_2 = Re_2 + jXe_2$

$Ze_2 = \sqrt{Re_2^2 + Xe_2^2}$

from eq^n–①

$Re_1 = R_1 + R_2 \left(\frac{I_2}{I_1}\right)^2$

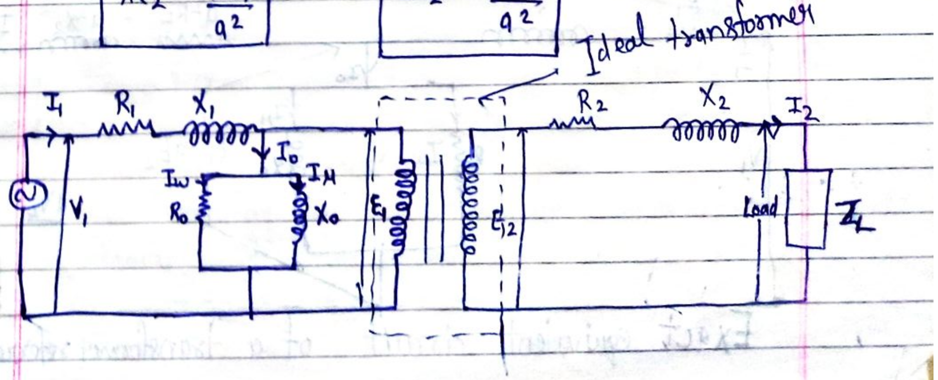
$Re_1 \left(\frac{I_2}{I_1}\right)^2 = R_1 \left(\frac{I_2}{I_1}\right)^2 + R_2$

from eq^n–②

$\boxed{\frac{Re_1}{a^2} = Re_2}$

$\boxed{Xe_2 = \frac{Xe_1}{a^2}}$

$\boxed{Ze_2 = \frac{Ze_1}{a^2}}$

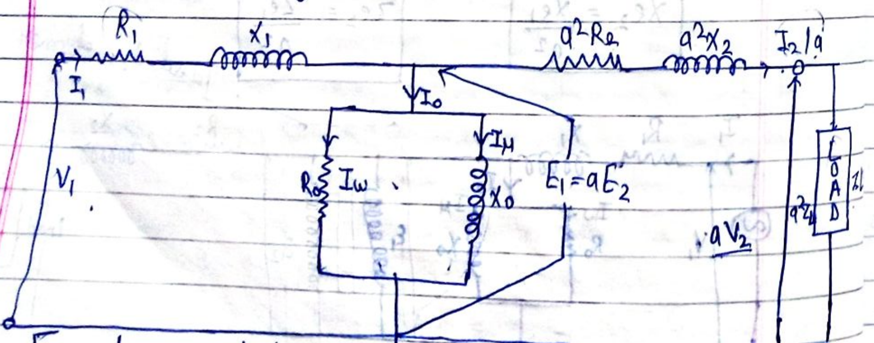


The about figure shows the complete equivalent circuit of a transformer and exact equivalent circuit referred to the primary can be ~~re~~ deduced as follows :—

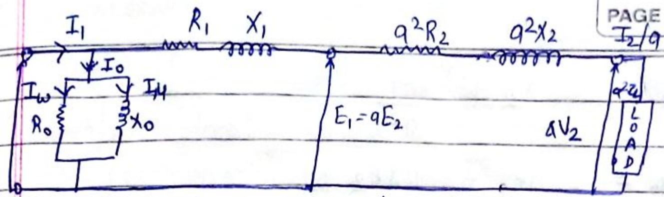
(i) All secondary resistances, reactances & impedances are reflected to the primary as a multiple of the square of the transformation ratio. i.e. R_2, X_2 & Z_L in the secondary becomes a^2R_2, a^2X_2 & a^2Z_L, and then referred to the primary.

2.) All voltages are reflected from seconda to primary directly as the product of the transformation ratio that is V_2 & E_2 in the secondary becomes aV_2 & aE_2 when referred to the primary.

3.) All the secondary currents are reflected to the primary as inversely of the transformation ratio. i.e. I_2 in the secondary becomes I_2/a when referred to primary.



Exact equivalent circuit of a transformer referral to prim



Approximate equivalent circuit of a transformer referral to primary

This approximation gives the following advantages :—

1.) The primary & secondary impedances reflected to the primary can be added easily.

2.) The calculations for voltage regulation of the transformer become easier.

The following result are obtain from the approximate equivalent circuit.

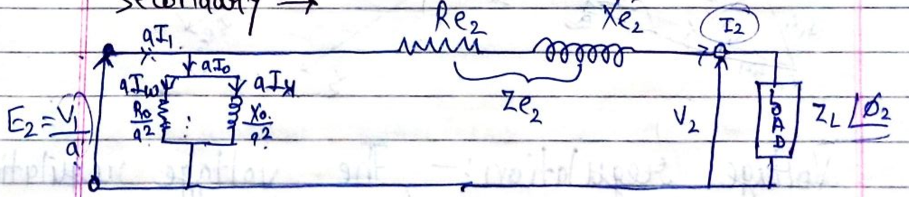
(i) $Re_1 = R_1 + a^2R_2$

$Xe_1 = X_1 + a^2X_2$

$Ze_1 = Re_1 + jXe_1$

$I_1 = \dfrac{V_1}{Ze_1 + a^2Z_L}$ where Z_L is the load impedance.

Approximate equivalent circuit referred to the secondary ⇒



The following results are obtain from this circuit

1.) $Re_2 = R_2 + \dfrac{R_1}{a^2}$

$$X_{e_2} = X_2 + \frac{X_1}{a^2}$$

$$Z_{e_2} = R_{e_2} + jX_{e_2}$$

$$I_2 = \frac{V_2}{Z_L}$$

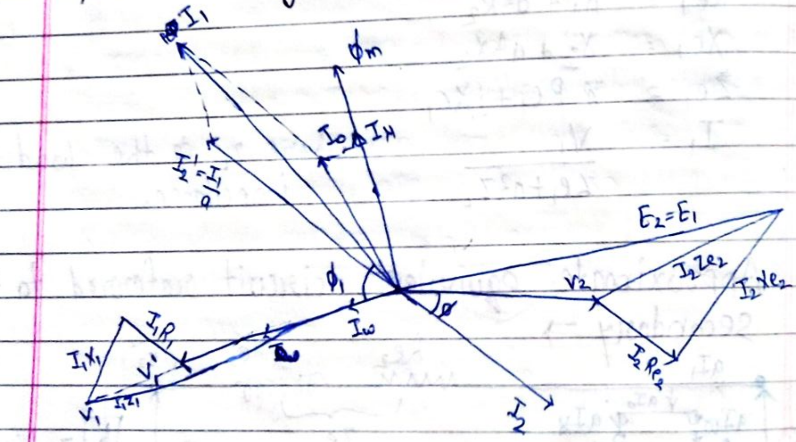
$$I_2 = \frac{E_2}{Z_{e_2} + Z_L}$$

$$E_2 = \frac{V_1}{a}$$

$$E_2 = I_2 Z_{e_2} + I_2 Z_L$$

$$\boxed{\frac{V_1}{a} = E_2 = V_2 + I_2 Z_{e_2}}$$

Phasor Diagram ⇒



Voltage regulation :- The voltage regulation of a transformer is defined as the ~~ea~~ arthmetical difference in the secondary terminal voltage b/w no load & full rated load. ~~As~~ At a given power factor with a same

value of primary voltage for both no load & rated load. It is expressed as either ~~a~~ per unit or a percentage of the rated load voltage.

Per-unit voltage regulation at full load

$$= \left| \frac{|V_{2nl}| - |V_{2fl}|}{|V_{2fl}|} \right|_{|V_1| = \text{constant}}$$

Percentage voltage regulation at full load

$$= \left| \frac{|V_{2nl}| - |V_{2fl}|}{|V_{2fl}|} \right| \times 100 \quad |V_1| = \text{constant}$$

Where V_{2nl} is the no load secondary terminal voltage & V_{2fl} is the rated secondary terminal voltage.

Voltage regulation in terms of primary

$$V_{2nl} = \frac{V_1}{a}$$

$$= \frac{\left|\frac{V_1}{a}\right| - |V_{2fl}|}{|V_{2fl}|}$$

Transformer efficiency ⇒ The ratio of the output power to the input power in a transformer is known as transformer efficiency.

$$\eta = \frac{\text{Output Power}}{\text{Input Power}} \quad \text{(per unit)}$$

$$\eta = \frac{\text{Output power}}{\text{Output power + Losses}}$$

$$\eta = \frac{V_2 I_2 \cos\phi_2}{V_2 I_2 \cos\phi_2 + \text{Cu loss} + \text{iron loss}}$$

$$\eta = \frac{V_2 I_2 \cos\phi_2}{V_2 I_2 \cos\phi_2 + I_2^2 R_{e_2} + P_i}$$ (per unit)

Losses in transformer ⟹ The losses which occur in a transformation are

1.) Iron loss or core loss (P_i)
2.) Cupper loss or I^2R loss (P_c)

(1.) Iron loss :— Iron loss occurs in the magnet core of the transformer. This loss is the sum of hysteresis loss P_h & eddy current loss P_e so

$$\boxed{P_i = P_h + P_e}$$

where $P_h = k_h f B_m^x$
$P_e = k_e f^2 B_m^2$

k_h = Constant of proposnality which depend upon the volume and quality of the core material.
k_e = Constant of proposatiality which depends upon the volume & resistiv of the core material.
B_m = max. flux density in the core.

f is the frequency of the alternating flux. and the exponant 'x' is called 'Steinmetz constant'. It value varies from 1.5 to 2.5 depending upon the magnetic properties of the core material.
So the total core loss can be written as $P_i = P_h + P_e$

$$\boxed{P_i = k_h f B_m^x + k_e f^2 B_m^2}$$

$V_1 = E_1 = 4.44\, \phi_m f T_1$
$V_1 = E_1 = 4.44\, B_m A_i f T_1$

$$B_m = \frac{V_1}{4.44 A_i f T_1}$$

$P_h = k_h f B_m^x$

$$P_h = k_h f \frac{V_1^x}{(4.44 A_i f T_1)^x}$$

$$P_h = \frac{k_h V_1^x}{4.44 A_i^x T_1^x} \frac{f}{f^x}$$ $$K_h = k_h \left(\frac{1}{4.44 A_i T_1}\right)^x$$

$$\boxed{P_h = K_h V_1^x f^{1-x}}$$

This relation shows that the hysteresis loss depends upon both the applied voltage and frequency
Similarly

$$P_e = k_e f^2 \frac{V_1^2}{(4.44 A_i f T_1)^2}$$

$$P_e = \frac{k_e V_1^2}{(4.44 A_i T_1)^2} \frac{f^2}{f^2}$$ $$\left\{ K_e = \frac{k_e}{(4.44 A_i T_1)^2} \right\}$$

$$\boxed{P_e = K_e V_1^2}$$

This relation shows that the eddy current loss depends on the square of the applied voltage and independent to frequency.

The total core loss is

$$\boxed{P_i = K_h V^{x} f^{1-x} + K_e V^2}$$

2.1 Copper loss ⟹ Copper loss is the I^2R loss which takes place in the primary and secondary windings because of the winding resistances.

Total copper loss in a transformer

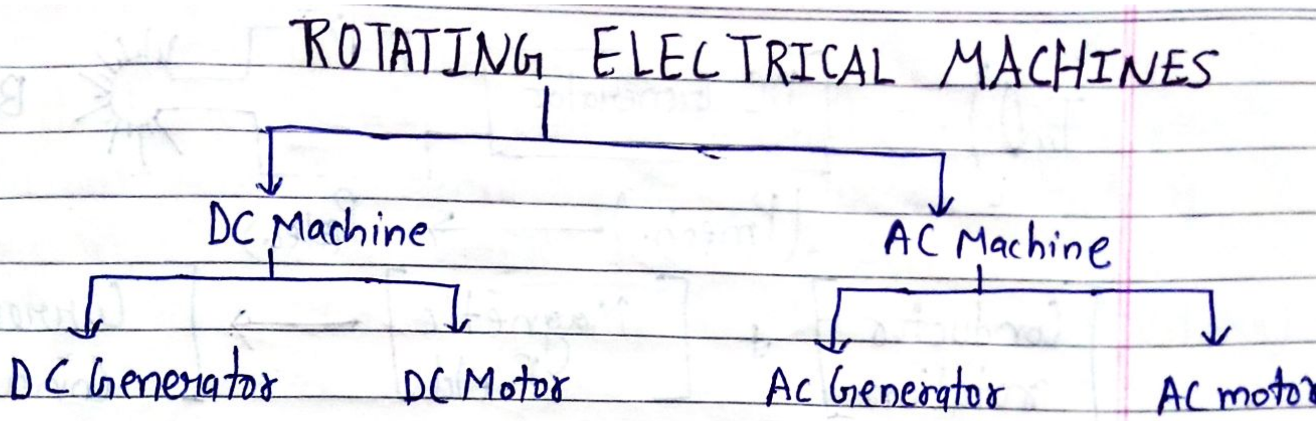
= primary winding copper loss + secondary winding copper loss

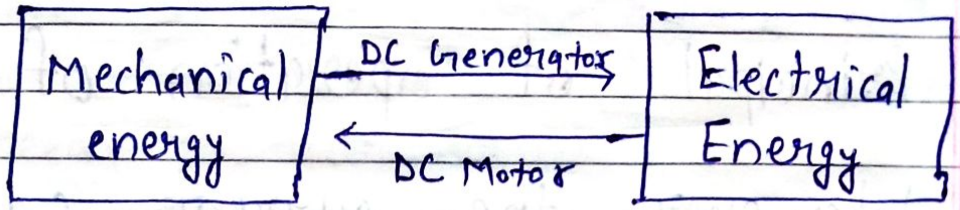
$$\boxed{P_c = I_1^2 R_1 + I_2^2 R_2}$$

or

$P_c = I_1^2 Re_1$, $P_c = I_2^2 Re_2$

dow





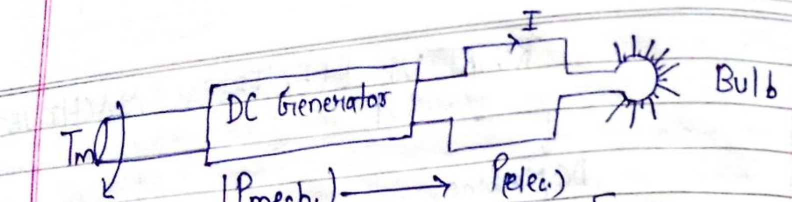
The rotating electrical machines are the electro machanical ~~electro~~ energy conversion devices that converts mechanical energy into electrical energy and electrical energy into mechanical energy. Their are two types of electrical machine—

1.) DC Machine 2.) AC Machine

The DC Machine is further devided into two parts the I^st one the 'DC Generator' & II^nd 'DC Motor'.

Principal of operation of a DC Generator

⟹ If an externally applied force makes the conductor to move into the magnetic field. The current starts to flow in the conductor. Thus, converting ~~electrical~~ mechanical energy into electrical energy. The figure shows the operating principal of the DC Generator.

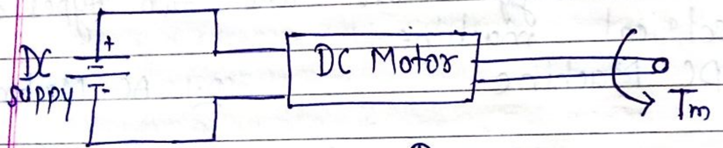


(Pmech.) ⟶ Pelec.)

[Conductor rotation] + [Magnetic Field] ⟶ [Current in Conductor]

Principal of operation of DC Motor ⟹

When ever the current caring conductor placed in the magnetic field it experience a force that tents to ~~oppose~~ move it. Theirefore converting the electrical energy into mechanical energy.



Pele. ⟶ Pmech.

[Current Carrying Conductor] + [Magnetic Field] ⟶ [Rotation of Moveable shaft]

NOTE ⟹ 1. Dc Motor follows the Fleming's left hand.
2. Dc Generator follows the Fleming's Right Hand Rule.

EMF Eq^n of DC Machine ⟹ In generator as ~~are~~ the ~~no~~ armature rotates an emf is generated across its conductor and

this emf is called generating emf. (Eg). Similarly Motor due to the armature rotation and emf is induced which is known as back emf. (Eb)

→ Let us consider ø = Flux per pole (Wobers)
P = No. of poles
Z = Total no. of armature conductor.
A = No. of parallel paths through armature
N = Speed of armature (rpm)

During one revolution of armature in a P pole generator each armature conductor cuts the magnetic flux P-times. So the flux cut by one conductor in one revolution is equal to Pø.
Now the No. of revolution made by the armature per second is N/60. So the average induced emf in one conduction is equal to

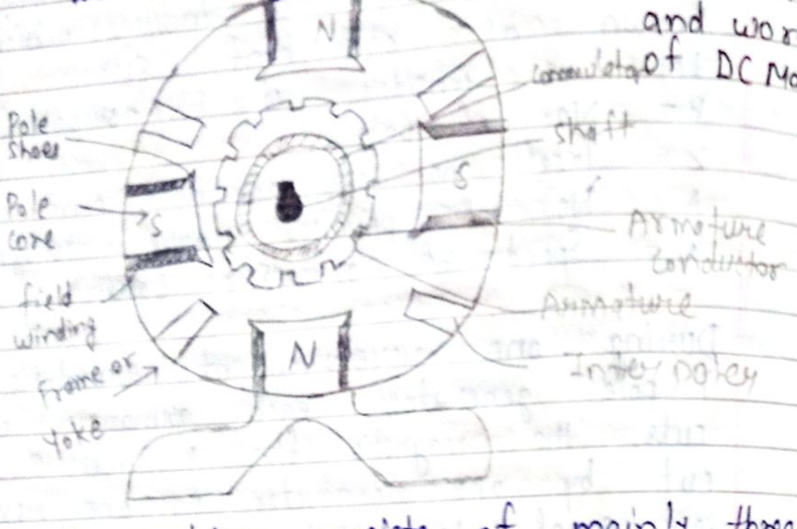
$$\boxed{e = \frac{P\phi N}{60}} \text{ Volts}$$

If the number of armature conductor per parallel path is equal to $\frac{Z}{A}$. so the total emf generated b/w the terminals is equal to E = (Avg. induced emf inone conductor) X (No. of conductor per parallel path)

$$\boxed{E = \phi \frac{PN}{60} \cdot \frac{Z}{A}} \text{ Volt}$$

Lap winding ⇒ $\boxed{P = A}$
Wave winding ⇒ $\boxed{A = 2}$

Construction and working of DC Machine



A Dc machine consists of mainly three part :-
(i) Magnetic field system
(ii) ~~Ar~~ Armature
(iii) Commutator & brush gear

(i) Magnetic field system ⇒ The magnetic field system is the stationary part of the machine. The magnetic field system consists of different parts :-

(a) Frame or yoke :- The outer frame or yoke is a hollow cylinder made up of cast steel. The Yoke serves the following two purposes

(1) It supports the pole ~~core~~ core and acts as the protecting cover for machine.

