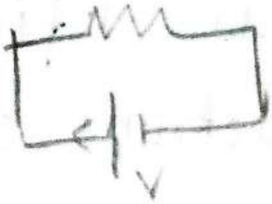
UNIT-1 Electric Circuit

Voltage: Potential difference b/w 2 points. (or) work done for moving a unit charge from one point to other point.

$$V = \frac{W}{q}$$



It is defined as the potential difference b/w any two points known as voltage.

Voltage is denoted by 'V' and the unit of voltage is volts.

(or)

Voltage is defined as work done in moving unit charge from one point to other point.

$$V = \frac{W}{q} = \frac{Joules}{Colomb} \Rightarrow Volts.$$

Units of voltage is volts & Voltage is denoted by V.

$$V = \frac{dW}{dq}.$$

Current: Rate of flow of charge or Rate of flow of electrons.

'i' or 'I' is the denotion.

Unit : Ampere

It is defined as rate of flow of electrons or charge known as current and current is represented by 'I' or 'i' and the unit of current is amperes.

$$I = \frac{q}{t} = \frac{\text{columbs}}{\text{sec}} = \text{Amp.}$$

$$= \frac{dq}{dt}$$

Energy (W): Capacity to do the work.

Energy is nothing but capacity to do work it is represented by 'W' & unit of energy is joules.

$$w = \int P \cdot dt$$

<u>Power</u>: Power is nothing but energy with respect to time (or) product of voltage and current.

Power is denoted by 'p'

Units of power is watts.

$$\text{Power} = \frac{\text{Workdone}}{\text{Time}} = \frac{\text{Energy}}{\text{Time}} = \frac{w}{t}$$

$$\text{Power} = \frac{\text{Energy}}{\text{time}} = \text{watts}$$

$$P = V \times I$$

$$P = \frac{dw}{dq} \times \frac{dq}{dt}$$

$$P = \frac{dw}{dt}$$

$w = P \times t$

<u>Ohm's law</u>: It states that at constant temperature current is directly proportional to voltage and inversely

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proportional to resistance known as Ohm's law

Current is directly ∝ V

$$I \propto V$$

$$I \propto \frac{1}{R}$$

$V = IR$	A
$I = \frac{V}{R}$	V
$R = \frac{V}{I}$	Ω

Power formulas: ~~$P = V \times R$~~

$$P = V \times I$$

$$= V \times I = IR \times I$$

$$V = I^2R$$

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

$$P = \frac{V^2}{R} \text{ watts}$$

Energy:

$$W = \int P.dt = \int V \times I\, dt$$

$$W = \int I^2R\, dt$$

$$W = I^2Rt$$

limitations: Nature of the material

1) Ohm's law is not applicable to non linear circuits like SCR, diodes, transistors, Ohm's law also depends on the nature of the material.

2) Ohm's law is also not applicable to metals.

Temperature also effects ohm's law.

Problems:

1) A 12 Ω resistor is connected across 6 volts battery find how much current flows through the resistor.

$$V = I R.$$

$$6 = I \times 12$$

$$I = \frac{6}{12}$$

$$I = 0.5 \text{ Amp.}$$

$V = IR$

$6 = I \times 12$

$I = \frac{1}{2}$

0.1-2

2Q) If 0.6 A current flows through a resistor voltage of 2 points of a resistor is 12 volts. what is the resistance of resistor.

$I = 0.6 A$

$V = 12 V$

$$R = \frac{V}{I} = \frac{12}{0.6} = 20 \Omega$$

3Q) If charge of a material is 30 coulomb, we take the time 5 sec. I = ?

$$I = \frac{q}{t} = \frac{30}{5} = 6 \text{ Amp.}$$

Resistor: Resistor is nothing but

Resistor opposes the very flow of current through it

It is denoted by R.

Units = ohm (Ω)

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

ρ = Specific resistance (or) resistivity.

Factors effecting resistors:

1) Resistance depends upon length of the material

$$R \propto l.$$

2) Area of Cross section

Resistance depends upon area of

cross section $\boxed{R \propto \frac{1}{a}}$

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

ρ = specific resistance or resistivity.

l = length

a = cross sectional area.

Conductance(G): It is the reciprocal of resistance. Denoted by G.

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

$$= \frac{1}{\Omega}$$

$$= \Omega^{-1} \text{ (or) } Mho (\mho)$$

Unit of conductance is ~~moho~~ mho

Resistivity: It is defined as resistance of unit area and unit length it is denoted by 'ρ'. & the units are 'ohm-m' (Ω-m)

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

$$\boxed{\rho = \frac{Ra}{l}}$$ = resistance per unit area by unit length

$$\rho = \frac{ohm\text{-}m^2}{m} = ohm\text{-}m.$$

conductivity!

It is defined as reciprocal of resistivity it is represented by 'σ'. Unit of conductivity is $\boxed{\sigma = \frac{1}{\rho}}$.

Q Determine the resistance of 564m length of aluminium conductor whose rectangular cross section is 4cm x 2cm assume resistivity is equal to 2.826×10^{-8} ohm-m

$$2.826 \times 10^{-8} = \frac{R \times 8 \times 10^{-4}}{564}$$

53,16
7,232

$$\frac{2.826 \times 10^{-8} \times 564}{8 \times 10^{-4}} = R.$$

$= 1.413 \times 141 \times 10^{-4}$

$R = 1.99233 \times 10^{-2}\ \Omega$

Q) Calculate the length of copper wire 1.5mm in diameter to have a resistance of 0.3 ohm the resistivity of copper is 0.017 ~~µOhm~~ µΩ-m.

$r = \frac{1.5}{2} \times 10^{-3}$. $a = \frac{\pi d^2}{4}$.

$R = 0.3\ \Omega$.

$\rho = 0.017 \times 10^{-6}$.

$$\begin{array}{r} 1413 \\ \times\ 141 \\ \hline 1413 \\ 5652 \\ 1413 \\ \hline 1.99233 \end{array}$$

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$a = \frac{\pi d^2}{4}$

$= \frac{3.14 \times 1.5 \times 1.5 \times 10^{-6}}{4}$

2)

$= 1.57 \times 0.75 \times 1.5 \times 10^{-6}$

$= 1.76625 \times 10^{-6}$

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

$\mu = 10^{-6} m$

1 meter = 100 cms

1 cm = 10 mm

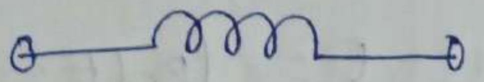
$0.3 = \frac{0.017 \times 10^{-6} \times l}{1.76625 \times 10^{-6}}$

$l = \frac{0.3 \times 1.76625 \times 10^{-6}}{0.017 \times 10^{-6}}$

$l = 31.19 m$

Inductor (L): It dousnot allow any sudden change of current through it. It stores energy in the form of electromagnetic field. It is denoted by 'L'. It is a storage element. When a wire is wound forms L

Unit of Inductor is Henry (H)

Symbol : 

$V \propto I$ (from Ohm's law)

voltage across inductor

$$V \propto \frac{di}{dt}$$

$$\boxed{V = L\frac{di}{dt}}$$

current across the inductor:

$$\frac{di}{dt} = \frac{V}{L}$$

$$\int di = \int \frac{V}{L}\, dt$$

$$\boxed{i = \frac{1}{L}\int V dt}$$

Power across the inductor

$$P = V \times I$$

$$= L \frac{di}{dt} \times I$$

$$\boxed{P = I L \frac{di}{dt}}$$

Energy stored in inductor.

$$E = \int P dt$$

$$= \int I L \frac{di}{dt} \cdot dt$$

$$= L \int I \, di$$

☆ $$\boxed{E = \frac{L I^2}{2}}$$

When the inductor is connected to the battery it stores its energy in the form of electronmagnetic fied & when the battery is removed it provides its energy to the circuit or to the capacitor.

Capacitor (C) :

It is a basic electric element

It is works on the principle of capacitance

capacitor is a storage element which stores energy in the form of electro static field.

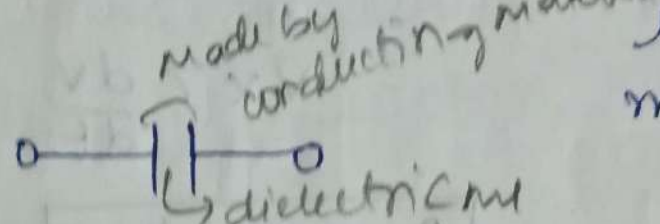
It is denoted by 'c'

unit of capacitor is Faraday (F)

μF

mF

symbol:



Current stored in the capacitor:

Note: It stores energy in the form of electrostatic field

It doesnot allow the sudden change of voltage in the circuit.

$q = CV$

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

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

$q = cv$

$\frac{dv}{dt} = \frac{1}{c}$

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

$\frac{dq}{dt} = \frac{d}{dt}(cv)$.

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

Voltage across the capacitor:

$$\frac{dv}{dt} = \frac{1}{c} i$$

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

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

Power across the capacitor:

$$P = V \times I$$

$$= V \times c\frac{dv}{dt}$$

$$P = cv\frac{dv}{dt}$$

Energy across the capacitor:

$$E = \int P\,dt$$

$$= \int cv\frac{dv}{\cancel{dt}}\cancel{dt}$$

$$E = \frac{1}{2}cv^2$$

Types of Elements:

(i) Active & passive (capable to deliver energy) ↳ not capable to provide energy but store energy

(ii) linear & non linear.

(iii) lumped & Distributed.

(iv) Unilatural & Bilateral.

Active & Passive elements:

Active elements: capable to provide energy for a very long time

There are nothing but energy sources like voltage and current source & the passive elements ~~indu~~ includes √Resistor, Inductor, capacitor. they are not capable of providing energy for a very long period of time

linear & Non linear

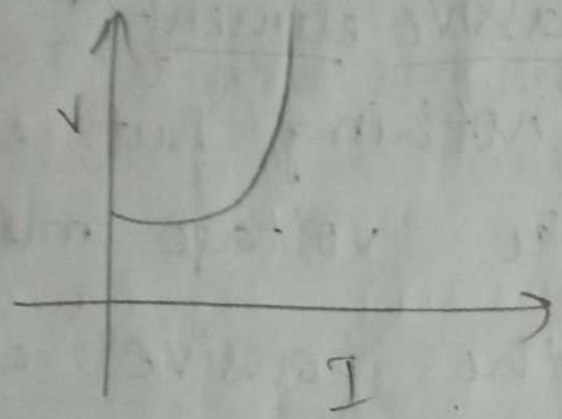
I & V characteristics of these types of elements which passes through the origin and satisfies superposition theorem, ~~principle~~ & ohm's law. principle known as linear elements:

Ex: R, L, C.

Non linear:

In current & voltage characteristics of these types of elements does not pass through origin & Doesnot satisfy superposition theorm, Principle called **Non linear elements**.

Ex: semiconductors like diodes.



(iii) **Lumped & Distributed: elements/parameters**

Lumped ↓ physically separable small size devices.

Distributed ↓ non physically separable.

Lumped elements: which are very small in size and we can separate it easily.

Ex: R, L, C.

Distributed elements:

size is very high which cannot be separated physically

Ex: Transmission lines.

(iv) Unilateral & Bilateral elements:

current passes from anode to cathode

Elements which can conduct current in only one direction known as Unilateral elements

Ex: Diode, SCR (Silicon control Rectifier)

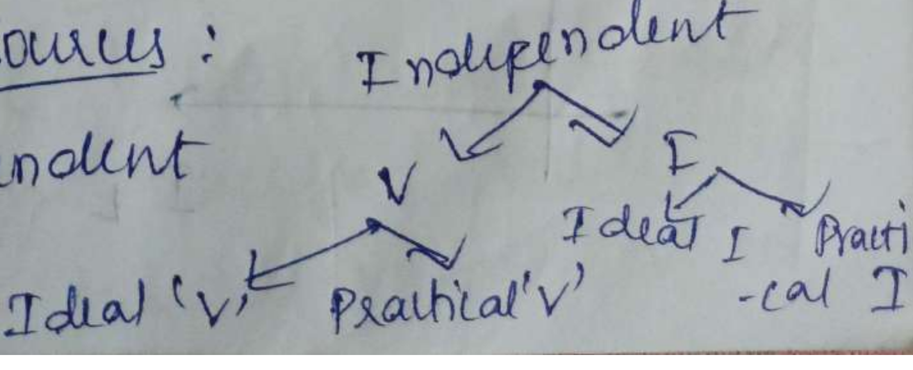
anode, cathode are terminals

Elements which are having two directions or which can conduct current in both the directions known as Bilateral elements.

Ex: R, L, C.

Types of Sources:

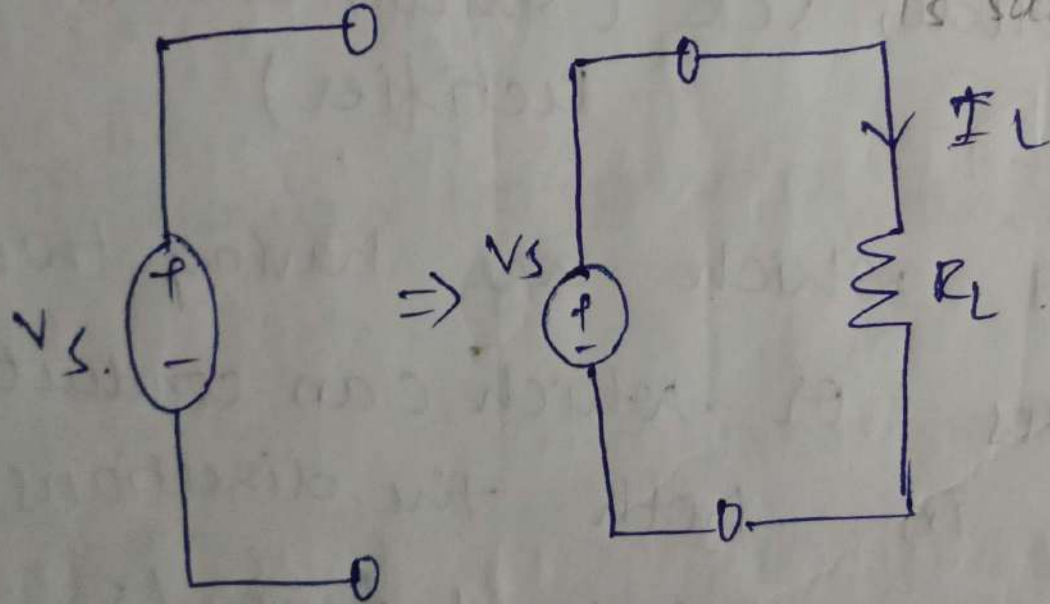
(i) Independent

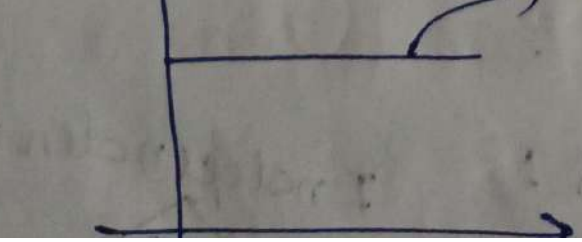


(ii) Dependent

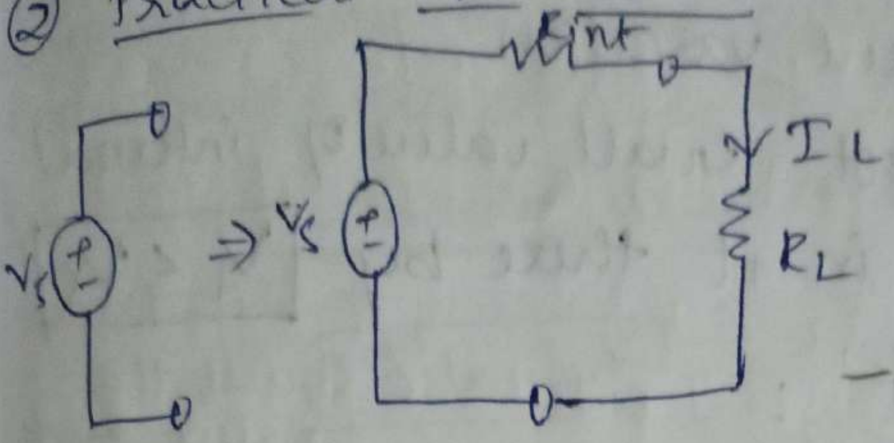
- VDVS — voltage dependent voltage source
- VDCS — voltage dependent current source
- CDCS — current dependent current source
- CDVS — current dependent voltage source

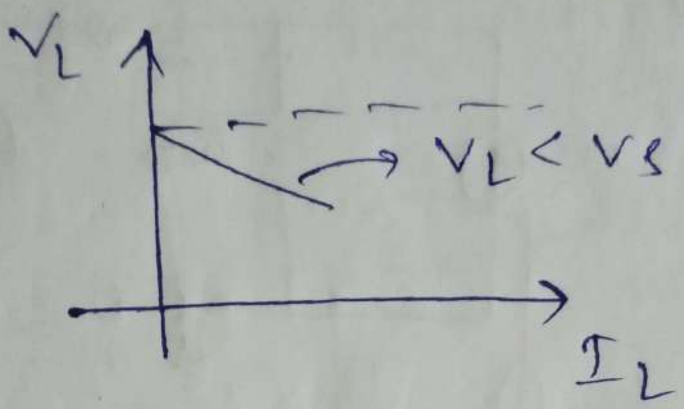
① <u>Ideal (V) source</u>: voltage across the load & source is same irrespective of difference in current





② Practical 'V' source:





① Ideal voltage source:

It is a voltage source which gives constant to the load terminals irrespective of load current variation $\boxed{V_L = V_s}$

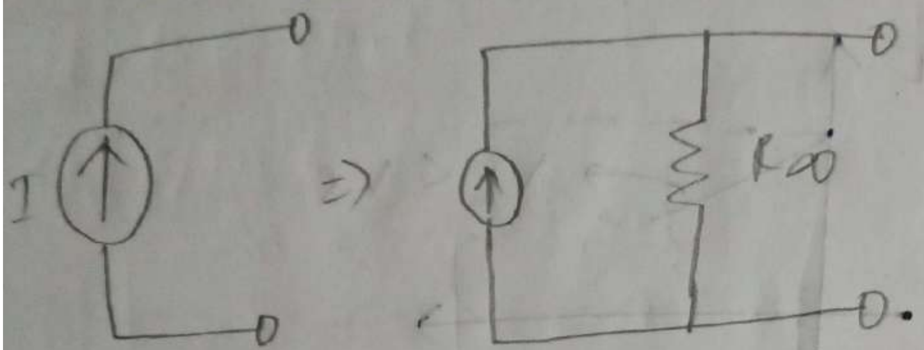
② Practical voltage source:

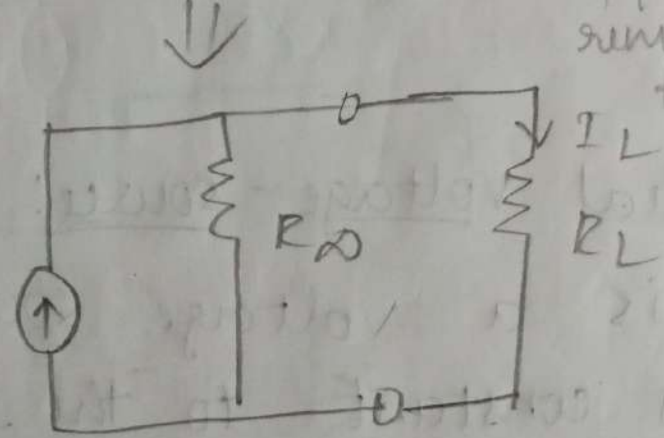
It is the voltage source which delivers the specified value of voltage or reduced voltage to the

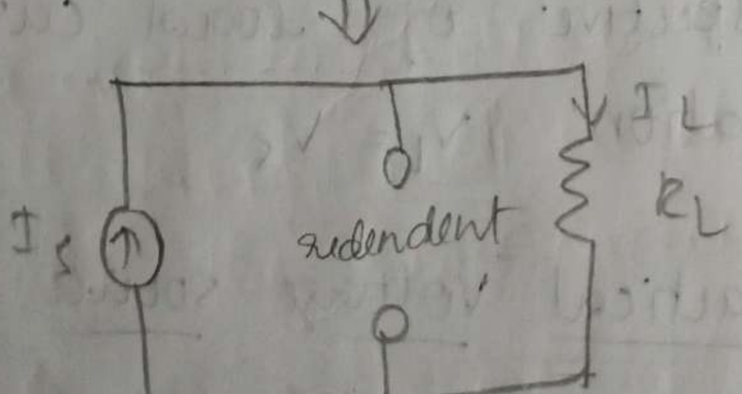
the load terminals with respect to load current variation.

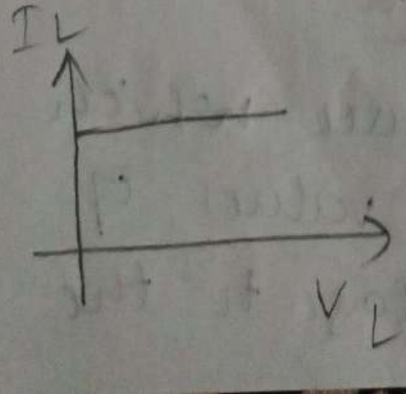
It has got small value of internal resistance in it there by $V_L < V_s$

(iii) Ideal 'I' : In Ideal 'i' source the value of R is ∞ (very high) so 'i' doesn't flow through it. & we remove R_∞ this is called redundant





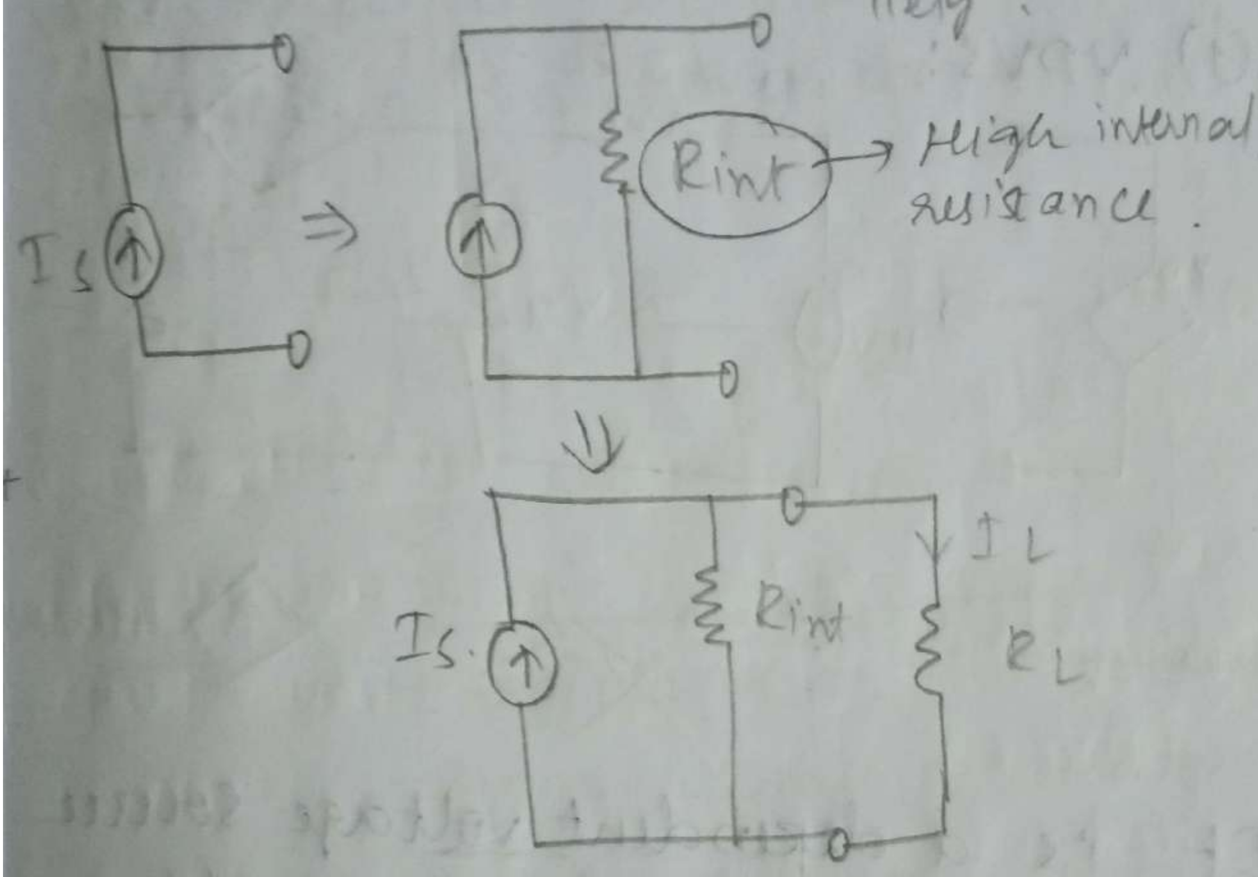


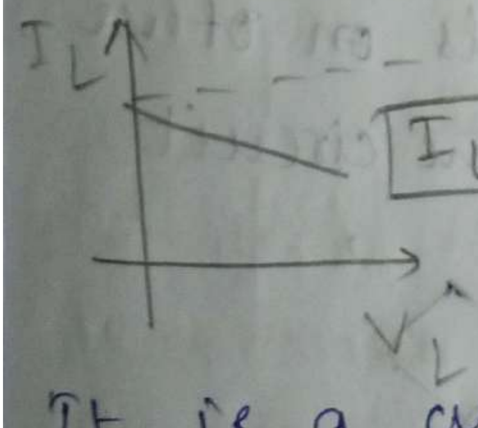


It is a current source which delivers constant value of load current to load terminals irrespective of load variations. It has infinite value of internal resistance.

$$I_L = I_S$$

(iv) Practical I : In current source int resistor is connected ||ely.





$$I_L < I_S$$

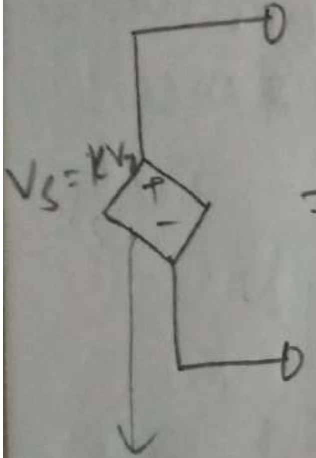
It is a current source which delivers specified value of current or reduced value of current to load terminals w.r.t load voltage variation.

→ It has got high internal resistance

$$\boxed{I_L < I_S}$$

(2) Dependent :

(i) VDVS:



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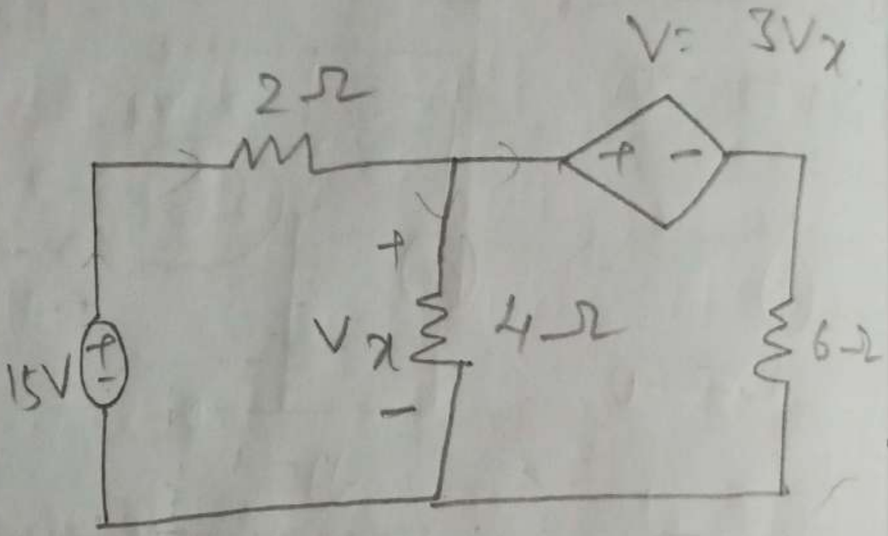
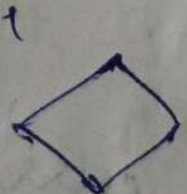


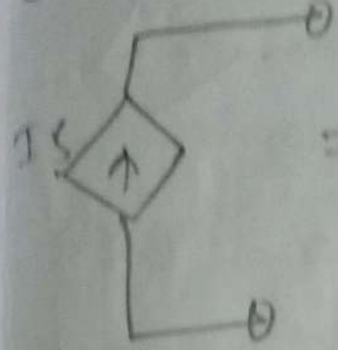
dependent voltage source

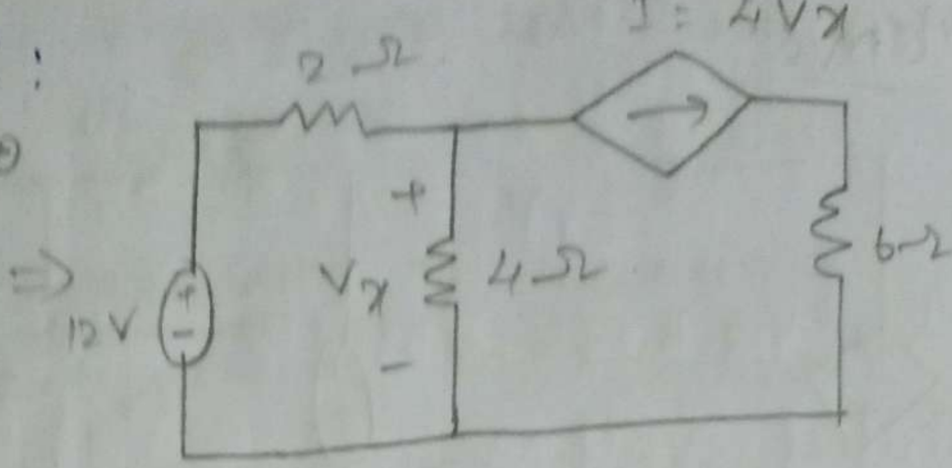
It is a dependent voltage source whose voltage depends on other element voltage in the same circuit

Dependent source



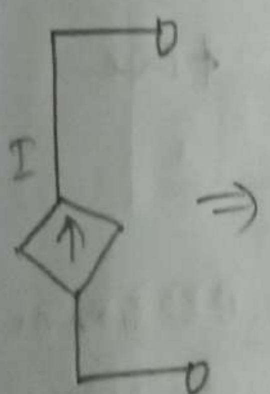
(ii) VDIS:

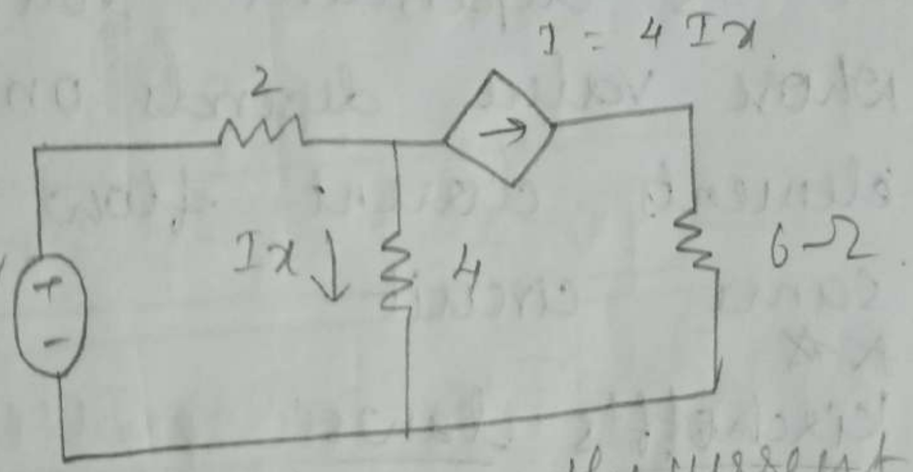




It is a dependent current source which depends on other element voltage in the same circuit.

(iii) CDCS:



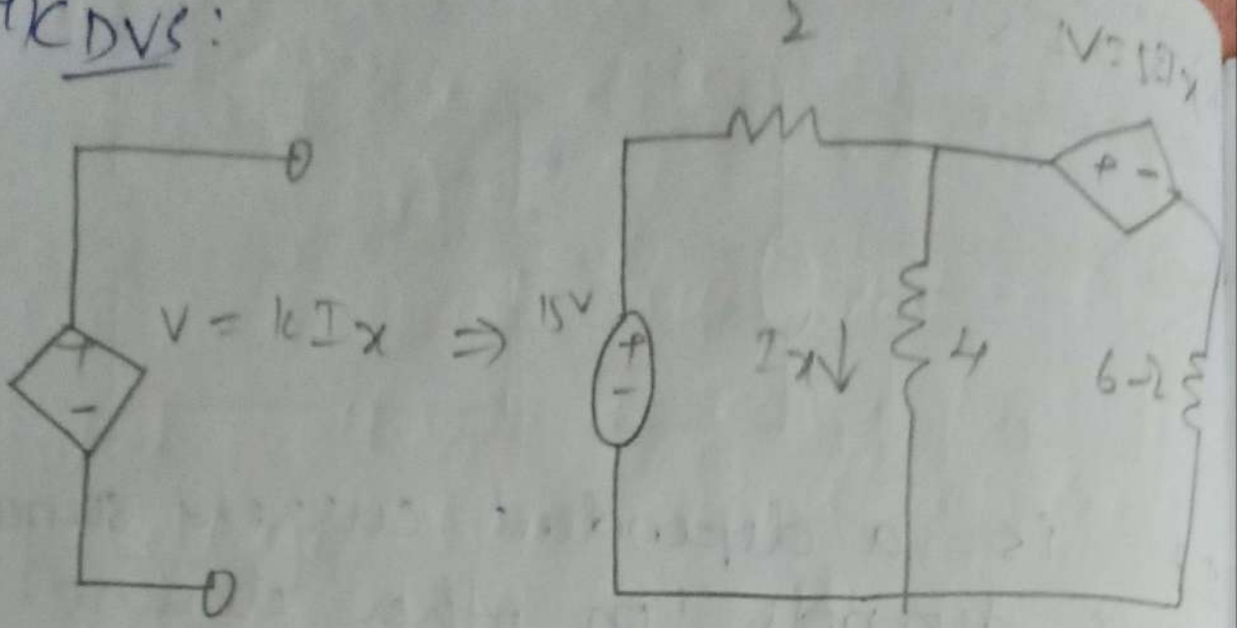


depending on the current from some element in the same circuit

current dependent current source

It is dependent current source whose value depends on other elements in the same circuit.

4) CDVS:



current dependent voltage source

It is dependent voltage source whose value depends on other elements current flow in the same circuit.

**

Kirchoff's laws! problem in exam

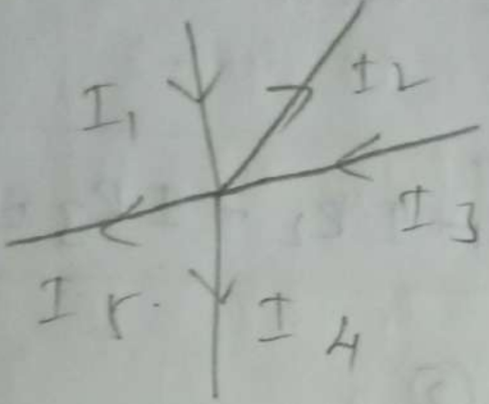
1. KCL
2. KVL.

1) Kirchoff's current law:

It states that algebraic sum of all the currents meeting at a common point or junction or node is equal to zero

(or)

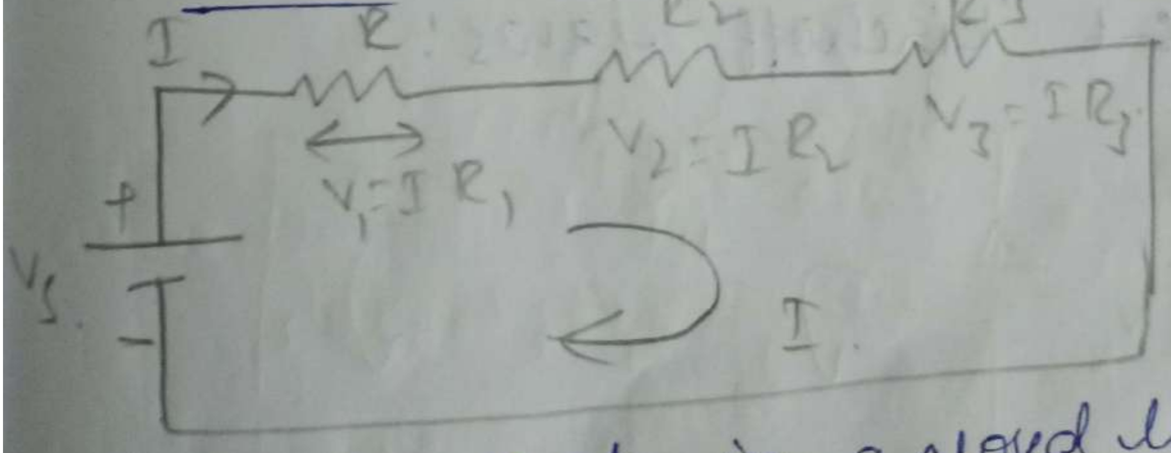
The algebraic sum of incoming currents is equal to algebraic sum of out going current.



$$I_1 + I_3 = I_2 + I_4 + I_5 \quad \text{— (1)}$$

$$I_1 + I_3 - I_2 - I_4 - I_5 = 0 \quad \text{— (2)}$$

(ii) Kirchoff's Voltage law:



It states that in a closed loop algebraic sum of voltage drop across the each and every element is equal to zero

(or)

In a closed loop total voltage total voltage is equal to sum of voltage drop across each & every element.