(2.) Its ~~pole~~ forms a part of magnetic circuit.

(b) Pole core :- An even no. of pole cores are bolted to the yoke. Since the poles project inwards they are called Salient poles.

(c) Pole shoes :⇒ Each pole core has a pole shoes having occured surface and serves the following two purposes :-
(i) It supports the field windings
(ii) It increases the cross sectional area of the magnetic circuit and reduces its relactance.

(D) Field windings :⇒ Each pole core have one or more field windings placed over it to produce the magnetic field in the machine.

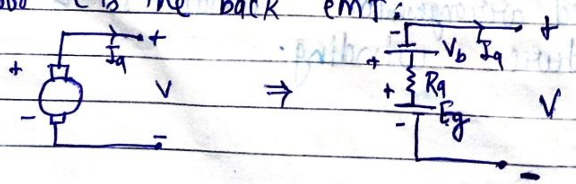
(2) Armature ⇒ The rotating part of the DC Machine is called armature. The armature consists of a shaft upon which a laminated cylinder called armature core is mounted. The armature core has slots on its outer surface. The insulated conductor are put in the slots of the armature core. And these conductor are suitably connected. This connected arrangement of conductor is called armature winding.

5.) Commutator and brush gear ⇒ Alternating voltage is produced in the windings rotating in a magnetic field. To obtain the direct current in the external circuit a commutator is needed. This commulator is required in the system to convert the AC into DC & DC into AC supply. It is made up of no. of warged shape, copper brass insulator from each other and from the shaft.

Brushes:- Current is collected from the armature winding by means of two or more carbon brushes mounted on the commulator. Each brush is supported in a metal box called the brush box or brush holder.

Equivalent circuit of a DC Machine:— The armature of a DC Machine can be represented by an equivalent electric circuit: It can be represented by 3 series connected elements e, r_a & V_b. The element 'e' is generated Voltage. r_a is armature resistance & V_b is the brush contact voltage drop. The equivalent circuit of the armature of a generator & of a DC motor is shown by the figure below. In case of the DC motor e is the back emf.

DC Generator



DC Motor:—

In case of generator, current flows from armature to line

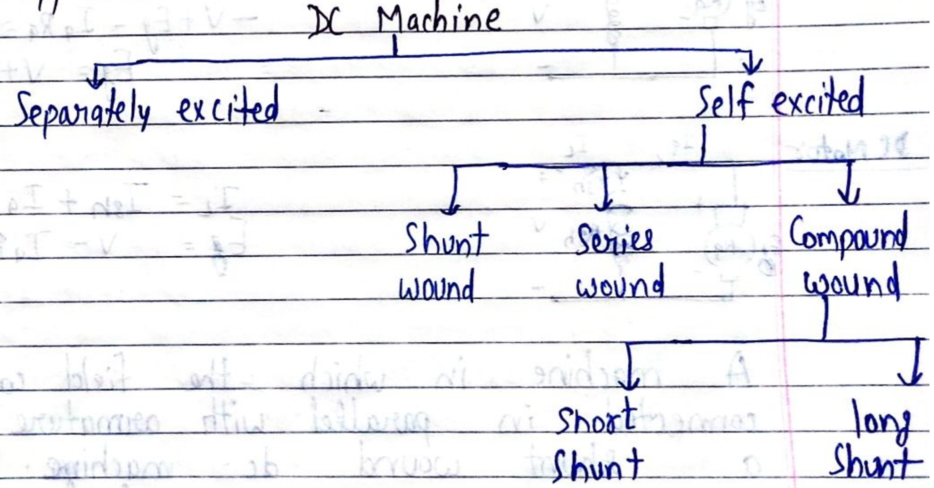
$V = E_g - I_a R_a - V_b \Rightarrow \boxed{V = E_g - I_a R_a}$ eqn "fundamental generator"

In case of motor, current flows from line to armature

$V = E_g + I_a R_a + V_b \Rightarrow \boxed{V = E_g + I_a R_a}$ eqn "fundametal motor",

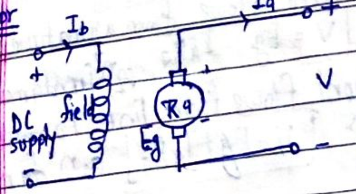
Back emf:— When the motor armature rotate its conductor cut the magnetic flux there fore the emf of rotation Er is induced in them and in case of the motor this emf of rotation is known as "back emf" or "counter emf" because it opposes the apply voltage.

Types of DC Machine ⇒



1.) Separately excited DC Machine ⇒ When the field windings are energized by a separate DC source the connection is called separately excited DC Machine.

DC Generator



Line current $I_L = I_a$

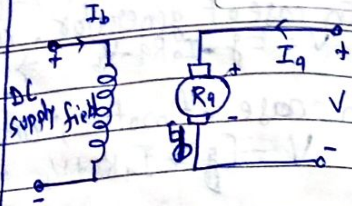
Generated EMF :-

$E_g = V + I_a R_a$

Terminal voltage :-

$V = E_g - I_a R_a$

DC Motor



Line current $I_L = I_a$

generated emf :-

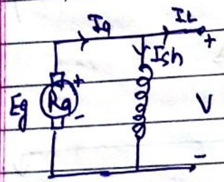
$E_b = V - I_a R_a$

Terminal voltage :-

$V = E_b + I_a R_a$

Shunt (parallel) wound DC Machine :-

DC generator

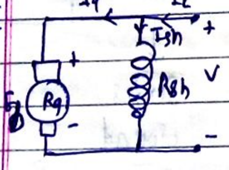


$I_a = I_{sh} + I_L$

$-V + E_g - I_a R_a = 0$

$E_g = V + I_a R_a$

DC Motor



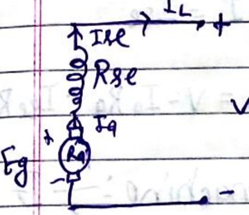
$I_L = I_{sh} + I_a$

$E_b = V - I_a R_a$

A machine in which the field coils are connected in parallel with armature called a shunt wound dc machine. Since the shunt field receives the full output volt of a generator or the supply voltage of a motor it is generally made up of large no. of turns of a fine wire.

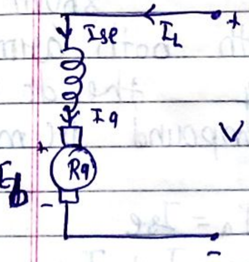
Series wound DC Machine ⇒ A DC machine in which the field coils are connected in series with the armature is called series wound DC machine.

The series ~~w~~ field winding consists of few turns of wire of large cross sectional area because it has to carry the large armature current.



$I_a = I_{se} = I_L$

$V = E_g + I_a R_a + I_{se} R_{se}$

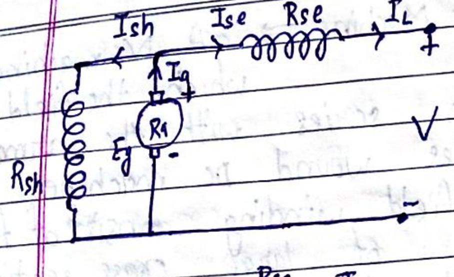


$I_a = I_{se} = I_L$

$E_b = V - I_a R_a - I_{se} R_{se}$

Compound wound DC machine ⇒ A Dc machine having both shunt & series field is called a compound dc machine. The compound machine may be connected into two waves.

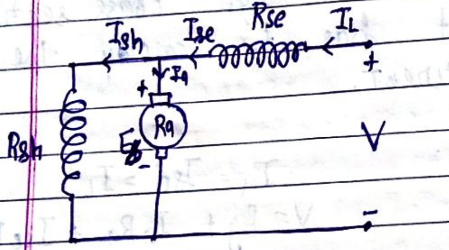
(i) Short shunt compound machine :- If the shunt field is connected in the parallel with armature along the machine is called short shunt compound machine.



$I_a = I_{sh} + I_L$

$I_L = I_{se}$

$E_g \cancel{V} = \cancel{E_g} V + I_a R_a + I_{se} R_{se}$

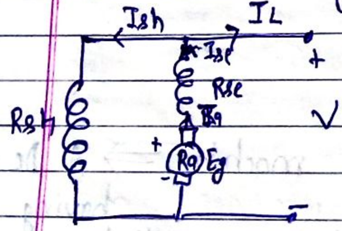


$I_L = I_{sh} + I_a$

$I_L = I_{se}$

$E_b = V - I_a R_a - I_{se} R_{se}$

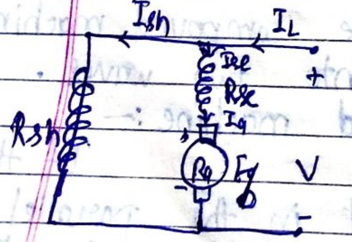
2.) Long shunt compound DC machine :— If the shunt field is connected in parallel with both armature & series field winding the dc is called long shunt compound DC machine



$I_a = I_{se}$

$I_{se} = I_L + I_{sh}$

$E_g = V + I_a R_a + I_{se} R_{se}$



$I_a = I_{se}$

$I_L = I_{se} + I_{sh}$

$E_g = V - I_a R_a - I_{se} R_{se}$

Q. A 4 pole 900 rpm dc machine has a terminal voltage of 220 volt & induced voltage of 240 volt. At raited speed the armature resistance is 0.2 Ω. Is the machine operating as a generator or a motor? Comput the armature current & the no. of armature conductor if the flux per pole is 10 megawab & the armature wave wound.

Note- When induce voltage is greater than the terminal voltage the machine working as generator and viceverger.

Ans - $V_T < V_I$ so generator

$E_g = V + I_a R_a$

$240 = 220 + I_a (0.2)$

$\frac{20}{0.2} = I_a \Rightarrow \boxed{I_a = 100A}$

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

$240 = \frac{4 \times 10 \times 10^6 \times 900}{60} \times \frac{Z}{2}$ (∵ wave winding A=2)

$\frac{\overset{8}{\cancel{24}} \times \overset{3}{\cancel{6}} \times \cancel{100} \times \cancel{2}}{{}_{2}\cancel{4} \times \underset{3}{\cancel{9}} \times \cancel{100} \times 10^7} = Z$

$\boxed{Z = 8 \times 10^{-7}}$

Speed of a DC Machine ⇒ The emf equation of a DC machine is given by

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

Now, solving of $N = \frac{E \times 60A}{PZ\phi}$

$$\boxed{N = \frac{E}{K\phi}}$$

where $\boxed{K = \frac{PZ}{60 \times A}}$

K = machine cons.
E = induce emf
ϕ = flux per pole & field flux

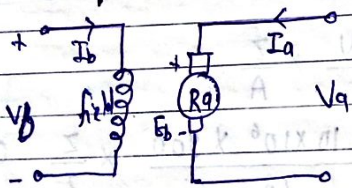
In case of generator

$$N = \frac{V + I_aR_a}{K\phi}$$

motor :-

$$N = \frac{V - I_aR_a}{K\phi}$$

Torque speed characterstic of a DC Motor →



In separately excited DC motor the field windings are excited from a separate DC source. So the motor back emf or speed voltage is given by E_b & by appling KVL, we got $E_b = V_a - I_aR_a$

And the armature induced voltage with motor rotating at a speed ω is given by $\boxed{E_b = k_e\phi\omega}$

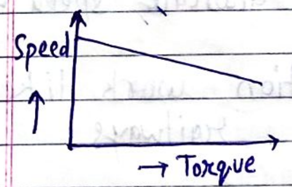
where ϕ is the field flux & ke is machine constant. Similarly the motor torque is given by $\boxed{T = k_e\phi I_a}$

So from the about two equations the expression for speed ω in terms of torque T can be obtained as

$$\boxed{\omega = \frac{V_a}{K_e\phi} - \frac{R_a}{(k_e\phi)^2} T_a}$$

Now if we plot the torque speed characterstic we found that as the torque developed is increased the speed will fall with the gradient of $\frac{R_a}{(k_e\phi)^2}$.

The torque speed characterstic is ~~give~~ shown below:-



$V = E_b - I_aR_a$
$E_b = V + I_aR_a$

Q. A 4 pole generator having wave wound armature winding has 51 slotts and each slots containing 20 conductor. what will be the generated voltage when the machine is derived at 15000 rpm & flux per pole is 7 milli vober.

Ay- $E = \frac{NP\phi}{60} \times \frac{Z}{A}$

$$E = \frac{\cancel{15000}^{5} \times \cancel{4}^{2} \times 7 \times 10^{-3}}{\cancel{60}} \times \frac{102\cancel{0}}{\cancel{2}} = 357\cancel{0} \text{ VoH}$$

DATE : / /
PAGE NO. :

Application of DC machine :—

DC Generator :— 1.) DC Generators are used for light and power supply requirements.
2.) It is used for charging battery.
3.) It is used for arc lighting & the balding.
4.) It is used for dc loco motive for re-generative breaking.

DC Motor:— 1.) It is used for the production of high starting torque.
2.) It is used in steel rolling mills, paper mills, etc.
3.) It is used where very accurate speed is required.
4.) It is used for traction work like lifts, trains & in electric railways.

Speed control of a DC Motor ⇒ The speed of a DC motor is given by the relationship.

$$N = \frac{V - I_a R_a}{k\phi}$$

The above eqn. shows that the speed is depended upon the supply voltage V, the armature resistance R_a & the field flux ϕ in practice the variation of these 3 factors is used for speed control. Thus, there are 3

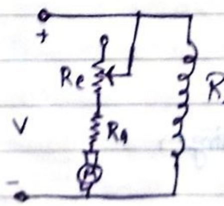
DATE : / /
PAGE NO. :

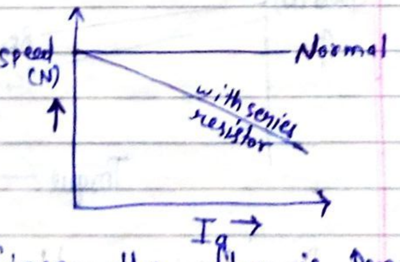
general method of speed control of DC motor :- (i) Variation of resistance in the armature circuit ⇒ This method is called armature resistance control.

(ii) Variation of field flux ϕ ⇒ This method is called field flux control.

(iii) Variation of applied voltage ⇒ This method is called armature voltage control.

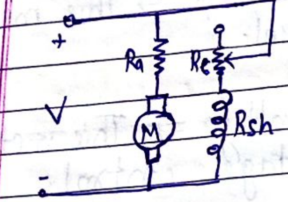
(i) Armature resistance control :- In this method a variable series resistor Re is put in the armature circuit. In this case the field is directly connected across the supply and flux ϕ is not affected by variation of Re.
The voltage drop in Re reduces the voltage applied to the armature & therefore the speed is reduced. This method is only used for small motors.





(ii) Field flux control ⇒ Since the flux is produced by the field current the control of speed by this method is obtained by controlling the field current. In th.

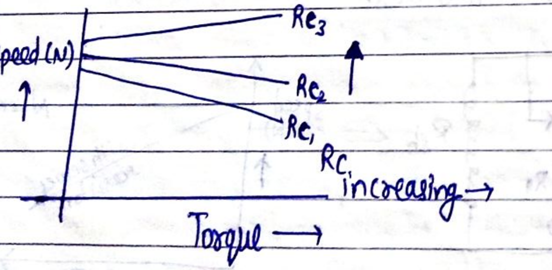
Shunt motor this is done by connecting a variable resistor Rc in series with the shunt field winding. The resistor R_c is called the shunt field regulator.



the shunt field current is given by

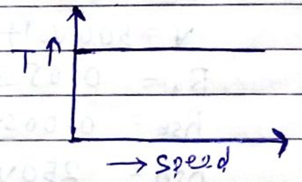
$$I_{sh} = \frac{V}{R_{sh} + R_c}$$

The connection of Rc in the field reduces the field current and hence the flux ϕ is also reduced. The reduction in the flux will result in an increase in the speed. Consequantly the motor run at a speed higher than the normal speed. for this region the method of speed control is used to give motor speed aboute the normal



(iii) Armature voltage control ⇒ Speed control of DC motor can also be obtain by varing the applied voltage to the armature. This method

of speed control is based on the principal of ward / leonard system. Since the speed control is carried out with the raitded current I_a & with constant motor field flux ϕ_m. Constant torque upto the base speed is obtain. Hence, with the armature voltage control method constant torque is obtained from the speed below the base speed.



Q. DC shunt machine connected to 250 Volt supply Has an armature resistor 0.12 Ω & the resistance of the field circuit is 100 Ω find the ratio of speed as a generator to the speed as a motor, the line current in each case is 80A.

Ay - $N_1 = \frac{V + I_a R_a}{K\phi} = \cancel{\frac{250 + 80\times(0.12+100)}{K\phi}}$

$\cancel{N} = \cancel{250 +}$

$N_2 = V - I_a R_a / K\phi$

$\frac{N_1}{N_2} = \frac{V + I_a R_a}{V - I_a R_a}$

$I_{sh} = \frac{V}{R_{sh} + R_c} = \frac{250}{0.12+100} = \frac{25000}{10012}$

$I_{sh} = 2.49\text{ A}$

motor $I_a = I_L = I_{sh} = 80 - 2.5 = 77.5\text{A}$

generator $I_a = I_L + I_{sh}$

Q. A long shunt compound generator delivers a load current of 50 A at 500 Volt And have armature resistance of 0.05 Ω, series field of 0.003 Ω and shunt field of 250 Ω. Calculate the generator voltage & the armature current.

Ap. $I_a = I_{se}$ $I_L = 50A$

$V = 500$ Volt

$I_a = I_L + I_{sh}$

$I_a = 50 + 2 = 52\,\Omega$ $R_a = 0.05\,\Omega$

$R_{se} = 0.003\,\Omega$

$R_{sh} = 250$ Volt

$E_g = V + I_aR_a + I_{se}R_{se}$

$I_{sh} = \frac{V}{R_{sh}} = \frac{500}{250} = 2$

$E_g = 500 + 52 \times 0.05 + 52 \times 0.003$

$500 + 2.6 + 0.156$

$E_g = 502.756$ Volt

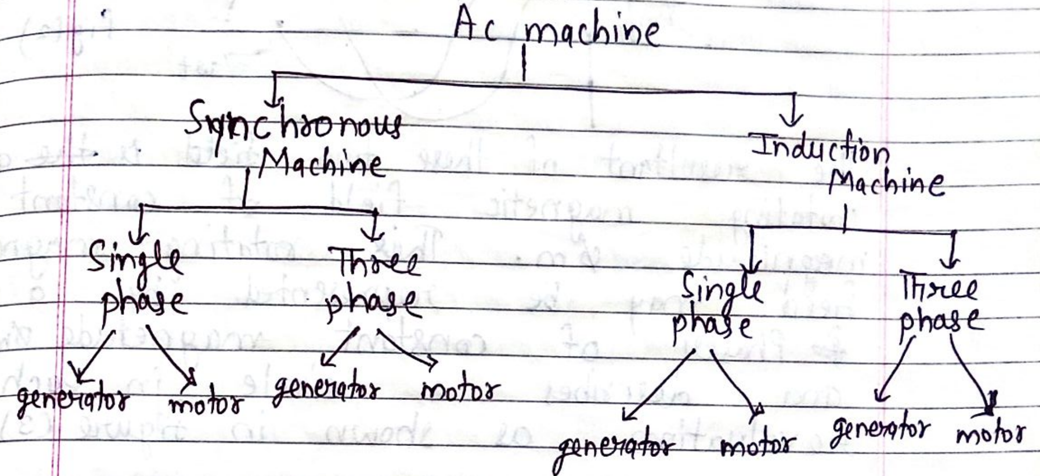
260

52
×3
156

Speed regulation ⇒ It is defined as the chang in speed from full load to the no-load and it is expressed as a percentage of the full load speed

$$\boxed{\% \text{ speed regulation} = \frac{N_o - N_f}{N_f} \times 100}$$

where N_o = no load speed
N_f = full load speed of the motor



(i) Single phase induction motor ⇒

(a) Production of rotating field :— Consider two windings A & B and they are displaced by 90° in space. Suppose that these windings produce magnetic field equal in megnetude & 90° Apart in time as shown in figure (i). so

$\phi_A = \phi_m \sin \omega t$

$\phi_B = \phi_m \sin(90° + \omega t)$

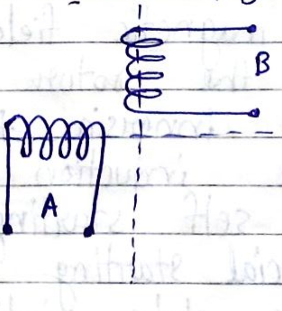


figure (i)

The waveforms of the field are shown in the figure (2).

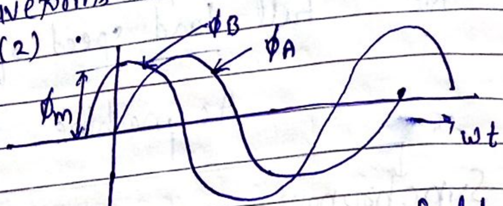
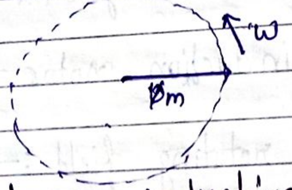


fig (2)

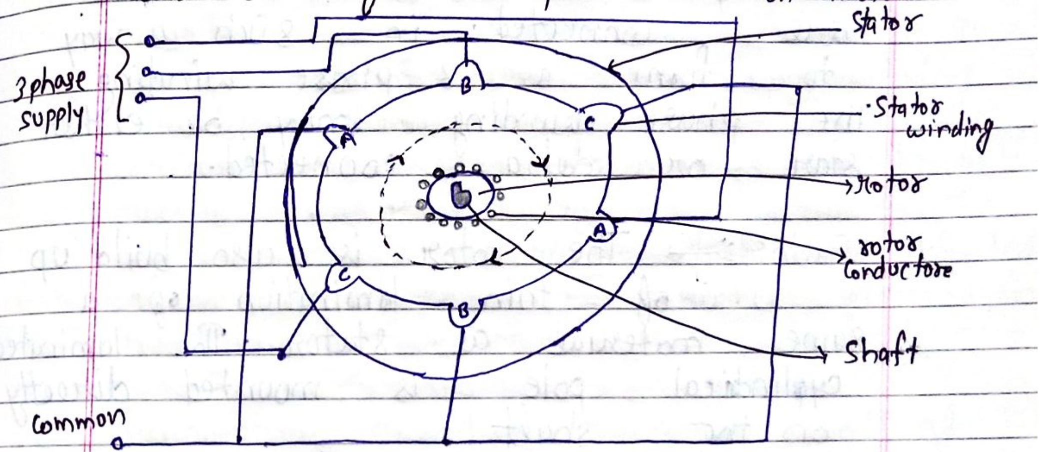
The resultant of these two field is ~~the~~ a rotating magnetic field of constant magnitude ϕm. This rotating magnetic field may be represented by a ~~a~~ Phaser of constant magnetude ϕm and describes a circle in each revaluation as shown in figure (3)



single phase induction motor principle⇒

A single phase induction motor consists of a single phase winding mounted on ~~the~~ a stator and a cage winding on the rotor. when a single phase supply is connected to the stator winding a pulsating magnetic field. Under these condition the rotor doesn't rotate due to the innersia there (इसलिए) -fore a single phase induction motor is inherently (गहनरूप से), not self starting and requires some special starting means. If however the single phase stator winding is exited and the rotor of the motor is started by an auxilary ~~observing~~ mean and the starting device is then removed, the motor continuous to rotate in the direction in which it is started.

Construction of a 3 phase induction motor :—



3 phase induction motor is the most popular type of a AC motor. An induction motor doesn't require any starting device. So It is called self started. An induction motor is very commonly used for industrial drive since it is cheap, effigent, reliable and robust. It has good speed regulation, high starting torque and requires little maintenance. A 3 phase induction motor essentially consists of 2 part. The Stator & the rotor.

1.) Stator :— The stator is the stationary part build up of high grade alloy steel lamination. The laminations are slotted on the inner peripery and are insulated from each other. The insulated stator conductors are placed in these slotts and are connected in such a way to form a 3 phase winding. The phase winding may be either star or delta connected.

2.) Rotor :— The rotor is also build up of thin lamination of a same material as stator. The laminated cyplindrical pole is mounted directly on the shaft. These lamination are slotted on their outer peripery to receive the rotor conductor. There are two type of induction motor rotors.

1.) Squirel / cage rotor
2.) Phase wound or slip ring rotor

1.) Cage rotor :— It consists of a cylandrical laminated core with slotts paralled to the shaft axis. Each slot contain bars of aluminum or copper at each end of

rotor. the rotor bar conductor are short circuited by heavy and rings to form a cage of the tire.

2.) Slip ring rotor :— The wound rotor consists of a slotted armature insulated conductors, are placed in the slotts and connected to form a 3-phase double layer distributed winding similar to the stator winding. The rotor winding are connected in star. And brought (लाया) outside of the rotor & connected to the 3 insulated slip rings. which are mounted on the shaft with brushes resting on them

Synchronous speed ⇒ It is the speed of rotation of the magnetic field in the stator winding of the motor at which emf is produced by the AC machine. And it is given by

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

where f is frequency & P = No. of pole

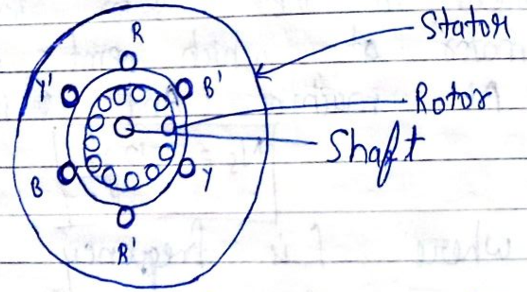
Cogging or magnetic locking ⇒ Some time even when full voltage is applied to the stator winding the rotor of a 3 phase cage induction motor fails to start this happens when the no. of stator & rotor slotts a

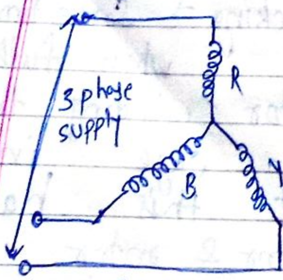
cylin

either equal or have an integral ratio. With the no. of stator slots equal or an integral multiple of rotor slots, strong aliment forces are produce b/w the: stator or rotor at the instant of starting.
These forces make create an aliment torque greater then the accilerating torque with the failier of the motor to start. This Phenomenon of magnetic ~~rotoring~~ locking b/w stator or rotor is called cogging.

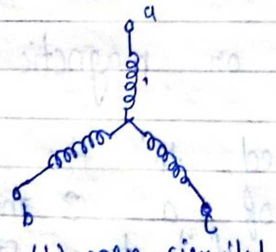
Crawling ⇒ Induction motor has the tendency to run at a very low speed compared to its synchronous speed that is up to 1/7th of the synchronous speed, this phenomena is called crawling.

\# Principal of operation of a 3 phase induction motor ⟹

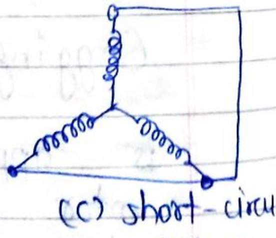




(a) Stator



(b) open-circuited Rotor


(c) short-circuit Rotor

Let us consider a 3 phase induction motor as shown about with stator & rotor wound force for 3 phase and having an identical no. of poles. Initialyse assume that the rotor winding is open circuit and the stator is connected to a 3 phase supply.
As we know that when the stator winding carrys the 3 phase current a rotating magnetic field is produced in the air gap b/w the stator and the rotor which runs at the synchronous speed.
This rotating magnetic field induces an emf in the stator winding which balances the supply ~~to~~ voltage and at the same time this rmf (rotating —) also induces the emf in the rotor winding. But as the rotor is open circuited so no-rotor current flows and the rotor remains stationary. Now if the rotor winding is short circuited so the rotor winding will carry a 3 phase current due to the induce emf in rotor.
Now the rotor behave like a current carrying conductor placed in the rotating magnetic field of the stator and experiences a torque. Hence the motor starts rotating.

Principal of operation of a 3 phase synchronous generator ⟹ The working princi of these machines are goverend by two ~~law~~

laws :—

1.1 Farady 's law of electro magnetic induction

2.1 Law of interaction

1.1 Faraday's Law of EMI ⇒ According to this law when the machine is used as a generator and emf is induced in the armature conductors when ever cuts its the magnetic field.

2.1 Law of interaction ⇒ This law relates to the production of force or torque that is when ever a current carrying conductor is placed in the magnetic field by the interaction of the magnetic field produce by the current carrying conductor. and the main field force is exerted on the conductor producing torque. So the mechanical power spent in maintaning the relative motion of the conductor is convert~~ing~~ed into electrical energy.

EMF equation of AC Machines :—

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

$$e = \frac{P\phi N}{60} \times Z_{ph}$$

$$T_{ph} = \frac{Z_{ph}}{2}$$

$$e = \frac{P\phi N}{60} \times 2T_{ph} \times \frac{2}{2}$$

$$e = \frac{4P\phi N T_{ph}}{120} = 4T_{ph}\phi \times \frac{NP}{120}$$

$$e = 4\phi T_{ph} f$$

$$(E_{ph})_{rms} = \text{Avg} \times \text{foam factor}$$

$$= 4\phi T_{ph} f \times (1.11)$$

$$\boxed{E_{ph} = 4.44\phi T_{ph} f}$$

Q. A 3 phase star connected 2 pole alternator run at 3600 rpm if their are 500 conductor per phase and flux per pole is 0.1 weber determine the frequency & magnitude of the generated emf.

Ay –

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

$$\frac{\overset{60}{\cancel{3600}} \times \cancel{2}}{\cancel{120}} = f \qquad \boxed{f = 60Hz}$$

$$E_{ph} = 4 \times 0.1 \times \frac{500}{2} \times 60 \times 1.1$$

$$E_{ph} = 120 \times 100 = 12000 \times 1.1 = \frac{13200}{2} = 6600$$

$$\frac{V_L}{\sqrt{3}} = V_P$$

$$E_L = \sqrt{3} \times 6600 = 1.73 \times 6600 = \cancel{22440}$$

$$E_L =$$

Armature reaction ⇒ In DC machine the main field is producelby field windings. In both generating and motoring mode the armature carrys the current and a magnetic field is produced which is called the armature flux. So the effect of armature flux on the distribution of the main field flux is called the "armature reaction".

→ It demagnetizes and cross magnetizes the main field, decrease the value of flux per pole and increase the iron losses in the machine.

Torque Slip charactorstic~~s~~ :—

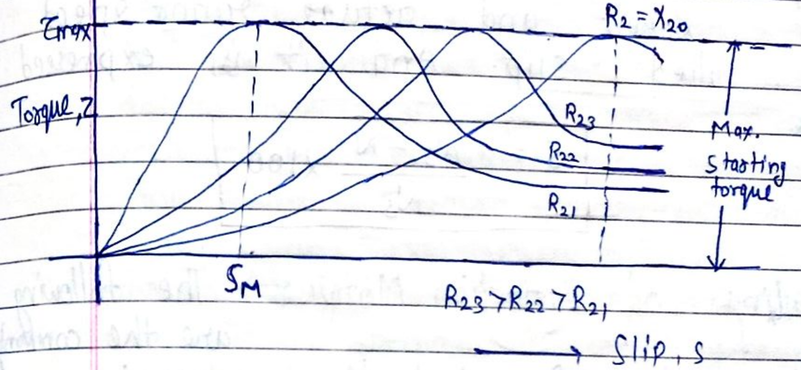
we have $\tau = \frac{K S R_2 E_{20}^2}{R_2^2 + (SX_{20})^2}$

where K = constant , s = Slip speed
R_2 = Resistance / Phase of rotor
E_{20} = Emf induced / phase of rotor at standstill
X_{20} = Reactance / Phase of rotor at standstill

if R_2 and E_{20} are constant then the torque depend upon the slip So the torque slip charactorstic ~~occur~~ curve can be devided into 3 reason:—

1) **Low slip reason:**— At synchronous speed s=0 therefore the torque is also zero. when the speed is very near to synchronous speed the slip is very low and $(SX_{20})^2$ is neglible in comparison with R_2. Therefore

$\boxed{\text{torque} = \frac{k_1 S}{R_2}}$ if R_2 is constant the torque is directly proposnal to the slip. Hence the torque slip curve is a straight line in this reason.



2) **Medium Slip reason:**— As the slip increase the term $(SX_{20})^2$ becomes large so that $(R_2)^2$ may be negleted therefore

torque = $\frac{K_3 R_2}{(SX_{20})^2}$ Thus the torque is inversally proposnal to the slip. The torque Slip charactorstic is represented by a rectangular hyperbola in this reason. In doing so it passes through the point of maximum torque where $R_2 = X_{20}$ The maximum torque developed in an induction motor is called pullout & breakdown torque".

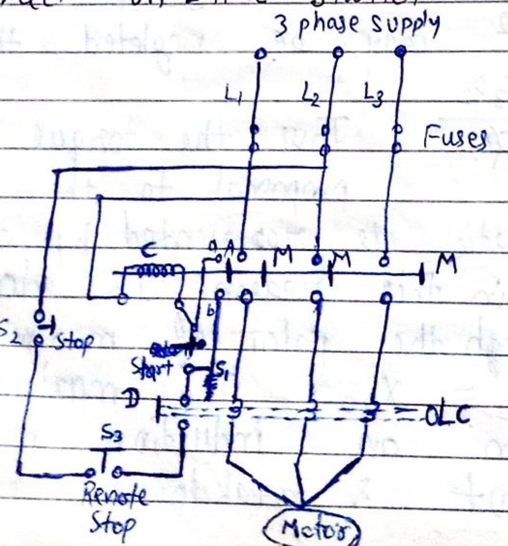
3.) High Slip reason:— The torque decreases beyond the point of max. torque as a result the motor slows down and evantually stop in this reason. At this stage the over load protection must immediatally disconnect the motor from the supply to prevent damage due to over heating.

Slip ⟹ The difference b/w synchronous speed and actual rotor speed is called slip. And it is expresed as

$$\boxed{S = \frac{N_s - N}{N_s} \times 100}$$

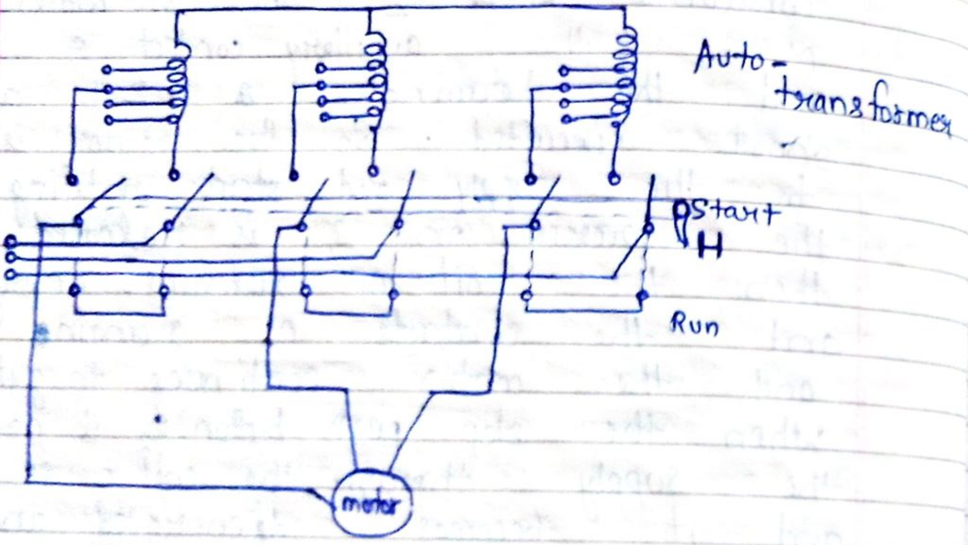
Starting of Induction Motor ⟹ The following are the common used starters for induction motor :—

(i) Direct - on - line starter :—

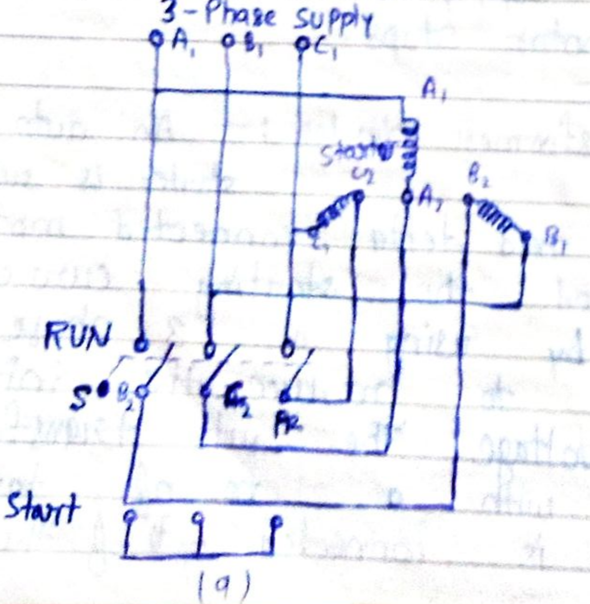


In this method starting the motor is connected by means of a direct - on - line starter. It consists of coil operated contector C contorlled by start and stop push buttons. on pressing the start button S_1 the coil C is energied from the 2 line conductor L_1 & L_2. The 3 main contects M & the auxillary contect A closed and the terminals a & b are short circuited. So the motor is connected to the supply and starts rotating. When the presser on S_1 is released, even then the coil C remains energied and the contacts M remains closed and the motor continues to get supply. When the stop push button S_2 is pressed the supply through the coil c is disconneted and it becomes dienergied and the main contact M and auxillary contact A become open. So the supply to the motor is disconnected and the motor stops.