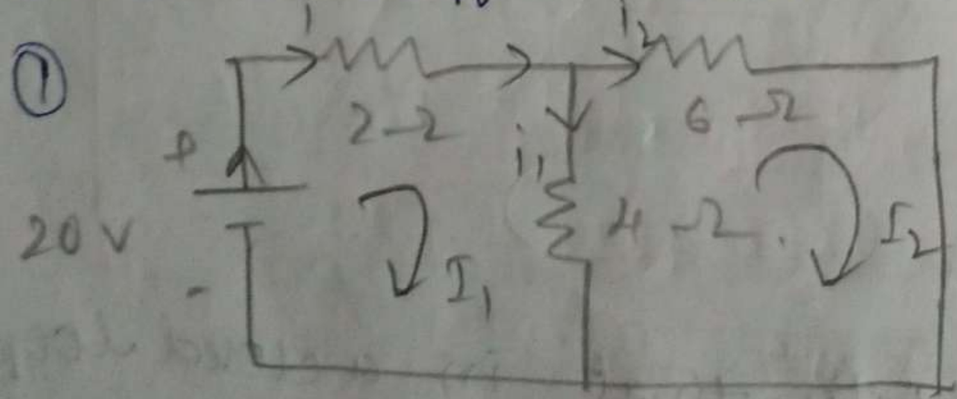
$$-V_s + IR_1 + IR_2 + IR_3 = 0. \quad -①$$

②

$$V_s = IR_1 + IR_2 + IR_3$$

Q) Determine current through each and every element using ~~KCL~~ kirchoff laws:

①



$-20V + 2i + i_1 4 + i_2 6$

Applying KVL to loop 1

$$-20+2I_1+4(I_1-I_2)=0$$

$$2I_1+4I_1-4I_2=20$$

$$6I_1-4I_2=20 \quad -(1)$$

Applying KVL to loop 2.

$$6I_2+4(I_2-I_1)=0$$

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

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

$$2(3I_1-2I_2=10)$$

$$3(-2I_1+5I_2=0)$$

$$6I_1-4I_2=20$$

$$-6I_1+15I_2=0$$

$$11I_2=20$$

$$I_2=\frac{20}{11}$$

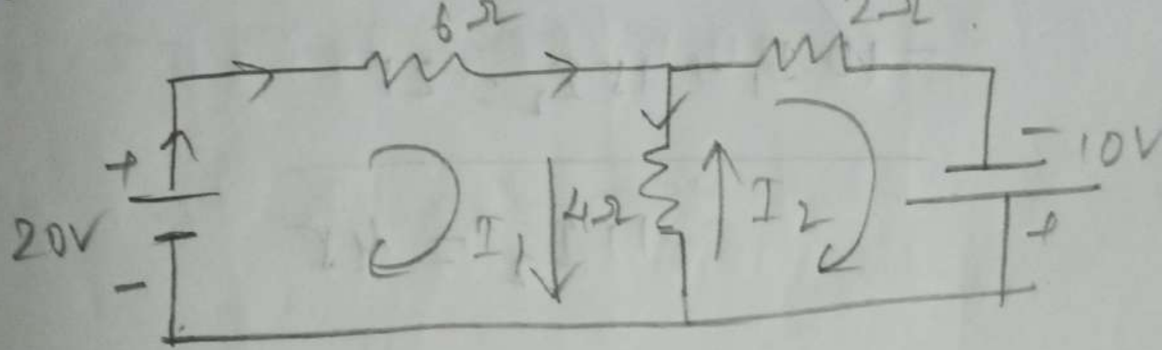
$-4I_1 + 10\left(\frac{20}{11}\right) = 0.$

$-44I_1 + 200 = 0$

$I_1 = \frac{50}{11}$ $-10V + 4(I_2 - I_1)$

$+ 2I_2$

1) Determine I value from the circuit.



loop 1

$-20 + 6I_1 + 4(I_1 - I_2) = 0.$

$6I_1 + 4I_1 - 4I_2 = 20.$

$10I_1 - 4I_2 = 20.$

$3(5I_1 - 2I_1 = 10.)$

loop 2

$2I_2 - 10 + 4(I_2 - I_1) = 0.$

$6I_2 - 4I_1 - 10 = 0.$

$5(3I_2 - 2I_1 = 5)$

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$$2(5I_1 - 2I_2 = 10)$$

$$5(-2I_1 + 3I_2 = 5)$$

$$10\,I_1 - 4I_2 = 20$$

$$-10\,I_1 + 15I_2 = 25$$

$$11I_2 = 45$$

$$I_2 = \frac{45}{11}$$

$$5I_1 - 2\left(\frac{45}{11}\right) = 10$$

$$55I_1 - 90 = 110$$

$$55I_1 = 200$$

$$I_1 = \frac{200}{55}\ 40$$

$$11$$

$$I_1 = \frac{40}{11}$$

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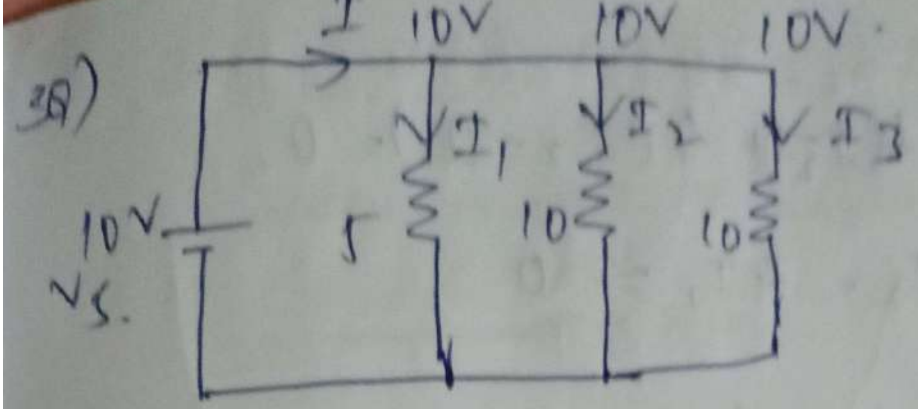
3a)



find out the value of i

→ KCL

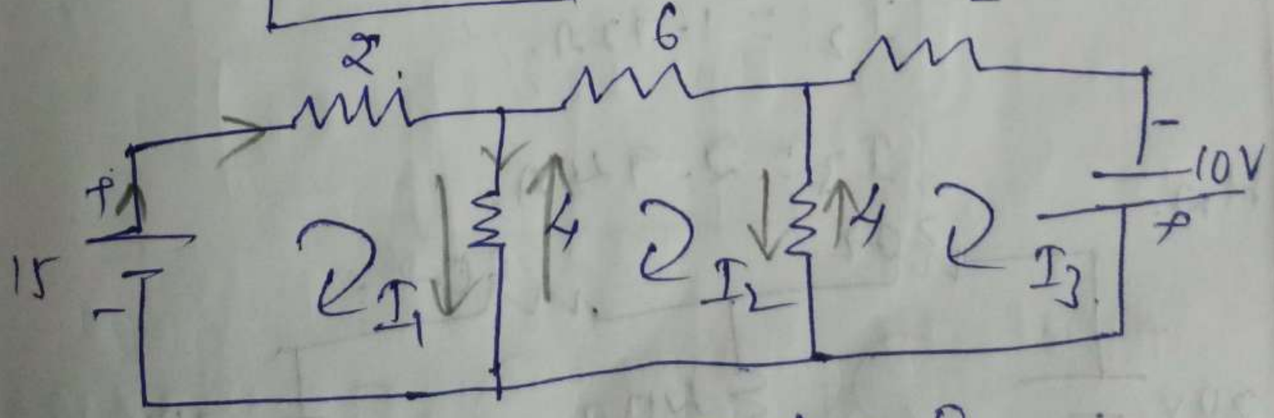
→ $I = I_1 + I_2 + I_3$.

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

$I = \frac{10}{5} + \frac{10}{10} + \frac{10}{10}$.

$= 2 + 1 + 1$

$\boxed{I = 4A}$



$-15 + 2 i_1 + 4(I_1 - I_2) = 0$.

$6 I_1 - 4 I_2 = 15$

loop 2:

$6I_2 + 4(I_2 - I_3) + 4(I_2 - I_1) = 0.$

$6I_2 + 8I_2 - 4I_1 = 0$

$14I_2 - 4I_1 = 0.$

$14I_2 - 4I_1 + 4I_3 = 0.$ — ②

loop 3:

$2I_3 - 20 + 4(I_3 - I_2) = 0.$

$2I_3 - 10 + 4I_3 - 4I_2 = 0.$

$6I_3 - 4I_2 = 10.$

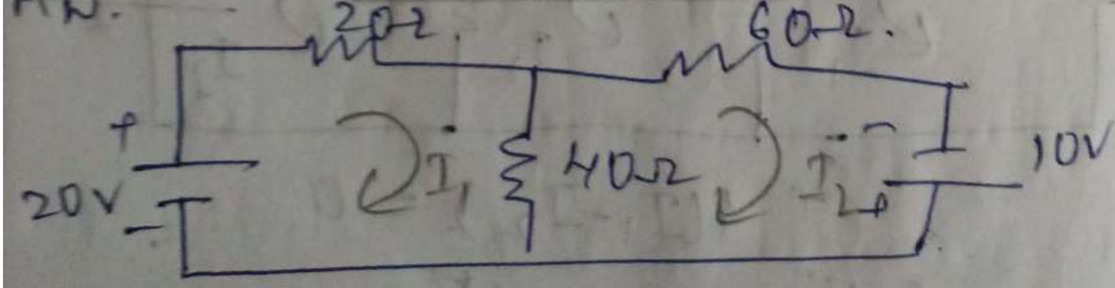
$3I_3 - 2I_2 = 5.$ — ③

$I_1 = 3.78A.$

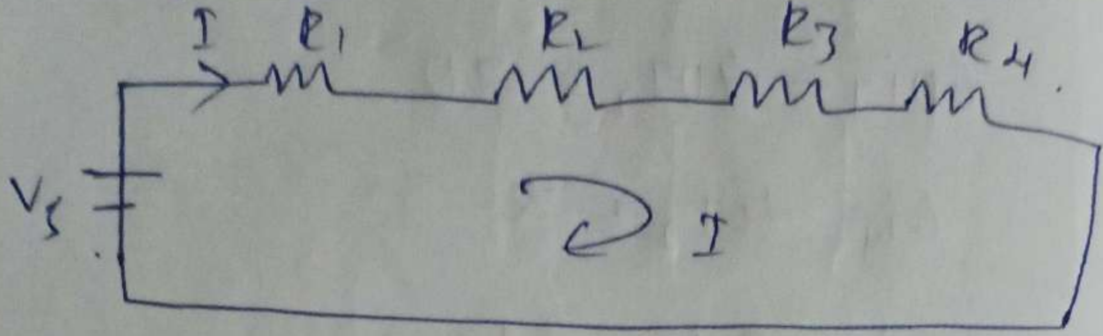
$I_2 = 1.92A.$

$I_3 = 2.94A.$

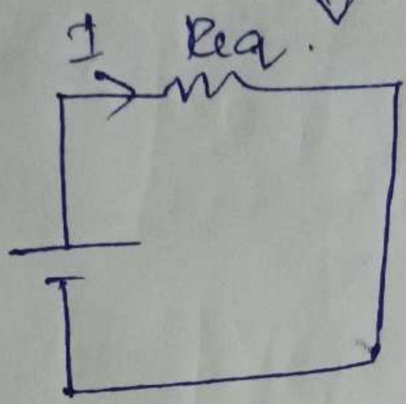
H.W.



→ Resistors - Series Connection:



⇓



Equivalence circuit.

$$-V_s + V_1 + V_2 + V_3 + V_4 = 0.$$

$$V_1 + V_2 + V_3 + V_4 = V_s.$$

$$I R_{eq} = I R_1 + I R_2 + I R_3 + I R_4.$$

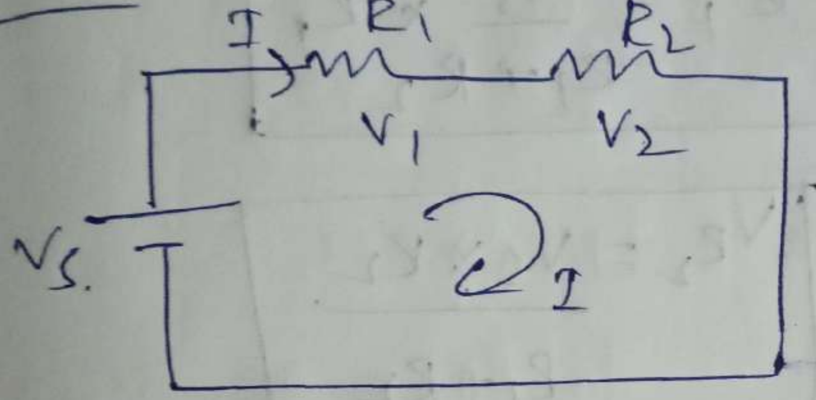
$$\boxed{R_{eq} = R_1 + R_2 + R_3 + R_4}$$

In series connection Req is equal to summation of all resistors.

Q) Consider a series, resistive circuit in which two resistors r_1 & r_2

are connected in series across one voltage source in these series circuits current is constant voltage drop across ~~ress~~ resistor is given by IR.

Voltage division principle:



consider a series resistive circuit in which R_1 & R_2 are connected in series across a single voltage source. Here, since the circuit is series current is constant

$$-V_s + V_1 + V_2 = 0$$

$$V_s = V_1 + V_2$$

$$V_s = IR_1 + IR_2$$

$$V_S = I(R_1 + R_2)$$

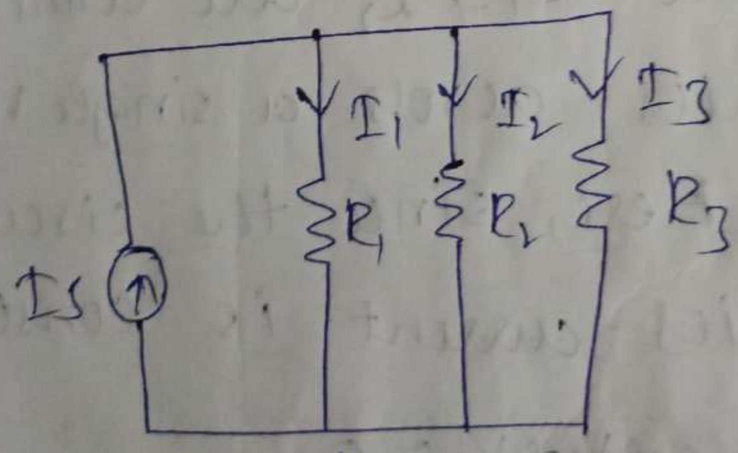
$$I = \frac{V_S}{R_1 + R_2}$$

$$V_1 = I R_1$$

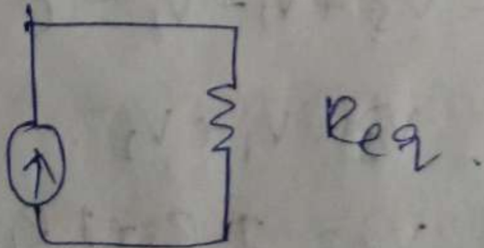
$$V_{R_1} = \frac{V_S}{R_1 + R_2} \times R_1$$

$$V_{R_2} = \frac{V_S \times R_2}{R_1 + R_2}$$

Resistor- Parallel combination:



⇒



KCL = $I_1 + I_2 + I_3$.

$$\frac{V}{R_{eq}} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$I_s = \frac{V}{R_{eq}}$$

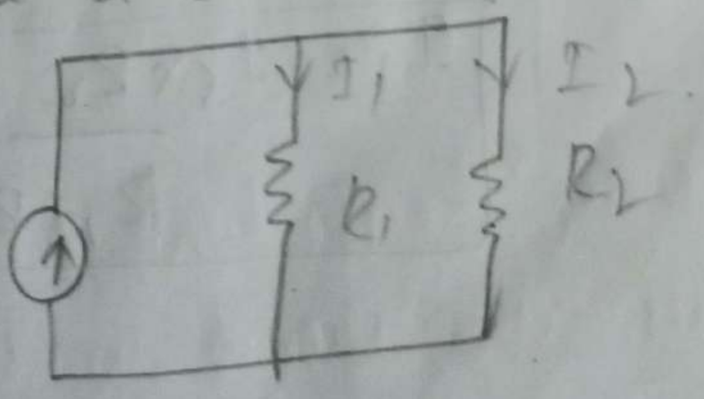
$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

If n resistors are connected in parallel

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots \frac{1}{R_n}$$

Current division principle:

current across single element in the circuit



KCL

$I_s = I_1 + I_2$

$V_s = V_1 = V_2$

$V_1 = V_2$

$I_1 R_1 = I_2 R_2$

$$I_1 = \frac{I_2 R_2}{R_1}$$

$I_s = I_1 + I_2$

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

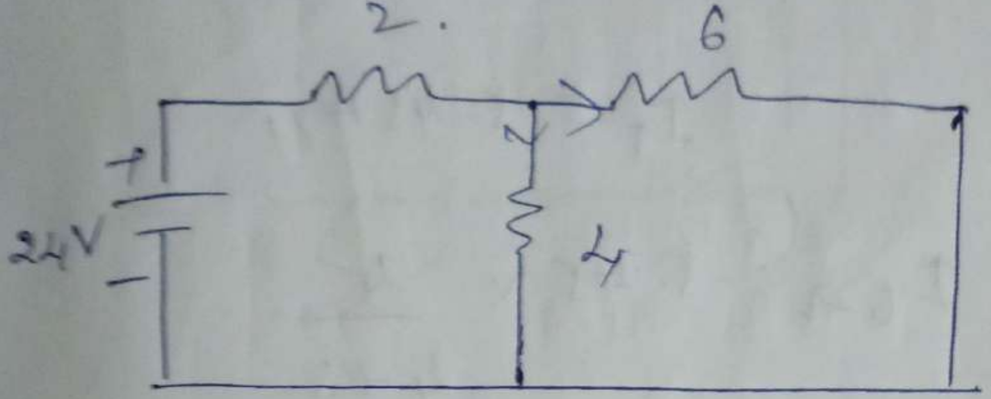
$$I_s = I_2 \left(\frac{R_2 + R_1}{R_1} \right)$$

$$\boxed{I_2 = I_s \cdot \frac{R_1}{R_1 + R_2}}$$

$$\boxed{I_1 = I_s \times \frac{R_2}{R_1 + R_2}}$$

Problem !

1) Determine power dissipated by 6 ohms resistor using required technique.



60
240
44
T1

60
11

11)60(5.4
55
50

$P = VI$.

$P_{6\Omega} = I_6^2 R$.

$I_6 = I_T \times \frac{4}{4+6}$.

$I_T = \frac{V}{Req}$

$R_T \text{ (or) } R_{eq} = \frac{6 \times 4}{6+4} + 2$

$= \frac{24}{10} + 2$

$Req. = 4.4\Omega$

$$I_T = \frac{V}{R_{eq}}$$

$$= \frac{24}{4.4}$$

$$I_T = 5.45A$$

$$I_{6\Omega} = 5.45 \times \frac{4}{4+6}$$

$$= \frac{5.45 \times 4}{10}$$

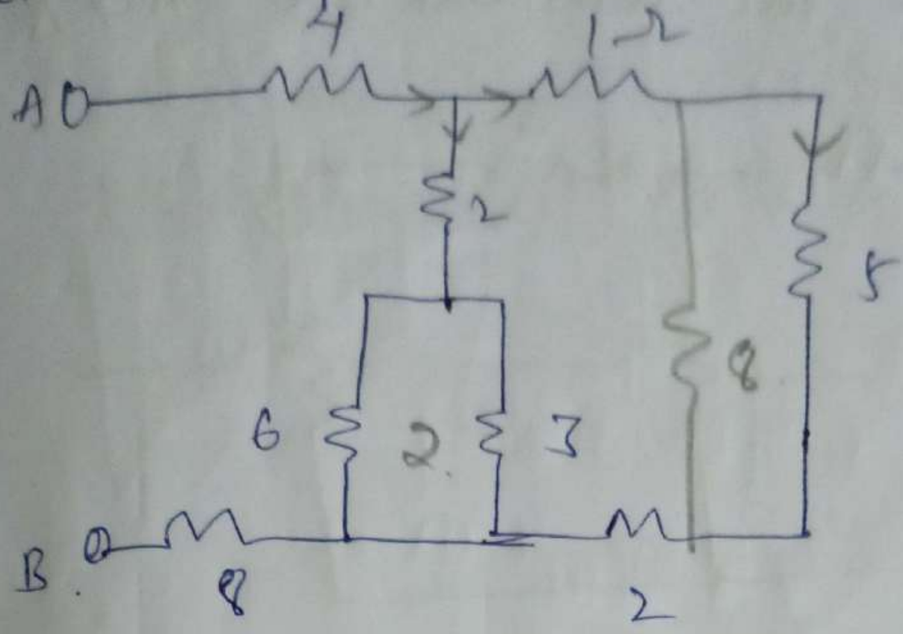
$$I_{6\Omega} = 2.18A$$

$$P_{6\Omega} = I_6^2 R_6$$

$$= (2.18)^2 \times 6$$

$$P_{6\Omega} = 28.512W$$

Q) Determine Req b/w A & B terminals as shown in the below circuit came in final exams



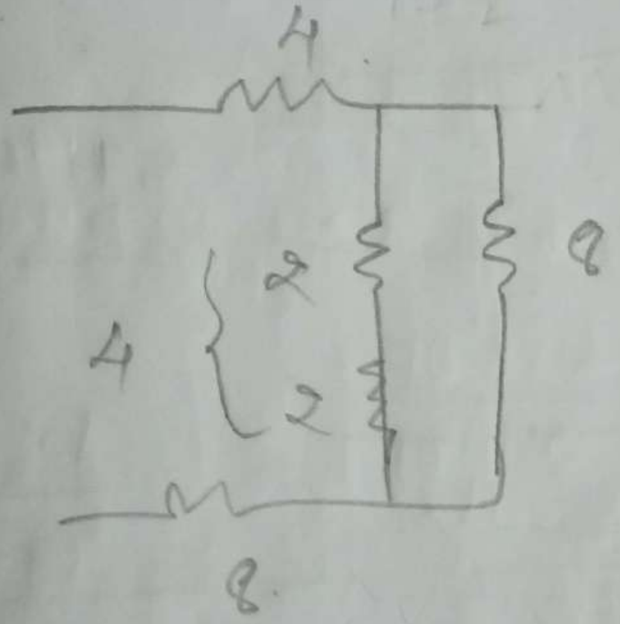
1+5+2

= 8

2

$\frac{6 \times 3}{9}$

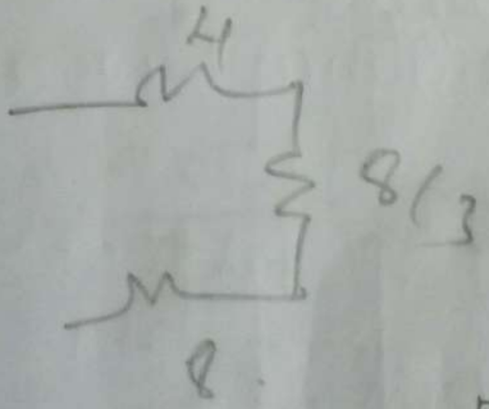
4+



$\frac{32}{4+8}$

$\frac{32}{12}$ 8

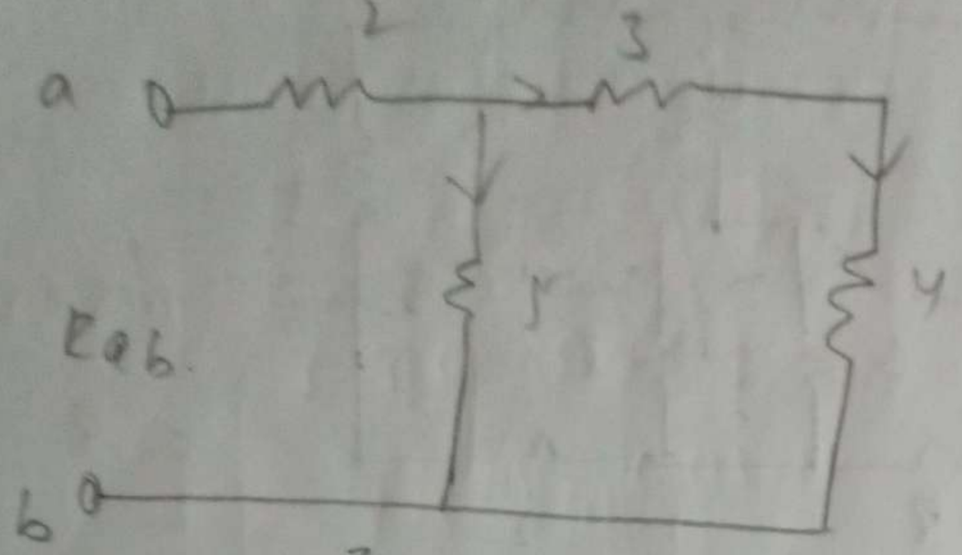
3



4 + 8/3 + 8

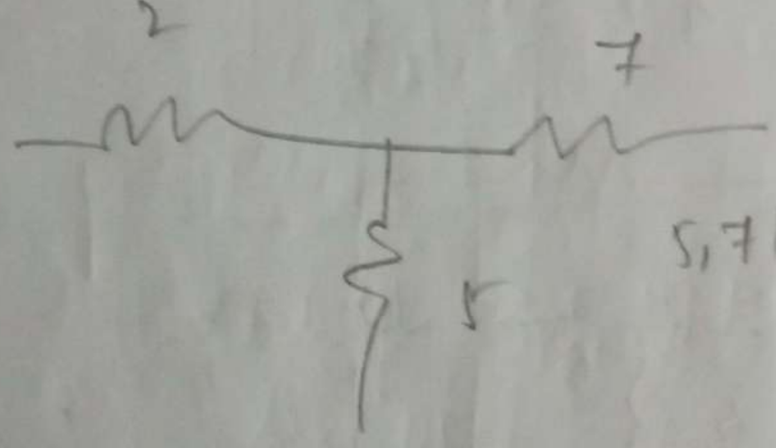
R_{AB} = 14.6Ω

8) Evaluate the resistance b/w A & B



3, 4 series

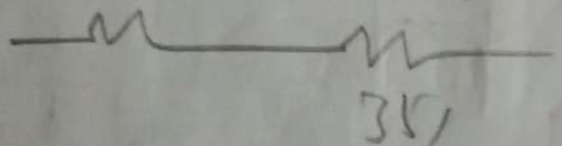
$3+4=7$



5, 7 ||el.

$\frac{5\times 7}{5+7}$

$\frac{35}{12}$



$2+35/12$

$\frac{24+35}{12} = \frac{59}{12}$

$R_{ab} = 4.91$

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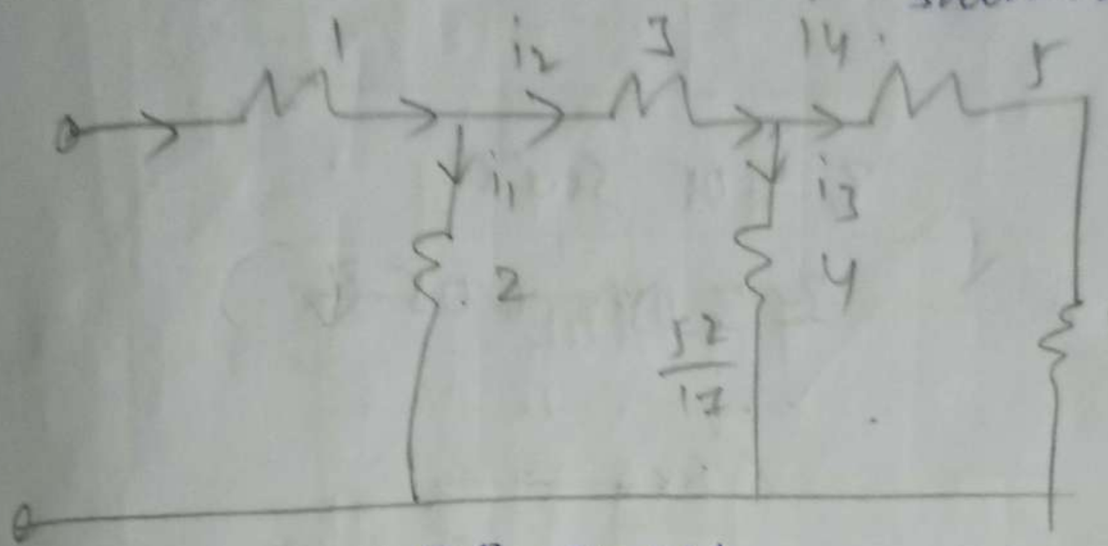
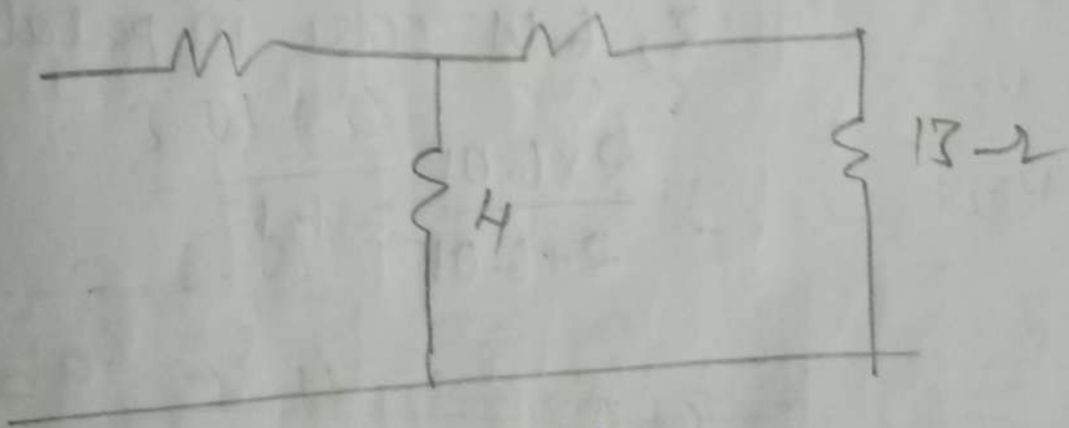
Always sort out series from right

Q) calculate the resistance b/w A B terminals of the circuit shown below.



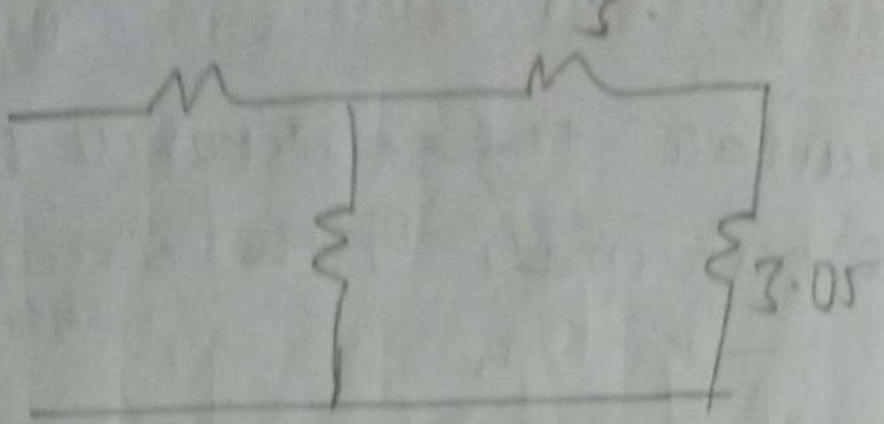
5, 8 series

5 + 8 = 13.



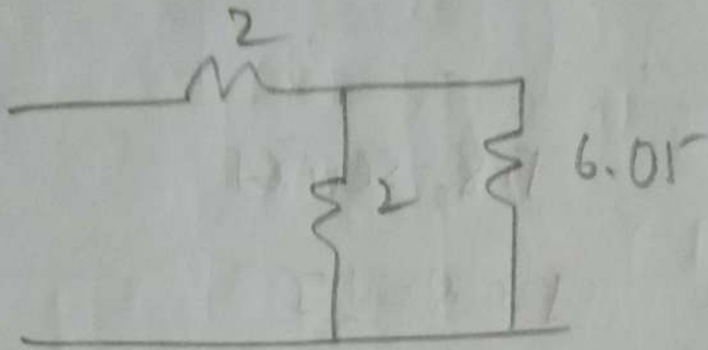
4, 13 ‖el.

$$\frac{4 \times 13}{4 + 13} = 3.05\ \Omega.$$



3, 3.05 series.

3+3.05 = 6.05 Ω.



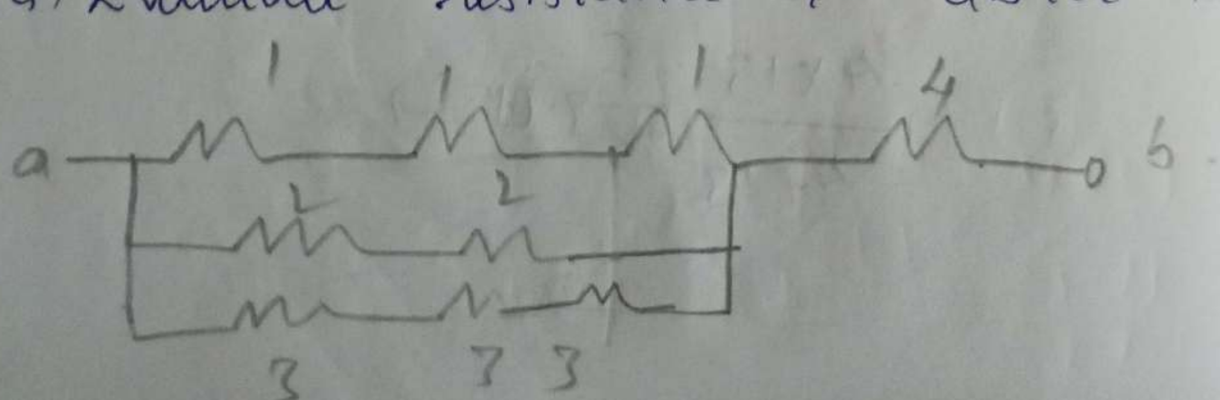
2, 6.05 are in parallel

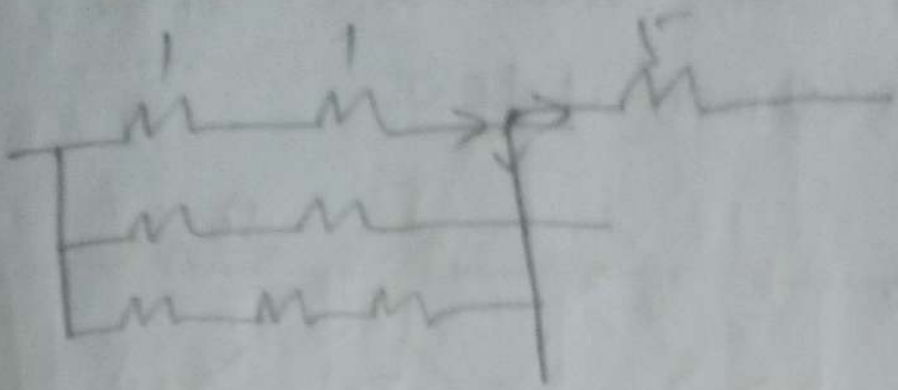
$$\frac{2\times6.05}{2+6.05} = 1.5$$

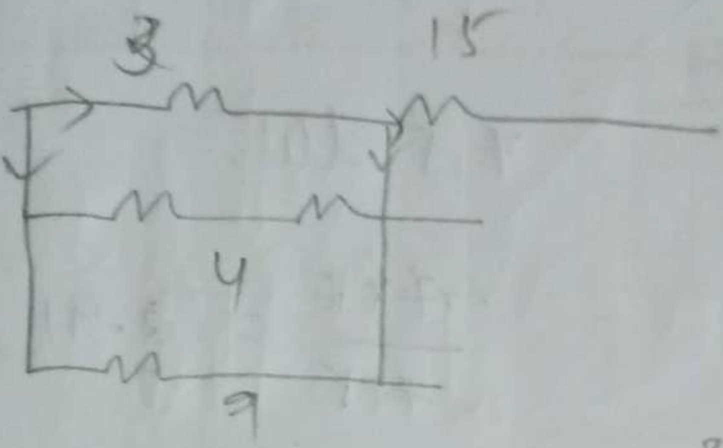
1+1.5 = **2.5 = Rab**

6marks.

Q) Evaluate resistance b/w ab terminals







$$\frac{\frac{12}{7}\times 9}{\frac{12}{7}+9}+15 \qquad \frac{3\times 4}{7} \quad \frac{12}{7} =$$

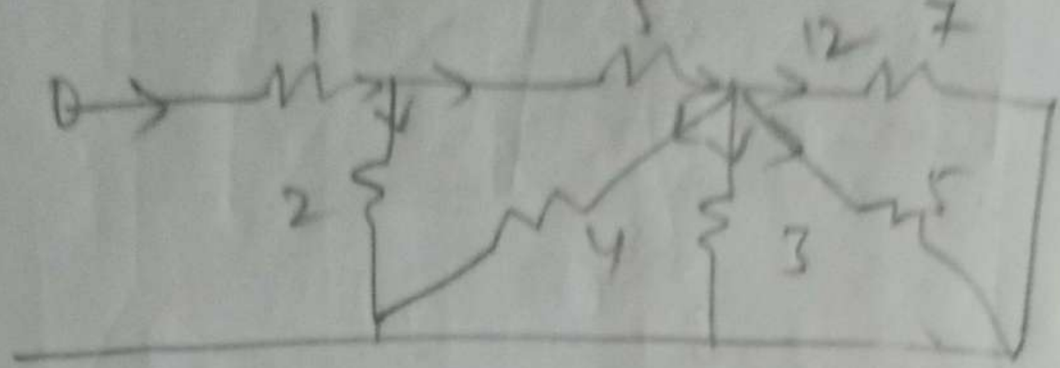
$$\frac{1.7\times 9}{1.7+9}+15$$

$$\frac{15.3}{10.7}+15$$

$1.42 + 4.$

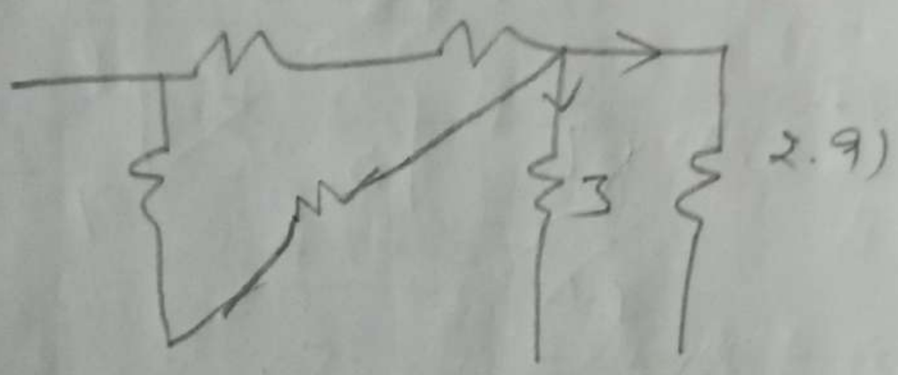
$R_{ab} = 5.42\,\Omega$

Q Calculate the total resistance of the circuit shown below:

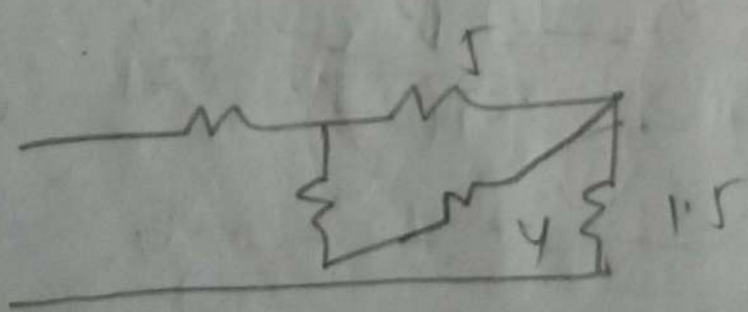


7,5 Ш.

$$\frac{7 \times 5}{7+5} = 2.91$$

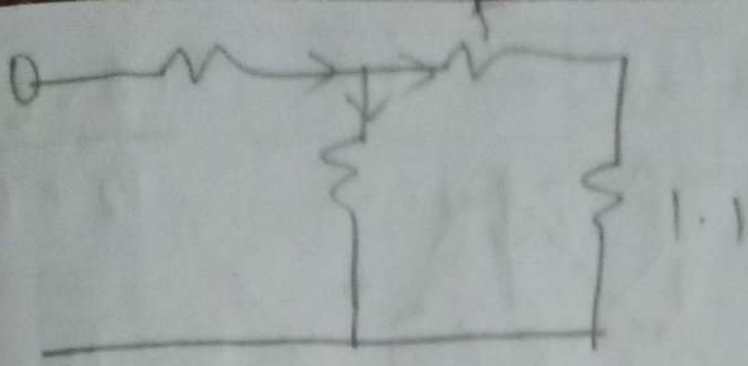


$$\frac{3 \times 2.91}{3+2.91} = 1.5$$

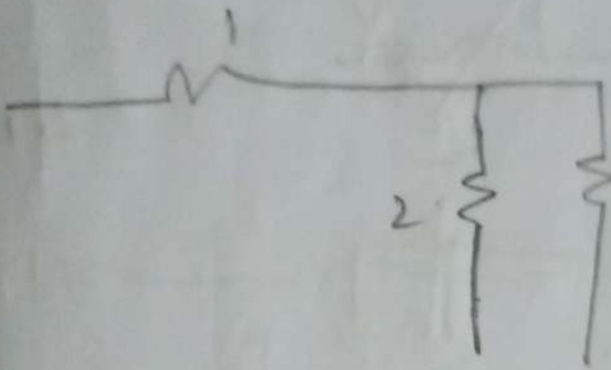


$$\frac{4 \times 1.5}{5.15}$$

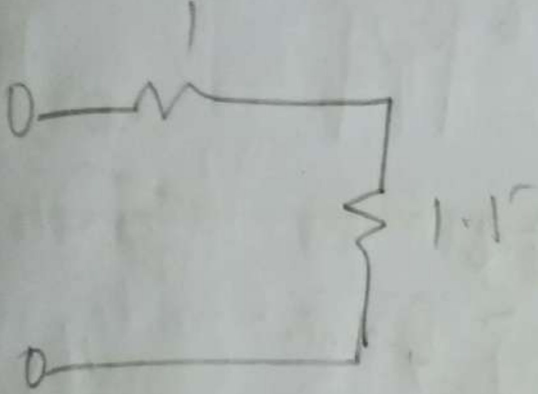
$= 1.1\Omega$



$5+1.1=6.1$



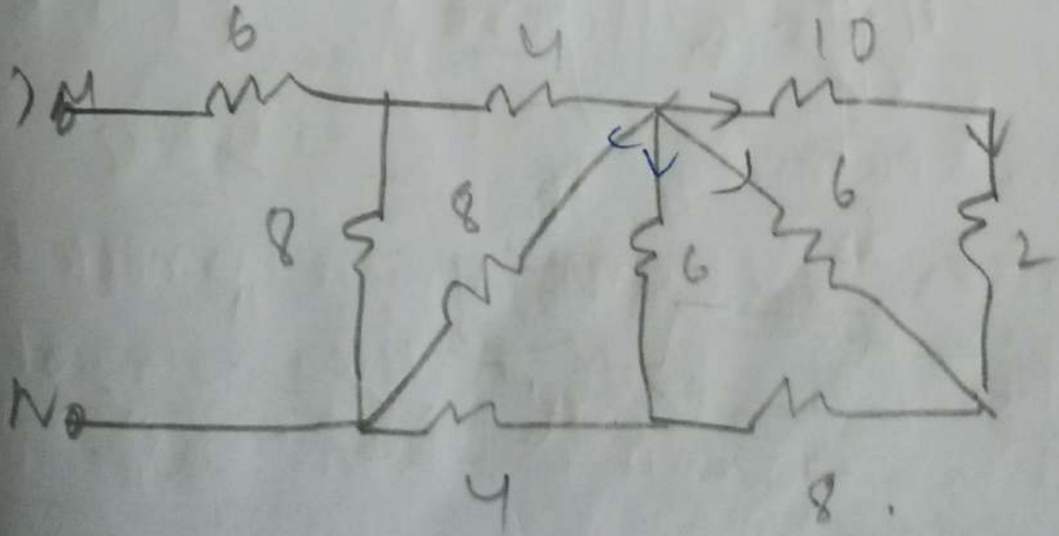
$6.1 = \frac{2\times 6.1}{2+6.1} = 1.5$



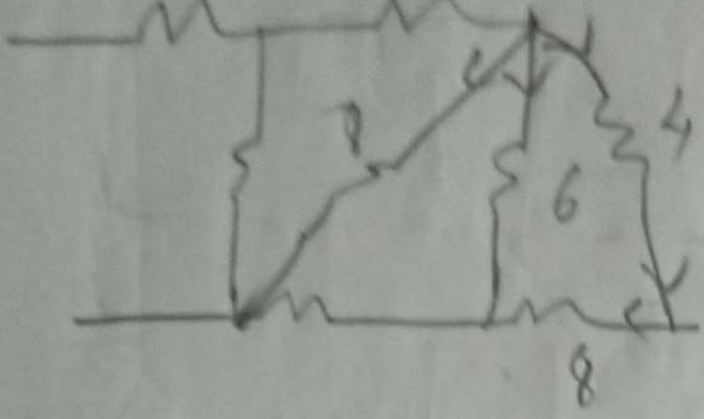
$1+1.5=2.5$

$2.5 = R_{ab}$

Q)

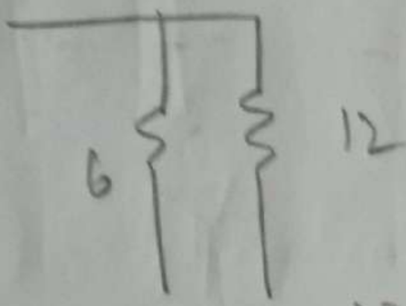


$\frac{12\times 6}{12+6}$



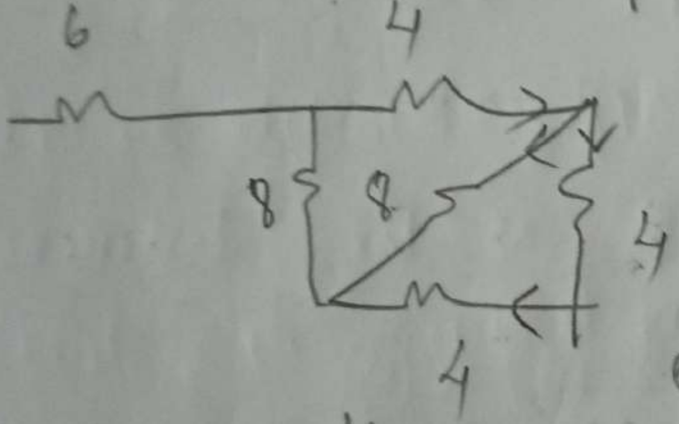
$4+8$

12



3

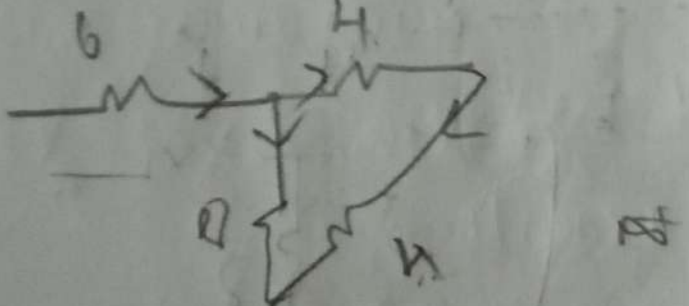
$\frac{12\times 4}{12+4} = \frac{12\times 4}{16}$ 4

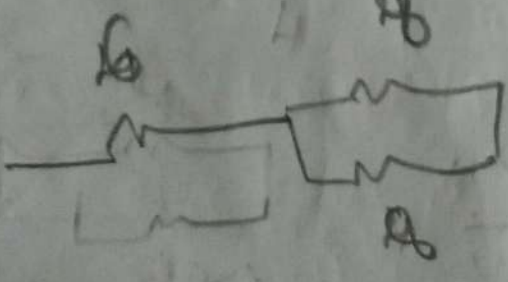


$\frac{8\times 8}{8+8} = 4$

$\frac{4\times 8}{4+8}$

$\frac{32}{12}$

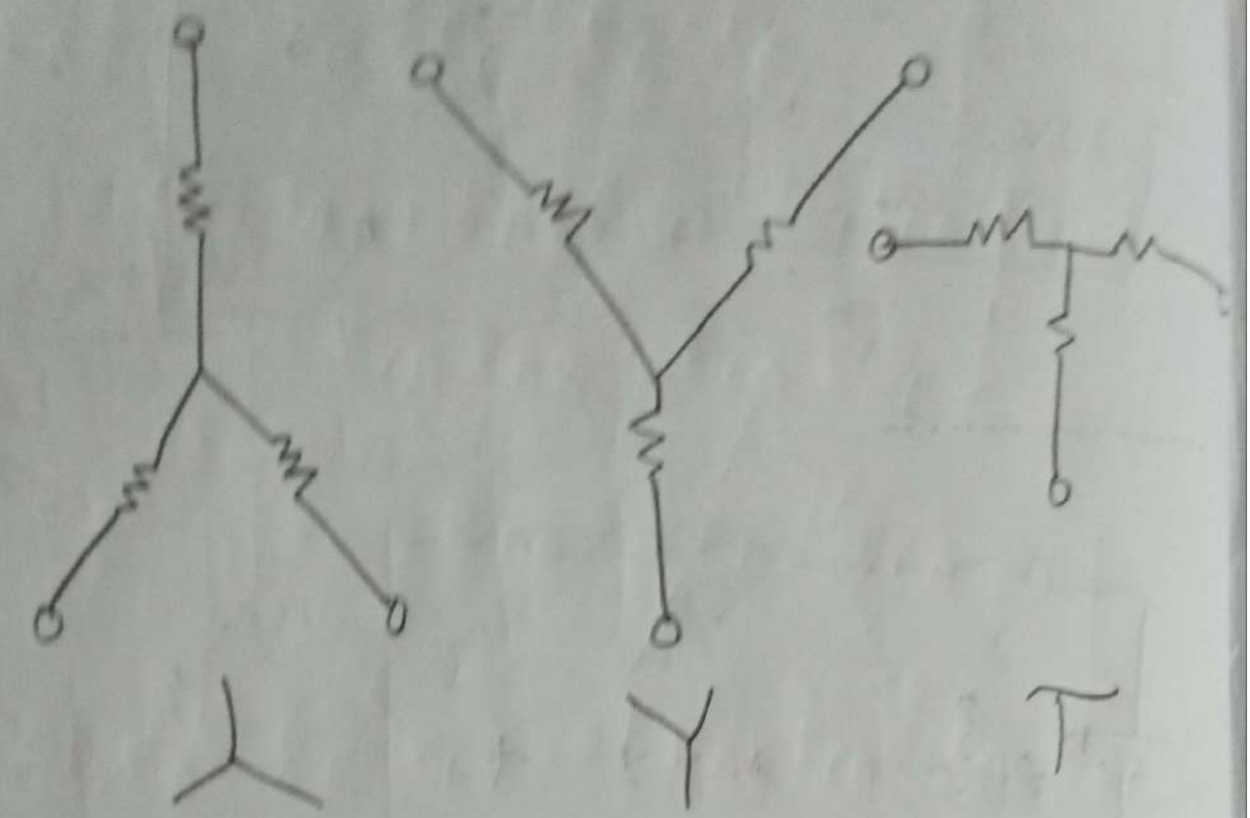




4

$6+4=10$

Star Connection:



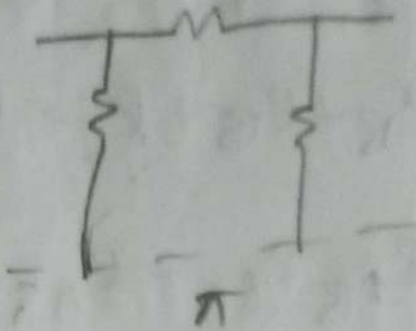
It is defined as the three elements connected at a single node, node point or neutral point known as star connection.

It is Represented by ⅄ (star) (Y-network) Y (T-Shape) T

Delta Connection:

Whenever 3 elements are connected together it forms a delta network either it will be Δlar shape or π shape.

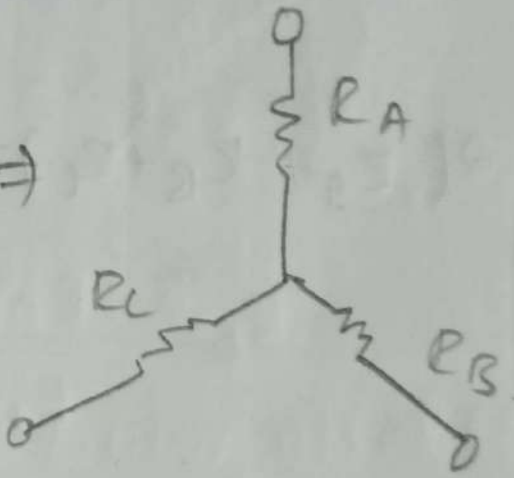
Delta Connection: 3 elements are taken

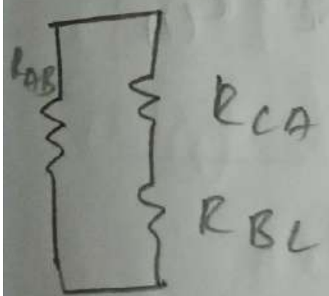


and connected together as a closed loop.

Delta to star Connection:

$R_{AB} \Rightarrow$





$$R_A + R_B = \frac{R_{AB} \parallel (R_{CA} + R_{BC})}{R_{AB} + R_{BC} + R_{CA}} \quad \text{— (1)}$$

$$R_B + R_C = \frac{R_{BC} \parallel (R_{CA} + R_{AB})}{R_{AB} + R_{BC} + R_{CA}} \quad \text{— (2)}$$

$$R_C + R_A = \frac{R_{CA} \parallel (R_{AB} + R_{BC})}{R_{AB} + R_{BC} + R_{CA}} \quad \text{— (3)}$$

Adding (1) + (2) + (3)

$$R_A + R_B + R_B + R_C + R_C + R_A = \frac{R_{AB}R_{CA} + R_{AB}R_{BC} + R_{BC}R_{CA} + R_{BC}R_{AB} + R_{CA}R_{AB} + R_{CA}R_{BC}}{R_{AB} + R_{BC} + R_{CA}}$$

$$2(R_A + R_B + R_C) = \frac{2(R_{AB}R_{CA} + R_{AB}R_{BC} + R_{CA}R_{BC})}{R_{AB} + R_{BC} + R_{CA}} \quad -(4)$$

(4) − (1)

$$\cancel{R_A} + \cancel{R_B} + R_C - \cancel{R_A} - \cancel{R_B}$$

$$= \frac{R_{AB}\cancel{R_{CA}} + R_{AB}\cancel{R_{BC}} + R_{CA}R_{BC}}{R_{AB} + R_{BC} + R_{CA}} - \frac{\cancel{R_{AB}R_{CA}} + \cancel{R_{AB}}R_B}{R_{AB} + R_{BC} + R_{CA}}$$

$$R_C = \frac{R_{CA} R_{BC}}{R_{AB} + R_{BC} + R_{CA}}$$

(4) − (2)

$$R_A + R_B + R_C - R_B - R_C$$

$$= \frac{R_{AB} R_{CA} + R_{AB} R_{BC} + R_{CA} R_{BC} - R_{BC} R_{CA} - R_{BC} R_{AB}}{R_{AB} + R_{BC} + R_{CA}}$$

$$R_A = \frac{R_{AB} R_{CA}}{R_{AB} + R_{BC} + R_{CA}}$$

(4) − (1).

$$R_A + R_B + R_C - R_A - R_C$$

$$= \frac{R_{AB} R_{CA} + R_{AB} R_{BC} + R_{CA} R_{BC} - R_{AB} R_{CA} + R_{CA} R_{BL}}{R_{AB} + R_{BC} + R_{CA}}$$

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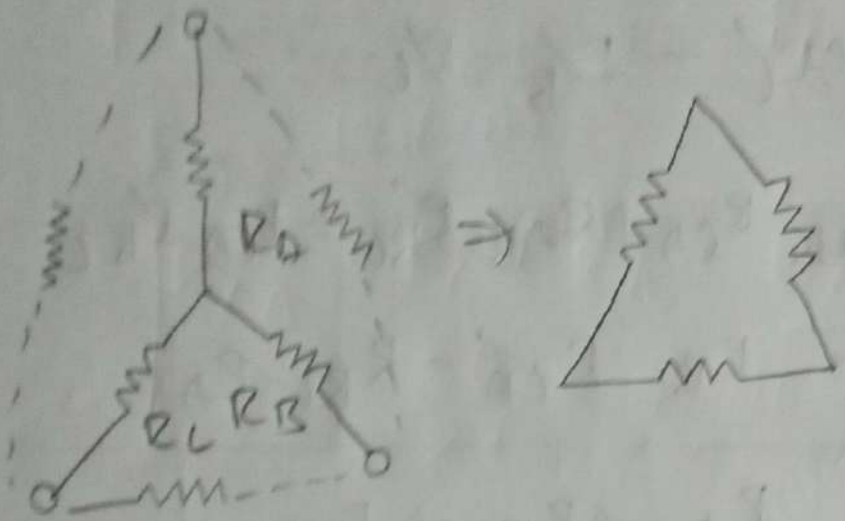
$$R_B = \frac{R_{AB} R_{BC}}{R_{AB} + R_{BC} + R_{CA}}$$

Star to Δ transformation:



$$R_A = \frac{R_{AB} R_{CA}}{R_{AB} + R_{BC} + R_{CA}} \quad - (1)$$

$$R_B = \frac{R_{BC} R_{AB}}{R_{AB} + R_{BC} + R_{CA}} \quad - (2)$$

$$R_C = \frac{R_{CA} R_{BC}}{R_{AB} + R_{BC} + R_{CA}} \quad - (3)$$

(1)(2) + (2)(3) + (3)(1)

$R_A R_B + R_B R_C + R_C R_A$

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$$= \frac{R_{AB}R_{CA} \cdot R_{BC}R_{AB}}{(R_{AB}+R_{BC}+R_{CA})^2} + \frac{R_{BC}R_{AB}\,R_{CA}R_{BC}}{(R_{AB}+R_{BC}+R_{CA})^2}$$

$$+ \frac{R_{CA}R_{BC}R_{AB}R_{CA}}{(R_{AB}+R_{BC}+R_{CA})^2}$$

$$= \frac{R_{AB}^2 R_{CA}R_{BC} + R_{BC}^2 R_{AB}R_{CA} + R_{CA}^2 R_{AB}R_{BC}}{(R_{AB}+R_{BC}+R_{CA})^2}$$

$$R_A R_C + R_A R_B + R_B R_C$$

$$= \frac{R_{AB}R_{BC}R_{CA}(R_{AB}+R_{BC}+R_{CA})}{(R_{AB}+R_{BC}+R_{CA})^4} \quad - (4)$$

4/1

$$\frac{R_C R_A + R_A R_B + R_B R_C}{R_A} = \frac{\dfrac{R_{BC}R_{AB}R_{CA}}{R_{AB}+R_{BC}+R_{CA}}}{\dfrac{R_{AB}R_{CA}}{R_{AB}+R_{BC}+R_{CA}}}$$

Scanned with ACE Scanner

$$R_C + R_B + \frac{R_B R_C}{R_A} = R_{BC}$$

$$R_{AB} = R_A + R_B + \frac{R_A R_B}{R_C}$$

$$R_{CA} = R_C + R_A + \frac{R_C R_A}{R_B}$$

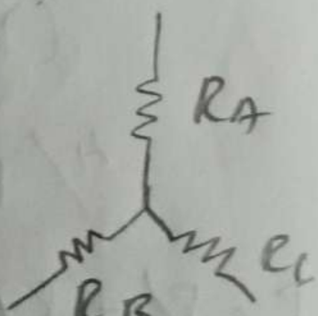
Problem:

Q) Delta values are given by 2Ω, 3Ω, and 4Ω resistances find star values

$R_{AB} = 2\Omega$

$R_{BC} = 3\Omega$

$R_{CA} = 4\Omega$



$$R_A = \frac{(2)(4)}{2+3+4}$$

$$= \frac{8}{9}\Omega = 0.88\Omega$$

$$R_B = \frac{(2)(3)}{2+3+4}$$

$$= \frac{6}{9}$$

$$= 0.66\,\Omega.$$

$$R_C = \frac{(4)(3)}{2+3+4}$$

$$= \frac{12}{9}$$

$$= 1.33\,\Omega.$$

8) Star values are given by 4Ω, 5Ω, 6Ω find delta values.

$R_A = 4\Omega$, $R_B = 5\Omega$, $R_C = 6\Omega$.

$$R_{AB} = 4 + 5 + \frac{20}{6}$$

$$= 9 + 3.3$$

$$= 12.33\,\Omega$$

$$R_{CA} = (4) + 6 + \frac{24}{5}$$

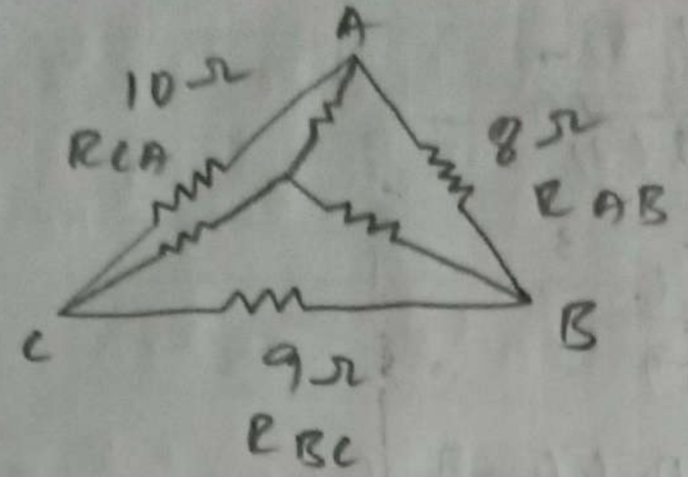
$$= 10 + 4.8$$

$$= 14.8\,\Omega$$

$$R_{BC} = 5 + 6 + \frac{30}{4} = \sout{18.5\Omega}$$

$$= 18.5\,\Omega$$

Q)



star from delta.

$$R_A = \frac{(8)(10)}{8+9+10}$$

$$= \frac{80}{27} = 2.96\ \Omega.$$

$$R_B = \frac{(8)(9)}{10+9+8}$$

$$= \frac{72}{27}$$

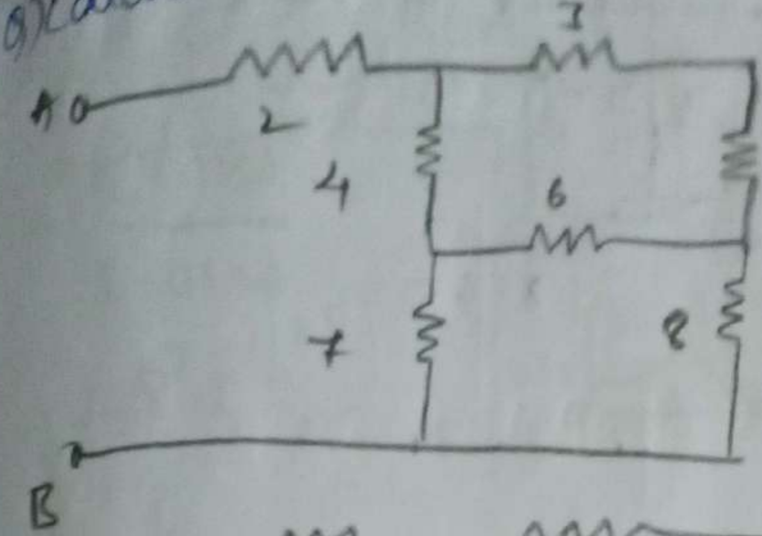
$$= 2.66\ \Omega.$$

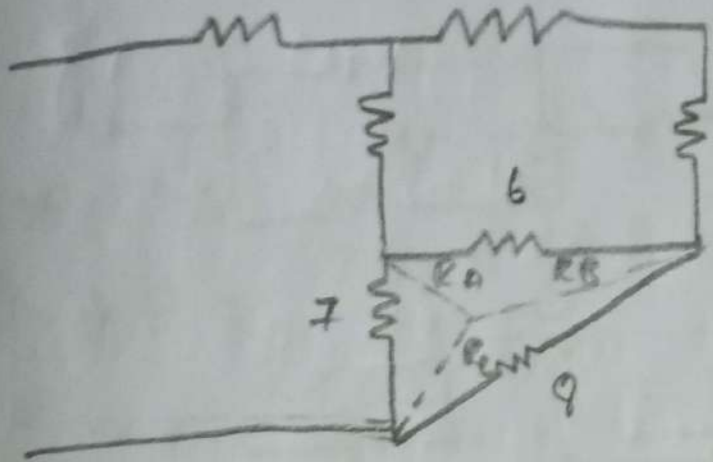
$$R_C = \frac{(10)(9)}{27}$$

$$= \frac{90}{27}$$

$$= 3.33\ \Omega$$

Q) calculate the resistance b/w AB terminals by using star delta transformat^n





4Ω

$\frac{7+9}{21}$

$$R_A = \frac{7\times6}{7+6+8} = 2\,\Omega$$

$$R_B = \frac{6\times8}{7+6+8} = 2.3\,\Omega$$

$$R_C = \frac{7\times8}{6+7+8} = 2.6\,\Omega$$

$\frac{1}{10.3} + \frac{1}{6}$

$\frac{10}{103} + \frac{1}{6}$

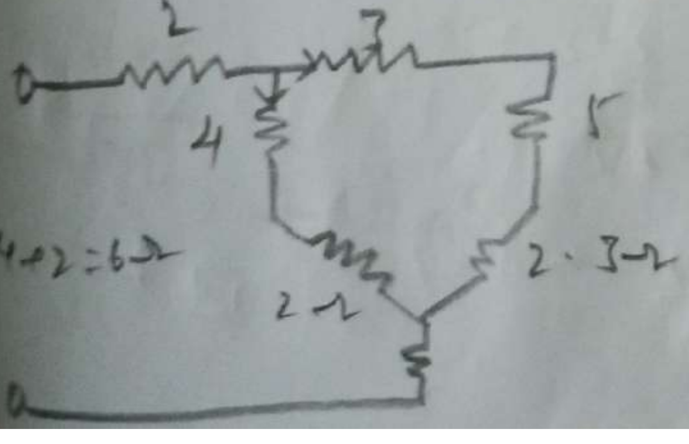
0.097 +

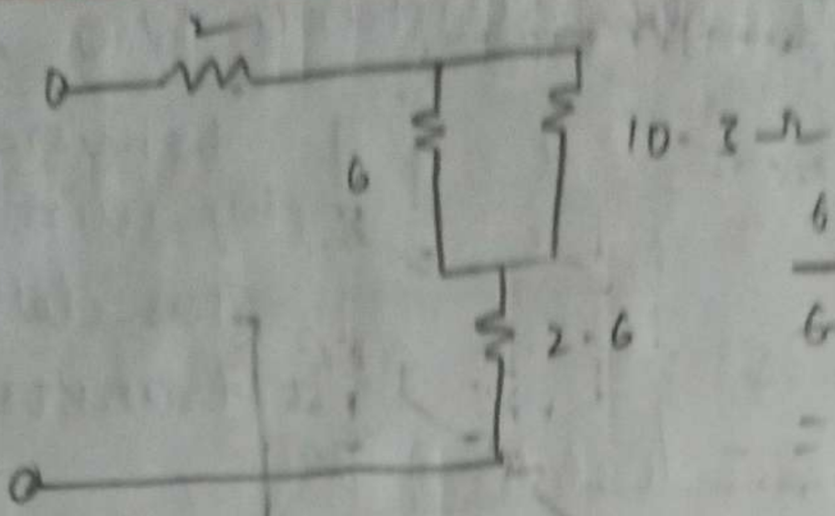
0.166

$\frac{1}{}$

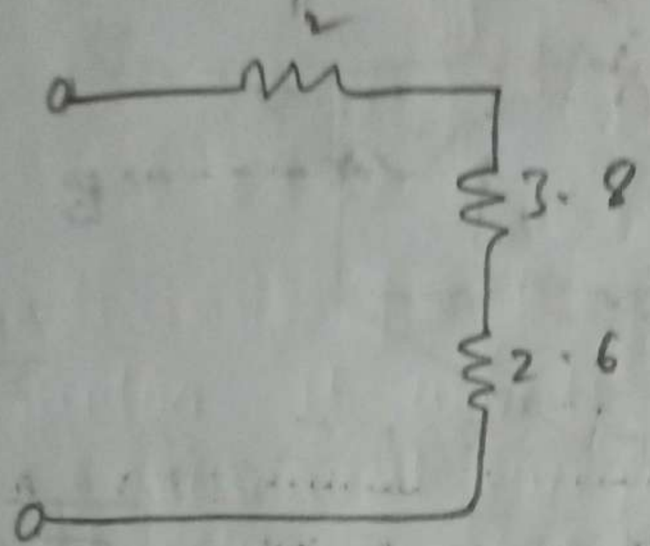
= 0.263

3+5+2.3 = 10.3



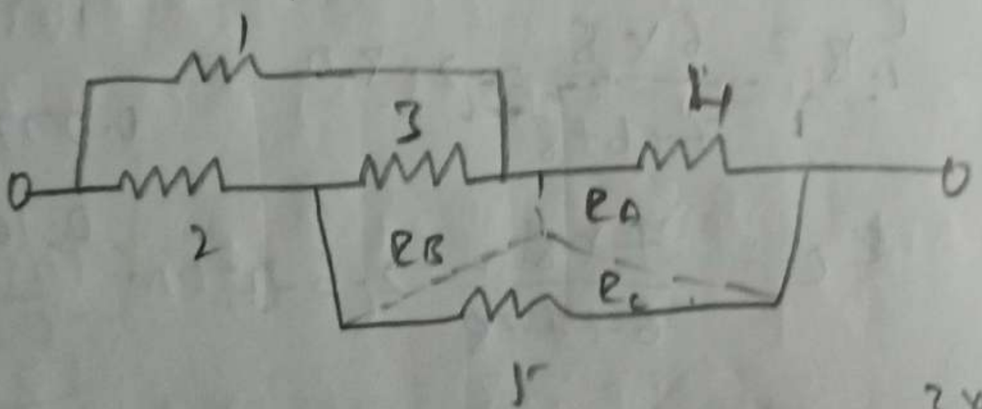


$$\frac{6\times10.3}{6+10.3} = 3.8\,\Omega$$



$2+3.8+2.6 = 8.4\,\Omega$

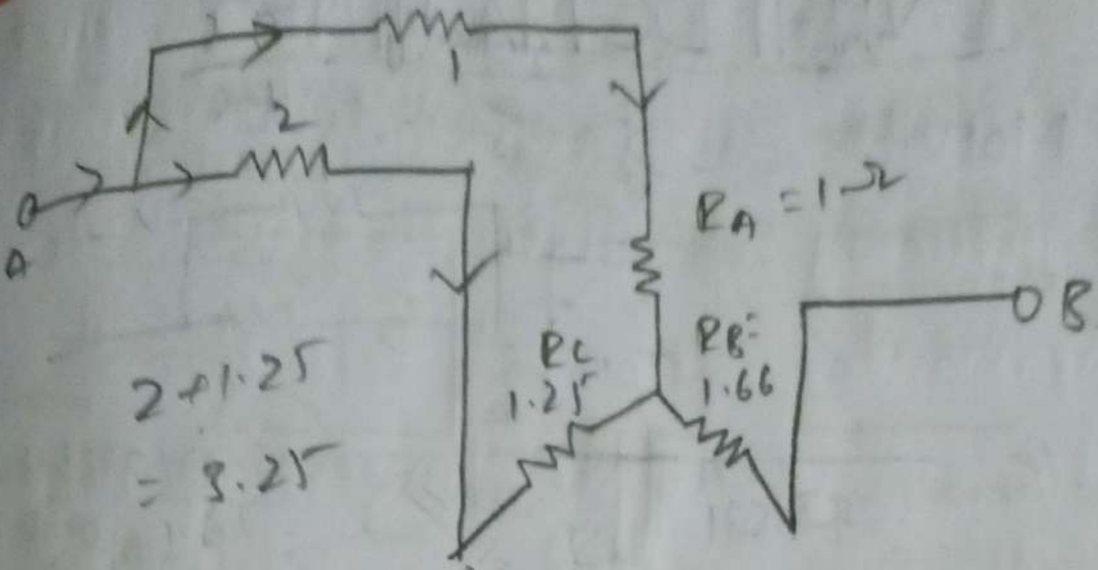
Q) Calculate resistance b/w AB terminals.