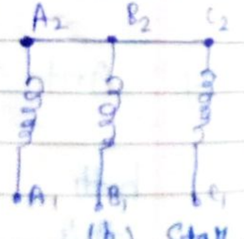
2.) Auto transformer starter :— An auto transformer starter is suitable for both star and delta connected motors. In this method the starting current is limited by using a 3 phase auto transformer to reduce the initial stator applied voltage. The auto transformer is provided with a no. of taping. The Starter is connected on of the tapping to obtain the most suitable starting voltage. A double throw switch is used to connect to auto transformer ~~with~~ ~~the~~ in the circuit for starting with the help of the handle H ~~D~~ as shown in the figure below



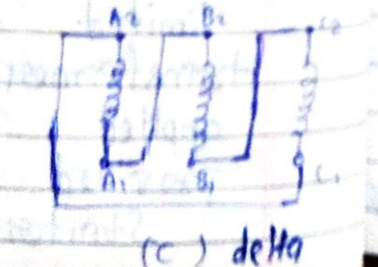
3) Star- delta Starter, -



(a)



(b) Star



(c) delta

A Star- delta starter is used for a cage motor ~~degi~~ design to run normally on delta connected stator winding. The figure 'a' shows the connection of a 3-phase induction motor with a star-delta starter. When the switch S is in the start position. The stator windings is connected in star as shown in figure 'b'. When the motor pics up the speed the change over switch 's' Automatically thrown quickly to the run position. Which connects the stator winding in delta as shown in figure 'c'. By connecting the stator winding first in star and then in delta the line current drawn by the motor at starting is reduced one third $(1/3)^{rd}$ So In this method the starting torque is reduced to $(1/3)^{rd}$ that obtained by direct delta staring.

Speed control of induction motor ⟹ The rotor speed of an induction motor is given by

$$N_r = (1-S)N_s$$

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

$$\boxed{N_r = \frac{120f}{P}(1-s)}$$

from the about eqⁿ it is seen that the motor speed can be changed by a change in frequency f, no. of pole p and slip 's'. The main method used for speed control of induction motor are as follows :—

(i) By changing the no. of stator pole.
(ii) stator voltage control
(iii) Supply frequency control
(iv) Rotor resistance control
(v) Slip energy recovery

(1) By Pole changing method :— The method of speed control by pole changing are suitable for cage motors only because the cage rotor automatically developes no. of poles equal to the poles of the stator winding. So by changing the no. of stator poles we can control the speed of the rotor. The no. of stator poles can be changed by 3 method

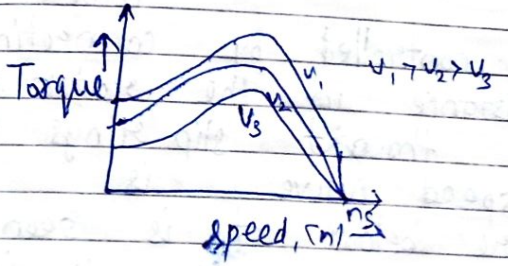
(i) Multiple stator winding
(ii) Method of consiquent pole
(iii) (PAM) ~~Ate~~ Pole amplitude ~~method~~ modulation

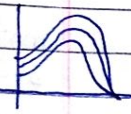
(ii) Stator voltage control :— ~~A~~ The speed of the 3-phase induction motor can be varied by variing the supply volt

we know that

$$\tau = \frac{K_s E_{20}^2}{R_2^2 + (sX_{20})^2}$$

From this relation torque developed is directly proposnal to the squal of the supply voltage. So the speed control obtained by variing the suppy volt until the torque required by the load is develope at the desire speed. There fore as the voltage is reduced to reduced the speed the torque developed by the motor also reduces. The torque speed charactorstic of a 3 phase induction motor for variing supply voltage is shown in the figure below :—





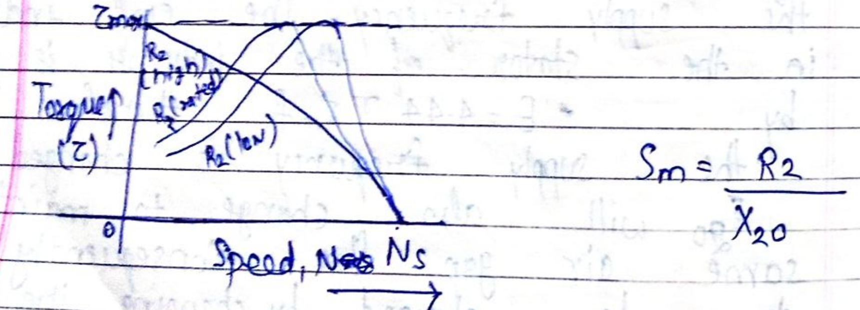
(iii) Variable frequency control ⇒ The synchronous speed of an induction motor is given by $N_s = \frac{120f}{P}$

therefore the synchronous speed and the speed of the motor can be controlled by the variing the supply frequency. The emf induced in the stator of the inductor is given by

• $E = 4.44\, T\, \phi_m f$ therefore if the supply frequency is changed E_{20} will also change to maintain the same air gap flux. Consequently the torque is also changed by changing the supply voltage. Thus the speed control of an induction motor can be done by using variable frequency supply. which requires a variable voltage source. The variable frequency

supply is generally obtained by the following
(i) Voltage source inverter
(ii) Current source invertor
(iii) Cyclo converter

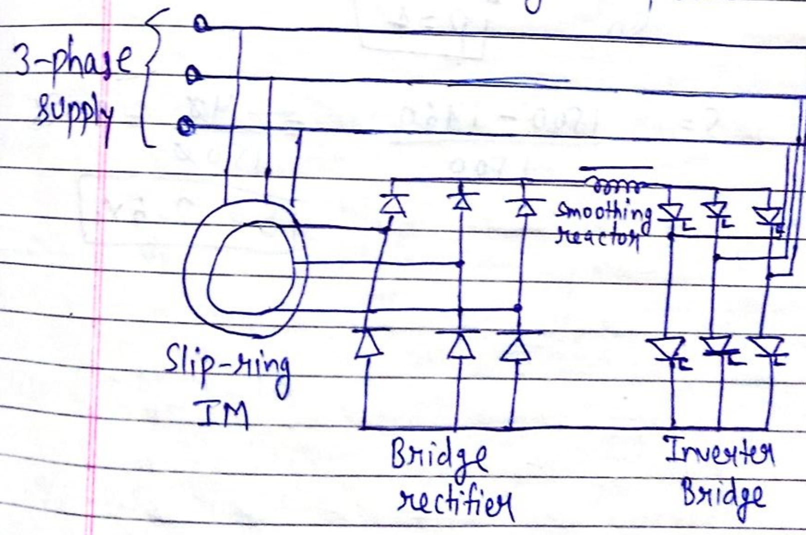
④ Rotor resistance control ⇒ The speed of wound induction motor can be controlled by connecting external resistance in the rotor circuit thought slip rings the torque speed curve is shown figure below it is seen that when the value of r_2 is increased as a result the slip will also increase and consequently the ~~peel~~ pull out ~~sdeet~~ speed decreases but maximum torque remain constant.
Therefore by this method control is provided to rated speed to lower speed.



$$S_m = \frac{R_2}{X_{20}}$$

⑤ Slip energy recovery ⇒ In the rotor resistance control the slip power is wasted as I^2R loss during the low speed operation.

So the efficiency of the dry system by this method of speed control is reduced. So the slip power from the rotor circuit can be recovered and fed back to the AC source thus the over all efficiency can be increased. This method for recovering the slip power is known as statics Scherbius drive. In this method a portion of the rotor AC power is converted into DC. By a diode rectifier. The rectified current is smoothe by the smothing ractor then the output of the rectifier is ~~produ~~ provided to the dc terminal of inverter. which inverter into AC power as feds its back to the AC source. This metho is used large power application.



Q. An induction motor runs at 1460 rpm under fullload condition when supplied by 50Hz supply find the no. of pole & slip of the motor?

Ans

$N = 1460\,rpm$

$f = 50Hz$

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

$P = \frac{120 \times 50}{\cancel{1460}} = \frac{600}{146} = \frac{300}{28}$

$N_s = \frac{120f}{P}$ if $P=2$

$N_s = \frac{\cancel{120}^{6} \times 50}{\cancel{2}} = 3000$

if $P=4$ $N_s = \frac{120 \times 50}{4} = 1500$

So $\boxed{P=4}$

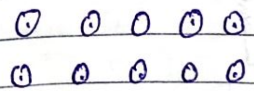
$S = \frac{1500 - 1460}{1500} = \frac{40}{1500} = 0.026$

$\boxed{S = 2.6\%}$

30/10/1

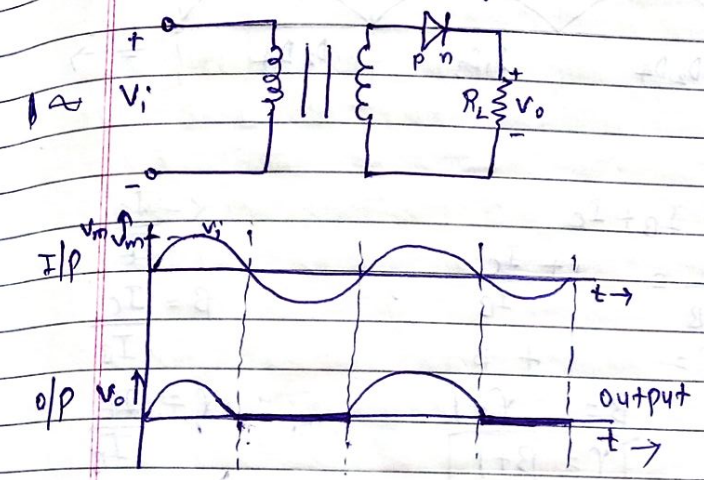
Semiconductor

conductivity of semiconductor :—



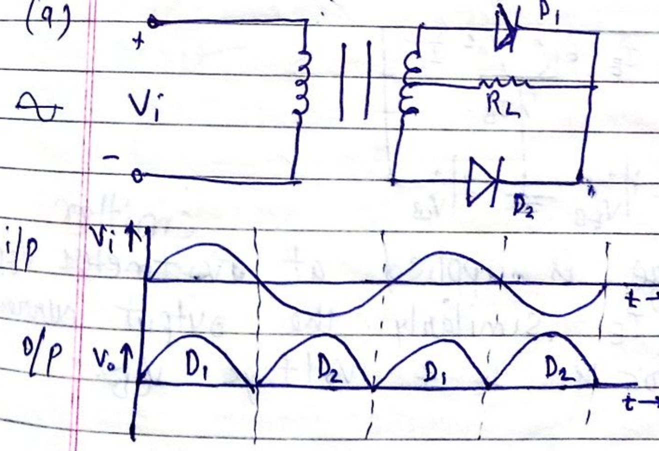
$\boxed{J = \sigma E}$

(i) Single phase half wave rectifier with R-load :—

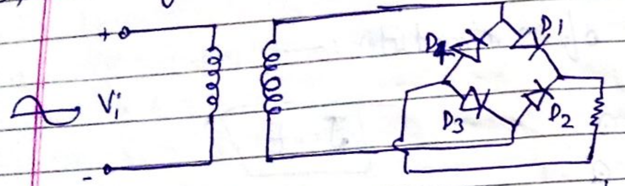


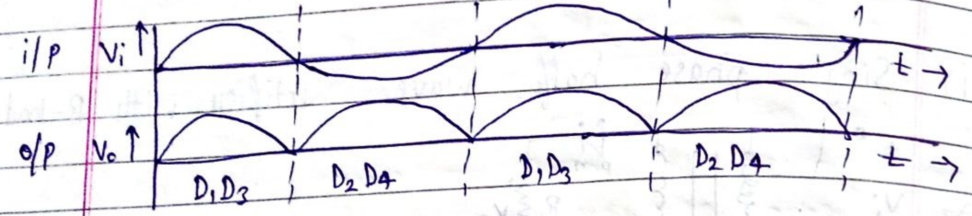
(ii) Single Phase full wave rectifier with R-load :—

(a)



(B) Bridge rectifier (In full wave rectifier)





$I_E = I_B + I_C$

$\frac{I_E}{I_B} = 1 + \frac{I_C}{I_B}$

$\gamma = 1 + \beta$

$\beta = \gamma - 1$

$\boxed{\gamma = \beta + 1}$

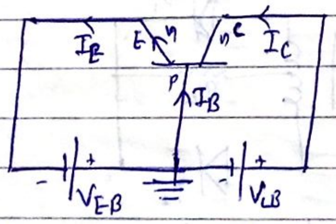
$\alpha = \frac{I_C}{I_E}$

$\beta = \frac{I_C}{I_B}$

$\gamma = \frac{I_E}{I_B}$

~~Transformer~~ Transistor configuration:—

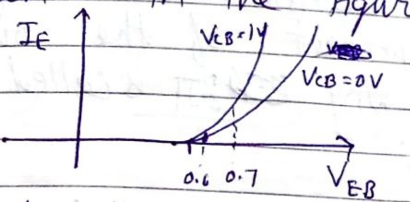
(i) CB



The input voltage is applied at emitter voltmeter V_{EB} & current I_E. similarly the output current at collector is I_C & voltage V_{CB}.

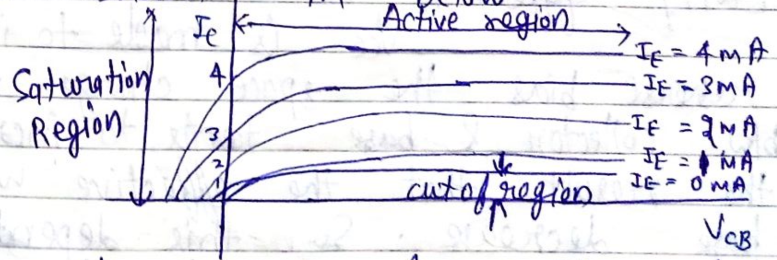
input characterstic:—

A curve is drawn b/w currents voltage that is I_E & V_{EB} at cons. output voltage that is V_{CB} And the input charactsti shown in the figure below:—



Due to the increase in output voltage V_{CB} the I_E increases for a small change in V_{EB} because increased reverse bias on BC juctio increase the deplition region width therefore reduces the base width for the recombination and increases the constration of majority carriers. So by changeing the output voltage V_{CB} increase the I_E.

Output characterstic:— The curve of output curren I_C v/s output voltage V_{CB} are plotted for the constant value of input current I_E. And the output char. is shown in below:—



The three region of operation of a transistor can be seen on the output characterstic curve.

(i) Active region :— In this region the transistor work as a Amplifier. when the input juction is forward bias & output juction is reverse bias. The output current Ic is almost constant for a given input current independent of the output voltage VCB. That is why BJT is called a current control device.

(forward reverse)

(ii) Cut of region :— When the input juction is in reverse bias and the device is set to be off. This region lie below $I_E = 0$. However a small character current flow due to minority carriers.

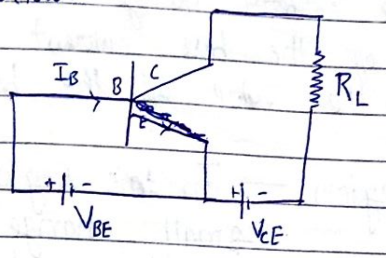
(reverse reverse)

(iii) Saturation region ! – The output juction is forward biased and the transistor is said to be saturated this region lie at the left of $V_{CB} = 0$. In this region a small change in V_{CB} will raipidly increase the I_C

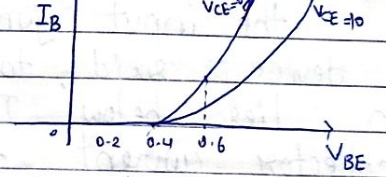
(forward forward)

Note- Early effect → As the collector voltage V_{CC} is made to increase the reverse bias the space charge width b/w collector & base tents to increase with the result that the effective width of the base decrease. So this dependiness of base width on collector to emitter vontter is known as the early effect

(ii) Comman emitter configuration :- Transistor in common emitter~~parameter~~ is shown in figure below.

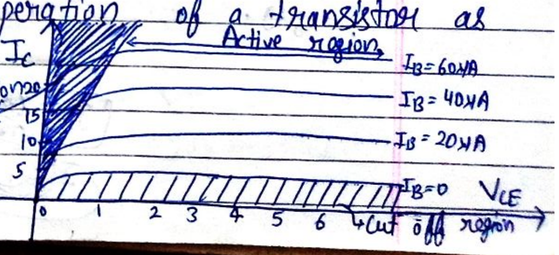


(a) Input characterstics :- To determine the input char. the collector to emitter voltage V_{CE} is ~~cape~~ kept constant and the base current is increased from zero in equal steps by increasing V_{BE} as shown in figure below.



In input char. for a fixed value of V_{BE} base current reduces for an increase in voltage V_{CE} due to the early effect.

(b) Output characterstics :- The curve of the output current I_C v/s output voltage V_{CE} are plotted for different constant values of input current I_B. The output char. curve drawn for the 3 region of a operation of a transistor as shown in figure below



(i) Active region :— In this region transistor work as an amplyfier. In this region the effect of the collector voltage is very small for low value of the base current but the effect increases with the value of the base current.

(ii) Saturation Region :— In this region of operation a small change in V_{CE} forwar bias the output junction and the transistor is said to be saturated. ~~a~~ In this region a small change in V_{CE} will rapidlally incre the I_C.

(iii) Cut off region :— In this region of operation of the input junction is reverse bias so the device is said to be off. This region lies below $I_B = 0$. However a small collector current flows due to minority carriers.

(iii) Stray loss. :— Leakage flux in a transformer produces eddy current in the conductor, transformer ~~tail~~ oil etc. And these eddy ~~a~~ currents are responsible for ~~straight~~ stray losses.