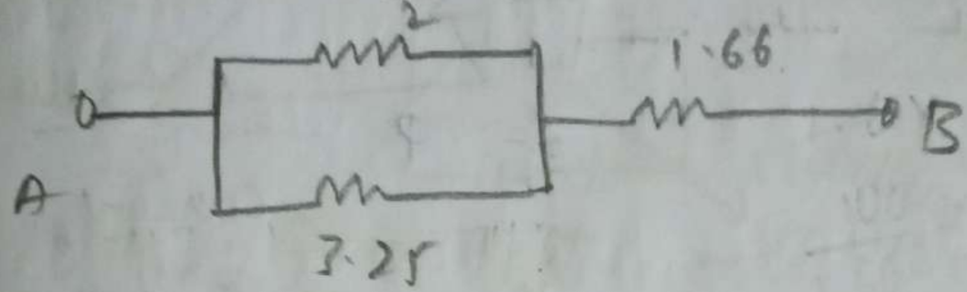


$$\frac{3\times5}{12} = \frac{15}{12} = 1.25$$

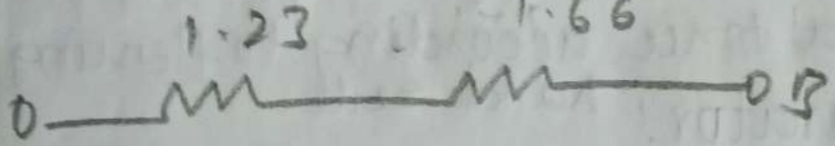
$R_A = 1\,\Omega$

$$\frac{3\times4}{3+4+5} = \frac{12}{12}$$





$$\frac{2 \times 3.25}{5.25} = \frac{6.5}{5.25} = 1.23\,\Omega$$

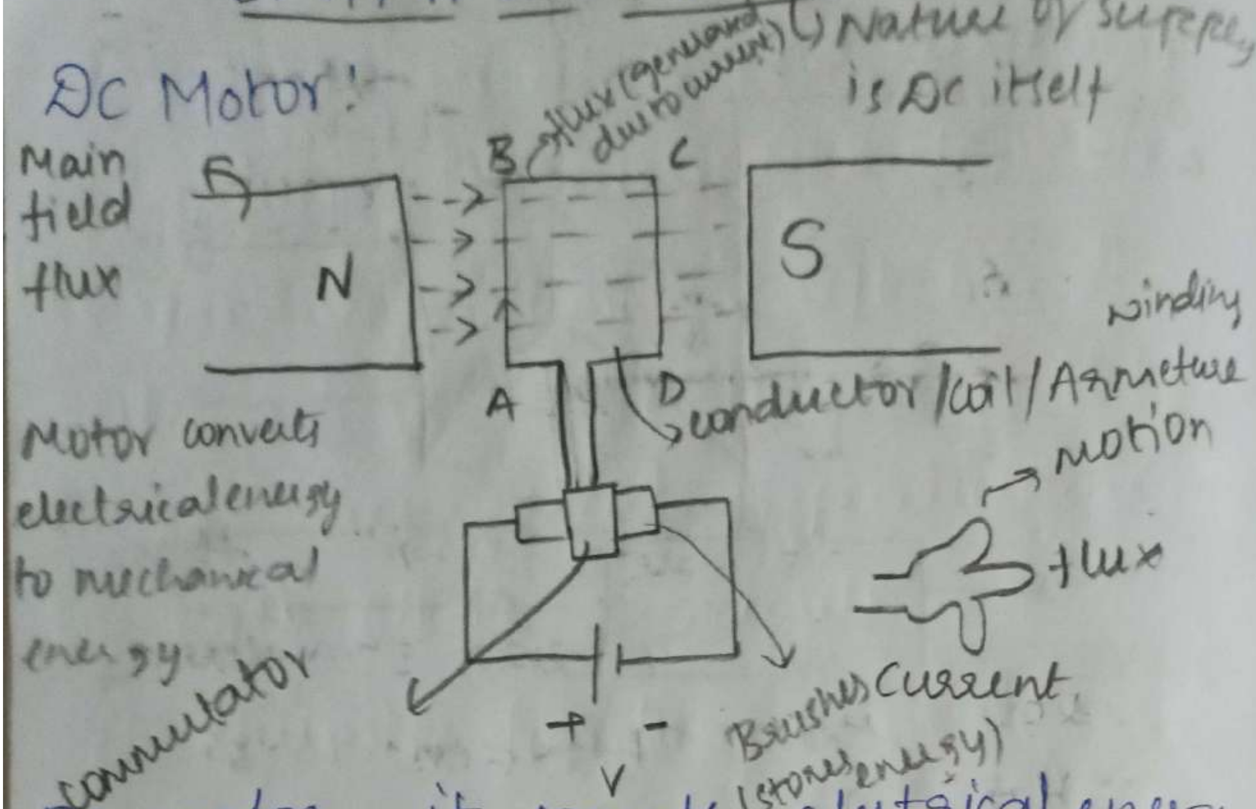


$R_{eq} = 2.89\,\Omega$.

DC Machines

UNIT-II DC MACHINES

DC Motor:

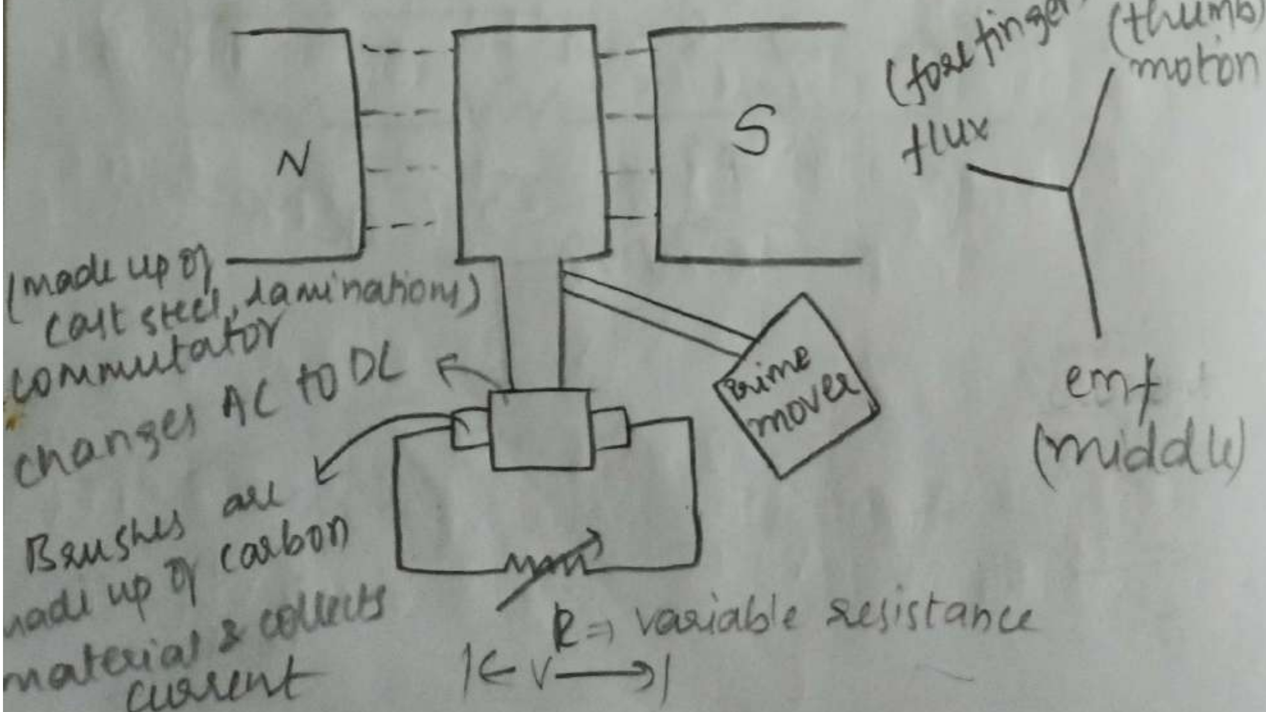


Motor converts electrical energy to mechanical energy

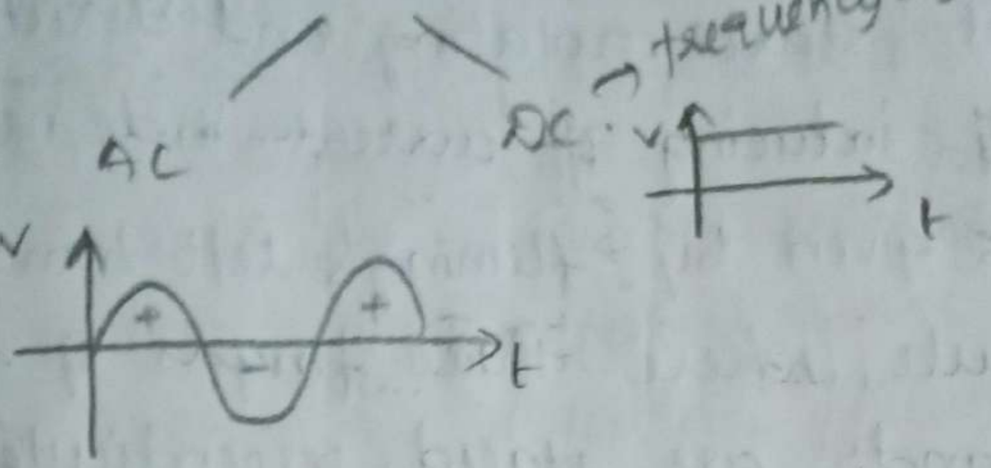
DC motor it converts electrical energy into mechanical energy ~~Prin~~

Principle: when a current carrying conductor is placed in a magnetic field it experiences mechanical force according to Fleming's left hand rule

DC Generator:



electric supply



1ø, 3ø supplies will be there
↓ ↓ Indian standard
240V, 415V, frequency 50Hz
50Hz 50Hz
US standard
frequency 60Hz

DC motor:

There are two fluxes produced in DC motor

1) Main field flux due to field winding
2) flux which is produced due to current flow in the conductor

Due to interaction b/w these two fluxes there is a twisting or turning force produced which is nothing but torque.

When torque is exerted on the coil it starts rotating and direction of inducing of current in dc motor is given by fleming's left hand rule where three fingers of left hand are placed perpendicular(90°) to each other & namely

thumb, forefinger, middle finger

where

thumb - Represents motion of the conductor

forefinger - Indicates the directn of flux lines

middle finger - Represents direction of inducing of current in it

DC Generator:

Working principle of DC generator:

It is a rotating electrical machine

which works under the principle of electromagnetic induction here it is a two pole DC generator with a armature coil of ABCD sides placed in magnetic field which is rotating with external prime mover known as rotating conductor or coil. Whenever a rotating conductor cuts magnetic field there is a relative speed b/w flux and conductor according to faraday's laws of electromagnetic induction. an emf gets induced in ABCD coil.

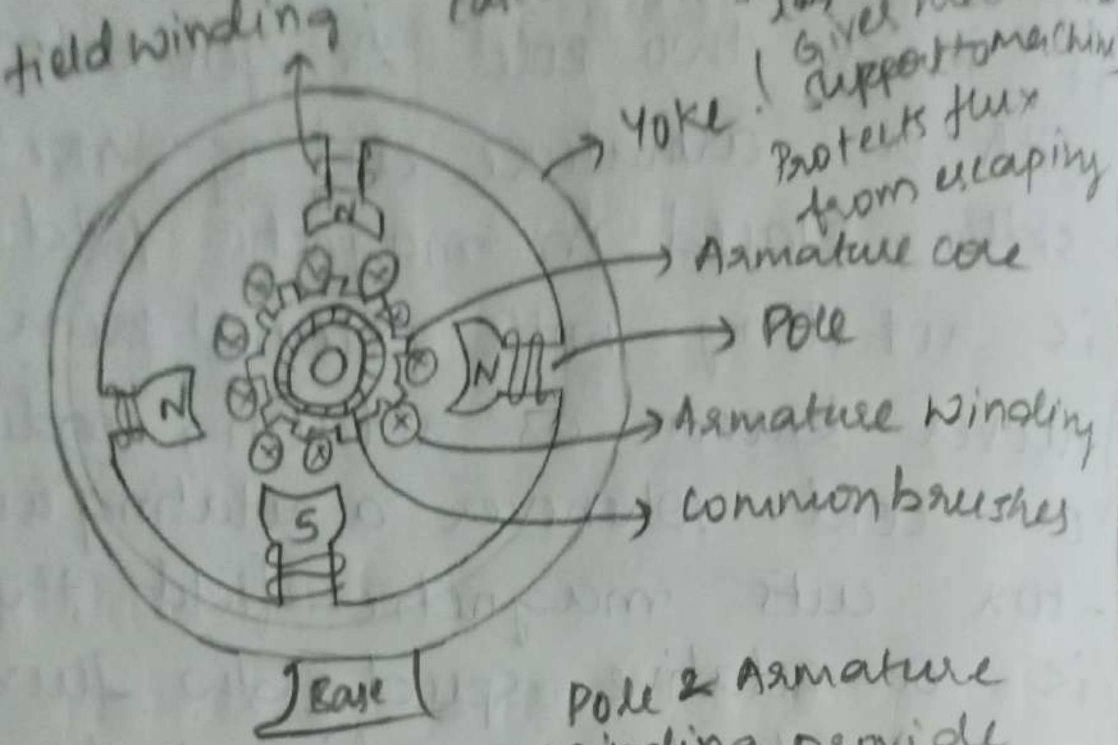
According to fleming's right hand rule :

fore finger - Indicates flux direction

Middle finger - Direction of induced emf

Thumb - Indicates motion of conductor!

Construction of DC generator:



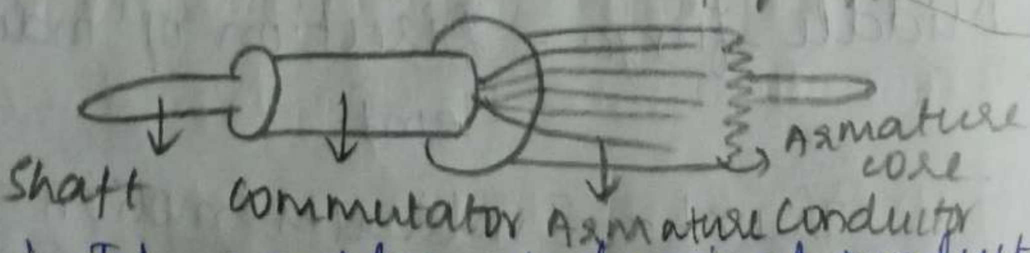
Pole & Armature winding provide required flux.

Purpose of pole is to hold the fieldwinding.

coil/ conductor => Armature winding

Armature core => to hold Armature winding

Armature winding => made up of copper



Yoke: It provides Mechanical protect -ion to the entire machine made up of cast iron or cast steel

Field Winding & Pole:

Pole is made up of high permeable material which holds field winding and also provides magnetic flux in the machine.

Field winding is made up of copper material which supports to devolop magnetic flux.

Armature core:

Armature core is a cylindrical drum shaped structure punched into slots on peripherals to hold armature winding made up of silicon lami-nated steel.

Commutator:

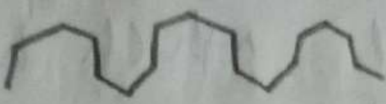
It is a mechanical rectifier used to convert pure AC to DC voltage. It is made up of Hard drawn copper.

Brushes: It is soft material

They are made up of carbon and used to collect current from rotating commutator.

Armature winding: Made up of copper.

① lap (It will be overlapped) 

② wave (↑V ↓I) 

At high current and low voltage

At high voltage & low current

Armature Winding:

It is a distributed winding as per the requirement it is classified into two types ① lap winding

② wave winding.

It is a main winding of the machine which supports to produce EMF and torque.

** EMF eqn of a DC generator:

According to faraday law of EMF induction

$$E \propto \frac{d\phi}{dt}$$

$$\boxed{E = N\frac{d\phi}{dt}}$$

$N = 1$

N = no of turns

E = Emf Induced per conductor

Change in $\phi = d\phi = \phi \times P$.

ϕ = flux

P = Poles (no of poles)

change in time. $dt = \frac{60}{N}$

$$E = \frac{d\phi}{dt} = \frac{\phi \times P}{\frac{60}{N}}$$

$$E = \frac{N\phi P}{60} \times \left(\frac{1}{A} \times Z\right)$$

A = no of ||el paths.

Z = no of conductors

ϕ = flux

N = speed.

P = poles.

$$\boxed{E_g = \frac{\phi Z N P}{60 A}}$$

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

E_g = EMF of induced for 'Z' no of conductors.

A = No of parallel paths.

P = Poles.

Z = No of conductors.

N = Speed.

ϕ = flux.

lap $A = P$ ↑I V↓

$$\text{lap } E_g = \frac{\phi Z N P}{60 A} = \frac{\phi Z N}{60}$$

$$\text{lap } E_g = \frac{\phi Z N}{60}$$

wave = $A = 2$ ↑V ↓I

$$\text{wave } E_g = \frac{\phi Z N P}{60 \times 2} = \frac{\phi Z N P}{120}$$

$$\text{wave } E_g = \frac{\phi Z N P}{120}$$

A four pole generator having wave wound armature winding has 51 slots each slot consisting of 20 conductors determine the generated EMF in the machine when driven at 1500 RPM if flux per pole is 7milliwebers.

P=4.

flux units = Milli webers
= mWb.

ϕ = 7mWb. = 7×10^{-3} = 0.007.

P = 4.

Z = 51×20.

N = 1500. A=2.

$$E_g = \frac{\phi Z N P}{60 A} = \frac{10^{-3}\times 7\times 51\times 20\times 1500\times 4}{60\times 2}$$

$$= \frac{7\times 51\times 18\times 4}{60}$$

E = 357V

Q) A 4 pole DC generator has a lap wound armature with 792 conductors if flux per pole is 0.0121 weber determine the speed at which it should run to generate 240V

P=4.
P=A
ϕ = 0.0121
N=?
E=V=240.

$$E_g = \frac{\phi Z N P}{60 A}.$$

$$240 = \frac{0.0121 \times 792 \times N \times}{60.}$$

$$N = \frac{240 \times 60}{121 \times 792 \times 10^{-4}}$$

$$= \frac{24 \times 6 \times 10^6}{121 \times 792.}$$

$$= \frac{144 \times 10^6}{95832.}$$ = ~~15 026~~ = 1502.6

1500 → Rated RPM. if load is there there would be around 1400.

8) A 6 pole DC generator have wave wound armature with 574 conductors and armature is rotating with a 1492 RPM determine flux per pole at which it should run to generate 220V

[A22]

P = 6
Z = 574
N = 1492
ϕ = ?
E = 220V

$$220 = \frac{6 \times 574 \times 1492 \times \phi}{60 \times 2}$$

$$\phi = \frac{220 \times 60 \times 2}{6 \times 574 \times 1492}$$

$$= \frac{26400}{5138448}$$

$$= 5.137 \times 10^{-3}$$

$$= 5.137 \text{ mWebers}$$

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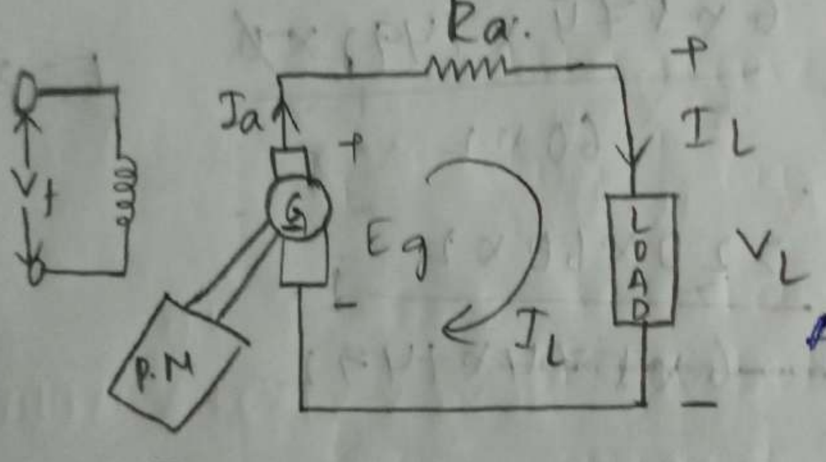
Types of DC Generator:

(i) sep. Excited

(ii) self excited (capable to work on its own)

- ⓐ series
- ⓑ shunt
- ⓒ compound
  - ⓓ long shunt
  - ⓔ short shunt

(1) seperatly generated DC generators:



Apply KVL

$$-E_g + I_a R_a + V_L + B.C.D = 0.$$

B.C.D = Brushes contact Drop.

In problems

If mentioned about BCD take that BCD value if not take

BCD = 2V in problems.

$$E_g = I_a R_a + V_L + BCD$$

armature generated power

$$P_g = E_g I_a$$

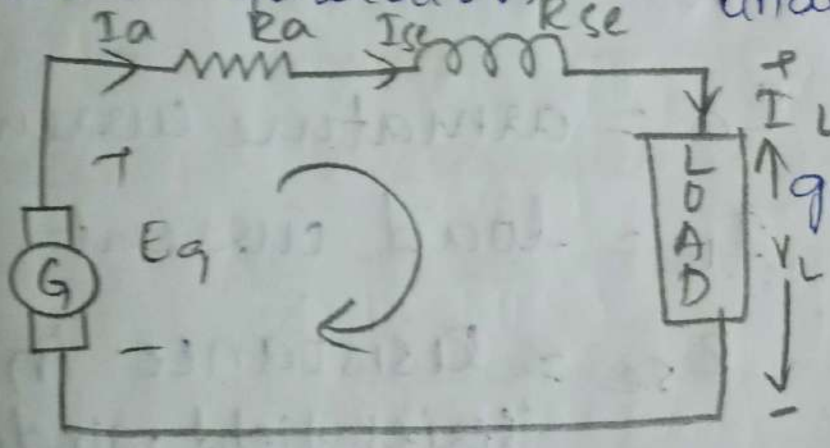
Power consumed ~~generated~~ by load.

$$P_L = I_L V_L$$

$$I_a = I_L$$

(ii) Self ~~Gene~~ Excited:

(a) Series Generator: The field winding under self excited of DC generator



Apply KVL

$$-E_g + I_a R_a + I_{se} R_{se} + V_L + BCD = 0$$

$$E_g = I_a R_a + I_{se} R_{se} + V_L + BCD$$

$$P_g = E_g I_a$$ Power generated in armature.

$$P_L = V_L I_L$$ Power consumed by load.

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The field winding of DC generator connected in series with armature winding known as series generator.

I_{se} = current in series field winding

I_a = armature current.

I_L = load current.

R_{se} = Resistance in series field winding.

R_a = armature resistance

E_g = Generated voltage.

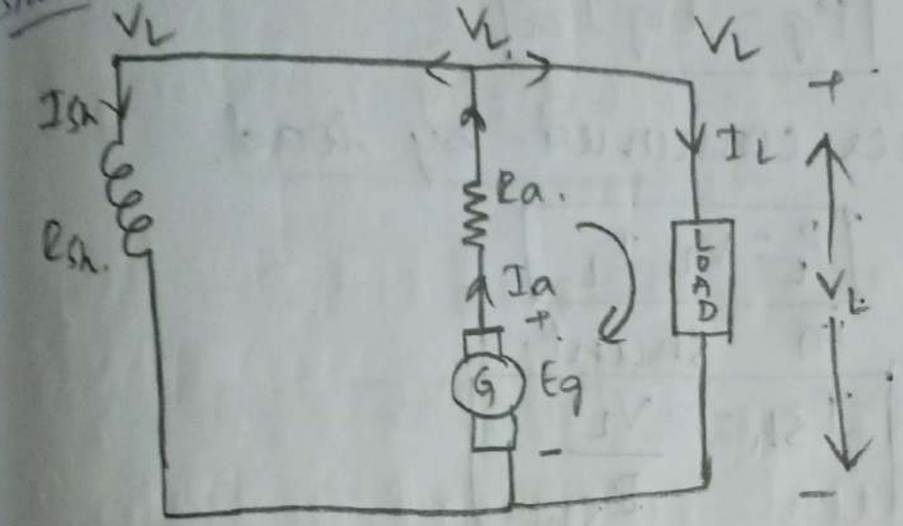
V_L = load voltage.

BCD = Brush contact drop.

Separatly Generated:

we need to separatly provide external electrical energy to the ~~the~~ stator get working flux on armature.

Shunt Generator:



The field winding of the generator connected in parallel to armature known as shunt generator.

I_L = load current.

I_a = armature current.

E_g = generated EMF.

R_a = armature resistance.

R_{sh} = shunt field resistance.

V_L = load voltage or terminal voltage

I_{sh} = shunt current.

Applying KVL

$-E_g + I_a R_a + V_L + BCD = 0.$

$E_g = I_a R_a + V_L + BCD$

(5)

: Armature Current

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

Power generated by armature

$$P_g = E_g I_a$$

Power consumed by load.

$$P_L = V_L I_L$$

current in shunt.

$$I_{sh} = \frac{V_L}{R_{sh}}$$

crane weight lifting → compound generator

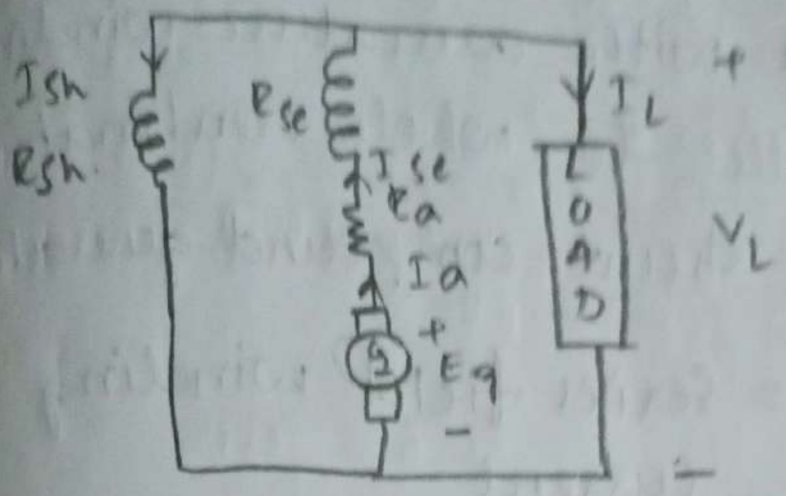
train → series generator → to produce more torque

mills → shunt generator → for constant speed

We use field winding in these series & shunt for flux.

(c) Compound:
↳ combination :

① long shunt compound generator:



$$-E_g + I_a R_a + I_{se} R_{se} + V_L + BCD = 0.$$

$$E_g = I_a R_a + I_{se} R_{se} + V_L + BCD$$

current through armature and shunt are same

$$\boxed{I_a = I_{se}}$$

current is getting divided in I_{sh} & I_L

$$\boxed{I_a = I_{se} = I_{sh} + I_L}$$

Emf

$$\boxed{E_g = I_a R_a + I_{se} R_{se} + V_L + BCD.}$$

$$\boxed{E_g = I_a (R_a + R_{se}) + V_L + BCD}$$

Power generated by armature

~~$P_g = V$~~ $\boxed{P_g = E_g I_a} = E_g I_{se}$

$$\boxed{P_L = V_L I_L}$$

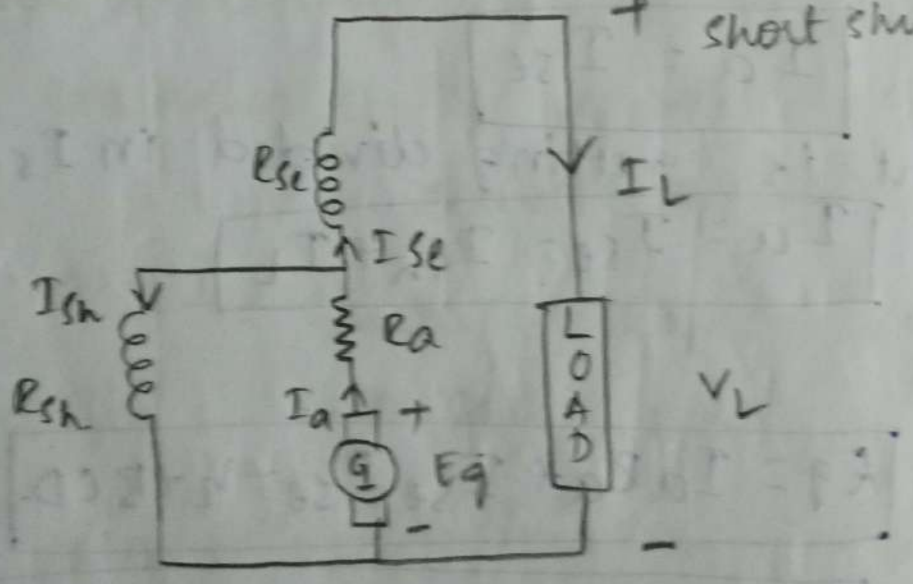
Long shunt: The field winding in series with armature winding and parallel to whole combination is long shunt compound generator

I_{se} = Series field winding current.

R_{se} = series field winding resistance.

Short shunt compound generator:

Application for short shunt

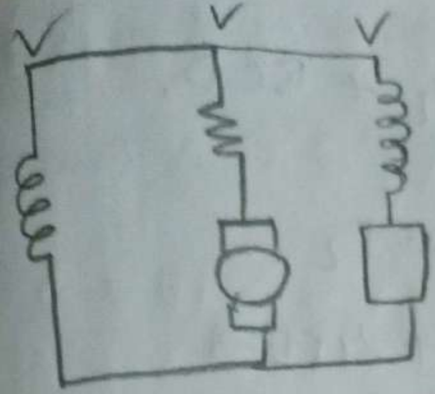


$$-E_g + I_a R_a + I_{se} R_{se} + V_L + BCD = 0$$

$$I_{sh} R_{sh} = I_{se} R_{se} + V_L$$

32

$$\boxed{I_{sh} = \frac{I_{se} R_{se} + V_L}{R_{sh}}}$$



$I_a = I_{sh} + I_L$

$I_{se} = I_L$

$P_g = E_g I_g$

$P = V_L I_L$

Q) A shunt generator delivers 450A at 230V the resistance of shunt field and armature resistance are 50 Ω and 0.03 Ω respectively calculate the generate emf.

~~I_L $I_{sh} = 450$ A.~~ $I = 450A$

~~$V_{sh} = 230$ V~~

~~$R_a = 50\ \Omega$.~~ ~~$R_{sh} = 50\ \Omega$~~

~~$R_a = 0.03\ \Omega$.~~

~~V_{sh}~~

$I_L = 450A$, $V_L = 230V$.

$R_{sh} = 50\ \Omega$ $R_a = 0.03\ \Omega$.

$E_g = I_a R_a + V_L + BCD.$

$I_a = I_{sh} + I_L$

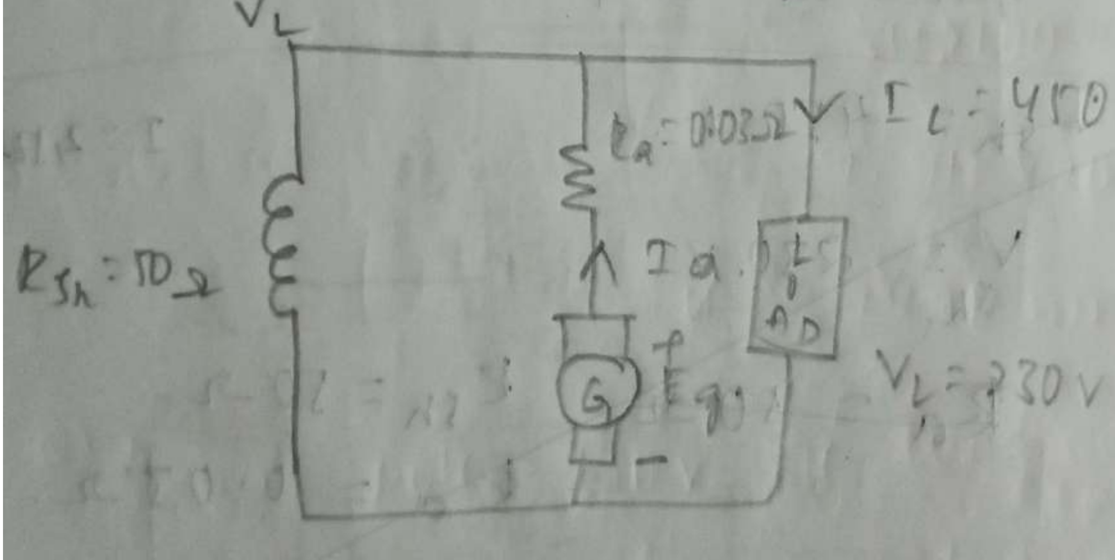
$= \frac{230}{50} + 450\,A.$

$= 4.6 + 450.$

$= 454.6.$

$E_g = (454.6)(0.03) + 230 + 2$

$= 245.638\,V$ //



Q) A ~~8V~~ 8 pole DC generator with 778 wave connected armature running at 500 RPM supplies a load of 12.5Ω resistance

$P = 8$
$N = 500$ $A = 2$

$R_L = 12.5$ terminal voltage is 250V

calculate 1) Armature current

2) Generated EMF

3) Flux per pole

Assume armature resistance is $0.24\,\Omega$ and shunt field resistance is $250\,\Omega$.

A

Armature current.

$R_{sh} = 250\,\Omega$

$I_a = I_{sh} + I_L.$

V_L, $R_{sh} = 250\,\Omega$

$R_a = 0.24\,\Omega$

$Z = 778$

$I_a = \frac{V_L}{R_a}$

$= \frac{250}{0.24} + \frac{250}{12.5}$

$= 1041$

$I = 213$

$\frac{V_L}{R_{sh}}$

$I_L = \frac{V_L}{R_L} = \frac{250}{12.5} = 20A.$

$= \frac{V}{R_{sh}} = \frac{250}{250} = 1A.$

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$I_a = 21A$.

$E_g = I_a R_a + V_1 + BCD$

$= (21)(0.24) + 250 + 2$.

$E_g = 257.04 V$.

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

$257.04 = \frac{\phi \times 7.78 \times 8 \times 500}{120}$.

$\phi = \frac{30844.8}{3112000}$

$= 9.911 \times 10^{-3}$

$\phi = 9.91 mWb$.

Q) A 4 pole 250V DC long shunt compound generator supplies a load of 10kW at the rated voltage. the armature, series field and shunt field resistances are 0.1, 0.15, 250 Ω respectively the armature is lap connected

$P = 4$

$N = ?$

$P_2 = 10 kW$

$\phi = 50 mwb$

$A = P$

$Z = 50 \times 6$

with 50 slots each slot containing 6 conductors if the flux per pole is 50 mwb. calculate N.

$R_a = 0.1 \Omega$

$V_L = 250 V$

$R_{se} = 0.15 \Omega$

$R_{sh} = 250 \Omega$

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

$E = I_a R_a + I_{se} R_{se} + V_L + BCD$

~~$I_a = \frac{250}{0.1} = 2500 A$~~

~~$I_{se} = \frac{V_L}{R_{se}} = \frac{250}{0.15} = 1666.66$~~

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

$$E_g = I_a R_a + I_{se} R_{se} + V_L + BCD$$

$$I_a = I_{se}$$

$$= I_a (R_a + R_{se}) + V_L + BCD$$

$$P_L = 10kW = V_L I_L$$

$$I_L = \frac{P_L}{V_L} = \frac{10 \times 10^3}{250}$$

$$= 40A$$

$$I_{sh} = \frac{V}{R_{sh}} = \frac{250}{250} = 1A$$

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

$I_a = 1+40 = 41A.$

$E_g = 41(0.1+0.15)+250+2$

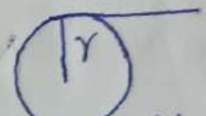
$= 262.25V.$

$$262 = \frac{50\times10^{-3}\times 300\times N\times P}{60\times P}$$

$\therefore N = 1049\,rpm$ //.

Torque eqn of a DC motor:

Torque is defined as twisting/



pully.

turning ~~force or of~~ movement of force and it is given by product of force × and radius.

let us consider a pully of radius r acted upon circumferen-tial force newton's which causes it to rotate at 'N' rpm

$T = F \times r$ $\left(\because P = \frac{W}{t}\right)$

$W = F \times D$

where D = Distance travelled in 1 revolution.

Work done to complete 1 revolution

$W = F \times D$

$= F \times 2\pi r.$

time taken complete 1 revolution

N - rpm.

N rev — 60 sec.

rev — ? $\Rightarrow \frac{60}{N}$.

$t = \frac{60}{N}$.

$P = \frac{W}{t} = \frac{F \times D}{\frac{60}{N}}$

$P = \frac{F \times 2\pi r}{60/N}$

$$= F \times r \times \frac{2\pi N}{60}$$

$$\boxed{P = T \times \omega}$$

$$\omega = \frac{2\pi N}{60} \Rightarrow \text{Angular velocity}$$

$$V \times I$$

$$P = E_b \times I_a$$

$$E_b I_a = T \times \omega$$

$$E_b = \frac{T \times \omega}{I_a}$$

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

$$\boxed{T_a = \frac{\phi Z P \times I_a}{2\pi \times A}} \quad N\text{-}m$$

Units of torque are 'N-m'.

where ϕ = flux

Z = speed

P = pole

I_a = armature current

A = No of ||el paths.

Q) calculate the value of Torque established by the armature of a 4 pole motor having 774 conductors. 2 paths in ||el 24 mwb flux per pole when I_a is 50 A.

$P = 4 \quad Z = 774$

$A = 2 \quad \phi = 24 mWb$

$I_a = 50 A.$

$$T_a = \frac{4 \times 24 \times 774 \times 50 \times 10^{-3}}{2 \times 3.14 \times 2.}$$

$$= \frac{4 \times 9288 \times 10^{-1}}{12.56.} = 295.718 \text{ N.m.}$$

295.796.
(or)

8) Determine the value of T in N-m developed by armature of 6 pole wave wound motor having 492 conductors and has an armature current of 40A find out Eg?

$P = 6$ $A = 2$ $Z = 492$

$\phi = 30 \times 10^{-3}$ $I_a = 40$

$$E_g = \frac{6 \times 30 \times 10^{-3} \times 40 \times 492}{60 \times 2}$$

$$= \frac{3542.4}{60 \times 2} = 29.52$$

$$= \frac{30 \times 40 \times 492 \times 10^{-2}}{20}$$

$$= 15 \times 492 \times 10^{-2}$$

$$= 282.0392$$

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Q) A 250V dc motor runs at 1500 rpm and takes Ia of 50 A back emf of DC motor is 240 V obtain Torque developed in motor.

$V_L = 250$

$N = 1500\,rpm$

$I_a = 50\,A$

$E_b = 240\,V$

$$E_g = \frac{\phi Z N P}{60\,A}$$

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

$$\frac{9420}{60}$$

$$240 = \frac{157 \times T}{50} \qquad \omega = 157$$

$$\frac{12000}{157} = T$$

$T = 76.433\ N\text{-}m$

8) A 250V 4 pole wave wound dc series generator delivers a current of 180A take $R_{ar} = 0.75\Omega$ and $R_{se} = 0.15\Omega$ calculate Emf generated & I_a of generator.

$P = 4$ $A = 2$

$I_{L} = 180$. $R_a = 0.75\Omega$.

~~$E_g = 250V$~~

$R_{se} = 0.15\Omega$ $V_L = 250V$.

$I_a = I_{se} = I_L$

~~$I_a = \frac{E_g}{R_a} = \frac{250}{0.75}$~~

~~$I_a = 333.3$.~~

$E_g = I_a R_a + I_{se} R_{se} + V_L + BCD$.

$= (180)(0.75) + (180)(0.15) + 250 + 2$.

$= 135 + 27 + 252$

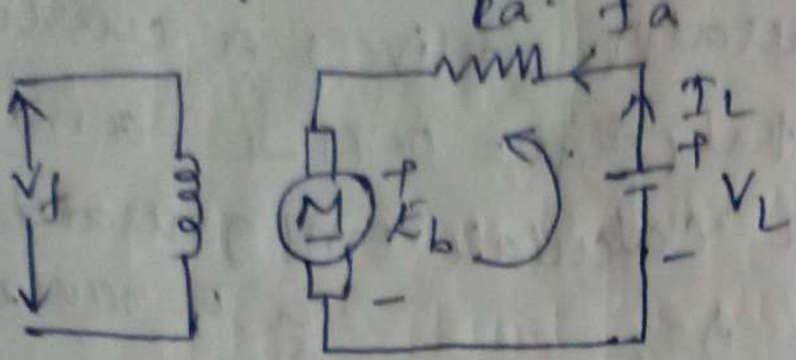
$= 414V$.