(iv) ~~Direc~~ Dielectric loss :— It occurs in the insulating material such as in the transformer oil and ~~in~~ soild insulation of transformer.

The stray loss & dielectric loss are usually very small so there existance will be negligible in an transformer.

—x—

$15 - 8I_1 - 3I_1 + 3I_2 + 8I_3 = 0$

~~or~~ $15 = 11I_1 - 3I_2 - 8I_3$ ——①

$5I_3 + 3I_1 = 10 I_2$ ——②

$5I_2 + 8I_1 = 23I_3$ ——③

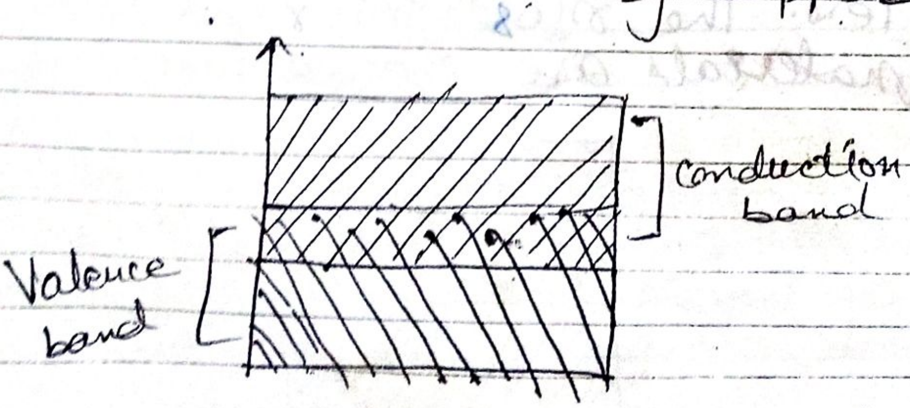
Unit # 4

BASIC ELECTRONICS

☆ Introduction :

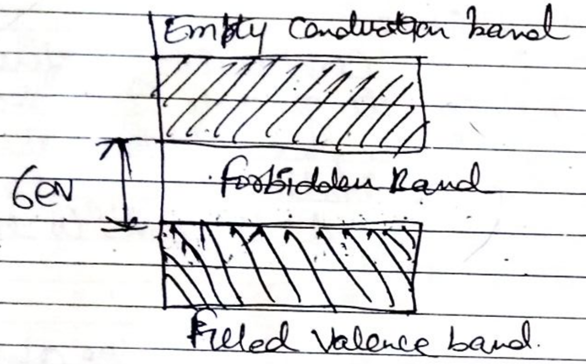
Conductivity :
Conductivity refers to the ability of a material to generate free electrons to conduct current. These free electrons are generated by providing excitation energy to the electrons in valence band to move to the conduction band.

Conductors (Metals) : In the absence of the energy gap, a large number of electrons are available for conduction at room temp. So without conduction even at room temp. Such materials conduct easily and hence called as conductor. eg copper, iron etc.



(b) Insulator :

The materials which posses large forbidden gap between the energy bands approx. 6ev. So it becomes impossible for an electron to jump from valence to conduction band. So such materials do not conduct called an insulator. eg Diamand.



(c) Semi-conductor :

The material for which the forbidden energy gap is relatively ver small is called a semi-conductor. appro 1ev. The most important semi-conductor materials are Germanium and Silicon.

★ Semiconductors :

Semi-conductors have resistivity in between that of conductors and insulators. They have negative temp. coefficients of resistance and when suitable metallic impurities are added, the conductivity of semiconductors change.

Based on the absence and presence of these intended impurities, semiconductors are classified as intrinsic and extrinsic semi conductors.

Intrinsic (Pure) semiconductors :

A piece of semiconductor in its purest form is known as Intrinsic Semi-conductor.

At 0° temp. no free electron is available as the electrons in the valence shell makes bond and share the valence electrons of other neighbouring atoms to attain 8 electron position in valence shell and get completely filled and stable. So they behave as perfect insulator.

Now, at room temperature, a no. of electrons in valence band absorb the thermal energy from surrounding, due to this they break covalent bond and drift to conduction band.

So each electron drifted to conduction band, one hole is created in valence band. Thus, free electrons and holes are generated in the intrinsic semi-conductor

★ Extrinsic Semi-conductors :

When some impurity generally referred to as dopant is added to intrinsic semiconductor, its conductivity can be increased. These types of semi-conductor are called extrinsic semi-conductors.

This process of adding impurity is called doping. The dopant added is generally of two types, either trivalent or pentavalent atoms.

When an intrinsic semi-conductor is doped with pentavalent atom i.e atom having five electrons in its valance shell, it is called donor doping. This type of doping creates more number of free electrons and results into N-type of semiconductor.

When an intrinsic semi-conductor is doped with trivalent atom i.e atom consisting of three electrons in valence shell, it is called acceptor doping). This type of doping creates more number of holes and resulting extrinsic semi-conductor is called as P-type semi-conductor.

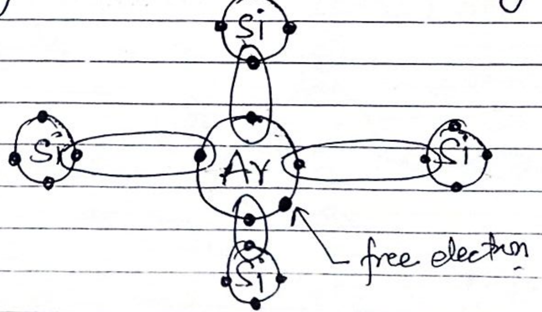
★ N-type semi-conductor :

To form N-type ~~impurities~~ semi-conductor, pentavalent impurity such as antimony, phosphorous and arsenic is added to intrinsic semi-conductor.

Each atom of dopant donates one free electron. After donating one electron, each dopant atom acquires a positive charge.

Current conduction in N-type is due to free electrons so they are called majority carriers and the holes are small in number they are called as minority carriers.

$5e^-$ N-type
$3e^-$ P-type



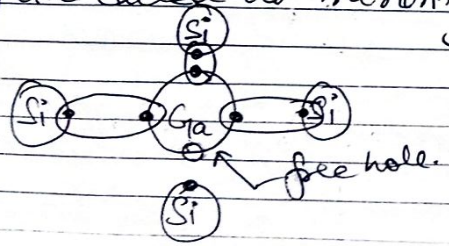
So, as the donor impurity is added, energy level are also introduced just below the conduction band. The donor energy level is 0.05 eV distance below the conduction band.

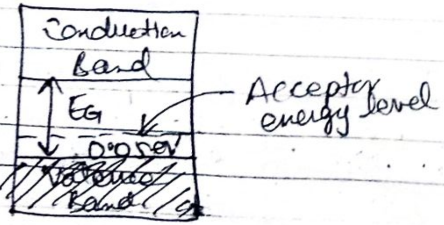
(b). P-type semi-conductor:

When a small amount of trivalent impurity such as Boron, Gallium or Indium is added to an intrinsic or pure semi-conductor it is called as P-type semi-conductor.

In this, the three valence electron of the dopant makes covalent bond with the three adjacent silicon atom. Due to shortage of one electron, the fourth covalent bond remains incomplete. This results in vacant space called as hole.

So in p-type semi-conductors, the current conduction is due to by holes, hence holes are majority carriers and the free electrons are small in number they are called as minority carriers.

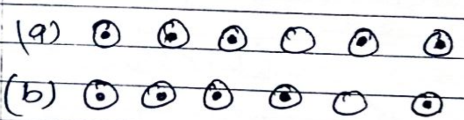




Conductivity of semiconductor:

In a pure semi-conductor, the no. of holes are equal to the no. of free electrons. With each electron-hole pair created, two charge-carrying particles are formed. One is negative, which is a free electron with mobility μ_n and other is positive i.e. the hole with mobility μ_p.

The mechanism by which hole contributes to conductivity is that when hole exists, the valence electron can jump into it and thus hole leaves its original position. Hole moves in the opposite direction to the electron.



So, the total current density J :

$$J = J_n + J_p$$

$$J = q \cdot n \cdot \mu_n E + q \cdot p \cdot \mu_p E$$

$$J = q [n\mu_n + p\mu_p] E$$

$$\boxed{J = \sigma E}$$

★ For pure semi-conductor, $n = p = n_i$ where n_i is refered to as intrinsic Concentration.

$$\therefore J = n_i(\mu_n + \mu_p)qE$$

where $\boxed{\sigma_i = q\, n_i(\mu_n + \mu_p)}$

★ For N-type semi-conductor, $n >> p$.

So, $\boxed{\sigma \simeq q\, n\, \mu_n.}$

Unit of conductivity is S/m.

★ For P-type semi-conductor, $p >> n$,

So, $\boxed{\sigma \simeq q n \mu_p.}$

Diode is a one-way device which allows the current to flow in one direction.

★ Conduction in Semi-conductor diode :

If the donor impurities are introduced into one side and acceptors into the other side of a single crystal of a semiconductor, a p-n junction is formed. N-type material and P-type materials have higher concentrations of electrons and holes resp. So at the junction there is a tendency for the free electrons in N-type material to diffuse

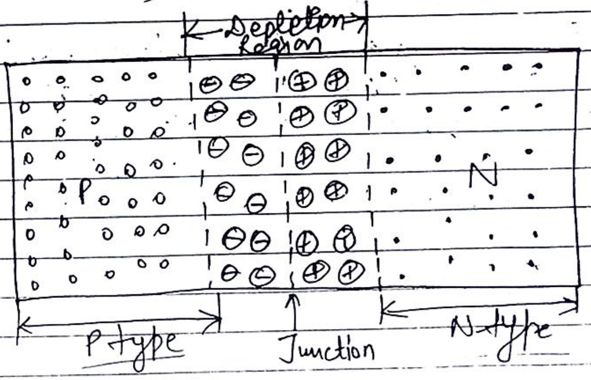
---

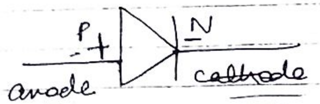
Depletion region :- It is an insulating region within a conductive material where the mobile charge carriers have been diffused away leaving behind the impurities.

to the P-side and holes from P type to the N- side. This process is called diffusion.

When the electrons diffuse to P-type region and holes to N-region, there is a region of charged ions formed at the junction. Since the region at the junction is depleted with mobile charges. It is called depletion region.

And at a result, a potential difference is established between the N-type and P-type regions which is called potential barrier. (V_γ).





$$\boxed{V_\gamma = V_T \ln \frac{N_D N_A}{n_i^2}}, \text{ where } V_T = \frac{T}{11,600}.$$

★ Biasing of a PN Junction :

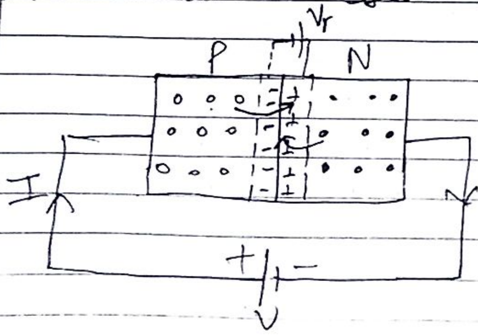
At equilibrium, under open circuit, the current through the junction is zero. In order to make current flow through the junction, we need to apply some potential to the P-N diode.

This application of DC voltage across the device is called biasing.

★: There are two type of biasing :

(i) **Forward biasing :**

A diode is said to be forward biased, when an external voltage source is connected with its positive towards P-side of the diode and negative towards the N-side of the diode.



When the applied voltage is greater than the potential barrier (V_r), then

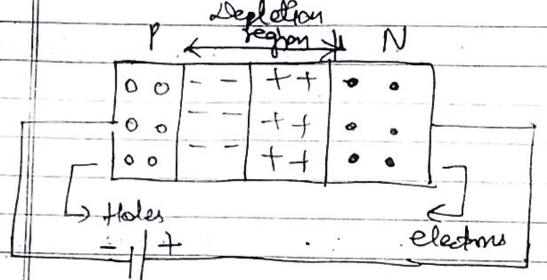
the holes in the P-side are repelled by the positive terminal of the battery and forced to cross the junction.

Similarly, the electrons in the N-side are also repelled by the negative of the battery and forced to cross the junction. So this results in the reduction of the potential barrier and allows large forward current to flow.

(ii) Reverse bias :

When the negative terminal of the battery is connected to the P-side and positive terminal of the battery is connected to the N-side of the P-N junction, the bias applied is known as reverse bias.

Due to this, the holes of the P-side moves or attracted towards the negative terminal of the battery and electrons from the N-side are to the positive terminal of the battery so as a result the width of the depletion region increases, the potential barrier is increased which prevent the flow of majority carriers. (रोकना)



Variation of diode current is given by,

$$I = I_0 \left(e^{\frac{V}{\eta V_T}} - 1\right).$$

where $V_T = \frac{T}{11600}$, T is temp.

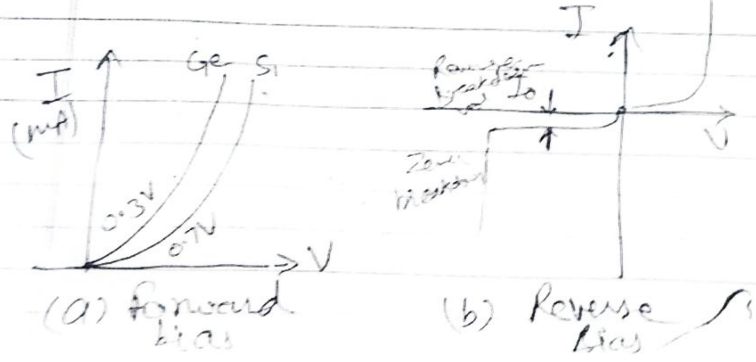
$\eta = 1$ for Ge, 2 for Si

I = Current through diode

V = Applied voltage

I_0 = Reverse saturation current

V-I characteristics :



(a) Forward bias (b) Reverse bias

★ **Rectifiers :**

Rectifier is defined as an electronic device used for converting AC voltage into unidirectional voltage or DC voltage. It uses the PN junction diode.

They are classified depending upon the period of conduction :

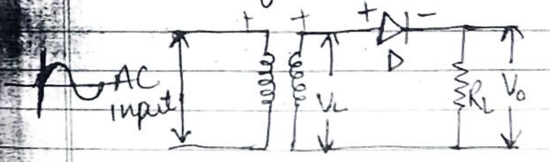
i) Half wave rectifier

ii) Full wave rectifier

Centre-tap   Bridge

i) Half wave rectifier :

The basic circuit and waveforms of a half wave rectifier is shown below :



It uses a single diode which conducts in one half of the input AC cycle, thus, pulsating DC voltage is obtained for half cycle of input AC. Hence, the circuit is called half wave rectifier.

(i)

DATE: / /

Let the V_i be the voltage to the primary of the transformer and given by the eqⁿ.

$$V_i = V_m \sin \omega t \cdot$$

Case 1: During the positive half cycle of the input signal, the p side of diode becomes more positive with respect to the cathode and hence, diode D conducts. So the whole input voltage will appear across the load resistance R_L.

Case 2: During negative half cycle of the input signal, the p-side of the diode becomes negative with respect to the cathode and hence, diode D [illegible] is reversed biased and so does not conduct. So the voltage across R_L is zero.

(i) Avg. value :

$$V_{avg.} = \frac{1}{2\pi}\left[\int_0^{\pi} V_m \sin \omega t \, d(\omega t) + \int_{\pi}^{2\pi} 0 \cdot d\omega t\right]$$

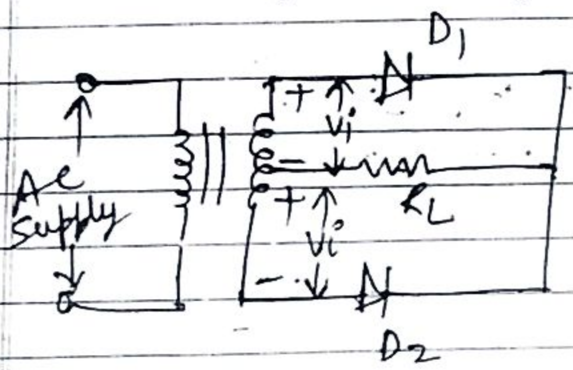
$$V_{avg.} = \frac{V_m}{2\pi}\left[-\cos \omega t\right]_0^{\pi}$$

$$\boxed{V_{avg.} = \frac{V_m}{\pi}} = 0.318\, V_m .$$

(ii) Full wave rectifier :

(i) Centre Tap rectifier :

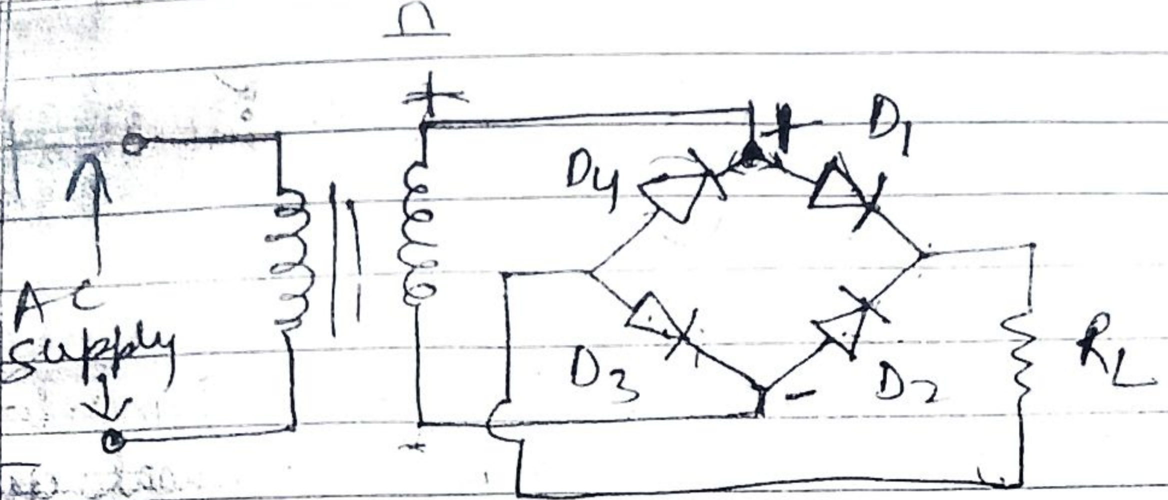
Full wave rectifier is an electronic device ~~that~~ converts an A.C voltage into a pulsating DC voltage using both half cycles of the applied A.C voltage. It uses two diodes of which one conducts during one half cycle while the other diode conducts during the other half cycle of the AC voltage.



Anode ⇒ (+)
Cathode ⇒ (−)

Case I: During positive half ~~cycle~~ cycle, the p side of D_1 is become positive and at the same time, the anode of diode D_2 is negative so D_1 conducts and D_2 does not conducts.

Case 2: During negative half cycle of the D_2 becomes forwar biased and D_1 becomes reversed biased so D_1 does not conduct and D_2 conducts



Case I : For positive half cycle of the input AC voltage, diodes D_1 and D_3 conduct whereas [illegible] and D_4 do not conduct and load current flows through R_L.

Case II : For negative half cycle of the input AC voltage, diodes D_2 and D_4 conduct whereas D_1 and D_3 do not conduct and load current flows through R_L.

A Bipolar Junction Transistor (BJT) :

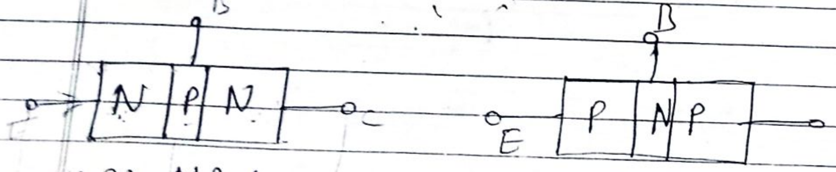
A BJT is a three terminal semi-conductor device in which the operation depends on the interaction of both majority and minority carriers and hence the name bipolar. With three terminals, two junctions are present, hence it is a bijunction device.

Transistor refers to as 'Transfer of resistor' because it transfers the signal from low resistance input junction to high resistance output junction

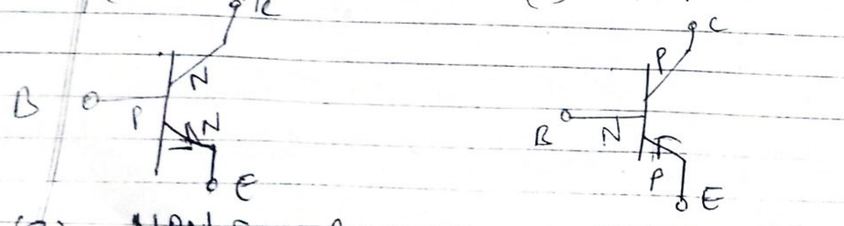
Construction:

The BJT consists of a silicon crystal in which a thin layer of N-type silicon is sandwiched between two layers of P-type silicon. This transistor is referred to as PNP.

And when a thin layer of P-type is sandwiched b/w the two layers of N-type silicon. This transistor is reffered as NPN. And the three terminals are emitter, Base and collector.



(a) NPN (b). PNP



(a) NPN Symbol (b) PNP Symbol

(i) **Emitter:** The main function of this region is to supply majority carriers to the Base and it is most heavily doped.

(ii) **Base:** This is the middle terminal of the transistor which is thinnest of the three and it is very less doped as it [illegible] the most of injected [illegible] collector.

[illegible] the main purpose of this terminal [illegible] collect the carriers through base and having larger area than the other [illegible]als.

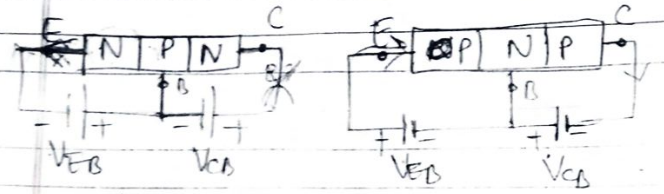
Transistor Biasing:

The application of external voltages is reffered to as biasing. As for diodes, the junctions of BJT can also be forward and reversed biased.

So, depending on the nature of biasing transistor works in either of the three regions:

(i) Active region or (mode):

When emitter base junction is forward biased and collector-base junction is reverse biased

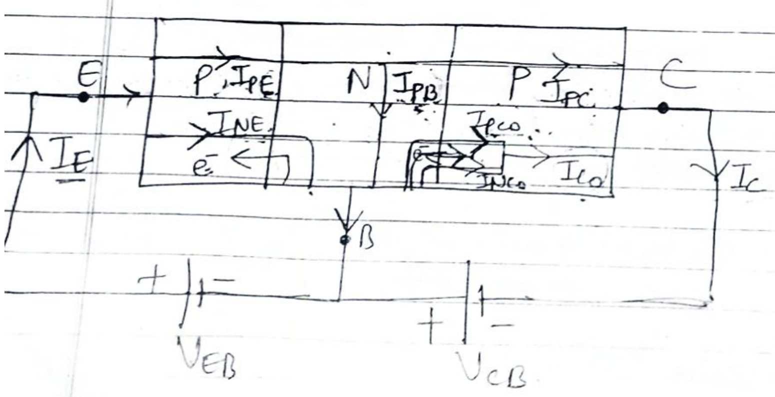


(a) NPN (b) PNP.

(b) Cut-off region : When both the junctions are reversed biased.

(c) Saturation region :- When both the junctions are forward biased.

Transistor current components :



(i) Emitter current :

$$I_E = I_{PE} + I_{NE}$$

As $I_{PE} >> I_{NE}$

$$I_E = I_{PE}.$$

Collector current :

$$I_C = I_{PC} + I_{CO}.$$

and $I_{CO} = I_{PCO} + I_{NCO}$.

I_{PCO} is due to holes.
I_{NCO} is due to e^-.

So, net collector current :

$$I_C = \underline{\alpha} I_E + I_{CO}$$

where $\alpha = \frac{I_{PC}}{I_E}$ is the large current gain

and I_{CO} is the reverse saturation curre

(iii) Base current :

$$I_B = I_{NE} + I_{PB} - I_{CO}.$$

★ Current Amplification factor :

(i) The alpha factor (α) : It is the ratio of (I_C) to I_E.

$$\alpha = \frac{I_C}{I_E} \quad \frac{\text{Collector current}}{\text{Emitter} \quad "}$$

(ii) Beta factor (β) : Ratio of collector current (I_C) to I_B.

$$\beta = \frac{I_C}{I_B}$$

(iii) Gamma factor (γ) : Ratio of I_E to I_B

$$\gamma = \frac{I_E}{I_B}.$$

★ Relationship between α and β and γ.

As we know, $I_E = I_B + I_C$

Now, incremental change in emitter current

$$\Delta I_E = \Delta I_B + \Delta I_C$$

$$\Delta I_B = \Delta I_E - \Delta I_C$$

So, $\beta = \frac{\Delta I_C}{\Delta I_B} = \frac{\Delta I_C}{\Delta I_E - \Delta I_C}$

Dividing numerator and denominator by ΔI_E we get,

$$\beta = \frac{\Delta I_C / \Delta I_E}{\frac{\Delta I_E}{\Delta I_E} - \Delta I_C / \Delta I_E}$$

$$\boxed{\beta = \frac{\alpha}{1-\alpha}}$$

or $\beta(1-\alpha) = \alpha$

$\beta - \beta\alpha = \alpha$

$\beta = \alpha + \beta\alpha$

$\beta = \alpha(1+\beta)$

$$\boxed{\alpha = \frac{\beta}{1+\beta}}$$

$\alpha \quad \frac{I_C}{I_E}$

$\beta = \frac{I_C}{I_B}$

$\gamma = \frac{I_E}{I_B}$

Now, $\gamma = \frac{\Delta I_E}{\Delta I_B}$

$$\gamma = \frac{\Delta I_E}{\Delta I_E - \Delta I_C}$$

$$\gamma = \frac{1}{1 - \frac{\Delta I_C}{\Delta I_E}} = \boxed{\frac{1}{1-\alpha}}$$

We know that,

$$\alpha = \frac{\beta}{1+\beta}$$

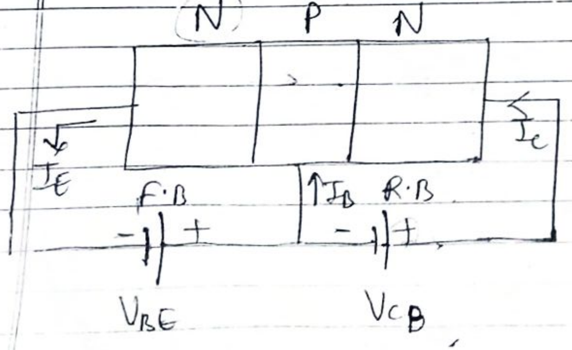
$$\gamma = \frac{1}{1-\alpha}$$

$$\gamma = \frac{1}{1-\left(\frac{\beta}{1+\beta}\right)}$$

$$\gamma = \frac{1+\beta}{1+\cancel{\beta}-\cancel{\beta}}$$

$$\boxed{\gamma = 1+\beta}$$

★ Operation of transistor:



Transistor is a semiconductor device used to amplify and switch electronic signals and electrical power.

As shown in the fig; the forward bias applied to the emitter base junction of an NPN transistor causes a lot of electrons from the emitter region to cross over to the base region. and ~~[illegible]~~ as the base is lightly doped with P-type impurity, the no. of holes in the base region is very small. and the no. of electrons that combine with the holes in the p-type base region is also very small. Hence a few electrons combine with holes to constitute a base current I_B. The remaining electrons cross over into the collector region and move towards the positive terminal of the supply V_{CB}.

So, the magnitude of the emitter current I_E is given by,

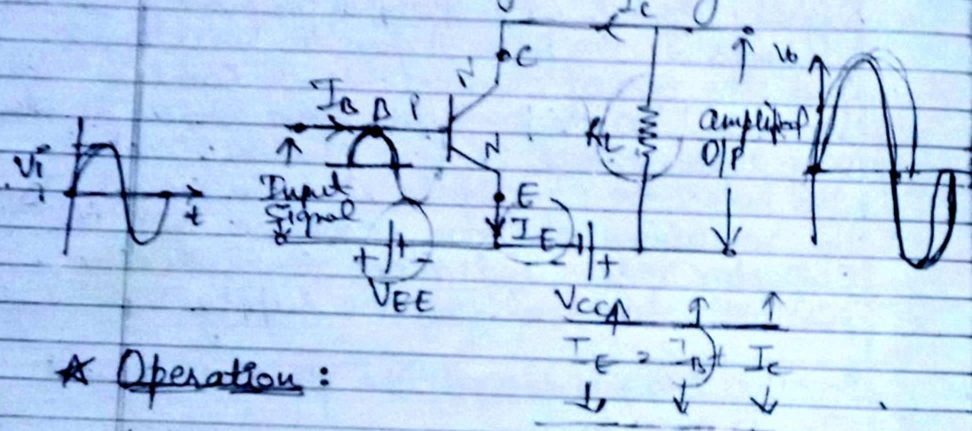
$$I_E = I_C + I_B.$$

★ Transistor as an Amplifier:

The very first requirement for a transistor to work as an amplifier is that its Emitter junction is forward biased and collector junction is reversed biased i.e transistor operates in its active region.

They can be used to increase the strength of the input signal without altering it significantly.

The fig. below shows the basic circuit of a common-emitter transistor amplifier. In this, the EB junction is forward biased by the battery VEE and CB is reverse biased by the battery Vcc.



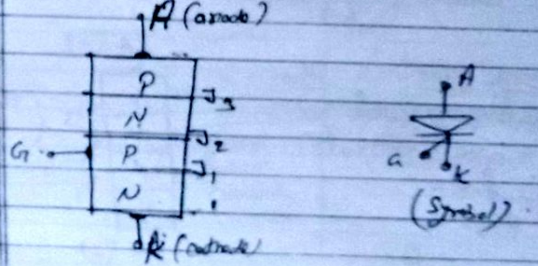
★ **Operation :**

When a weak signal to be amplified is applied b/w emitter base junction during +ve half cycle, the forward bias across the junction increases and in turn increases the flow of electrons from E to C through base and hence increases I_C and this increase in I_C causes more voltage drop across the load resistor R_L.

During (-ve) half cycle, the forward biased voltage across the E-B decreases and this decreases the I_C and also the voltage drop across R_L so an amplified signal appears across R_L.

Thyristor (SCR)

- It is a Solid State device like Transistor but their characteristic similar to thyratron tube.
- It is a 3-terminal (Anode, cathode, Gate), 4 layer (P-N-P-N) and three junction (J_1, J_2, J_3) device.
- Gate terminal is connected near to the cathode terminal.
- SCR is a uni-directional device
- SCR is a Semi-controlled device
- SCR is a charge controlled device
- SCR is a uni-directional device, which block the current from cathode to anode, but unlike diode it also block current flow from anode to cathode.
- Inner two layer of SCR are lightly dopped so that strength of junction J_2 is more than strength of junction J_1 & J_3.



★ Characteristics of SCR

① V-I characteristic
② Gate characteristics

4) Static V-I Characteristics :-

It has 3-Mode of operation:

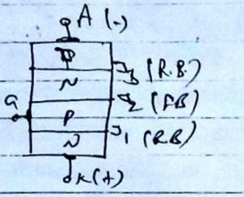
1. Reverse Blocking Mode :-

Anode -> -ve terminal

Cathode -> +ve terminal

J_1 & J_3 are Reversed Biased

J_2 are forward Biased.



(The device is in off State)

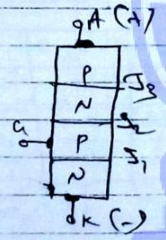
- In this region only Small amount of reverse leakage current is flow (due to minority carrier) in this region.
- When the reverse voltage become more V_{BRO} then Avalanche Breakdown occurs at reverse bias junction J_1 & J_3 and device start conducting at reverse direction

2. forward Blocking Mode :-

- anode -> +ve terminal
- Cathode -> -ve terminal

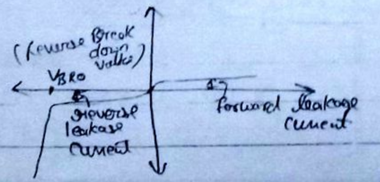
J_1 & J_3 are F.B.

J_2 are R.B.



(The device in off State)

- Only Small amount of forward leakage current flow in this region
- The device remains in this mode untill the anode voltage reaches a Creticle value called forward Breakover voltage (V_{FBO})



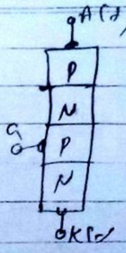
3) forward Conducting Mode :-

Anode -> +ve terminal

Cathode -> -ve terminal

Gate pulse available

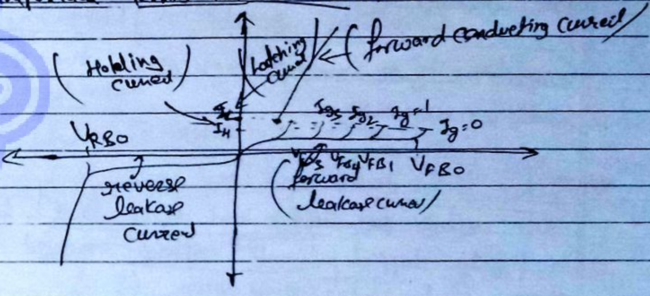
J_1 & J_2 & J_3 are forward Biased



(The device in ON switch)

- When anode voltage is greater than the forward Breakover voltage than Avalanche Breakdown occurs at J_2 and device Start Conducting.
- SCR start conducting only if current through the device greater than a minimum current called Latching current during turn ON process.

Some important terms in V-I characteristic



a) Latching current :- It is the minimum anode current required to turn on the SCR during turing on process. When J_2 Breakdown then large number of ~~Barrier~~ Carriers are generated So, large currents starts flowing. this current is latching current

5) Holding Current:- When the device is already in Conducting State and if anode current is reduced below a minimum level, the device gets turn off. This minimum current required to turn off device is called Holding current.

c) Forward Breakover Voltage :-

- It is the critical or minimum voltage required for Breakover of junction J_2 under forward Biased condition for turn on device.

- When anode voltage equal to forward breakover voltage the junction J_2 Breakdown due to Avalanche breakdown.

- When the gate current increases the forward Breakover voltage decreases.

d) Zener Breakdown :-
It's depends on voltage and doping level, both layer must be highly dopped, Small voltage required for breakdown. It is electrostatic breakdown

e) Avalanche breakdown :-
It's depends or occurs due to thermal effect or temperature. It occurs in lightly doped Semi-conductor junctions.

Single-Phase Inverter :-

An inverter is a circuit which converts a DC power into an AC power at desired output voltage and frequency. The AC output voltage could be fixed or variable voltage and frequency. The output voltage waveform of an ideal inverter should be sinusoidal.

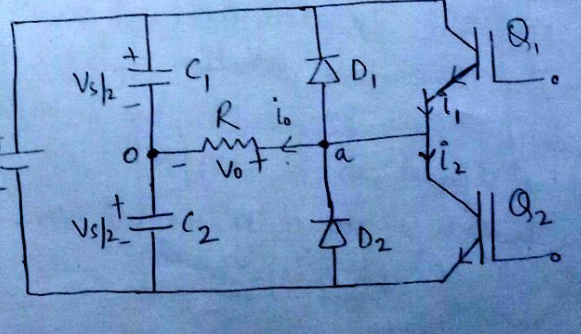
There are two types of single-phase inverters :-

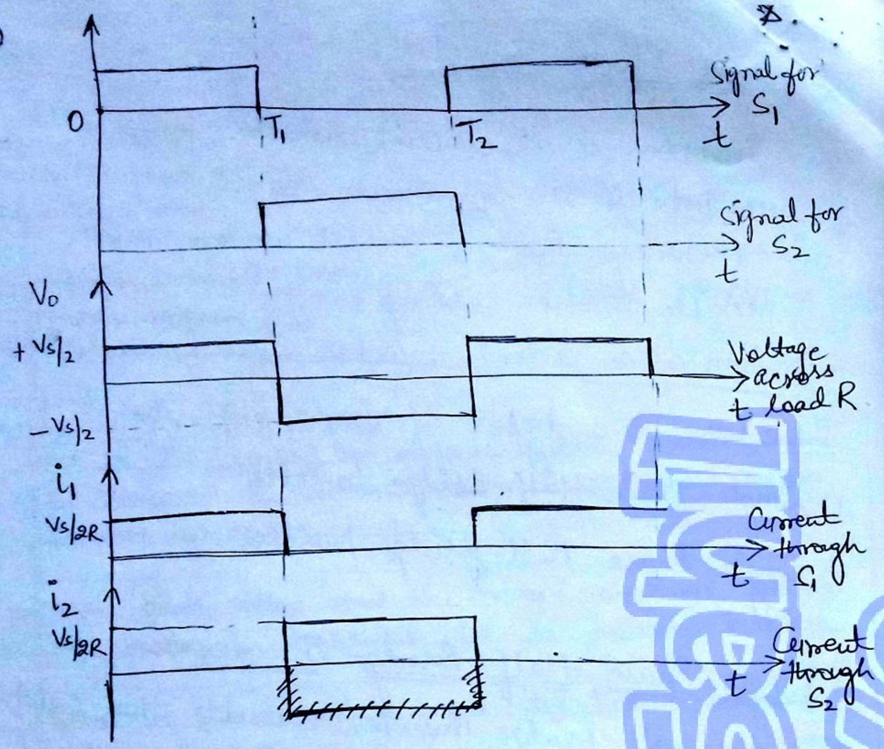
1) Single-Phase Half-Bridge Inverter.