Types of DC Motors:

1) Sep. Excited DC Motors

2) Self excited DC motors
- (a) DC series
- (b) shunt
- (c) compound
  - (i) long shunt compound motor
  - (ii) short shunt

① Seperatly excited DC motor :



$I_L = I_a$

Applying KVL

$-V + I_a R_a + E_b = 0$.

$E_b = V - I_a R_a \mp BCD$

Power generated across source.

$P_S = V_L I_L$

Mechanical Power generated by motor/armature

$P_m = E_b I_a$

→ whenever excitation to the field winding is provided by some external source is called separatly excited DC motor.

V_L = linevoltage.

I_L = line current

I_a = Armature current

R_a = armature Resistance.

V_f = field excitation.

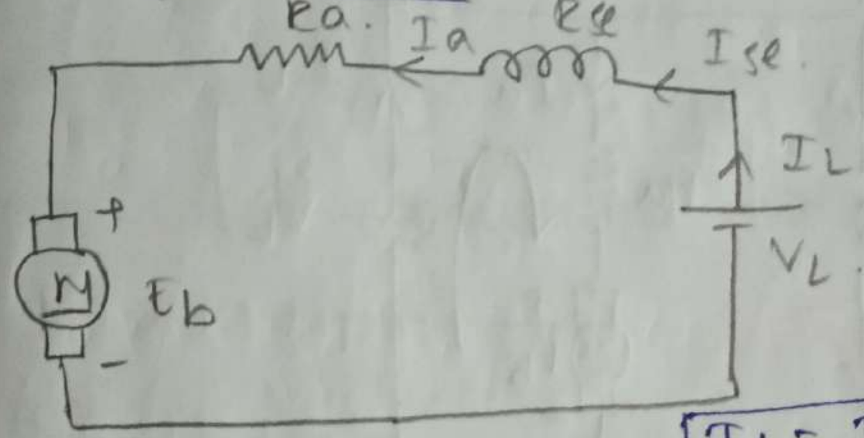
P_s = Source power.

E_b = back emf.

P_m = Mechanical power generated by armature.

2) Self-Excited DC motors:

a) DC series motor:



$$I_L = I_a = I_{se}$$

Applying KVL

$$-V_L + I_{se} R_{se} + I_a R_a + E_b = 0$$

~~$V_L = I_{se} R_{se} + I_a R_a + E_b + BCD$~~

$$-V_L + I_a(R_a + R_{se}) + E_b = 0$$

$$E_b = V - I_a(R_a + R_{se}) - BCD$$

Source Power

$$P_s = V_L I_L$$

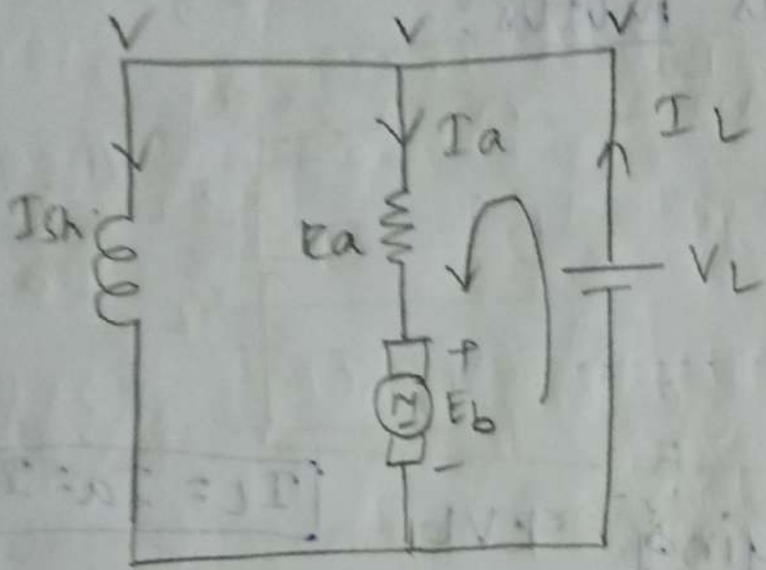
Mechanical power generated

$$P_m = E_b I_a$$

R_{se} = shunt resistance

I_{se} = shunt current

b) DC shunt motor:



Applying KVL

$$-V + I_a R_a + E_b = 0$$

$$E_b = V - I_a R_a - BCD$$

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

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

$$P_s = V_L I_L$$

$$P_m = E_b I_a$$

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DC series motor:

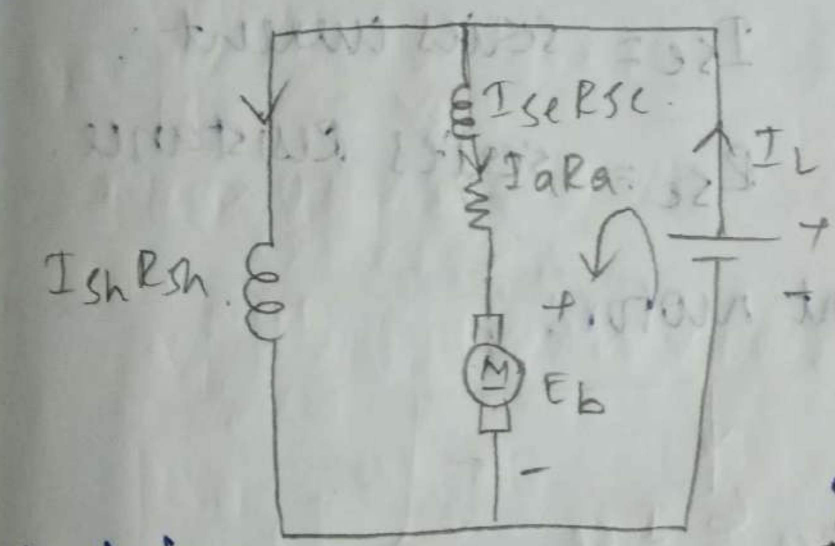
Whenever the fieldwinding is connected in series with armature is called DC series motor.

DC shunt motor:

Whenever the field winding is connected in parallel with armature is called DC shunt motor.

(c) compound motors:

long shunt compound motor:



$$I_{sh} = \frac{V_L}{R_{sh}}$$

$I_a = I_{se}$.

~~$I_a = I_{sh} + I_L$~~

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

Applying KVL

$-V_L + I_{se}R_{se} + I_aR_a + E_b = 0$.
$+BCD$.

~~$V_L = I_{se}R_{se}$~~

$$E_b = V_L - I_{se}R_{se} - I_aR_a - BCD$$

$$E_b = V_L - I_a(R_{se} + R_a) - BCD$$

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Power in motor

$$P_m = E_b I_L$$

Power across source

$$P_s = V_L I_L$$

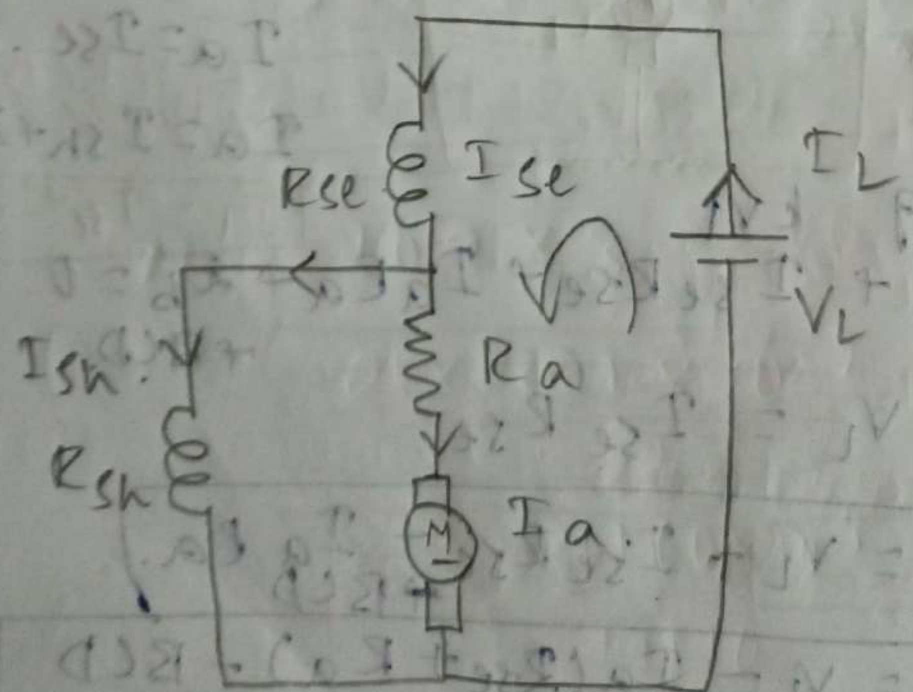
$$I_{sh} = \frac{V}{R_{sh}}$$

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

I_{se} = series current.

R_{se} = series resistance.

short shunt motor:



$$-V_L + I_{se}R_{se} + I_aR_a + BCD = 0.$$
$$+ E_b$$

$$E_b = V_L - I_{se}R_{se} - I_aR_a - E_b - BCD.$$

$$I_L = I_{se}$$

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

$$V_L \; I_L + I_{se}R_{se} = I_{sh}R_{sh}.$$

$$I_{sh} = \frac{I_{se}R_{se} + V_L}{R_{sh}}.$$

Q) A DC 6 pole shunt motor has wave connected armature with 87 slots, each slot containing 6 conductors the $\phi = 30 mWb$. The armature has Resistance $= 0.10 \Omega$. calculate N, when motor is connected to 250V supply & taking $I_a = 80A$.

$P = 6, \quad A = 2$

$Z = 87 \times 6$

$\phi = 30 mWb = 30 \times 10^{-3}$

$R_a = 0.10 \Omega$

$V_L = 250V$

$I_a = 80A.$

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

$E_b = V - I_a R_a + BCD$

$= 250 - 80 \times 0.10 + 2$

$= 250 - 8 + 2$

$= 250 - 10 = 240.$

$I_L = I_a + I_{sh}$.

$P_s = V_L I_L$

$P_m =$

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

$$240 = \frac{30\times10^{-3} \times 87\times6\times N\times6}{60\times2}$$

$$\frac{240\times120}{3\times87\times6\times6\times10^{-2}} = N.$$

$$\frac{24\times12}{3\times36\times87} = \frac{288}{9396} = N = 0.03065$$

$= 306.5$

Q) A 4 pole DC shunt motor has $\phi = 0.04$ Wb & Armature is lap wound with 720 conductors

$P = 4$, $\phi = 0.04$ Wb $A = P$

$Z = 720$

shunt field resistance is 240 Ω &

$R_a = 0.2\,\Omega$ & $R_{sh} = 240\,\Omega$ & BCD is 1 V per

brush. Determine Drop the N of

machine running as motor at

60 A.

BCD = 2×1

= 2 V.

P = 4.

$I_L = 60A$.

$V_L = 240$ V.

$E_b = V - I_a R_a - BCD$

$E_b = 240 - (I_a)(0.2) - 2$.

$I_L = I_a + I_{sh}$.

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

$= \frac{240}{240}$

$= 1$

$60 = I_a + I_{sh}$.

$60 = I_a + 1$

$I_a = 59$.

$E_b = 240 - (59)(0.2) - 2$.

$E_b = 226.2$

$$\frac{226.2\pi}{0.04\times720\times} = E_b \quad \frac{\phi ZNP}{60A}$$

$$\frac{226.2\times60}{0.04\times720\times} = N$$

$$\frac{13572}{28.8} = N$$

$$N = 471.25 \text{ rpm}.$$

Power lost in the form of heat.

losses in DC machine:

losses

- Cu loss
  - armature $I_a^2 R_a$
  - series $I_{se}^2 R_{se}$
  - shunt $I_{sh}^2 R_{sh}$
- Iron (or) — Observed in core machine
  - W_h → histrisus losses
  - W_e → eddicurrent losses.
  - depends on materials used
- Mech — usually observed in shaft of machine.
  - friction
  - windage.

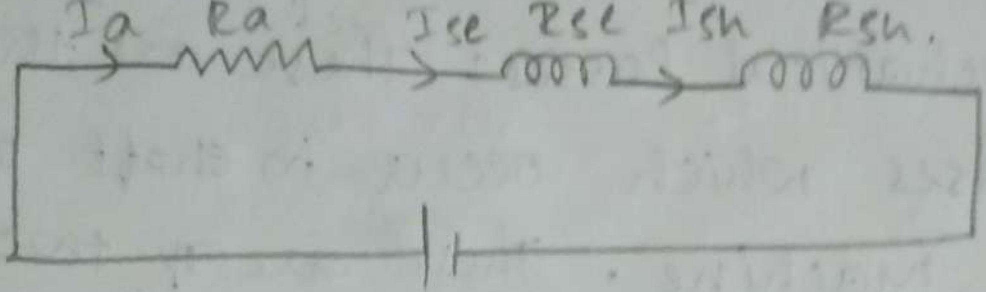
for mechanical energy we use shaft.

$B_n \Rightarrow$ max. flux density $\quad \eta_h \Rightarrow$ histone co-efficient

To reduce We   we laminate core

t = thickness of each lamination

(i) Cu losses:



Cu losses = $I_a^2 R_a + I_{se}^2 R_{se} + I_{sh}^2 R_{sh}$

load will be connected to shaft.

It will be coupled directly.

(ii) iron loss: η_e = eddycurrent co-efficient.

hysterysis(W_h) = $\eta_h B_m^{1.6} f V$.

eddy losses(W_e) = $\eta_e B_{max} f^2 t^2$

η_h = histyrisis co-efficient.

$B_m^{1.6}$ = maximum flux density.

f = frequency.

V = volume of core.

t = thickness of lamination

↳ to minimise the eddycurrent losses.

η_e = eddycurrent co-efficients.

Bmax = Maximum flux density.

f = frequency.

t = thickness.

Mechanical losses: These are the losses which occur in shaft of DC machine. These are of two types. 1) friction loss.

2) windage loss.

copper losses: Power wasted in the form of I^2R and these type of losses occur in dc winding of the machine are called copper losses. These are of three types.

Efficiency (η)

1) armature.

2) series

3) shunt.

Efficiency (η): The ratio of output power and input power is known as efficiency. It is denoted by η

$$\eta = \frac{\text{output power}}{\text{input power}}$$

$$\eta = \frac{P_0}{P_i}$$

$$= \frac{P_0}{P_0 + \text{losses}}$$

$$\% \eta = \frac{P_0}{P_0 + \text{losses}} \times 100.$$

Q) A 230V shunt motor delivers 30 Hp at the shaft at 1120RPM if the motor has efficiency of 87% at this load determine

i) Total input power

ii) line current. (I_L)

$V_L = 230V$. $N = 1120$ RPM.

$\eta = 87\%$. $P_{out} = 30$ Hp.

$= 30 \times 746$.

$$\eta = \frac{P_o}{P_i} \times 100$$

$$87 = \frac{30 \times 746}{P_i} \times 100$$

$$P_i = \frac{30 \times 746}{87} \times 100$$

$$P_i = 25724.137$$

$$= 25724.$$

$$I_L = \frac{V_L}{P_i} = \frac{230}{25724}$$

$$P_i = I_L V_L$$

$$I_L = \frac{P_i}{V_L}$$

$$= \frac{25724}{230} = 111.843 A$$

8) A shunt generator delivers 195A at a terminal voltage of 250V the armature & sh. R are 0.02Ω, 50Ω respectively. The iron & friction losses = 950W. find 1) Emf generated.

2) Cu losses.

3) output of generator.

4) η.

$I_L = 195A$.

$V_L = 250V$.

$R_a = 0.02\Omega$

$R_{sh} = 50\Omega$.

$\eta_h \cdot B_m^{1.6} f V$

friction, so take it as mechanical loss.

$W_i \& W_f$.

~~Wm~~ = 950 W.

$I_a = I_L + I_{sh}$.

$I_{sh} = \frac{V_L}{R_{sh}}$.

$= \frac{250}{50}$.

$= 5$.

$W_{cu} = ?$

$E_{mf} =$

$I_a = 195 + 5$

$= 200$.

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$E_{mf} = I_a R_a + V_L + BCD$

$= (200)(0.02) + 250 + 2.$

$= 4 + 252$

$= 256.$

$W_{cu} = I_a^2 R_a + I_{sh}^2 R_{sh}.$

$= (200)(200)(0.02) + (5)(5)(50)$

$= (200)(4) + (25)(50)$

$= 800 + 1250$

$= 2050.W.$

$P_0 = V_L I_L$

$= (250)(200)$

$= 500$

$= (250)(195)$

$= 48750.$

$\eta = \frac{P_0}{P_i}$

$950 + 2050.$

$= \frac{P_0}{P_0 + loss.}$

$\frac{48750}{51750}.$

$= \frac{48750}{48750 + 300} \times 100 = 94.2\%$

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$$\eta = \frac{P_0}{P_0 + losses}$$

$losses = W_{cu} + W_i + W_m$

$= 950 + 2050$

$= 3000$

~~W_i~~ .

Q) A long shunt compound generator, gives 240V at full load out put of 100 Amp resistance ~~of 100 Ω~~. the resistance of various windings of the machine are $R_a = 0.1\,\Omega$, $R_{se} = 0.02\,\Omega$, $R_{sh} = 100\,\Omega$. The iron loss on full load is 1000W. windage & friction losses 500W. calculate full load efficiency of the machine.

$V_L = 240V$	$R_a = 0.1\,\Omega$
$I_L = 100\,A$	$R_{se} = 0.02\,\Omega$
$W_i = 1000\,W$	$R_{sh} = 100\,\Omega$
$W_m = 500\,W$	

$$\eta = \frac{P_0}{P_0 + \text{losses}}$$

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

$E_g = I_a R_a + I_{se} R_{se} + V_L + E_L$ BCD

$P_0 = V_L \times I_L$.

$P_0 = (100)(240)$

$= 24000$.

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

$= \frac{240}{100}$

$= 2.4$.

$I_a = I_{sh} + I_L$

$= 2.4 + 100$.

$= 102.4$.

$E_g = 102.4(0.1 + 0.02) + 240$

$+ 2$.

$= (102.4)(0.12) + 242$.

$= 12.288 + 242$.

$= 254.288$.

$P_{cu} = (I_a^2 R_a) + I_{se}^2 R_{se} + I_{sh}^2 R_{sh}$

$= (102.4)(102.4)(0.1) + (102.4)$ lated

$(102.4)(0.02) +$

$(2.4)(2.4)(100)$

$= 1048.57 + .213 + .576.$

$= 1837.57.$

losses $= 1837.57 + 1000 + 500.$

$= 3337.57.$

$$\eta = \frac{24000}{240000 + 3337.57} \times 100.$$

$$= \frac{24000}{27337} \times 100.$$

$= 87.79.$

$= 87.8.$

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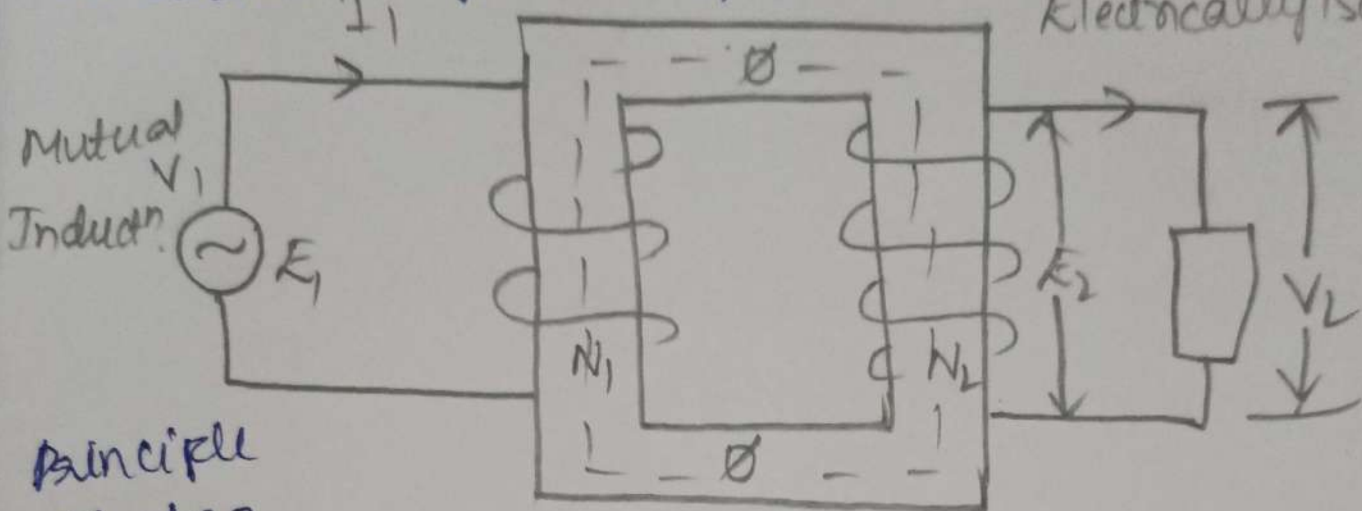
UNIT-III

AC MACHINES

Construction of Transformers:-

static machine.

Magnetically coupled
Electrically isolated



Principle
Electro

$V_1 \longrightarrow I_1 \longrightarrow \phi_1 \longrightarrow$ core $\longrightarrow \phi_2 \longrightarrow E_2 \longrightarrow$ 'I'

M.P
Magnetic path.

E_2 ↓ A.C

classification:

construction	windings	phase
1. core	1. step Up	1. 1ϕ
2. Shell	2. step down	2. 3ϕ
3. Berry		

Principle: Faraday's laws of electromagnetic inductⁿ,
mutual induction b/w 2 coils: .

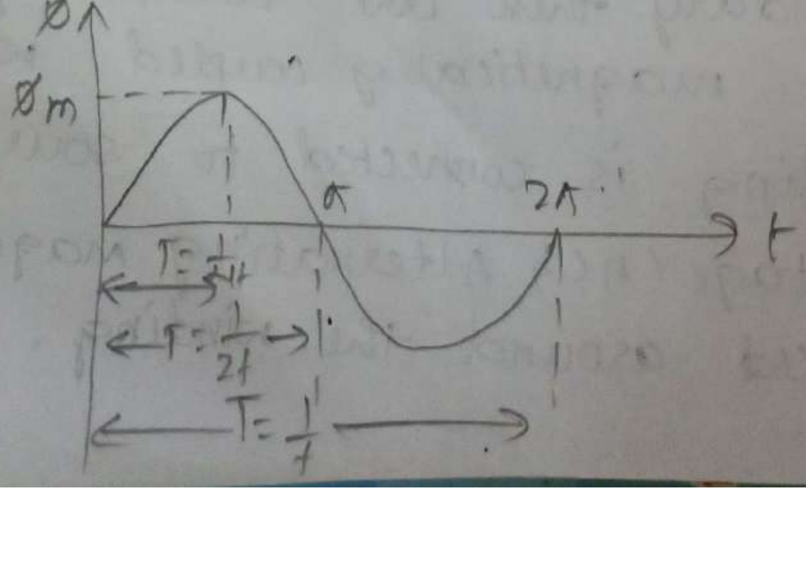
Working principle of transformer:

The basic principle behind working of transfor-mer is mutual induction b/w two windings linked by common magnetic flux. Basically a transformer consists of two inductive coils primary & secondary these are electrically separated but magnetically coupled when primary winding is connected to source of alternating voltage (AC); Alternating magnetic flux is produced around the winding.

The core provides magnetic path for the flux to get link with the secondary winding. Most of the flux gets linked with 2ndary is called useful flux or main flux. & the flux which doesnot link with 2ndary winding is called leakage flux. The flux which is produced is alternating in nature.

Emf gets induced in the 2ndary winding according to faraday's laws of electro magnetic inductⁿ. This emf is called mutually induced Emf & this frequency is same as supply emf. If the 2ndary winding is closed then mutually induced current flows through it & hence electrical energy is transferred from 1 circuit (primary) to another circuit (secondary)

Emf eqⁿ of a transformer:



According to faraday's laws of electromagnetic induction:

$$E = N\frac{d\phi}{dt}$$ N = no of turns

$N = 1$

$$E = \frac{d\phi}{dt}$$

change in flux

$$d\phi = \phi_m - 0$$

$$dt = \frac{1}{4f}$$

$$E = \frac{\phi_m}{\frac{1}{4f}}$$

$$E = 4f\phi_m$$

$$\text{form factor} = \frac{\text{Rms value}}{\text{avg value}}$$

form factor = 1.11 (sin)

$$E = 4f\phi_m \times 1.1$$

$$= 4.4 f\phi_m$$

Emf induced in primary winding

$$E_1 = 4.44 f\phi_m N_1$$

Emf induced in secondary winding

$$E_2 = 4.44 f\phi_m N_2$$

turns ratio

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

Q) A 40 kVA single phase single phase ideal transformer has 400 turns on primary & 100 turns on 2ndary the primary is connected to 2000V, 50 Hz (i) supply determine secondary voltage on f open circuit.

(ii) current flowing through 2 windings on full load.

(iii) Max value of ϕ.

$P = 40 kVA$.

$N_1 = 400$.

$N_2 = 100$.

$E_1 = 2000V$.

$f = 50Hz$.

$$\frac{V_2}{2000} = 4.$$

$V_2 = 8000$.

$$\frac{V_2}{2000} = \frac{1}{4}$$

$V_2 = 500V$.

$V_2 = ?$ $I_1 = ?, I_2 = ?$ $\phi = ?$ max.

$$\frac{V_2}{V_1} = \frac{N_2}{N_1}$$

$P = 40KVA.$

$N_1 = 400$

$N_2 = 100$

$E_1 = 2000V, f = 50Hz$

$E_2 = V_2 = ?\ I_1 = ?\ I_2 = ?\ \phi m = ?$

$$\frac{E_2}{E_1} = \frac{N_2}{N_1}$$

$P_1 = V_1 \times I_1$

$40 \times 10^3 = (2000) I_1$

$$I_1 = \frac{\overset{20}{\cancel{40}} \times 1\cancel{000}}{\cancel{2000}}$$

$I_1 = 20A.$

$40 \times 10^3 = (500) I_2$

$$I_2 = \frac{\overset{8}{\cancel{40}} \times 10\cancel{00}}{\cancel{500}}$$

$I_2 = 80A$

$E_1 = 4.44 f \phi_m N_1$

$2000 = 4.44 \phi m (400)(50)$

$\phi m = 0.022$

8) the number of load ratio required to a single phase 50 Hz transformer is $\frac{6600}{600}$ 6600/600V if the max value of ϕ in core is to be about 0.08 Wb find no of turns in each winding.

$f = 50 Hz$.

$\frac{V_2}{V_1} = \frac{6600}{600}$.

$\phi_m = 0.08$.

$N = ?$

$E = 4.4 f \phi m$.

$= 4.4 \times 50 \times 0.08$.

$E = 17.6$.

$E_2 = 6600$

$E_1 = 600$.

$6600 = 4.4 f \phi m N_2$

$\frac{6600}{4.44 \times 50 \times 0.08} = N_2$

$\frac{6600}{17.76} \Rightarrow$ ~~3.75~~.

$= 371.62$).

$E_1 = 4.4 f \phi m N_1$

$\frac{600}{4.44 \times 50 \times 0.08} = N_1$

$\frac{600}{17.76} = 33.78$.

losses in transformer:

1) Cu < Primary → $I_1^2 R_1$
Secondary → $I_2^2 R_2$

2) Iron loss < hysterisis → $W_h = \eta_h B_m^{1.6} f v$
Eddycurrent losses → $W_e = \eta_e B_m t^2$

$fv \Rightarrow$ Volume of core

$t \Rightarrow$ thickness of transformer.

Efficiency (η): ratio of output power & input power is called η.

$$\eta = \frac{P_o}{P_i}$$

~~$P_o = +$~~

$P_i = P_o + \text{losses}$

$\text{losses} = W_{cu} + W_{\text{iron losses}}(P)$

$$\% = \frac{P_o}{P_o + \text{losses}} \times 100$$

Q) A single phase transformer is connected to a 230V, 50Hz supply the net cross sectional area of the core is 60cm² the no of turns

efficiency in primary is 500 & in secondary is
100 determine transformation ratio

2) Max value of flux density in the core

3) Emf induced in 2ndary winding.

$f = 50Hz$.

$V_1 \Rightarrow E_1 = 230V$

$\phi_m = B_m A$.

$A = 60cm^2$

$B_m = ?$

$N_1 = 500$.

$N_2 = 100$.

$\frac{N_2}{N_1} = \frac{100}{500} = 0.2$.

~~$\phi_m = \phi_m B$~~

$k = \frac{E_2}{E_1}$

$E_2 = ?$

5) 230 (46
20
3

$\frac{E_2}{E_1} = \frac{N_2}{N_1}$.

$E_2 = \frac{100}{500} \times 230$ (46)

$\frac{23}{1332 \times 5}$

$\phi_m = B_m A$

$E_1 = 4.44 f \phi_m N_1$

$E_1 = 4.44 f B_m A N_1$

$$B_m = \frac{230}{4.44 \times 50 \times 60 \times 10^{-4} \times 500}$$

$B_m = 0.345 \ Wb/m^2$ (or) Tesla.

$E_2 = 4.44 f \phi_m N_2 = 45.95V.$

$\phi_m = B_m A = 2.07 mWb$

Q) A 500 kVA transformer is desired to have a 4.13 mWb maximum core flux in a transformer at 110V & 50 Hz determine the required no of turns in primary $N_1 = ?$

$P = 500 \times 10$

$\phi_m = 4.13 \times 10^{-3}$

$V_1 = E_1 = 110 V \quad f = 50Hz.$

$E_2 = 4.44\, \phi_m f N_2$

$110 = 4.44 \times 4.13 \times 10^{-3} \times 50 \times N_1$.

$110 = 916.86 \times 10^{-3}$

$110 = 0.916\, N_1$

$N_1 = 120.08$.

6400
×0.5

3200 + 1562.5

Q) A 400KVA transformer has a primary winding resistance of 0.5 Ω & a secondary winding resistance of 0.001 Ω & the iron loss is 2.5KW & primary & secondary voltages are 5KV & 320V respectively if the power factor of the load is 0.85 determine the efficiency of transformer on full load & Half full load.

$E_1 = 5 \times 10^3$ V $P = 400$ KVA. $\cos\phi = 0.85$

$E_2 = 320$V.

$\eta_{FL} = ?$

$r_1 = 0.5\,\Omega$

$\eta_{H.FL} = ?$

Power factor $= \cos\phi$

$r_2 = 0.001\,\Omega$.

$W_i = 2.5$ KW $= 2.5 \times 10^3$

$\eta = \frac{P_0}{P_0 + \text{losses}}$

4762.5

P_0 = rating × power factor

$P_0 = 400 \times 10^3 \times 0.85$

1619250×10^3

$= 340\,kW$.

losses = $W_{cu} + W_i$

$P = V_2 I_2$

$I_2 = \frac{400 \times 10^3}{320}$

$W_{cu} = I_1^2 R_1 + I_2^2 R_2$

$= 1250\,A$.

$P = V_1 I_1$

$\cancel{400} \times \cancel{10^3} = \cancel{5} \times \cancel{10^3} \times I_1$ (80)

$I_1 = 80\,A$

$W_{cu} = (80)^2 \times 0.5 \times (1250)^2 \times 0.001$

$= 4762.5\,W$.

$$\eta_{HFL} = \frac{\frac{1}{2} P_0}{\frac{1}{2} P_0 + \left(\frac{1}{2}\right)^2 w_{cu} + w_i}$$

$$\eta_{FL} = \frac{340 \times 10^3}{340 \times 10^3 + 4762.5 + 2.5 \times 10^3}$$

$$= \frac{340000}{340000 + 4762.5 + 2500} \times 100$$

$$= \frac{340000}{347262.5} \times 100$$

$$= 97.9$$

$$\eta_{HFL} = \frac{\frac{1}{2} P_0}{\frac{1}{2} P_0 + \frac{1}{4} w_{cu} + w_i}$$

$$\frac{12.5 \times 10^3}{12.5 \times 10^3 + 450} = \frac{125 \times 100}{12500 + 450} = 96.52$$

Q) In a 25kVA, 2000/200V power transformer the Iron loss & full load copper loss are 350 & 400 W respectively calculate the η at unity power factor at full load & HFL

$P = 25kVA$

$\frac{V_2}{V_1} = \frac{2000}{200}$

$\cos\phi = 1$ $\eta_{FL} = ?$

$W_i = 350$.

$W_{cu} = 400$. $\eta_{HFL} = ?$

P_0 = rating x power factor.

$P_0 = 25 \times 10^3$.

losses = 350 + 400 = 750.

$\eta_{HFL} = \frac{P_0}{P_0 + losses} \times 100$.

$\eta_{HFL} = \frac{\frac{25}{2} \times 10^3}{\frac{25}{2} \times 10^3 + \frac{1}{4}(750)} \times 100$.

$= \frac{12.5 \times 10^3}{12.5 \times 10^3 + 187.5}$

$= \frac{125 \times 10^2}{12500 + 187.5}$

$= \frac{25 \times 10^3}{25 \times 10^3 + 750} \times 100$

$= \frac{25 \times 10^3}{25750}$

$= 97.087$.

Q) calculate the current drawn by the primary of transformer which steps down 200 to 20V to operate a device of resistance 20 Ω assume η of transformer to be 80 %.

$V_1 = 200 V$ $I_1 = ?$

$V_2 = 200 V.$ $R_2 = 20 \Omega.$

$\eta = 80 \%.$

I_2

$80\% = \frac{V_2 \times I_2}{V_1 \times I_1} \times 100.$

$\frac{V_2}{R_2} = I_2.$

$80 = \frac{200 \times 10}{20 \times I_1} \times 100$

$I_2 = \frac{200}{20}$

$0.8 = \frac{2000}{20 I_1}$

$I_2 = 10$

$20 I_1 = \frac{20000}{8}$

$I_1 = \frac{20000}{8 \times 20}$

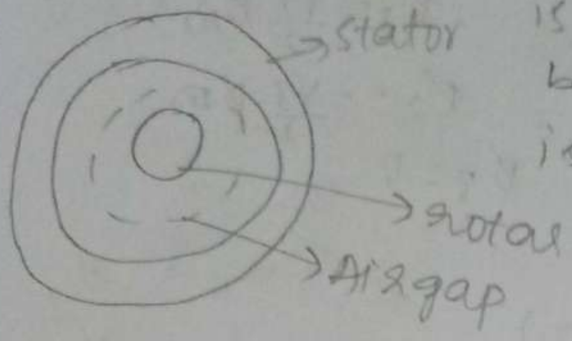
$= \frac{1000}{8}$

$I_1 = 125.$

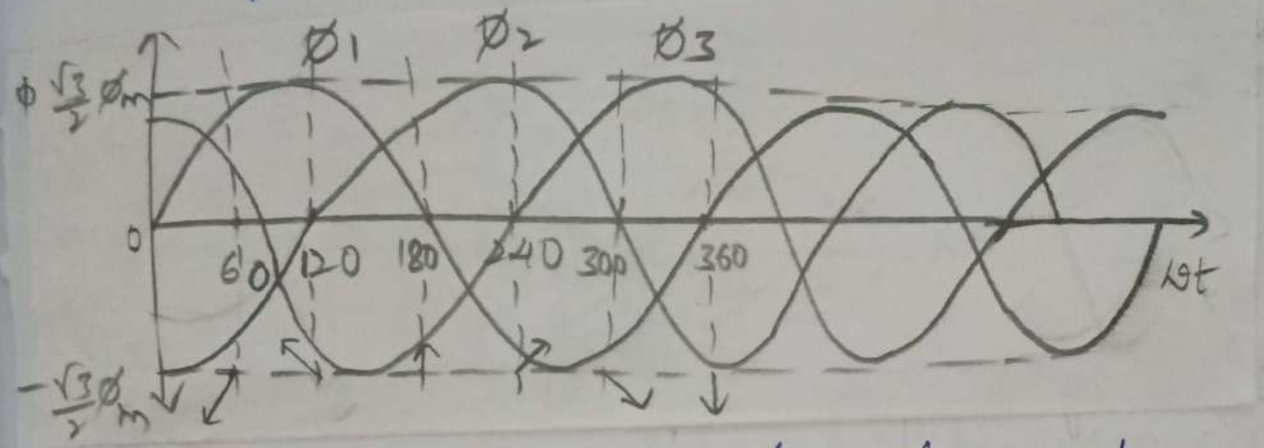
Induction Motors:

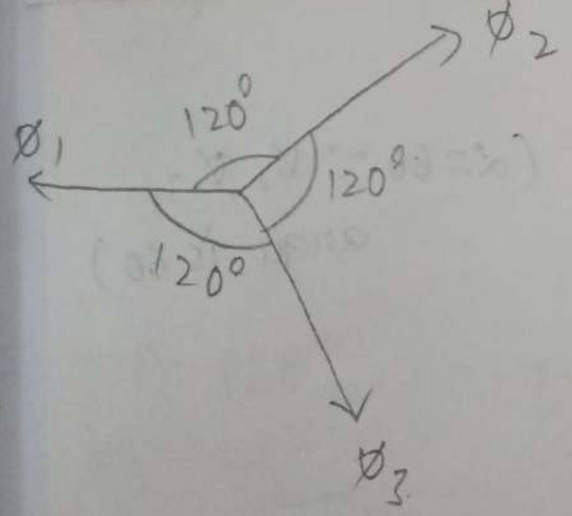
It consists of two parts stator, rotor & has air gap in b/w them & due to current in R, Y, B a magnetic flux is generated & due to the interaction b/w these fluxes a rotating field is produced in the air gap

(i)



(i) Rotating Magnetic field:





$\phi_1 = \phi_m \sin wt$

$\phi_2 = \phi_m \sin(wt - 120°)$

$\phi_3 = \phi_m \sin(wt - 240°)$

a) at position 1; $wt = 0$

$\phi_1 = \phi_m \sin(0) = 0$

$\phi_2 = \phi_m \sin(0 - 120°)$

$= -\phi_m \sin 120°$

$= -\phi_m \sin(90+30)$

$= -\phi_m \cos 30°$

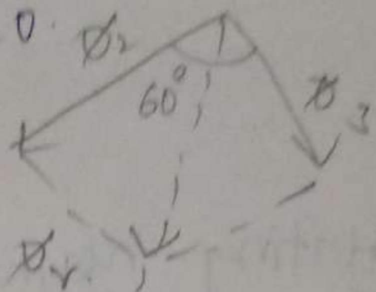
$\phi_2 = -\frac{\sqrt{3}}{2}\phi_m$

at position (3)

$\phi_1 = \frac{\sqrt{3}}{2}\phi_m$

$\phi_2 = -\frac{\sqrt{3}}{2}\phi_m$

$\phi_3 = 0$



$\phi_3 = \phi_m \sin(0-240)$

$= -\phi_m \sin(180+60°)$

$= +\phi_m \sin 60°$

$\phi_3 = \phi_m \frac{\sqrt{3}}{2}$

According to parallelogram law resultant phasor magnitude flux $\phi_r = 2a\cos\frac{\alpha}{2}$

($\alpha = 60$ ∵ ϕ_2, ϕ_3 angle is 60)

$= 2\frac{\sqrt{3}}{2}\phi_m \cos\frac{60}{2}$

$= 2\frac{\sqrt{3}}{2}\phi_m \cos 30°$

$= 2\left(\frac{\sqrt{3}}{2}\right)\left(\frac{\sqrt{3}}{2}\right)\cdot\phi_m$

$= \frac{3}{2}\phi_m$

$\boxed{\phi_r = 1.5\phi_m}$

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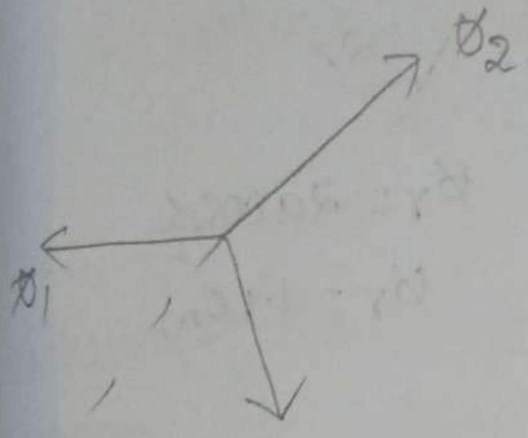
a) at position ②

$\phi_1 = \frac{\sqrt{3}}{2}\phi_m$

$\phi_2 = -\frac{\sqrt{3}}{2}\phi_m$

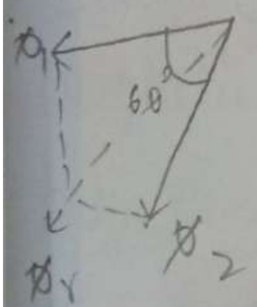
$\phi_3 = 0$



$\phi_r = 2a\cos 30°$

$= \left|\frac{\sqrt{3}}{2}\phi_m\right|$

$\boxed{\phi_r = 1.5\phi_m}$

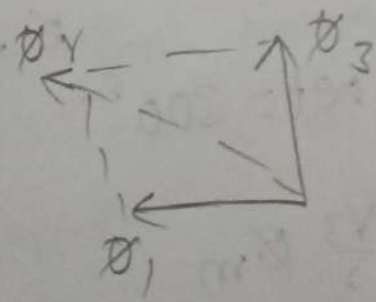


3) $\omega t = 120°$

$\phi_1 = \frac{\sqrt{3}}{2}\phi_m$

$\phi_2 = 0$

$\phi_3 = -\frac{\sqrt{3}}{2}\phi_m$



$\phi_r = 2a\cos 30°$

$= \left|\frac{\sqrt{3}}{2}\phi_m\right|$

$\boxed{\phi_r = 1.5\phi_m}$

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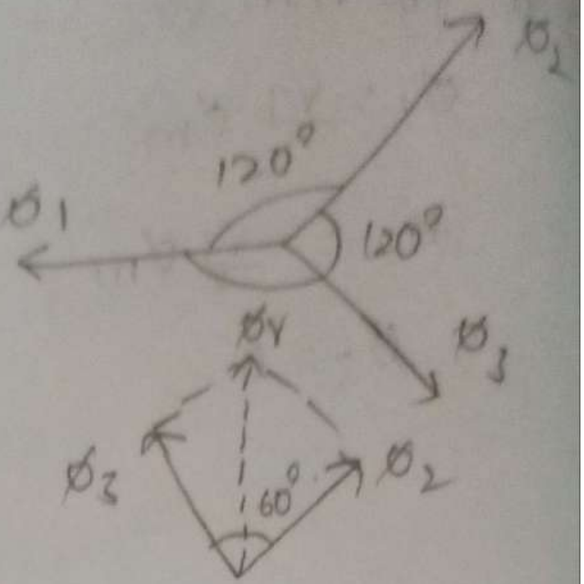
at ④ position. $\omega t = 180°$

$\phi_1 = 0$

$\phi_2 = \frac{\sqrt{3}}{2}\phi_m$

$\phi_3 = -\frac{\sqrt{3}}{2}\phi_m$



$\phi_r = 2a\cos\frac{\alpha}{2}$

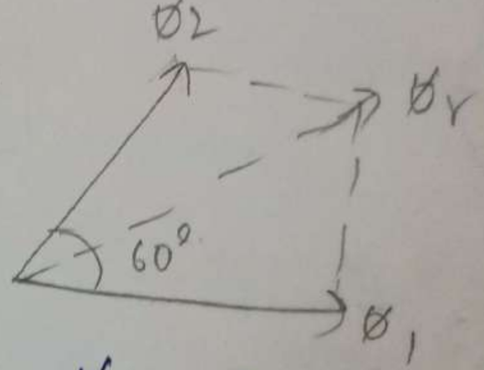
$\phi_r = 1.5\phi_m$

at position ⑤ $\omega t = 240°$

$\phi_1 = -\frac{\sqrt{3}}{2}\phi_m$

$\phi_2 = \frac{\sqrt{3}}{2}\phi_m$

$\phi_3 = 0$



$\phi_r = 2a\cos\frac{\alpha}{2}$

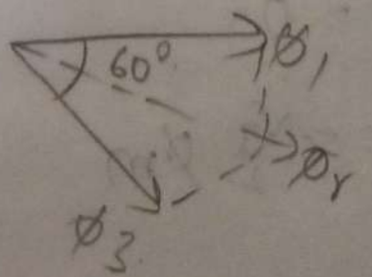
$\phi_r = 1.5\phi_m$

at position ⑥ $\omega t = 300°$

$\phi_1 = -\frac{\sqrt{3}}{2}\phi_m$

$\phi_2 = 0$

$\phi_3 = \frac{\sqrt{3}}{2}\phi_m$



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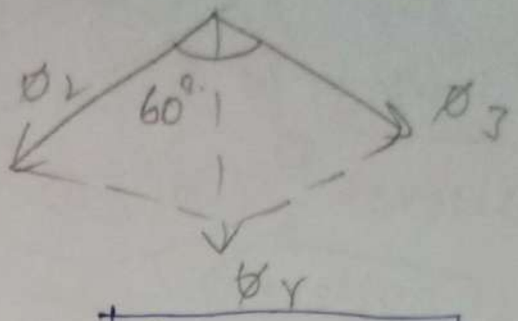
at position ⑦ $\omega t = 360°$:

$\phi_1 = 0$

$\phi_2 = -\frac{\sqrt{3}}{2}\phi_m$

$\phi_3 = \frac{\sqrt{3}}{2}\phi_m$



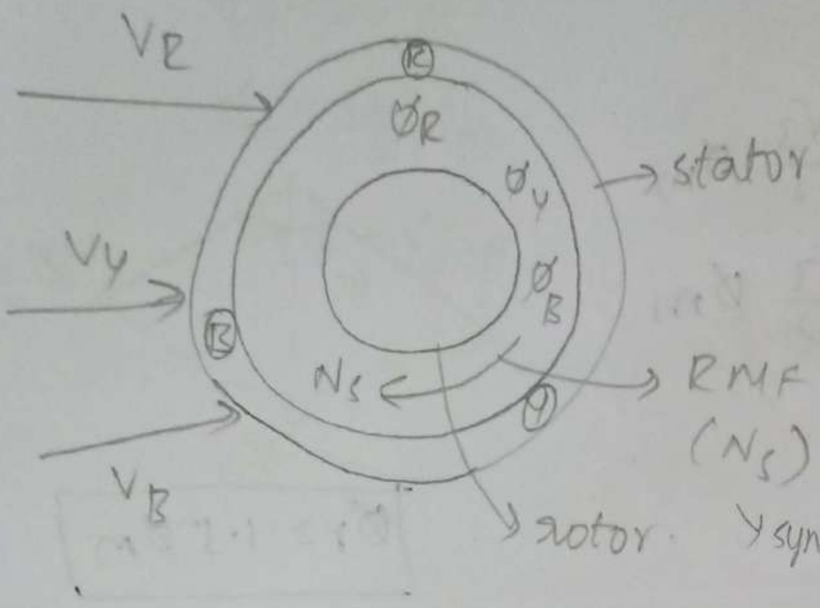
$\boxed{\phi_r = 1.5\phi_m}$

∴

whenever three phase (3ϕ) input AC voltage given to the induction motor three phase currents starts flowing which produce magnetic flux a

Definition of rotating magnetic field (RMF):
The magnetic field due to three phase flux interaction ~~the magnetic~~ rotates in the air gap with a fixed speed & constant magnitude is known as rotating magnetic field!

Working principle of 3ø induction motor: 3ø.



3øV
↓
RMF
↓
cuts cond
↓ faraday's
Emf
↓
I
↓ cuts
M.F.
↓ T
Mech.f
↓
$< N_s$

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

rotating transformer.

1ø I.M ⇒ fan

Whenever a 3ø ac (AC) voltage is applied to the induction motor due to 3ø flux interaction an rotating magnetic field produced in the air gap which cuts the rotor conductors due to relative speed according to faraday's laws of Electromagnetic induction an Emf gets induced in the conductor due to this current starts flowing through rotor winding which acts as current carrying conductor now. Whenever a current carrying conductor placed in the magnetic field it will experience a mechanical force. This twisting or turning movement of force is called Torque. Because of this torque the rotor starts in the direction of RMF. rotor always tries to catch the synchronous speed but it can never catch the N_s (synchronous speed) and will always runs less than synchronous speed.

3ϕ Induction motor:

Principle: BiH

Induction motor works on the principle of electromagnetic induction when three phase supply is given to stator winding RMF is produced and the induction motor will rotate with synchronous speed (N_s). The induction motor is also called as rotating transformer

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

f = frequency

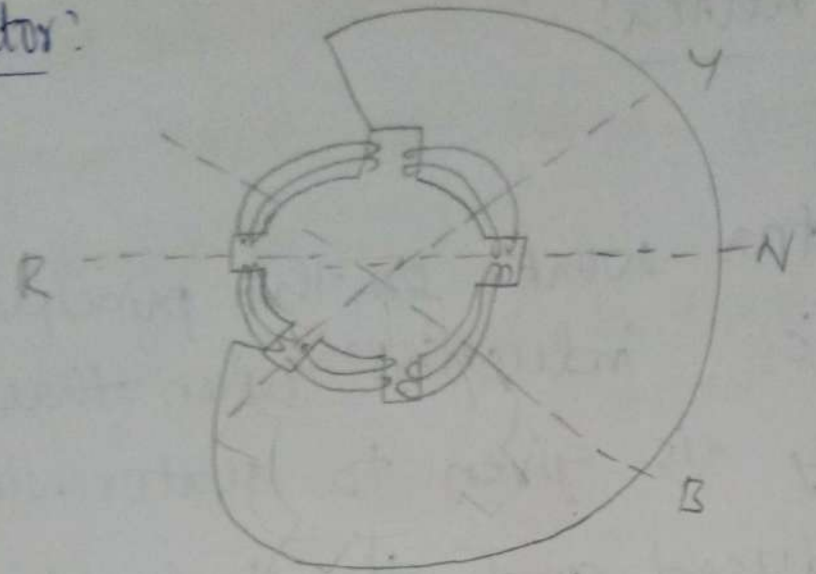
P = Poles.

units of N_s is r.p.m

Construction of Induction motor:

1) stator
2) Rotor — squirrel cage rotor / slip ring motor.

Stator:

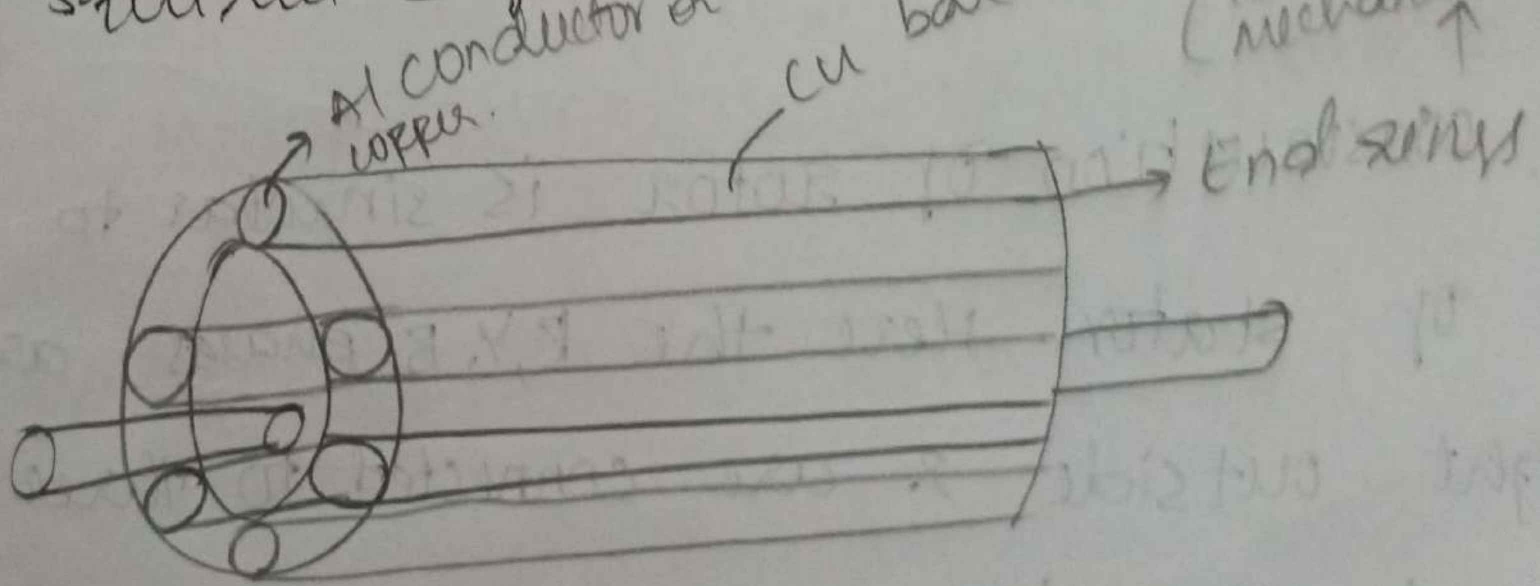


stator has laminated type of construction and madeup of stampings and thickness of each stamping is 0.4 to 0.5mm. And these stampings are slotted to carry stator winding. Stator core carries a 3 phase winding connected either in star or delta. So, this winding is excited by 3Ø supply produces rotating magnetic field.

2) Rotor:

low torque appli

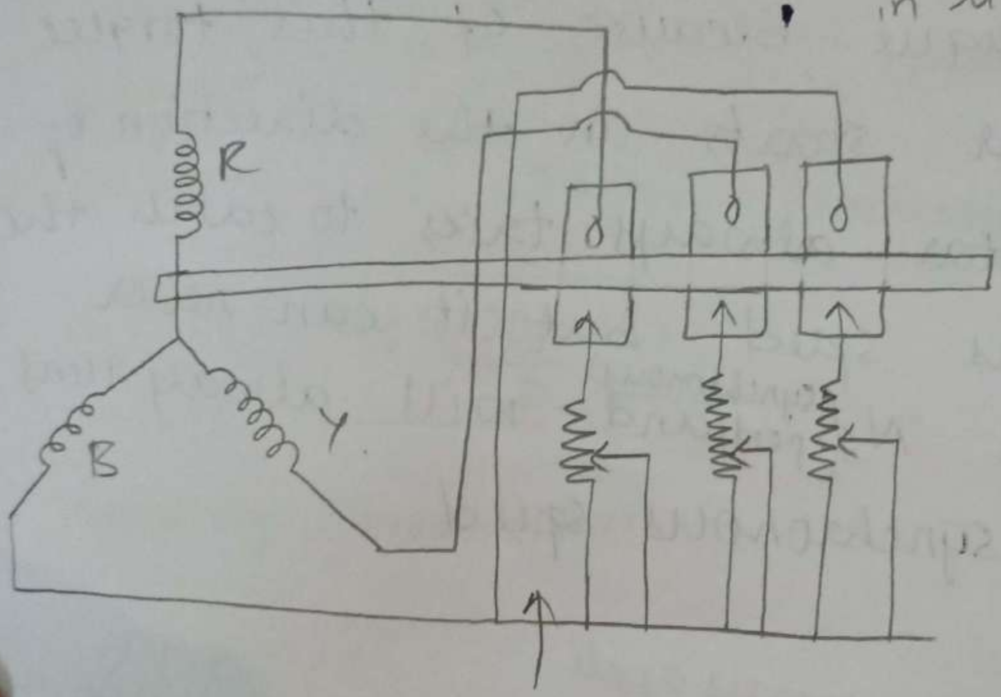
(i) squirrel cage rotor: low cost due to no use of resistance.



incase of low starting torque we use it

The rotor consisting of copper and aluminium bar conductor these are the rotor conductors the copper bars are permanantly shorted at each end with the help of end rings. These end rings provide good mechanical strength.

~~2)~~ (ii) slip Ring rotor: To limit the starting current & are allowed in lifts.



$T_{st} \propto \frac{R_2}{X_2}$

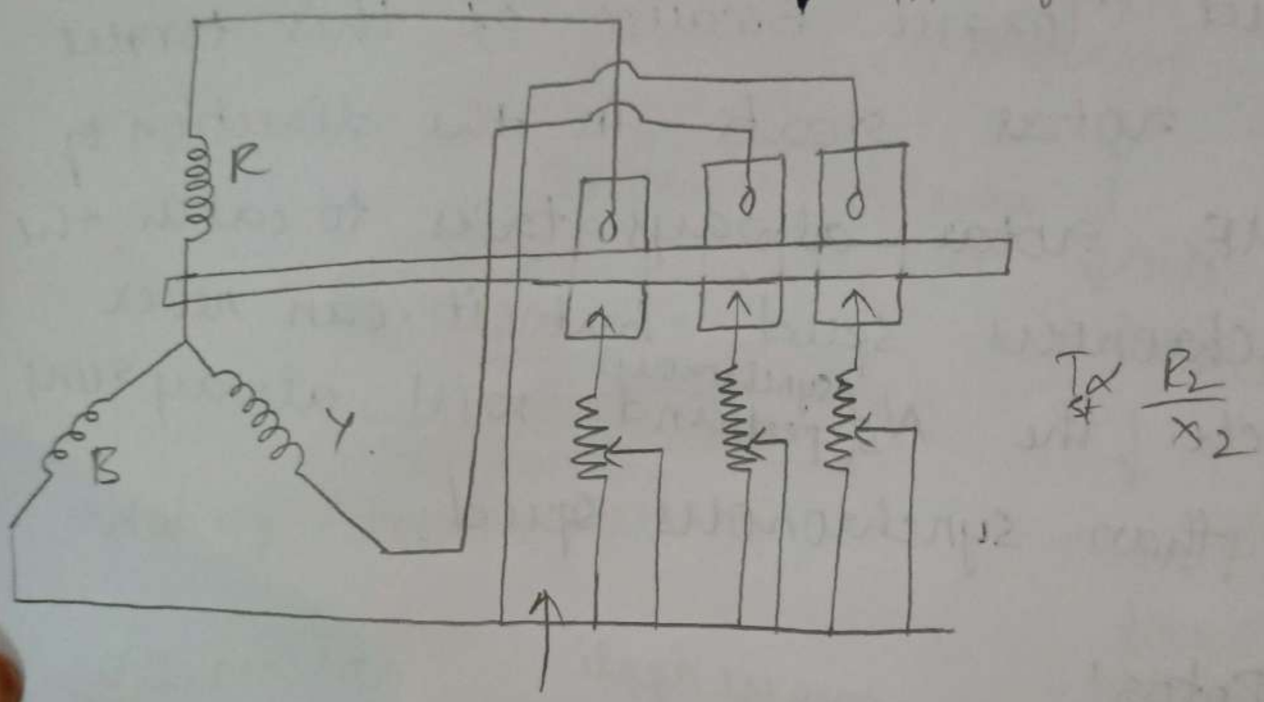
External resistance box

in case of High torque applications
High cost due to the use of resistances & brushes.

The construction of rotor is similar to that of stator. Here the R, Y, B phases are brought outside & are connected to three slip rings with the help of brushes & then external resistances will be added in each phase to ~~impo~~ improve the starting Torque.

shorted at each end with the help of end rings. These end rings provide good mechanical strength.

(ii) slip Ring rotor: To limit the starting current & are also used in lifts.



External resistance box

in case of High torque applications
High cost due to the use of resistances & brushes.

The construction of rotor is similar to that of stator. Here the R, Y, B phases are brought outside & are connected to three slip rings with the help of brushes & then external resistances will be added in each phase to ~~impo~~ improve the starting Torque.

Under running condition the brushes will be removed & now 3 slip rings form closed path that is joined together to form a simple bar. Now, it will act similar to that of squirrel cage rotor (motor) to limit losses.

slip(s):

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

N_s = synchronous speed.

N_r = rotor speed / motor) actual speed.

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

$$sN_s = N_s - N_r.$$

$$N_r = N_s - sN_s$$

$$\boxed{N_r = N_s(1-s)}$$

$$\boxed{\%\, s = \frac{N_s - N_r}{N_s} \times 100}$$

It is defined as the ratio of difference b/w synchronous speed & motor speed to the synchronous speed.

And it is denoted by s.

Rotor frequency (f_r):

slip speed = $N_s - N_r$

dividing with N_s on both sides.

$$\frac{\text{slip speed}}{N_s} = \frac{N_s - N_r}{N_s}$$

$$\frac{\frac{120 f_r}{p}}{\frac{120 f}{p}} = s$$

$$f_r = sf$$

f_r = rotor frequency.

f = supplied frequency.

s = slip.

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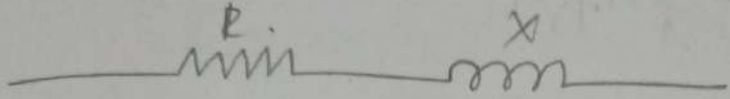
Rotor Emf (E_{2r}):

Emf induced is $\propto$ N_s (synchronous speed) in rotor.

E_{2r} = rotor emf at running cond^{n}.

$I = \frac{V}{R}$ ⇒ for DC circuits



$I = \frac{V}{Z}$ ⇒ for AC.

Z ⇒ Impedence.

$= \frac{V}{R+jX}$

$= \frac{V}{\sqrt{R^2+X^2}}$ $\sqrt{R^2+X^2}$ ⇒ magnitude

$E_2 \propto N_s$

$E_{2r} \propto N_s - N_r$

$\frac{E_{2r}}{E_2} \propto \frac{N_s - N_r}{N_s}$

$\frac{E_{2r}}{E_2} = s$

$\boxed{E_{2r} = sE_2}$

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→ Rotor resistance (R_2):

$$R_{2r} = R_2$$

→ Rotor reactance X_2:

$X_2 = \omega L$ $[\because \omega = 2\pi f]$

$= 2\pi f_r L$

$X_{2r} = 2\pi (f_s s) L$ $f_r = s f_s$

$= (2\pi f_s) \cdot s \cdot L$

$$X_{2r} = s \cdot X_2$$

→ Rotor Impedence Z_2

$Z_2 = \sqrt{R_2^2 + X_2^2}$

$Z_{2r} = \sqrt{R_{2r}^2 + (X_{2r})^2}$ $[\because R_{2r} = R_2]$

$$Z_{2r} = \sqrt{R_2^2 + (sX_2)^2}$$

Z_{2r} = Impedence of rotor at running condition

R_2 = Resistance of rotor.

X_2 = rotor reactance

s = slip

Rotor current (I_{2r}):

$$I_2 = \frac{E_2}{Z_2}$$

$$= \frac{E_2}{\sqrt{R_2^2 + X_2^2}}$$

E_{2r} = Emf induced in rotor under running condition.

$$\boxed{I_{2r} = \frac{E_{2r}}{Z_{2r}} = \frac{sE_2}{\sqrt{R_2^2 + (sX_2)^2}}}$$

Rotor power factor:

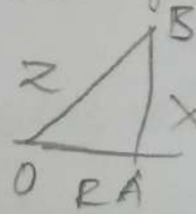
$$\cos\phi_2 = \frac{R_2}{Z_2}$$

$$= \frac{R_2}{\sqrt{R_2^2 + X_2^2}}$$

$$\cos\phi_{2r} = \frac{R_{2r}}{Z_{2r}}$$

$$\boxed{\cos\phi_{2r} = \frac{R_2}{\sqrt{R_2^2 + (sX_2)^2}}}$$

Impedence triangle.



$OB^2 = OA^2 + AB^2$

$OB = \sqrt{OA^2 + AB^2}$

$Z = \sqrt{R^2 + X^2}$

$\cos\phi = \frac{adj}{Hypotenuse}$

$= \frac{R}{\sqrt{R^2 + X^2}}$

** Torque Equation of 3 phase I.M:

$T \propto \phi I$

$T \propto \phi_2 I_{2r} \cos\phi_{2r}$

I_{2r} = rotor current at running condition.

$$T \propto E_2 \cdot \frac{E_{2r}}{Z_{2r}} \cdot \frac{R_{2r}}{Z_{2r}}$$

$$T \propto E_2 \cdot \frac{sE_2}{\sqrt{R_2^2+(sX_2)^2}} \frac{R_2}{\sqrt{R_2^2+(sX_2)^2}}$$

$$T \propto \frac{sE_2^2 R_2}{R_2^2+(sX_2)^2}$$

$$T = \frac{k \cdot sE_2^2 R_2}{R_2^2+(sX_2)^2}$$

$$k = \frac{3}{2\pi N_s}$$

$$T = \frac{3sE_2^2 R_2}{2\pi N_s (R_2^2+(sX_2)^2)}$$

$$\boxed{T = \frac{3}{2\pi N_s} \frac{sE_2^2 R_2}{R_2^2+(sX_2)^2}}$$

N_s = synchrous speed

E_2 = Emf induced in rotor

R_2 = rotor resistance.

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X_2 = rotor reactance

S = slip

T = Torque

I_2 = Current Induced In rotor

I_2 → stand still.

$\cos\phi_2$ = Power factor of rotor

X_{2r} = rotor reactance at running condition.

$\cos\phi_{2r}$ = Power factor of rotor at running condition.

Q) A 10 pole, 50Hz, 3Ø I.M runs at 485 rpm what will be the rotor frequency of rotor current.

$$\begin{array}{r} 600 \\ 485 \\ \hline 115 \end{array}$$

$P = 10$ $\quad f = 50Hz$ $\quad N_r = 485$

$f_r = sf$

$S = \frac{600 - 485}{600} = \frac{115}{600} = 0.191$

$N_s = \frac{120f}{P} = \frac{120(50)}{10} = 600rpm$

$\boxed{N_s = 600rpm}$

$s = 0.191$

$f_r = s.f$

$= 0.191 \times 50$

$f_r = 9.55 Hz$

Q) A 3ø induction motor is wound for 4 poles & is supplied from 50Hz system calculate:

(i) N_s

(ii) speed of motor at 4% of slip.

(iii) Rotor current frequency when motor runs at 600rpm.

$P = 4, \quad f = 50Hz \qquad s = 0.04$

$N_r = N_s(1-s)$

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

$= \frac{120 \times 50}{4}$ (30)

$= 1500 \text{ rpm}$

$s = \frac{N_r - N_s}{N_s} \times 100$

(ii) $N_r = N_s(1-s)$

$= 1500(1-0.04)$

$= 1500(0.96)$

$= 1440\,rpm$

(iii) $f_r = s \cdot f$

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

$= \frac{1500-600}{1500}$

$= \frac{900}{1500} = 0.6$

$f_r = 0.6 \times 50$

$= 30\,Hz$

Q) A 3Ø 6 pole 50Hz induction motor is running with a slip of 4% find
(i) N_s (ii) Motor speed (iii) slip speed
(iv) frequency of Induction rotor

$P = 6 \quad f = 50\,Hz \quad s = 0.04$

(i) $N_s = \frac{120 \times 50}{6} = 1000\,rpm$

(ii) $N_r = N_s(1-s) = 1000(0.96) = 960\,rpm$

$N_r = 960$ ~~the~~ rpm.

slip speed = 1000 - 960
= 40.

$f_r = s \cdot f_s$

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

$= \frac{1000 - 960}{960}$

$= \frac{40}{960}$

$= 0.041$

$= 0.04 \times 50$

$= 0.4 \times 5$

$= 2 Hz.$

Q) A 6 pole 3ø 50Hz induction motor is running at a full load with slip of 4% the rotor is star connected its resistance & reactances are 0.25 & 1.5Ω the emf of

$P = 6 \quad f_r = 50Hz \quad S = 0.04$

$R_2 = 0.25 \quad X_2 = 1.5 Ω$

$E_2 = 100V$

rotor is 100 V find $I_{2r} = ?$

$$I_{2r} = \frac{sE_2}{\sqrt{R_2^2 + (sX_2)^2}}$$

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

$$= \frac{120 \times 50}{6} = 1000 Hz$$

$$I_{2r} = \frac{0.04 \times 100}{\sqrt{(0.25)^2 + (0.04 \times 1.5)^2}}$$

$$= \frac{4}{\sqrt{0.0625 + 3.6 \times 10^{-3}}}$$

$$= \frac{4}{\sqrt{0.06286}} = \frac{4}{0.2507}$$

0.06

$= 15.5 A.$

Q) A 6 pole 3ø 50 Hz induction motor is running at full load with a slip of 4%. rotor is star connected & its resistances & reactance are 0.45 & 2.5 Ω

$f = 50 Hz$ $s = 0.04$ $R_2 = 0.45$, $X_2 = 2.5$

the emf b/w slip rings is 120V. Determine rotor current & power factor assuming the slip rings are short circuited.

$E_2 = 120V$

$$\cos\phi_{2r} = \frac{R_2}{\sqrt{R_2^2 + (sX_2)^2}}$$

$$= \frac{0.45}{\sqrt{(0.45)^2 + (0.04 \times 2.5)^2}}$$

$$= \frac{0.45}{\sqrt{0.2125}}$$

0.2025
0.01

$$= \frac{0.45}{0.4609}$$

$$\cos\phi_{2r} = 0.976$$

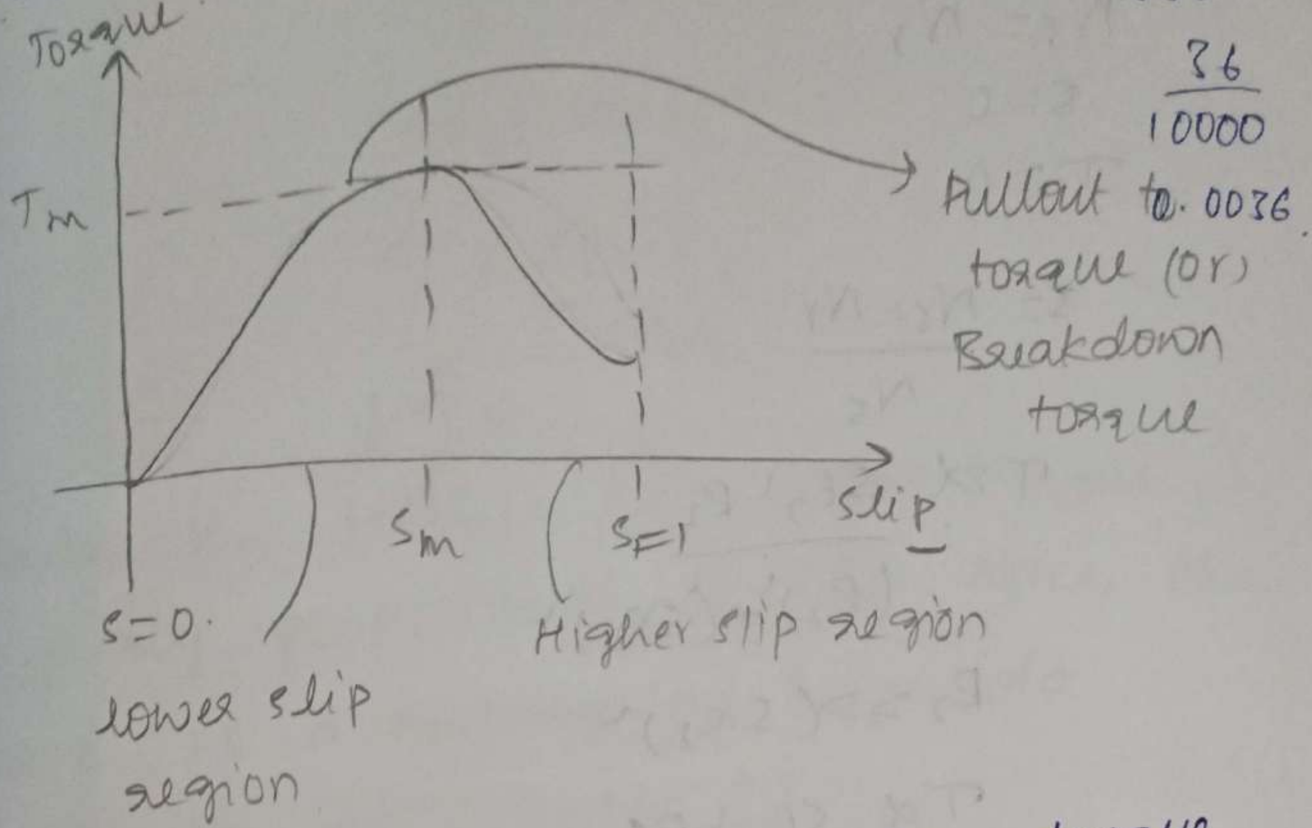
$$I_{2r} = \frac{0.04 \times 120}{\sqrt{(0.45)^2 + (0.04 \times 2.5)^2}}$$

$$= \frac{4.8}{0.4609} = 10.41A$$

Torque - slip characteristics of 3 phase induction motor:

$\frac{3.6}{1000}$

$\frac{36}{10000}$



0.0036

The performance curve drawn b/w torque against slip known as torque slip charac-teristics of an induction motor.

Torque expression:

$$T \propto \frac{s E_2^2 R_2}{(R_2)^2 + (sX_2)^2}$$

The relation b/w Torque and slip, the entire operating region b/w 0 & 1 is divided into two 1 is lower slip region & higher slip region:

lower slip region:

$$N_s = N_r$$
$$s = 0$$
$$T = 0.$$

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

$$T \alpha \frac{sE_2^2 R_2}{(R_2)^2 + (sX_2)^2}$$

$$R_2 >> (sX_2)^2$$

$$T \alpha \frac{sE_2^2 R_2}{R_2^2}$$

$$T \alpha s$$

as $T \uparrow$ $s \uparrow$

Under the lower slip region Torque is directly proportional to slip. Hence, the curve is a straight line.

Higher slip region:

When the slip further rises beyond $s = s_m$ then the term R_2^2 is very smaller than

& sx_2^2

$$T \propto \frac{sE_2^2R_2}{R_2^2+(sx_2)^2}$$

$$(sx_2)^2 >> R_2^2$$

$$T \propto \frac{sE_2^2R_2}{s^2x_2}$$

$$\downarrow T \propto \frac{1}{s} \downarrow$$

Under the Higher slip region Torque is inversely proportional to slip. Hence, the curve is a rectangular hyperbola.

<u>losses in 3ϕ induction Motor:</u>

losses are classified into two types.

(i) constant losses

(ii) variable losses.

(i) <u>Constant losses:</u>

These are classified into two types

(a) Iron losses

(b) Mechanical losses

(a) <u>Iron losses:</u> The losses which occur in the core of stator & rotor. Iron losses includes hysterisis & eddy current losses

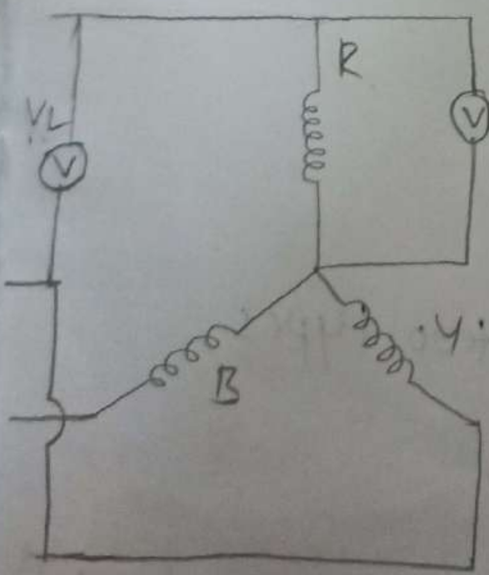
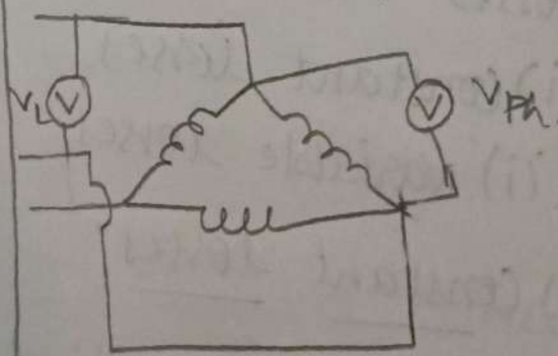
Iron losses are also known as core losses

(i) Mechanical losses:

losses which occurs in shaft of induction rotor losses includes friction & windage losses

(ii) Variable losses: These are also called as copper losses which occur at winding of stator & rotor. Power wasted in the form of i^2R losses known as variable losses.