2) Single-Phase Full-Bridge Inverter.

1) Single-Phase Half-Bridge Inverter :-

For, the half-bridge inverter circuit, the centre-tap of the DC supply is used as one of the load terminals. The centre-tap is created by the two series-connected equal-valued capacitors across the DC supply. The two-switches, Q_1 and Q_2 are switched alternately, at the desired output frequency, fo.





Working :-

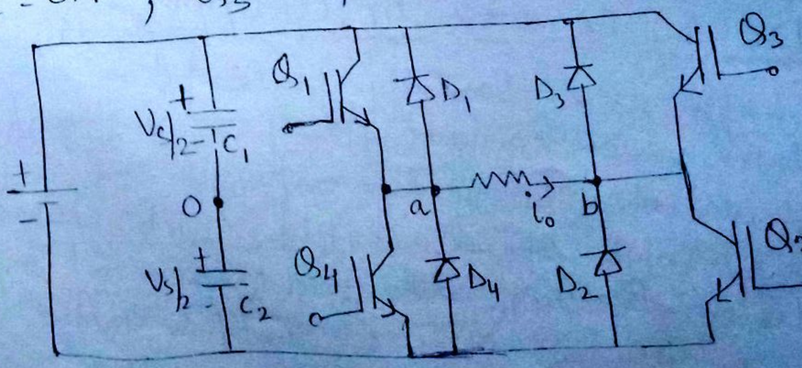
1) The current entering node a is considered to be positive.
2) The Switches S_1 and S_2 are unidirectional i.e they conduct current in one direction.
3) The switching sequence is so design that ~~oo~~ switch S_1 is on for the time duration $0 \leq t \leq T_1$ and the switch S_2 is on for the time duration $T_1 \leq t \leq T_2$.
4) When switch S_1 is turned On, the instantaneous voltage across the load is $V_0 = +V_s/2$
) When the switch S_2 is only turned On, the voltage across load is $V_0 = -V_s/2$.

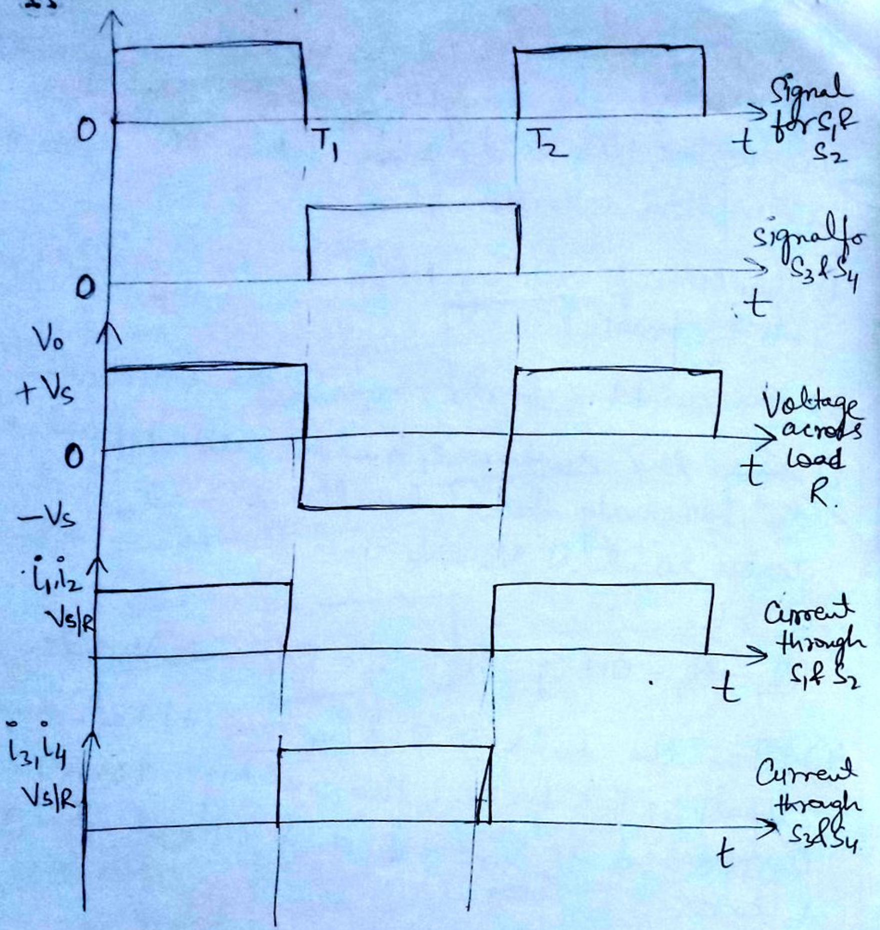
---

2) Single Phase Full Bridge inverter :-

A single phase bridge DC-AC inverter is shown in figure below. The analysis of the single phase DC-AC inverters is done by taking the following assumptions into account as :

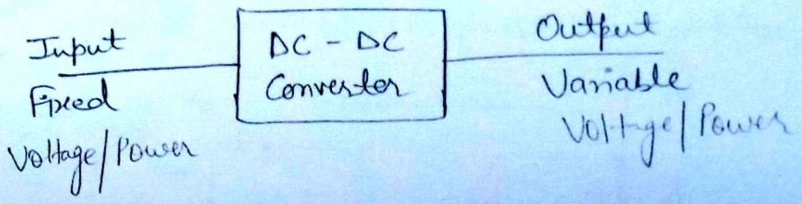
1) The current entering node a in figure is considered to be positive.
2) The switches S_1, S_2, S_3 & S_4 are unidirectional.
3) When the switches S_1 and S_2 are turned on simultaneously for a duration $0 \leq t \leq T_1$, the voltage across load is $V_0 = V_s$ and the current flows from a to b.
$Q_1 - Q_2 = ON$; $Q_3 - Q_4 = OFF \Rightarrow V_0 = V_s$.
4) When the switches S_3 & S_4 are turned on for a duration $T_1 \leq t \leq T_2$, the voltage across the load is reversed i.e $V_0 = -V_s$ and current flows from b to a
$Q_1 - Q_2 = OFF$; $Q_3 - Q_4 = ON \Longrightarrow V_0 = -V_s$

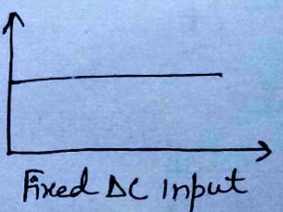


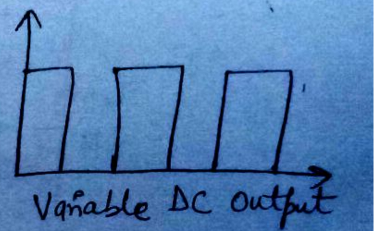


DC-DC Converter or Chopper :-

Chopper is a basically static power electronics device which converts fixed DC voltage / power to variable DC Voltage or power It is nothing but a high speed switch which connects & disconnects the load from source at a high rate to get variable or chopped voltage at the output



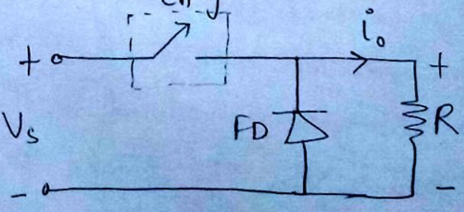




We can control and vary a constant DC voltage with the help of a chopper. Chopper can increase or decrease the DC voltage level at its opposite side. So, it is also known as DC transformer.

1) Step down chopper or Buck converter :-

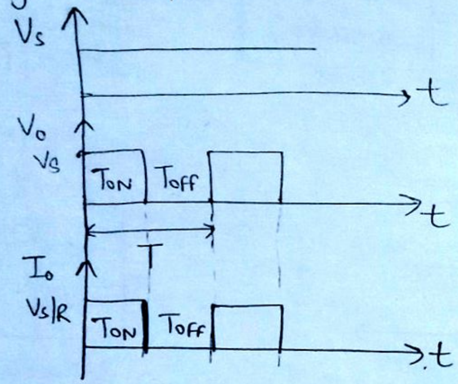
Step down chopper is used to reduce the input voltage level at the output side as shown in the circuit diagram below :-



When CH is turned ON, V_s directly appears across the load i.e $V_0 = V_s$.

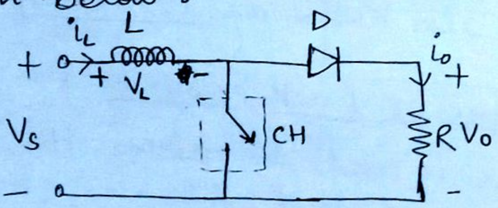
When CH is turned OFF, V_s is disconnected from the load ie $V_0 = 0$.

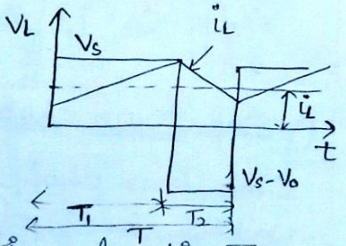
The voltage waveform is shown below :-



2) Step-up chopper or Boost Converter :-

Stepup chopper is used to increase the input voltage level of its output side as shown in the circuit diagram below :-

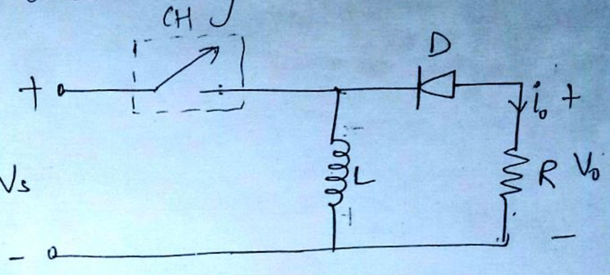




When the switch CH is closed for time duration T_1, the inductor current rises and the energy is stored in the inductor. If the switch CH is opened for time duration T_2, the energy stored in the inductor is transfered to the load via the diode D and the inductor current falls.

Buck-Boost Converter :-

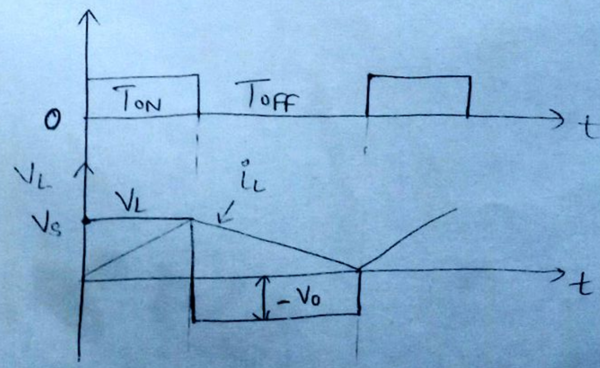
With the help of Buck-Boost converter, we can increase or decrease the input voltage level at its output side as per our requirement as shown in the circuit diagram below :-



When CH is ON, the source voltage V_s is applied across the inductor L and it will be charged and stored energy in the inductor so, $V_L = V_s$.

When chopper is Off, inductor L reverses its polarity and discharges through load and diode D.

So, $V_0 = -V_L$



☆ Power Measurement :-

Power is the rate at which work is done. In a purely resistive circuit, the voltage & current change direction at the same time. So, the formula is :

$$\boxed{P = V_{rms} I_{rms}.}$$

Power meter :-

Power meter is a multi-function device that measures precisely continuous current, alternative current, intensity of DC or AC and power in Watts.

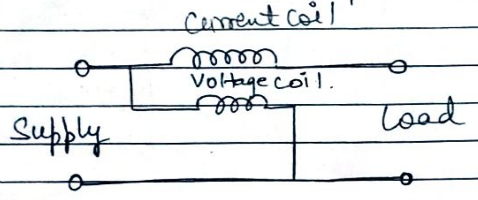
☆ Wattmeter :-

Wattmeter is an instrument used to measure the electrical power. The traditional form of Wattmeter is called as dynamometer wattmeter.

The wattmeter has two sets of coils :

1. Current Coil :- One coil is fixed and is made in two identical parts. It is made of heavy gauge copper wire. So, it has low resistance.

2. **Voltage coil :-** The other coil which is known as voltage coil, is wound from fine gauge wire. So, it has relatively high resistance. It is placed between the two parts of the current coil.



→ The current coil is connected in series with the load so that the circuit current flows through it.

→ The voltage coil is connected in parallel with the load.

→ Both the coils will produce magnetic field and these fields interect to each other and produce a deflecting torque on the voltage coil.

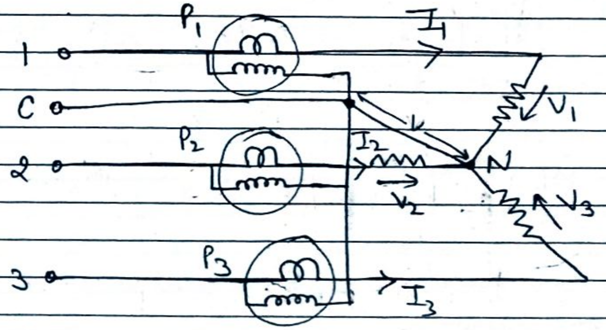
→ The interacting fields are proportional to the circuit voltage & current so the produced deflecting torque is proportional to the product of circuit voltage and current i.e VI which is nothing but a circuit power.

→ A dynamometer wattmeter reads both ac & dc power.

★ **Measurement of three phase Power :-**

Various methods are used for measurement of three-phase power in three phase circuits on the bases of number of wattmeters used.

1. **Three Wattmeter method :-**



The above figure shows a three phase four wire system having a current coil of all the three wattmeters marked as one, two and three connected to respective phases.

Pressure coils of all the three wattmeter are connected to common point at neutral wire. It is clearly seen that each wattmeter will give reading as product of phase current and line voltage which is a phase power.

The resultant sum of all the readings of wattmet will give the total power of the circuit.

So,

$$P = P_1 + P_2 + P_3$$

$$P = I_1(V_1-V) + I_2(V_2-V) + I_3(V_3-V).$$

$$\boxed{P. = V_1 I_1 + V_2 I_2 + V_3 I_3}$$

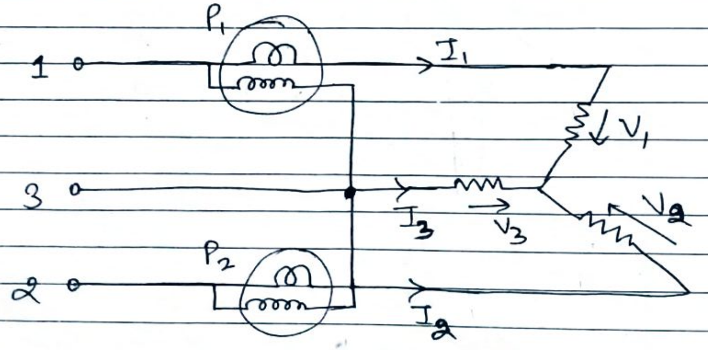
$$\boxed{\therefore I_1 + I_2 + I_3 = 0}$$

2. **Measurement of power by two wattmeter method:**

In this method, we have two types of connections:-

1. Star connection.
2. Delta Connection.

When the load is star connected, the diagram is shown below :-



→ For star connected load, it is clear that the reading of wattmeter one is product of phase current and voltage difference $(V_2 - V_3)$.

Similary, the reading of wattmeter two is the product of phase current and the voltage difference $(V_2 - V_3)$

Thus, the total power of the circuit is the sum of the reading of both the wattmeters.

So,

$$P = P_1 + P_2$$

$$P = I_1(V_1 - V_3) + I_2(V_2 - V_3)$$

$$P = I_1 V_1 - I_1 V_3 + I_2 V_2 - I_2 V_3$$

$$P = I_1 V_1 + I_2 V_2 - V_3(I_1 + I_2)$$

$$P = I_1 V_1 + I_2 V_2 - V_3(-I_3)$$

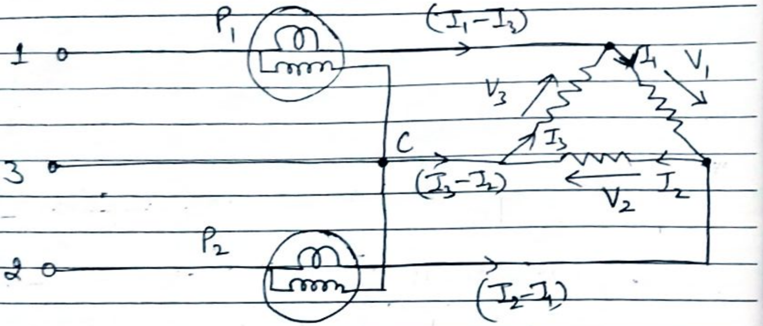
$$\boxed{P = I_1 V_1 + I_2 V_2 + I_3 V_3}$$

According to Kirchoff's law :-

we have, $I_1 + I_2 + I_3 = 0$

So, $\boxed{I_1 + I_2 = -I_3}$

When the load is connected in delta, the diagram is shown below :-



So, the reading of wattmeter one is given by,

$$P_1 = -V_3(I_1 - I_3).$$

and the reading of wattmeter two is given by,

$$P_2 = V_2(I_2 - I_1).$$

So the total power measured by the two wattmeter is the sum of the reading of the both wattmeters.

$$P = P_1 + P_2$$

$$P = -V_3(I_1 - I_3) + V_2(I_2 - I_1)$$

$$P = -V_3I_1 + V_3I_3 + V_2I_2 - V_2I_1$$

[illegible]

~~$P = V_1I_1 + V_2I_2 + [(-V_1 - V_2)](I_3)$~~.

$$P = V_2I_2 + V_3I_3 - I_1(V_2 + V_3)$$

$$\boxed{P = V_1I_1 + V_2I_2 + V_3I_3}$$

Since according to Kirchoff's law :-

$$\left[\begin{array}{c} V_1 + V_2 + V_3 = 0 \\ \text{or, } V_2 + V_3 = -V_1 \end{array}\right]$$

(3) One Wattmeter method :-

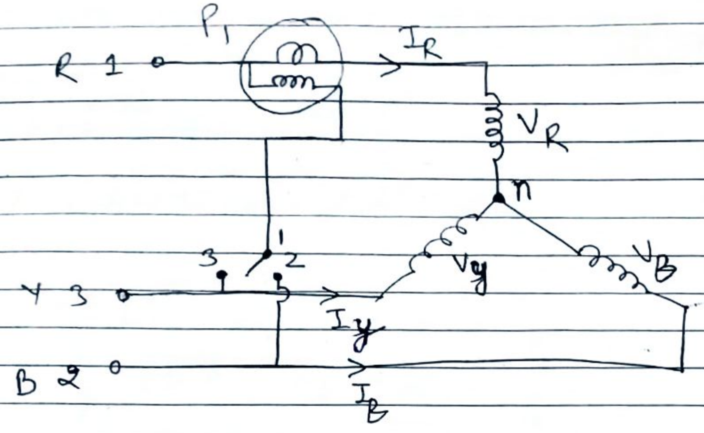
The main limitation of this method is it cannot be applied on unbalanced load.