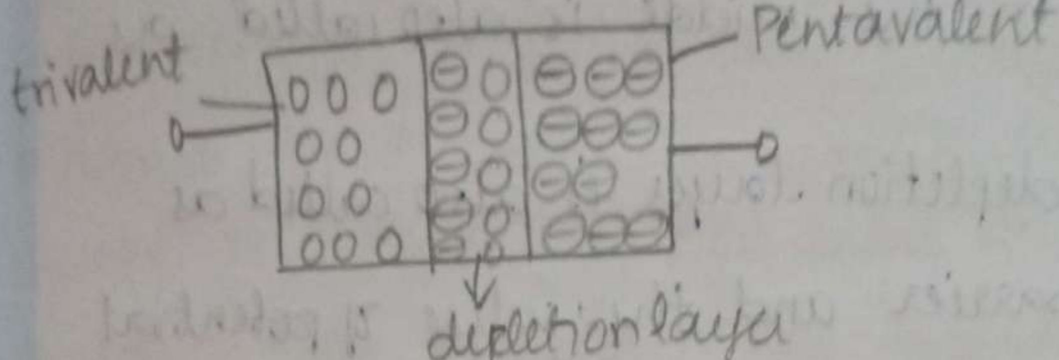
Cu losses usually occur in windings.

Star connection	Delta connection
	
$V_L = \sqrt{3} V_{ph}$ $I_L = I_{ph}$	$V_L = V_{ph}$ $I_L = \sqrt{3} I_{ph}$

UNIT-IV

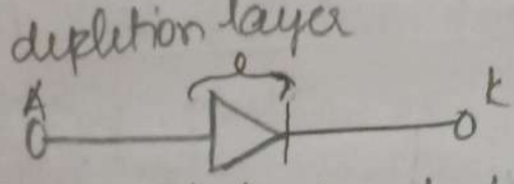
Diode and its characteristics

P-N Junction diode:



Potential barrier – Si – 0.7 V

Ge – 0.3 V



Diode symbol.

→ unidirectional device

→ conduction starts from Anode to cathode in forward bias

→ When a p-type semiconductor is sandwiched with n-type materials (trivalent impurities is added to pentavalent impurities) where p-type material consists of holes as majority carriers and electrons as minority carriers. Where as in n-type materials electrons are majority carriers & holes are minority charge carriers.

→ Whenever, it is joined to together minority carriers in p-type element moves away from the holes towards the junction & holes from n-type elements moves towards junction & thereby these holes & electrons from depletion region or layer in the middle is also called as junction.

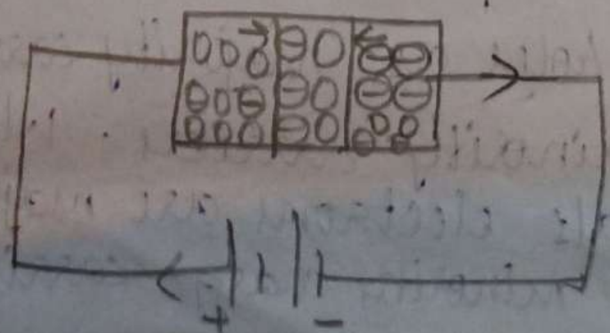
→ Where, depletion layer is also called as potential barrier and the value of potential barrier for silicon is 0.7V & germanium is 0.3V

Diode:

→ P-n junction diode is a two terminal device which allows electric current in only one direction while blocks current in opposite direction.

Working of P-N junction diode:

1. Forward biased mode: forward blocking mode:



ready to conduct

→ Excitation is called biasing

→ Insulation & resistance is reduced in forward bias

→ Depletion layer becomes thin in forward bias.

→ Whenever a +ve terminal is connected to p-type & -ve terminal to n-type & due to +ve charge to p-type repulsion takes b/w positive charge & holes so holes moves toward's junction & combine with electrons.

→ When the positive terminal of the supply or battery source is connected to p-type (Anode) and negative terminal is connected to n-type (cathode side) of the diode is known as forward bias.

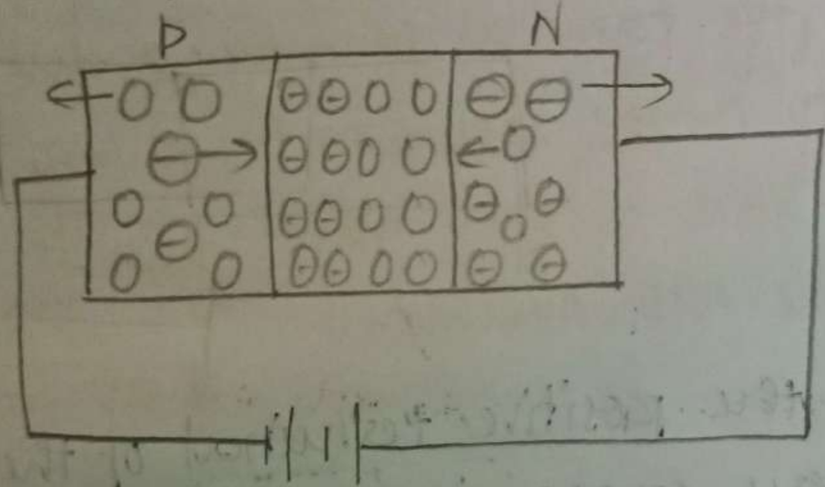
→ In forward bias mode the p-side holes repulse due to charge carriers of positive terminal & in ~~the~~ n-side electron repulse due to charge carriers of -ve terminal.

→ Due to this the width of depletion layer will be reduced at some forward voltage depletion layer will break known as

Breakdown voltage Current due to minority charge carriers in R.B is called leakage current

→ In forward biased condition p-n junction diode acts as on switch due to very low resistance of depletion layer.

Reverse biased mode:

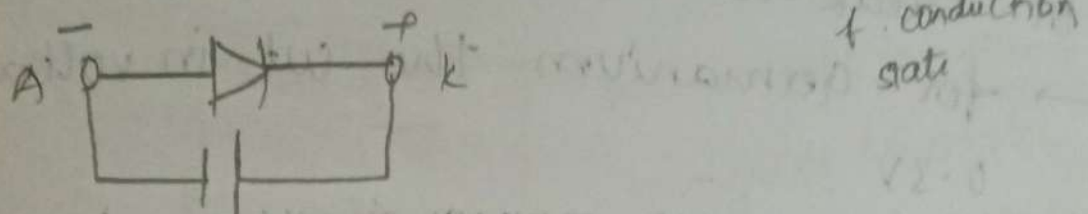


→ The supply or battery when positive terminal is connected to n-side & -ve terminal of battery connected to p-side. This mode is known as reverse biased mode.

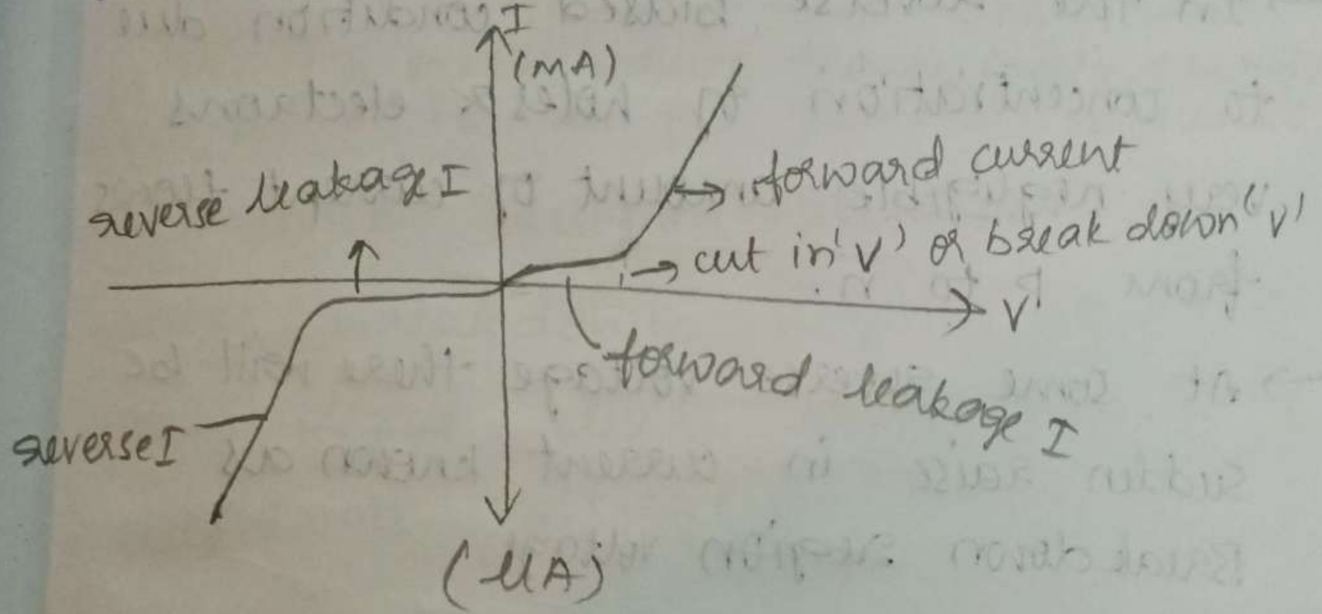
→ In the reverse biased condition holes are attracted by the -ve terminal & vice versa

→ Due to this the depletion layer width ↑ses & then there is no conduction from p to n

→ At this instant, p-n junction diode acts as off switch due to very high resistance of depletion layer.



V-I Characteristics:



In forward conduction state when the voltage is rised the diode conducts.

Cut-in V → Si – 0.7V

Ge – 0.3V

In the forward biased mode a small amount or negligible amount of current flows through the device in the range of micro Amperes to milli A

→ At some forward voltage the current instant-aneously raise known as cut in voltage or break down voltage.

→ for Germanium the cut-in voltage is 0.3V

→ for Silicon the cut-in voltage is 0.7V

→ In the reverse biased condition due to concentration of holes & electrons very negligible amount of current flows from p to n.

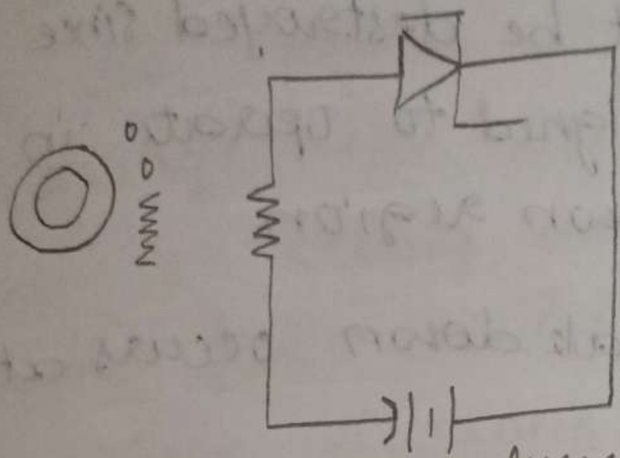
→ At some reverse voltage there will be sudden raise in current known as Break down ~~region~~ voltage.

→ The sharp increase in current in reverse direction due to which some heat is produced which may damage the device

Zener diode: Properly or heavily doped compared to normal diode.

1) Avalanch break down mode   properly or
2) Zener break down.   Heavily doped

1) Avalanche break down:



We connect resistance in series in order to provide protection as external resistance is applied current is reduced & heat reduces thereby safety is provided

Zener diode is a p-n junction semiconductor device designed to operate in reverse breakdown region. It is a highly doped diode which has sharp breakdown voltage.

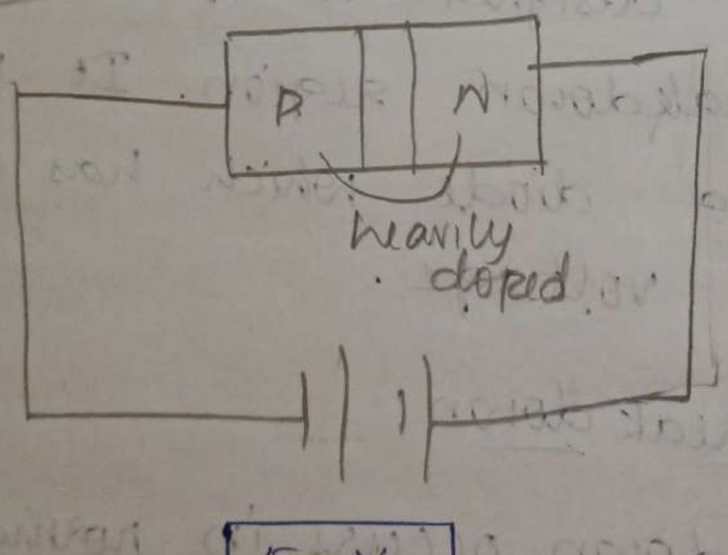
Avalanche break down:

This break down occurs in normal & zener diode at reverse voltage when high amount of reverse voltage is applied to p-n junction diode. free e⁻'s gain large amount of energy as a result electric current in diode rises rapidly.

This sudden increase in current may permanently destroy normal diode however zener diode may not be destroyed since it is carefully designed to operate in Avalanche break down region.

Avalanche break down occurs at greater than 6V.

2) Zener break down: Electrical intensity depends on width of depletion region

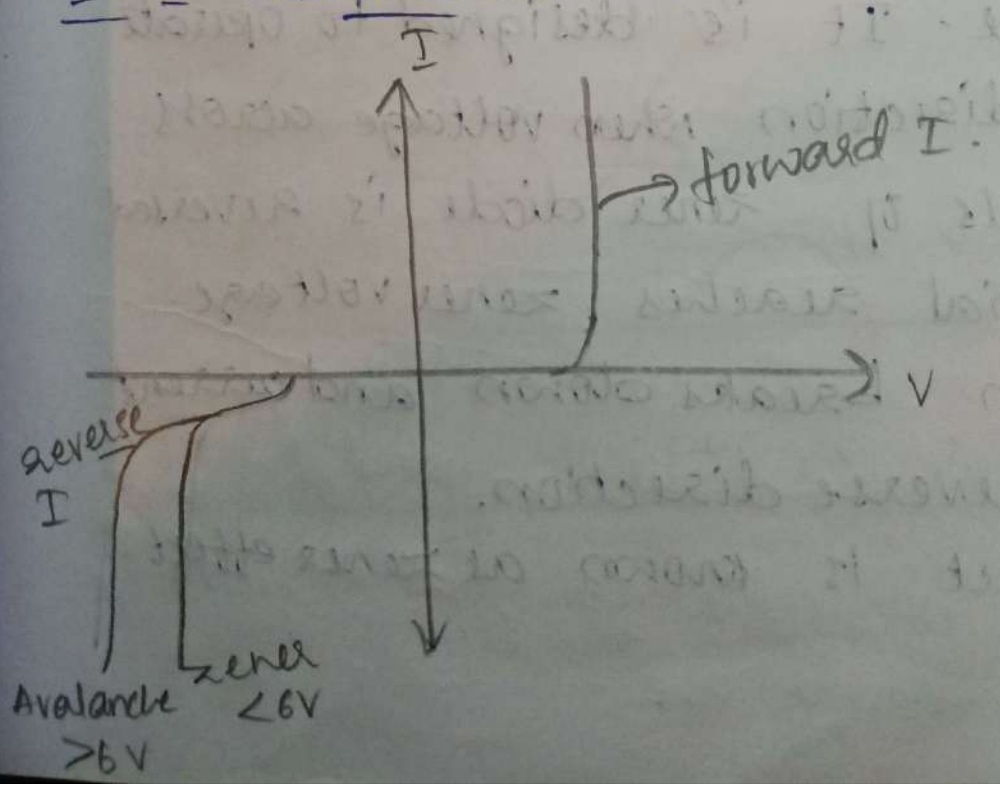


$$E = \frac{V}{d}$$

When high amount of voltage is given electrical field will be produced around the diode and due to the voltage the closely packed electrons with covalent bond in depletion region can be broken easily & electrons can be pulled out & depletion layer vanishes naturally.

When reverse biased voltage applied to diode the moment it reaches close to zener voltage the electric field in depletion layer is strong enough to pull the electrons from covalent bonds of depletion layer. As these electrons gains sufficient energy from electric field there by conduction starts & zener breakdown occurs at voltage less than 6V.

<u>I-V</u> characteristics:



Advantages:

1) Power dissipation capacity is very high
2) High accuracy
3) Small in size (compact)
4) low cost

Applications:

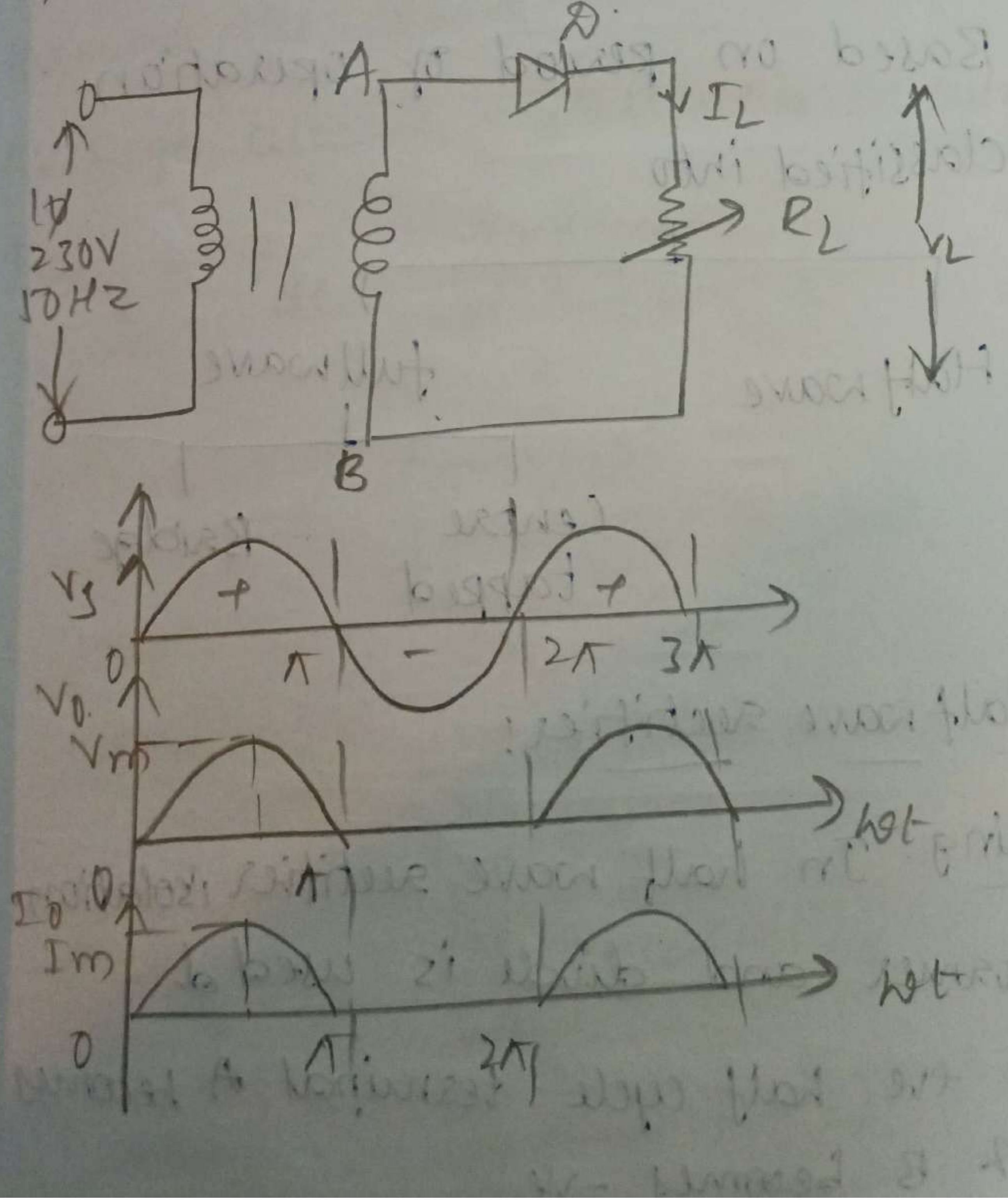
1) It is used in voltage stabilizers
2) As voltage references
3) Used ~~at~~ in switching operations.
4) Used in various protection circuits.

Zener effect:

The zener diode also known as break down diode. It is designed to operate in reverse direction when voltage across the terminals of zener diode is reversed and potential reaches zener voltage. The junction breaks down and current flows in reverse direction.

This effect is known as zener effect.

1ϕ Half wave rectifier !



Rectifiers! Purpose of recitifier!

It is an electronic device which converts fixed AC to variable dc.

Rectifiers are classified into two types:

1) Based on no of ~~fae~~ phases 1Ø, 3Ø

- 1Ø
- 3Ø

2) Based on period of operation

Classified into

- Half wave
- fullwave
  - Centre tapped
  - Bridge

<u>1Ø</u> <u>Half</u> <u>wave</u> <u>rectifier</u>!

<u>Working</u>! In half wave rectifier isolation transformer and diode is used ~~d~~

During +ve half cycle terminal A becomes +ve & B becomes -ve

Now diode is under forward biased mode and now current flows from anode to cathode and then to load.

During -ve half cycle: terminal A becomes -ve & B becomes +ve due to this diode comes into reverse biased mode. Due to which it doesnot allow the current flow through the load.

Average current expression (or) DC output Current:

$$I_{oavg} = I_{dc} = \frac{1}{T}\int_0^T I(\omega t)\, d\omega t$$

$$I = I_m \sin\omega t$$

$$= \frac{1}{2\pi}\int_0^{\pi} I_m \sin\omega t\, d\omega t$$

$$= \frac{I_m}{2\pi}\int_0^{\pi} \sin\omega t\, d\omega t$$

$$= \frac{I_m}{2\pi}(-\cos\omega t)_0^{\pi}$$

$$= \frac{I_m}{2\pi}(-(-1)+1)$$

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

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$$I_{dc} = I_{oav} = \frac{I_m}{\pi}$$

Average Voltage Expression (or) output dc voltage:

$$V_{oav} = V_{dc} = I_{dc} R_L$$

$$= \frac{I_m}{\pi} R_L \quad \left[\because I_m = \frac{V_m}{R_L}\right]$$

$$= \frac{V_m}{R_L \pi} R_L$$

$$V_{oav} = \frac{V_m}{\pi}$$

output power expression:

$$P_{dc} = I_{dc}^2 R_L$$

$$= \frac{I_m^2}{\pi^2} R_L$$

$$= \frac{V_m^2}{R_L^2 \pi^2} R_L$$

$$P_{dc} = \frac{V_m^2}{R_L \pi^2}$$

Rms value of output current:

$$I_{orms} = I_{ac} = \left\{ \frac{1}{T} \int_0^T I^2(\omega t)\, d\omega t \right\}^{1/2}$$

$$I = I_m \sin \omega t$$

$$= \left\{ \frac{1}{2\pi} \int_0^{\pi} I_m^2 \sin^2 \omega t \, d\omega t \right\}^{1/2}$$

$$= \left\{ \frac{I_m^2}{2\pi} \int_0^{\pi} \left(\frac{1 - \cos 2\omega t}{2} \right) d\omega t \right\}^{1/2}$$

$$= \left\{ \frac{I_M^2}{4\pi} \left[(\omega t)_0^{\pi} - \left(\frac{\sin 2\omega t}{2} \right)_0^{\pi} \right] \right\}^{1/2}$$

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

$$= \left\{ \frac{I_m^2}{4} \right\}^{1/2}$$

$$\boxed{I_{orms} = \frac{I_m}{2} = I_{ac}}$$

$$V_{orms} = V_{ac} = I_{ac} R_L = \frac{I_m R_L}{2}$$

$$= \frac{V_m}{2 R_L} R_L$$

$$\boxed{V_{orms} = V_{ac} = \frac{V_m}{2}}$$

$P_{ac} = I_{ac}^2 R_L$

$= \frac{I_m^2}{4} R_L$

$= \frac{V_m^2}{4R_L^2} R_L$

$$P_{ac} = \frac{V_m^2}{4R_L}$$

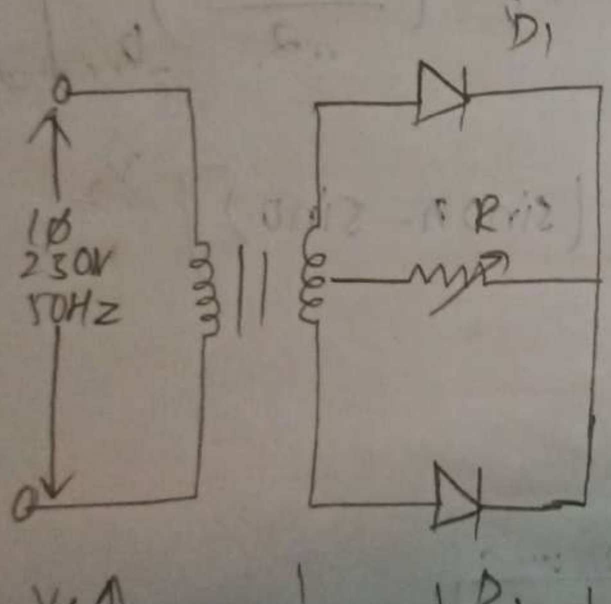
$\eta = \frac{P_{dc}}{P_{ac}} = \frac{\frac{V_m^2}{R_L \pi^2}}{\frac{V_m^2}{R_L 4}} = \frac{4}{\pi^2} = 40.6\%$

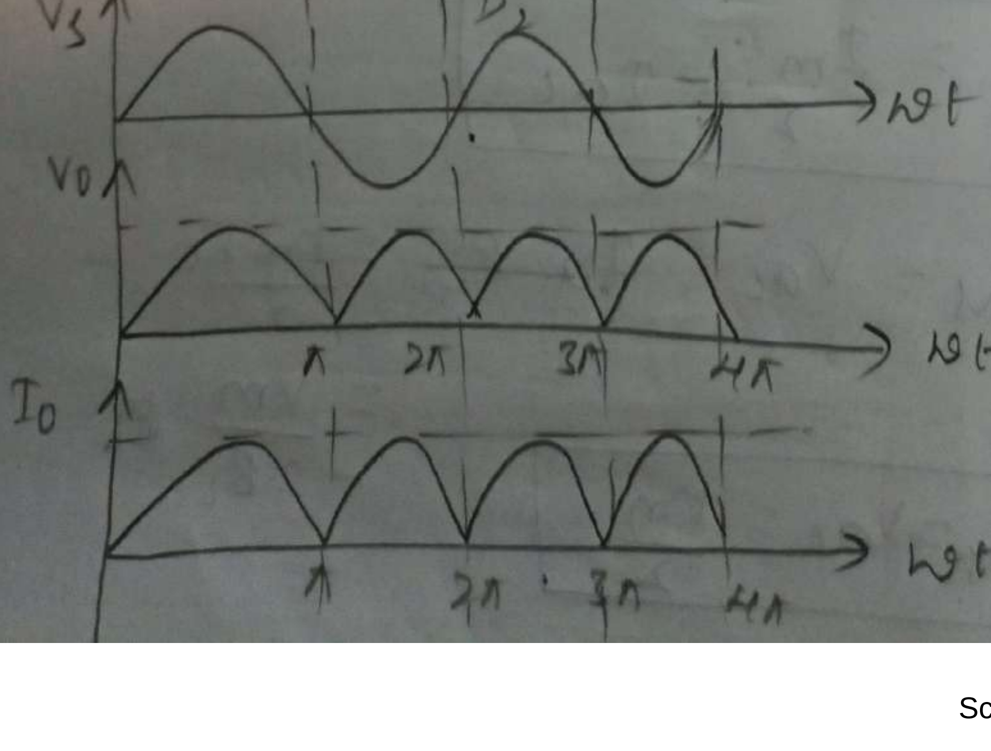
P.I.V = V_m

ripple factor $= \sqrt{\left(\frac{rms}{avg}\right)^2 - 1}$

ripple factor = 1.21.

full wave centre tapped rectifier:-

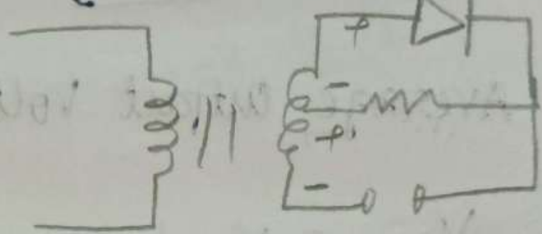




circuit consisting of two diodes D_1 & D_2
circuit will be operated during both +ve halfcycle as well as -ve half cycle

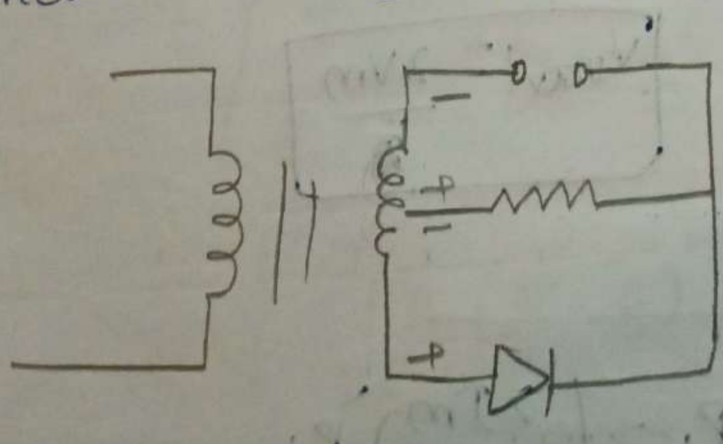
(i) Positive Halfcycle:

During +ve halfcycle diode D_1 gets forward biased and D_2 will be open circuited since it is reverse biased and now current flows through D_1 & then to load. And D_2 acts as open switch since it is reverse biased.



(ii) Negative halfcycle:

During -ve halfcycle diode D_2 conducts current through the load & D_1 remains open circuited since it is reverse biased.



Avg output current expression:

$$I_{oav} = I_{dc} = \frac{1}{T}\int_0^T I_m \sin\omega t \, d\omega t$$

$$= \frac{1}{\pi} \int_0^{\pi} I_m \sin wt \, dt$$

$$= \frac{1}{\pi} I_m \int_0^{\pi} \sin wt \, dt$$

$$= \frac{1}{\pi} I_m (-\cos wt)_0^{\pi}$$

$$= \frac{1}{\pi} I_m (2)$$

$$\boxed{I_{dc} = \frac{2I_m}{\pi}}$$

Average output voltage (V_{oav}):

$$V_{oav} = V_{dc} = I_{dc} R_L = \frac{2I_m}{\pi} R_L$$

$$= \frac{2V_m}{\pi R_L} R_L$$

$$\boxed{V_{oav} = \frac{2V_m}{\pi}}$$

output power

$$P_{dc} = I^2_{dc} R_L = \left(\frac{2I_m}{\pi}\right)^2 R_L$$

$$= \frac{4I^2_m}{\pi^2} R_L$$

$$= \frac{4V_m^2}{\pi^2 R_L^{\cancel{2}}}$$

$$\boxed{P_{dc} = \frac{4V_m^2}{\pi^2 R_L}}$$

AC component (or) I_{rms} (or) I_{ac}:

$$I_{orms} = I_{ac} = \left\{ \frac{1}{T} \int_0^T I_m^2 \sin^2 \omega t \, d\omega t \right\}^{1/2}$$

$$= \left\{ \frac{1}{\pi} \int_0^\pi I_m^2 \sin^2 \omega t \, d\omega t \right\}^{1/2}$$

$$= \left[\frac{I_m^2}{\pi} \left[\int_0^\pi \left(\frac{1 - \cos 2\omega t}{2} \right) d\omega t \right] \right]^{1/2}$$

$$= \left[\frac{I_m^2}{2 \cdot \pi} \left((\omega t)_0^\pi - \left(\frac{\sin 2\omega t}{2} \right)_0^\pi \right) \right]^{1/2}$$

$$= \left[\frac{I_m^2}{2\cancel{\pi}} (\cancel{\pi} - 0) \right]^{1/2}$$

$$\boxed{I_{orms} = \frac{I_m}{\sqrt{2}} = I_{ac}}$$

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$$V_{o\,rms} = V_{ac} = I_{ac} R_L = \frac{I_m}{\sqrt{2}} R_L = \frac{V_m}{\sqrt{2} R_L} R_L$$

$$\boxed{V_{o\,rms} = V_{ac} = \frac{V_m}{\sqrt{2}}}$$

$$P_{ac} = I_{ac}^2 R_L = \frac{I_m^2}{2} R_L = \frac{V_m^2}{2 R_L^2} R_L$$

$$\boxed{P_{ac} = \frac{V_m^2}{2 R_L}}$$

$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{\frac{4 V_m^2}{\pi^2 R_L}}{\frac{V_m^2}{2 R_L}} = \frac{8}{\pi^2} = 81.05\%$$

$$\boxed{\eta = 81.05\%}$$

$$\boxed{PIV = 2V_m}$$

$$\boxed{\text{ripple factor} = \sqrt{\left(\frac{rms}{avg}\right)^2 - 1}}$$

Ripple

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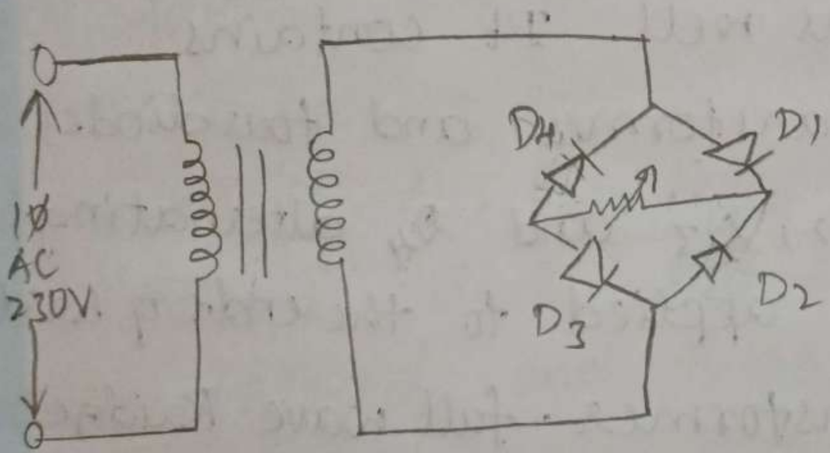
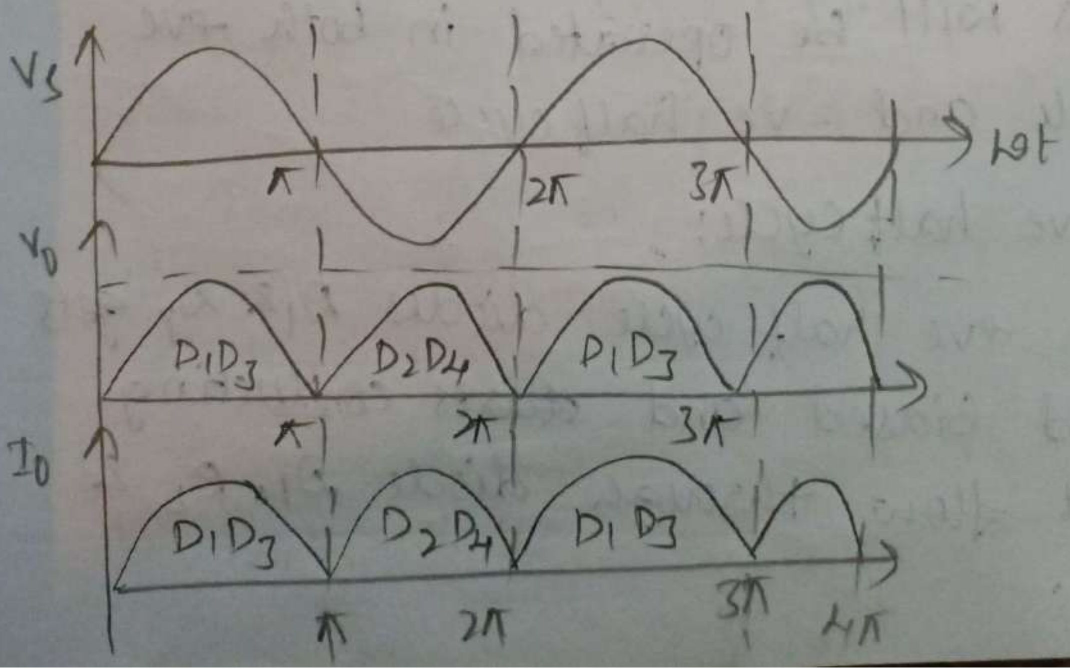
Ripple factor:
The unwanted AC component present in desired output is known as ripple factor.