So, in balanced condition,

We have, $I_1 = I_2 = I_3 = I$

& $V_1 = V_2 = V_3 = V$

As, shown in the diagram below, the load is star connected :



In the diagram, we can see there are two switches marked as (1-3) and (1-2). By closing the switch (1-3), we get the reading of wattmeter as;

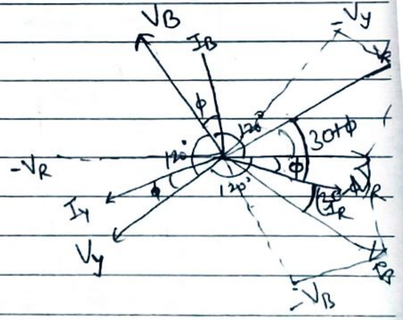
$$P_1 = V_{13} I_1 \cos(30+\phi)$$

$$P_1 = \sqrt{3} V I \cos(30+\phi)$$

Now by closing the switch (1-2), we get the reading of wattmeter as;

$$P_2 = V_{12} I_1 \cos(30 - \phi)$$

$$P_2 = \sqrt{3} V I \cos(30-\phi)$$



Total power is given by;

$$P = P_1 + P_2$$

$$\boxed{P = \sqrt{3} V I \cos\phi.}$$

☆ Energy Consumption formula :-

Energy consumption is the consumption of energy or power of a system using supply. The consumption is done in Kilograms of oil equivalent per year (Kgoe/a), Giga Joule per year and in watts.

So, the energy consumption formula is given by,

$$\boxed{E(\text{kWh/day})\ E(\text{kWh/day}) = \frac{P \times t}{1000} .\ \text{kWh}}$$

where, E is the energy in kilowatt-hours (KWh)
P is power in Watts.
t is time in hours per day.

Que. Calculate the energy consumption in a system that consumes 190 watts of power and works for 3 hrs a day.

Solution :-

Given : P = 190W
$t = 3$ hrs/day.

so, The energy consumption is given by :

$$E(KWh/day) = \frac{P \times t}{1000} \text{ KWh}$$

$$E(KWh/day) = \frac{190 \times 3}{1000} \text{ KWh}.$$

$$E(KWh/day) = 0.57 \text{ KWh}$$

☆ Introduction :-

An electrical installation is a combination of electrical equipment installed to fulfill a specific purpose.

In dealing with the electrical installation, it is necessary to ensure the safety of personnel as well as the ~~prop~~ protection of equipment from the electrical faults.

The most popular methods of protection are:
(1) Earthing or grounding of equipment.
(2) Use of fuses or Circuit Breakers (ie MCB & MCCB)
(3) Use of earth leakage and residual current circuit breakers.

☆ Switchgear :-

Switchgear is the combination of electrical disconnect switches, fuses or circuit breakers used to control, protect and isolate electrical equipment.

A switchgear or electrical switchgear is a generic term includes all the switching devices associated with mainly power system protection.

High-voltage switchgear was invented at the en of the 19th century for operating motors and othe electric machines and now be used with voltage up to 1,100 KV.

Switchgear in substations are located on both the high and low voltage sides of large power trans

★ Features of switchgear :-

(1) Complete reliability
(2) Absolutely certain discrimination.
(3) Quick Operation
(4) Provision for manual control.

★ Clasification of switchgear :-

Switchgear can be clasified on the basis of volt level into the following :-

(1) Low Voltage switchgear :-

The electrical switchgear rated upto 1KV is terme as low-voltage switchgear. These includes low-vol circuit breakers, switches, HRC fuse, MCB, ELC MCCB etc.

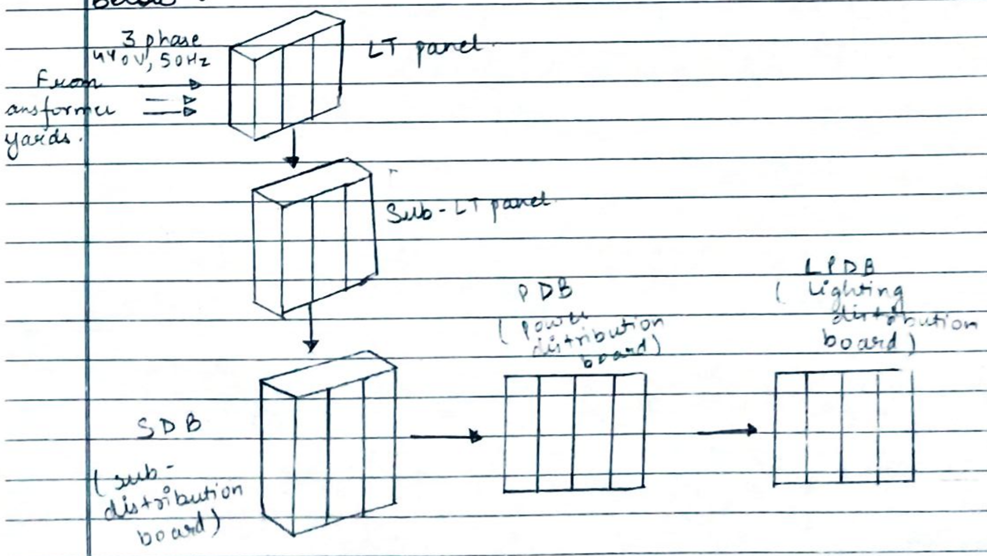
(2) Medium-Voltage switchgear :-

The electrical switchgear rated from 3KV to 36KV is termed as medium-voltage switchgear. It includes metal enclosed indoor type, metal enclosed outdoor type, oil CB, SFCB and vacuum CB.

(3) High voltage switchgear :-

The electrical switchgear rated beyond 36KV is termed as high-voltage switchgear. In these circuit breakers special care is taken during designing as the voltage level is very high.

An installation process of a switchgear is shown below :-



Switchgear installation process

★ Switch Fuse Unit (SFU) :-

→ SFU is a switching device having one switch an One fuse Unit. When we operate the breaker the contacts will get close through switch and then the supply will passes through the fuse ur to the output.

→ It is made of power fuse rating (80 - 250 - 400 A) and a switch which can be operated from outs using extended rotary handle to rotate the shaft which is inside it.

→ SFU is used for protecting power and control circu depends on the current rating required.

→ It has been used to trip the circuit particulary fo high capacity tripping.

→ It is used in industrial, residential and commercial buildings for electrical fittings.

Rating current : 16 - 32 - 63 - 100 - 200 Amp.
Rated Voltage : 240/415 V AC.

★ Miniature Circuit Breaker (MCB) :-

MCB is an automatically operated electrical Switch designed to protect the electrical applic and human beings from electrical shocks & faullts

These days MCB is more commonly used in low voltage electrical network than fuse. MCB is used for rating upto 100 Amps. in the motor feeders. In domestic sector, its rating is upto 10,000 Amps.

★ Working of MCB :-

Basically, MCB is operated under two effects of overcurrent.

(1) Thermal effect
(2) Short-circuit condition.

The thermal operation is achieved with a bimetallic strip, whenever continous over-current flows through MCB, the bimetallic strip is heated and deflects by bending. This deflection of bimetallic strip releases mechanical latch. As this latch is attached with operating lever, it causes to open the MCB contacts.

During short circuit condition, sudden rising of current, causes electromechanical displacement of plunger associated with tripping coil or solenoid of MCB. The plunger strikes the trip lever causing immediate release of latch and consequently open the MCB contacts.

★ Construction of MCB :-

MCB construction is very simple, robust and maintenance free. Generally a MCB is not repair or maintained, it just replaced by new one when required. A MCB has normally three main parts

(1) Frame
(2) Operating lever
(3) Trip unit.
(4) Bimetallic strip
(5) Fixed and moving contacts.

During the operation of MCB, the electric current carrying path of a MCB is arranged in series like firstly bi-mettalic strip — latch mechanism. trip unit — fixed and moving contacts and lastl the operating lever is outside the MCB.

So, whatever may be the condition or effect, may be due to deformation of bi-metallic strip, due to increased or sudden over current by short circuit condition of trip coil or may be due to manual operation, the same latch point is displaced and same spring is released which ultimately responsible for movement of the MCB co

★ Advantages of MCB over fuse :-

(1) It automatically switches off the electrical circuit during abnormal condition but fuse does not sense

(2) MCB is much more sensitive to over current than fu

(3) Quick restoration of supply cannot be possible in case of fuse.

(4) Handling MCB is more electrically safe than fuse.

(5) In MCB, the switch operating knob comes at its off position during tripping and can be easily identified but in case of fuse, the fuse wire should be checked.

The only disadvantage of MCB over fuse is that this system is more costlier than fuse unit system.

★ Moulded case circuit Breaker (MCCB) :-

MCCB are electro-mechanical devices which protect a circuit from over-current and short circuit with in the range of 32 amps to 3000 amps.

Their primary functions are to provide a means to manually open a circuit and automatically open a circuit under overload or short circuit conditions.

MCCB can be easily reset after a fault and offers improved operational safety and convenience without incurring operating cost.

★ **Working of MCCB :-**

MCCB generally have a,

→ Thermal element for over current and
→ Magnetic element for short circuit release.

Like MCB, the MCCB will operate under thermal effect and short-circuit effect.

The thermal effect is achived by deformation of bi-metallic strip by releasing the spring-loaded trigger which inturn will shut off-th electrical circuit.

During short-circuit condition, sudden rising of current causes the displacement of the trip unit directly and releasing the spring loaded trigger which inturn will shut off the MCCB Contac

MCCBs are now available with a Variety of releases and these are given below :-

(1) **Thermal magnetic Release :-**
It is used bimetall and electro-magnetic assemblies to provide over-cu protection. For higher level over-currents, instantan. trip allow MCCBs to interrupt suddenly.

(2) **Electronic Release MCCB :-**
Electronic release MCCBs uses power electronic circuitry to provide over-current protection. Mainly a current transformer (C.T) is used as an MCCB release in this type which act first during the short-circuit condition.

(3) **Microprocessor release MCCB :-**
Microprocessor release MCCBs uses microprocessors to provide the over-current protection. It works on monitoring of current with true value of current and give the tripping effect. It is highly flexible and reliable in comparison to other releases.

★ **Earth leakage Circuit Breakers (ELCB) :-**

Earth leakage circuit breaker (ELCB) is a device used to directly detect currents leaking to earth from an installation and cut the power.

There are two types of ELCBs :-

(1) Voltage Earth Leakage Circuit Breaker (V-ELCB).
(2) Current Earth leakage Circuit Breaker (C-ELCB).

(1) Voltage Base ELCB :-

Voltage ELCB is a voltage operated circuit breaker. The device will function when the curr passes through the ELCB.

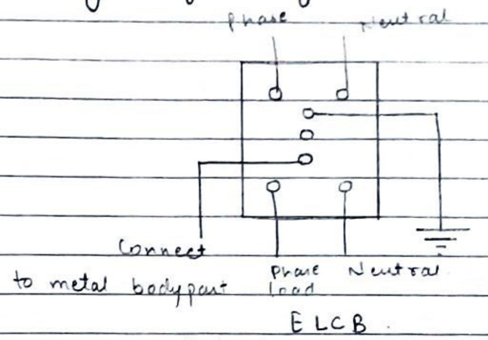
It contains a relay coil which it being connec to the metallic load body at one end and it is connected to ground wire at the other end.

If the voltage of the equipment body is rises which could cause the difference between earth & load body voltage, as a result the danger of electric shock will occur. This voltage differenc will produce an electric current from the load metallic body passes the relay coil and to the earth.

When the voltage on the equipment metallic bod rose to the danger level which exceed to 50 V the flowing current through relay coil could mov the relay contact by disconnecting the supply current to avoid from any danger electric shock

The ELCB detects faults from live to the ea wire within the installation it protects. If sufficient voltage appears across the ELCB's sen coil, it will switch off the power and remain off until manually reset.

The wiring diagram of V-ELCB is shown below:-



⇒ The way to identify an V-ELCB is by looking for green and yellow earth wires entering the device.

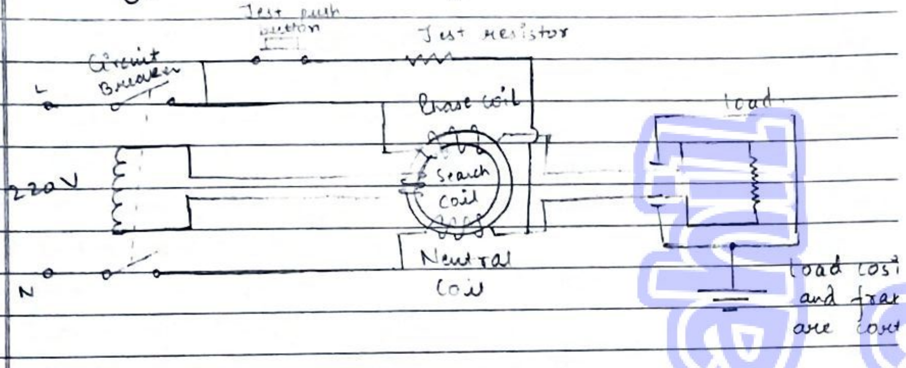
The ELCB is the brain for the shock protection and the grounding is the backbone. Therefore, without a functional grounding, there is no protection against electrical shock's in your house even if you have installed the ELCB.

(2) Current-operated ELCB (RCD) :-

Current-operated ELCBs are generally known as Residual current devices (RCD). These provide protection against earth leakage. Both the circuit conductors are run through a sensing coil, any imbalance of the currents means the magnetic field does not perfectly cancel. The device detects the imbalance and trips the contact.

★ **Working of RCD :-**

The typical circuit of RCD is shown below as



RCB circuit.

→ The supply coil, the neutral coil and the search coil all wound on a common transformer core.

During the normal operation, the same current pas through the phase coil, the load and return bac through the neutral coil. Both the phase and neutr coils are wound in such a way that they will produce an opposing magnetic flux. With the san current passing through both coils, their magnetic effect will cancel out each other under a normal condition.

During the faulty operation, or a leakage to eart in the load circuit, or anywhere between the loa circuit and the output connection of the RCB circ

The current returning through the neutral coil has been reduced. then the magnetic flux inside the transformer core is not balanced anymore. So, the total sum of the opposing magnetic flux is no longer zero. This net remaining flux is what we call a residual flux.

The periodically changing residual flux inside the transformer core crosses path with the winding of the search coil. This action produces an emf across the search coil which in turn producing a current inside the wiring of the trip circuit. This current operates the trip coil of the circuit breaker.

Sensitivity of RCB :-

→ High sensitivity :- 6-10-30 mA (for direct-contact / life, injury protection)

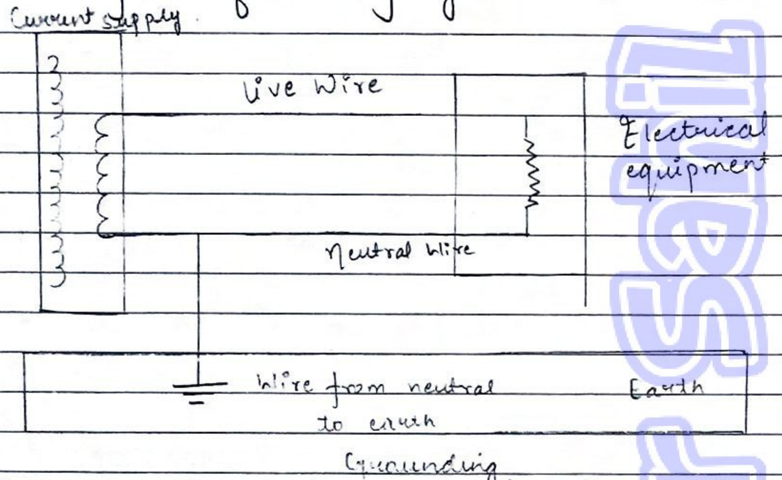
→ Medium sensitivity :- 100-300-500-1000 mA (for fire protection).

→ Low sensitivity :- 3-10-30 A (for protection of machine).

★ Earthing System / Grounding System :-

In an electrical installation, an earthing system or grounding system connects specific parts of ~~that~~ installation with the earth's conductive surface for safety and functional purposes.

The diagram of earthing system is shown below:



→ To connect the metallic parts of an electric appliance to the earth is called earthing.

→ Or, in other words, to connect the metallic parts of electric machinery and devices to the earth plate through a thick conductor wire of low resistance is known as Earthing.

→ The process of transferring the immediate discharge of the electrical energy directly to the earth by th help of the low resistance wire is known as earthi

Mostly, the galvanised Iron is used for the earthing. Earthing provides the simple path to the leakage current.

★ Types of earthing :-

The electrical equipment mainly consists of a non-metallic parts or the body of the equipment which does not carry current and a neutral wire or system of the equipment. So, the earthing is classified according these two parts of the electrical equipment and they are :-

(1) Neutral earthing :-

In neutral earthing, the neutral of the system is directly connected to the earth by the help of the GI wire. Such type of earthing is mostly provided to the system which has the star winding. for example, generators, transformers, motors etc.

(2) Equipment earthing :-

In equipment earthing the electrical equipment's body is directly connected to the earth by a conducting wire having low resistance. If any fault occurs in the apparatus the short-circuit current will pass through the conducting wire to the earth and thus protect the system from damage and shock.

★ Importance of earthing :-

The earthing is essential because of the following reasons :-

- → Protects the personnel from the short circuit curren
- → Provides the easiest path to the flow of short circuit current.
- → Protects the machinery and personnel from th high voltage surges and lighting discharge.

★ Difference between earthing and grounding

	Grounding	Earthing
Definition :	The current carrying part is connected to the ground.	The body of the equipment connected to the ground
Location :-	Between neutral & Earth.	Between equipment body & ea
Symbol :		
Potential :	It does not have zero potential	It has zero potential.
Application :	Provide the return path to current	Discharges the electrical energ to the earth.
Examples :	Neutral of Generator and Power transformers. Connected to the ground.	The enclosure of the appa connected to the ground