Peak inverse Voltage:
It is the maximum reverse voltage that diode can with stand without damage is known as Peak Inverse Voltage (PIV)

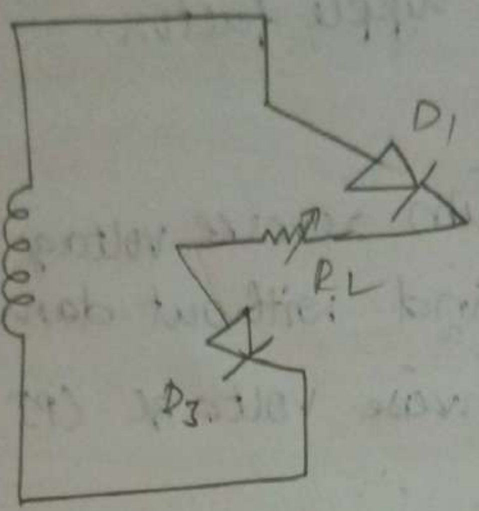
$$PIV = 2V_m$$

full wave Bridge rectifier:





case(i) -eve:



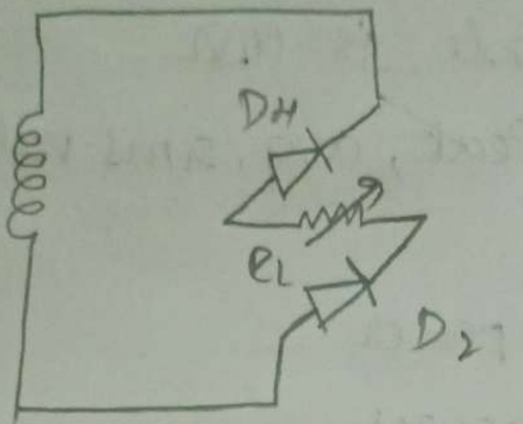
The full wave operation can be operation can be obtained without the bridge connection as well. It contains isolation transformer and four diodes that is D_1, D_2, D_3 and D_4 alternating voltage is applied to the ends of bridge through transformer. full wave Bridge rectifier will be operated in both +eve halfcycle and -ve half cycle

(i) Positive half cycle:

During +ve half cycle diodes D_1 & D_3 gets forward biased and starts conducting current flow through diode D_1, R_L & D_3.

Whereas D_2 & D_4 are reverse biased there by open circuited.

case(ii) Negative half cycle.



During -ve half cycle diodes D_2 & D_4 gets forward biased and there by it starts conducting current through load from diode D_2, R_L, D_4

Whereas diode D_1 & D_3 remains reverse biased and there by open circuited.

$V_{oav} = \frac{2V_m}{\pi}$ $\eta = 81.05\%$

ripple factor $= \sqrt{\left(\frac{rms}{avg}\right)^2 - 1}$

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

PIV = Vm

$P_{ac} = \frac{V_m^2}{2R_L}$

$V_{orms} = \frac{V_m}{\sqrt{2}}$

$P_{dc} = \frac{4V_m^2}{\pi^2 R_L}$

$I_{orms} = \frac{I_m}{\sqrt{2}}$

Q) A sinusoidal voltage of peak amplitude of 20 volts is applied to a half wave reactifier using P.n junction diode the load resistance is 1000Ω. the forward resistance of diode is 10Ω calculate (i) Peak, avg, rms values of load current.

(ii) Dc output power

(iii) Ac input power.

(iv) rectifier efficiency.

(V) PIV.

$V_m = 20V$, $R_L = 1000\Omega$, $R_f = 10\Omega$

$$I_m = \frac{V_m}{R_L + R_f} = \frac{20}{1000+10} = 0.0198$$

$$I_{rms} = \frac{I_m}{2} = \frac{0.0198}{2} = 9.5 \times 10^{-3}$$

$$I_{dc} = \frac{I_m}{\pi} = \frac{0.019}{3.14} = 6.050 \times 10^{-3}$$

$$P_{dc} = (I_{dc})^2 (R_L + R_f)$$

$$= (6.050 \times 10^{-3})^2 (1010)$$

$$= 0.0369 W$$

$$P_{ac} = (I_{ac})^2 (R_L + R_f)$$

$$= (9.5 \times 10^{-3})^2 (1000 + 10)$$

$$= 0.091 W$$

$$\% \eta = \frac{P_{dc}}{P_{ac}} \times 100 = \frac{0.0369}{0.091} \times 100$$

$$= 40.6 \%$$

$PIV = V_m = 20V$

Q) A full wave rectifier uses load resistor of 1200 Ω a forward resistance of diode is 8 Ω sinewave of peak voltage is 30V applied to each diode calculate

(i) Max, DC, rms load currents.

(ii) DC output power

(iii) AC input power

(iv) Rectifier efficiency

$R_L = 1200\,\Omega$. $R_f = 8\,\Omega$.

$V_m = 30V$.

$I_{max} = \frac{V_{max}}{R_L + R_f}$

$= \frac{30}{1200+8}$

$= \frac{30}{1208}$

$I_{max} = 0.0248\ A$.

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

$I_{dc} = \frac{2(0.0248)}{3.14}$

$= 0.0157$

$I_{rms} = \frac{I_m}{\sqrt{2}} = 0.0175\ A$

$$P_{dc} = (I_{dc})^2 (R_L + R_f)$$

$$= (0.0157)^2 (1208)$$

$$P_{dc} = 0.2977\ W$$

$$P_{ac} = (I_{ac})^2 (R_L + R_f)$$

$$= (0.0175)^2 (1208)$$

$$P_{ac} = 0.36995\ W$$

$$\eta = \frac{P_{dc}}{P_{ac}} \times 100$$

$$= \frac{0.2977}{0.36995} \times 100$$

$$= 80.4\%$$

Q) A sinosoidal peak voltage is 14.4V which is applied to half wave rectifier with the load of 1000Ω & it has forward resis-tance of 10Ω determine (i) Peak, Rms, Avg values of current (ii) DC & AC power (iii) η of HWR (iv) Ripple factor.

$V_m = 14.4V$ $R_L = 1000Ω$ $R_f = 10Ω$

(i) Peak current.

$$I_m = \frac{V_m}{R_L + R_f}$$

$$= \frac{14.4}{1010} = 0.0142 A.$$

$$I_{rms} = \frac{I_m}{2} = ~~0.071~~ = 7.1 \times 10^{-3}.$$

$$I_{avg} = \frac{I_m}{\pi} = \frac{0.0142}{3.14}.$$

$$I_{dc} = 4.522 \times 10^{-3}$$

$$P_{dc} = I_{dc}^2 (R_L + R_f)$$

$$= 4.522 \times 10^{-3} \times 4.522 \times 10^{-3} (1010)$$

$$= 0.0206 W$$

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$P_{ai} = (7.1\times10^{-3})^2 (1010)$

$= 0.0509. \Rightarrow \eta = \frac{0.0206}{0.0509} \times 100$

$\eta = 40.4.$

$\text{Ripple factor} = \sqrt{\left(\frac{I_{rms}}{I_{avg}}\right)^2 - 1}$

$= \sqrt{\left(\frac{0.007}{0.0044}\right)^2 - 1}$

$= \sqrt{\left(\frac{7.1\times10^{-3}}{4.522\times10^{-3}}\right)^2 - 1}$

Ripple factor = 1.21

Q) A pure sinosoidal maximum voltage is 15.4V ~~which~~ is applied to a full wave rectifier with the load of 1.2 kΩ & it has forward resistance of 14 Ω determine

(i) max, rms, avg values of current.

(ii) DC & AC power.

(iii) η of FWR.

$V_m = 15.4V$, $R_L = 1.2 \times 10^3 = \frac{12}{10} \times 10^3$

$R_f = 14\Omega$. $= 1200$

$$I_m = \frac{V_m}{R_L + R_f} = \frac{15.4}{1214} = 0.0126A$$

$$I_{dc} = \frac{2I_m}{\pi} = \frac{2 \times 0.0126}{3.14}$$

$$= 8.025 \times 10^{-3} A$$

$$I_{ac} = \frac{I_m}{\sqrt{2}} = 8.909 \times 10^{-3}$$

$$P_{dc} = I_{dc}^2 (R_L + R_f)$$

$$= (8.025 \times 10^{-3})^2 (1214)$$

$$= 0.078 AW$$

$$P_{ac} = I_{ac}^2 (1214)$$

$$= 0.0963 W$$

$$\eta = \frac{0.078}{0.096} = 0.812 \times 100$$

$$= 81.2\%$$

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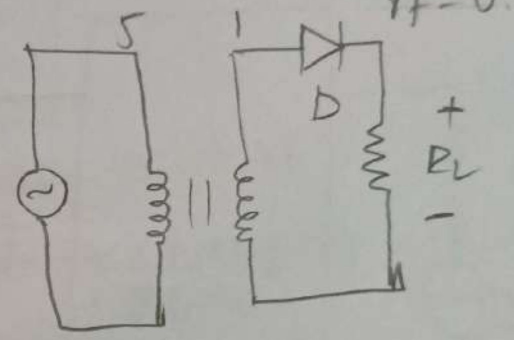
ripple factor = $\sqrt{\left(\frac{8.909\times10^{-3}}{8.025\times10^{-3}}\right)^2-1}$

$= 0.48$

8) An ac supply of 230V is applied to a half wave rectifier through a transformer find.



V_{DC}, η, PIV.

(i) DC output voltage.

(ii) Efficiency.

(iii) Peak inverse voltage.

1.110

DC output voltage = $\sqrt{2}$ Vac

1.2321−1

$= \sqrt{2}\times230$

$= 325.267V.$

DC output voltage = 325.267V.

$I_m=$

$R_f=0.$

$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{I_{dc}^2(R_L+R_f)}{I_{ac}^2(R_L+R_f)} = \frac{I_{dc}^2(R_L+0)}{I_{ac}^2(R_L+0)}$$

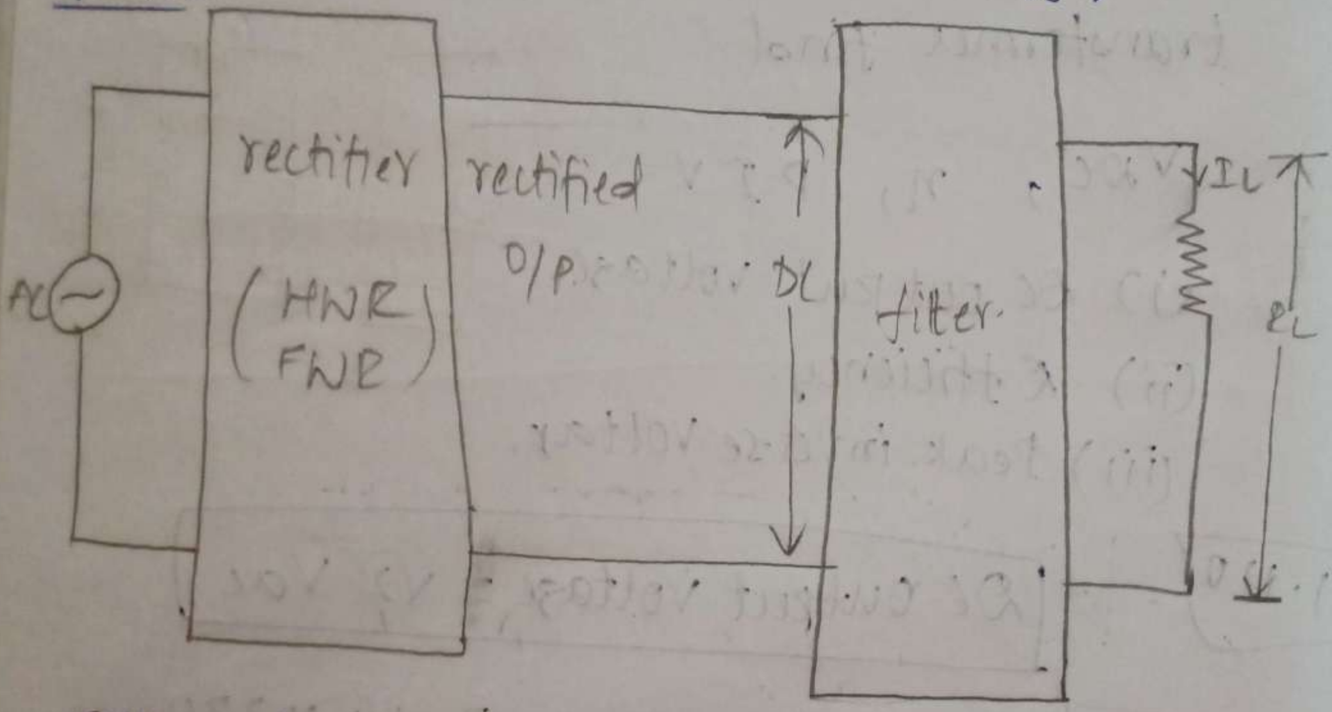
$$\therefore = \frac{I_{dc}^2 R_L}{I_{ac}^2 R_L} = \frac{\left(\frac{I_m}{\pi}\right)^2 R_L}{\left(\frac{I_m}{2}\right)^2 R_L} = \frac{\frac{V_m^2}{\pi^2 R_L^2} R_L}{\frac{V_m^2}{4 R_L^2} R_L} = \frac{4}{\pi^2} = 40.6\%$$

(iii) $PIV = V_m$

$$k \Rightarrow \frac{V_2}{V_1} = \frac{N_2}{N_1} \Rightarrow V_2 = V_1 \times \frac{N_2}{N_1} \Rightarrow 325.26 \times \frac{1}{5}$$

$$V_2 = 65.05\,V$$

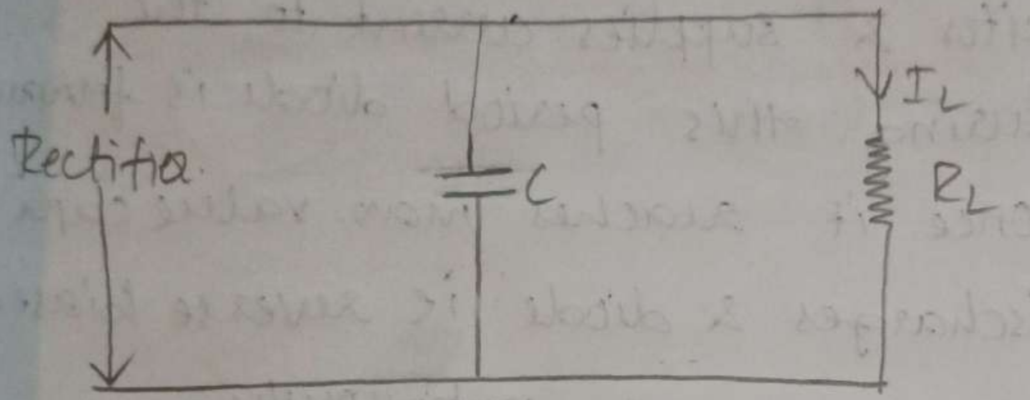
filter:



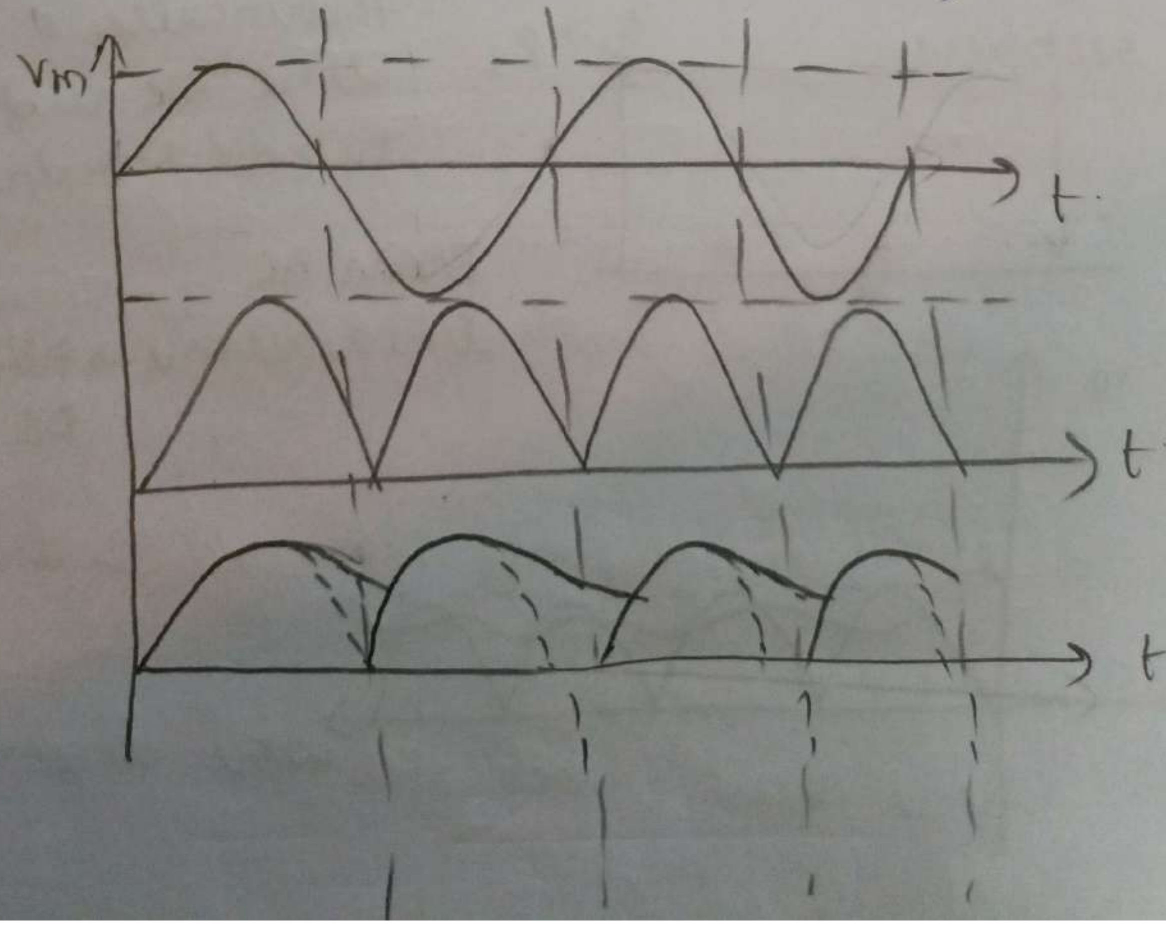
Filter is an electronic device which converts ripple content in rectifier output that is pulsating DC to pure DC it allows only DC component to reach the load. A filter circuit should be installed between rectifier & the load.

Filter circuit is classified into two types
(i) Capacitor filter
(ii) Inductor filter.

Capacitor filter: Blocks dc allows ac

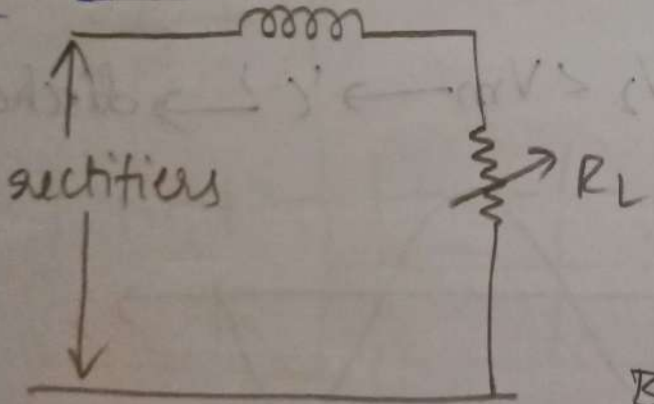


'D' → f.B → $V_2 > V_m$ → 'C' → Charging
'D' → R.B → $V_2 < V_m$ → 'C' → discharging.



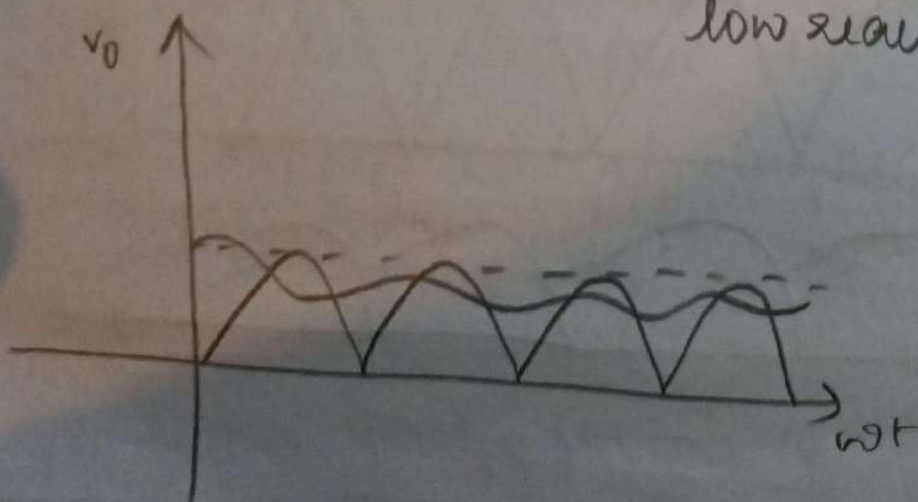
A capacitor filter consists of a capacitor placed across rectifier in parallel with load resistance the voltage of rectifier applied across rectifier as the input voltage rises to maximum voltage (Vm) it charges the capacitor & supplies current to the load during this period diode is forward biased once it reaches max. value capacitor discharges & diode is reverse biased & this process repeats continuously.

Inductor filter (choke) L → high resistance → Blocks AC



In order to get a theoretically st line we need to add regulator

Blocks AC
low reactance → Allows DC.



Inductor filter also known as choke filter it consists of an inductor which is inserted b/w rectifier & load resistance. When the output current passes through inductor it offers high reactance to AC component & low reactance to DC component which while reaching to load resistor.

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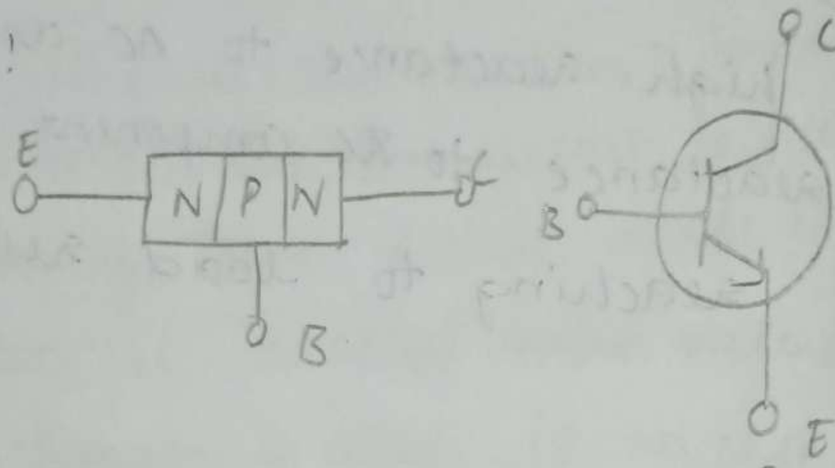
UNIT-V

Transistors

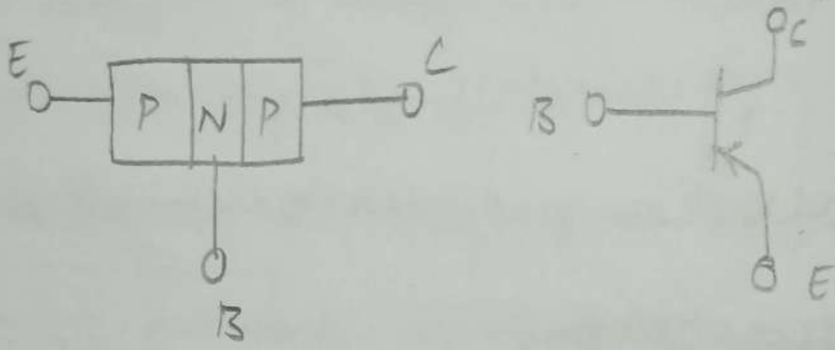
BJT:

Construction:

(i) NPN



(ii) PNP;



BJT:

Bipolar junction transistor (BJT).

Conduction of the current is due to both holes & electrons hence the name Bipolar device.

Purpose of transistor: it is used to strengthen a given weak signal

Here Arrow mark indicates the direction of current.

Transister has 3 different regions namely

1) Emitter

2) Base

3) Collector

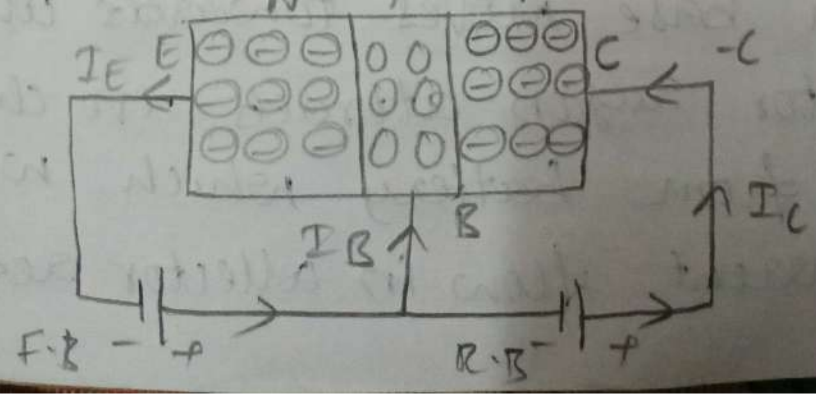
1) Emitter: It is a highly doped region which emits or supplies marjority charge carriers.

2) Collector: It is a moderately doped layer which accepts or collects charge carriers.

3) Base: It is a lightly doped layer located b/w emitter & collector due to narrow width it will not accept or emit charge carriers.

Working of Transistors:

(i) NPN Transistor:



Emitter Base junct

In NPN transistor E-B-Junction is forward biased & B-C-Junction is reverse biased

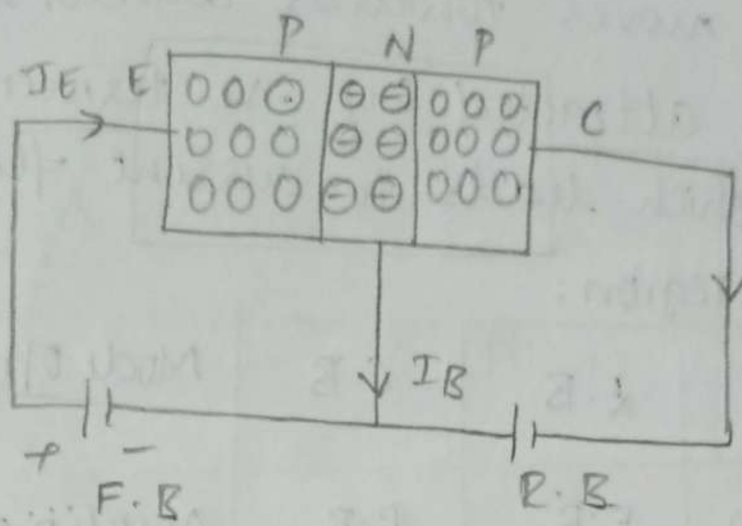
In E-B Junction positive terminal is connected to base & -ve terminal connected to emitter making it F.B. & In B-C Junction +ve terminal connected to collector & -ve connected to base region making it reverse biased.

In forward biased mode of E-B junction electrons moves towards base region it will cause current flow in emitter.

The electrons are recombined with holes in base causing current flow in base region.

Holes from base moves towards collector and collector region attracts +ve charge carriers from battery which will cause current flow in collector region.

(ii) PNP Transistor:



Emitter Base junction is forward biased & B-C junction is reverse biased so that transistor comes into active region. Positive terminal connected to emitter & -ve terminal connected to base region. making it forward biased & CB junction +ve terminal connected to base & -ve terminal connected to collector making it reverse biased.

In forward biased mode of EB junction holes moves towards base this will cause current flow in emitter & base region. Few electrons now gets recombined with holes causing current flow in base region.

Due to narrow width of base region. few electrons moves towards collector & also holes are attracted by -ve terminal of battery which leads to current flow in collector region.

Region	E·B	C·B	Mode of operation
Active region	F·B	R·B	Amplifier.
saturation	F·B	F·B	ON switch.
cut off	R·B	R·B	OFF switch.

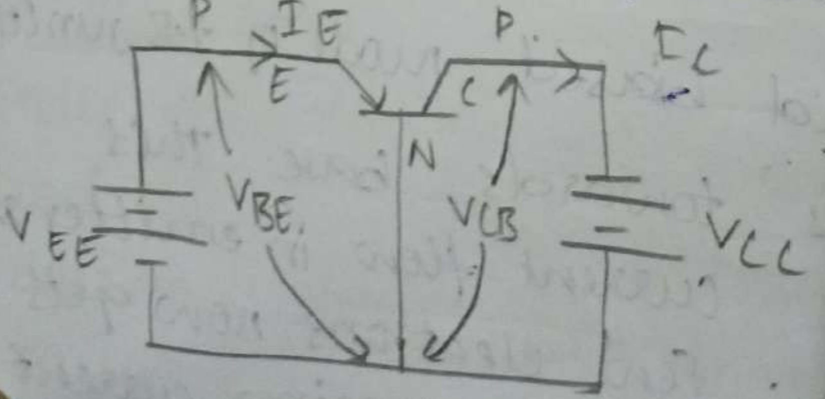
Types of configurations:

(i) Common base

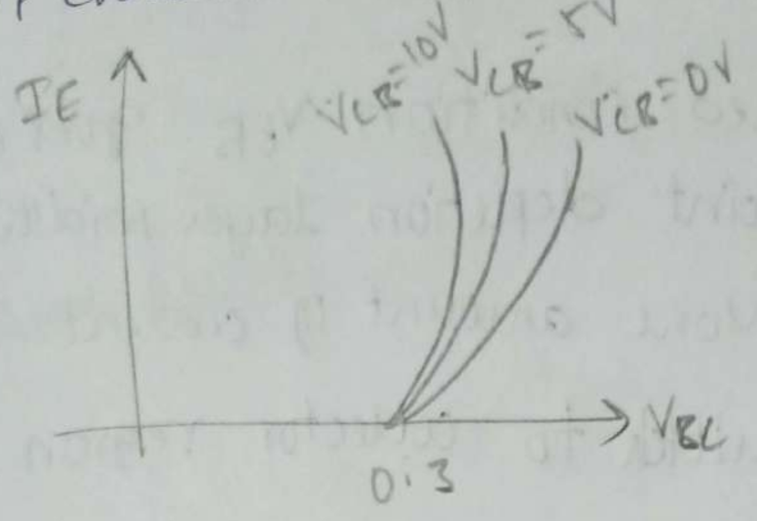
(ii) Common emitter

(iii) Common collector.

(i) Common Base configuration

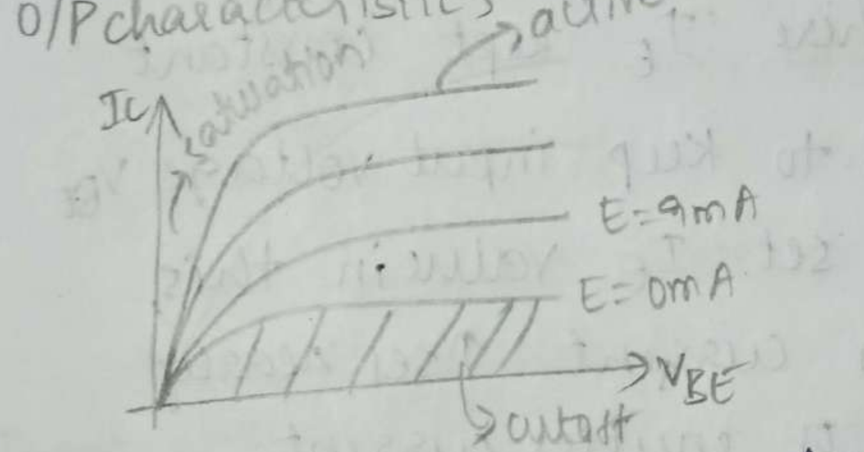


I/P characteristics:



$R_E = \frac{\Delta V_{BE}}{\Delta I_E}$

O/P characteristics



$R_0 = \frac{\Delta V_{BE}}{\Delta I_C}$

In PNP transistor base terminal should be common between input and output known as CB configuration.

The input performance curve plot b/w I_E against V_{BE} at output voltage V_{CB} kept constant

In this mode emitter to base junction forward biased during graph between I_E & V_{BE} output voltage kept constant & that is V_{CB} will be ↑sed in steps

0, 5V, 10V

In forward biased condition V_{EB} goes on ↑sing at some point depletion layer width becomes zero. More amount of current flows from emitter to collector region.

→ Output characteristics graph plot b/w I_C (vs) V_{CB} where I_E kept constant

→ here, we need to keep input voltage V_{BE} constant then set I_E value in this process collector current ↑ses nearly equal to that of emitter current.

	E.B	C.B
Saturation region	F.B	F.B
Active region	F.B	R.B
Cutoff region	R.B	R.B.

Current amplification factor :

$$\alpha = \frac{I_C}{I_E} \Rightarrow \frac{\Delta I_C}{\Delta I_E}$$

$$\boxed{I_C = \alpha I_E}$$

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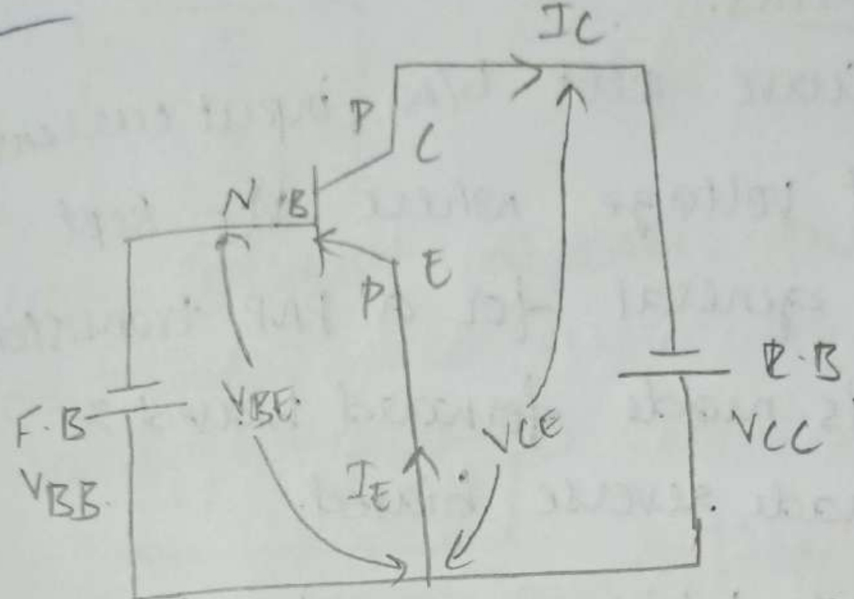
$$I_C = \alpha I_E + I_{CBO}$$

↓ leakage current (μA) — μs

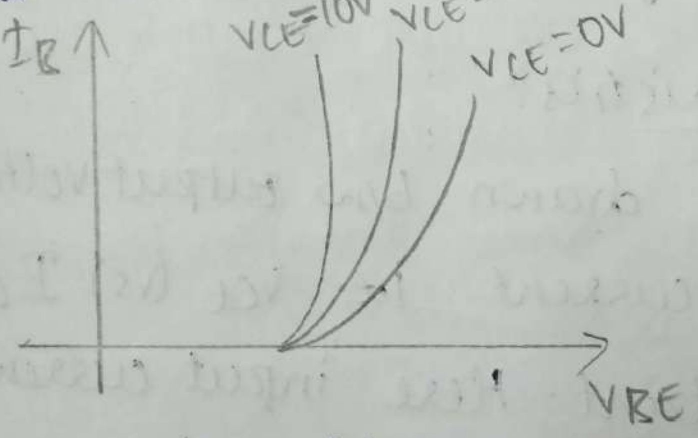
I_C units in μA

Common Emitter (CE):

Leakage current is due to biasing provided.

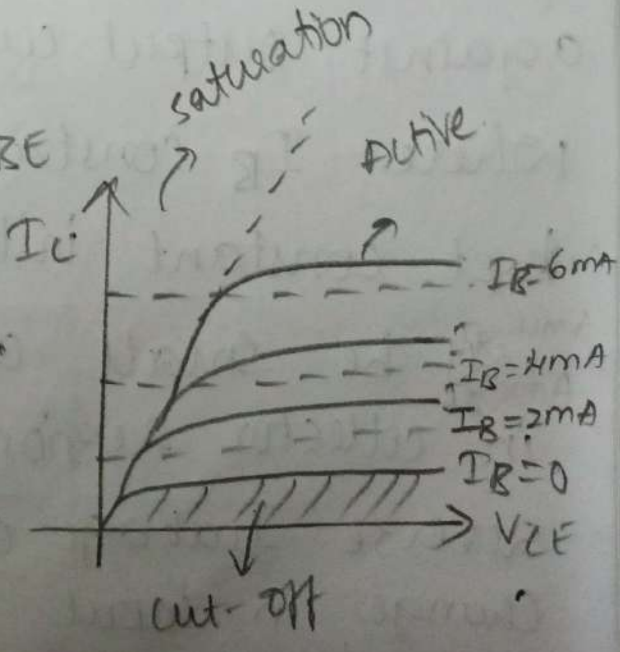


Input characteristics:



$$R_i = \frac{\Delta V_{BE}}{\Delta I_B}$$

Output Characteristics:



$$R_0 = \frac{\Delta V_{CE}}{\Delta I_C}$$

In this PNP transistor Emitter connected for both input & output known as CE configuration.

I/P characteristics:

Performance curve plot b/w input current against input voltage where V_{CE} kept constant in general for a PNP transistor EB junction is made forward biased & DC junction made reverse biased.

Input characteristics curve is similar to that of p-n junction diode.

Output characteristics:

Performance curve drawn b/w output voltage against output current i.e V_{CE} (Vs) I_C where I_B constant. Here input current kept constant initially $I_B = 0$ there will be small amount of current flows in collector region i.e I_{CBO} known as reverse leakage current for small change in input current there will be large change in output current I_C

Base amplification factor:

It is defined as the ratio of change in collector to current to base current

$$\beta = \frac{I_C}{I_B}$$

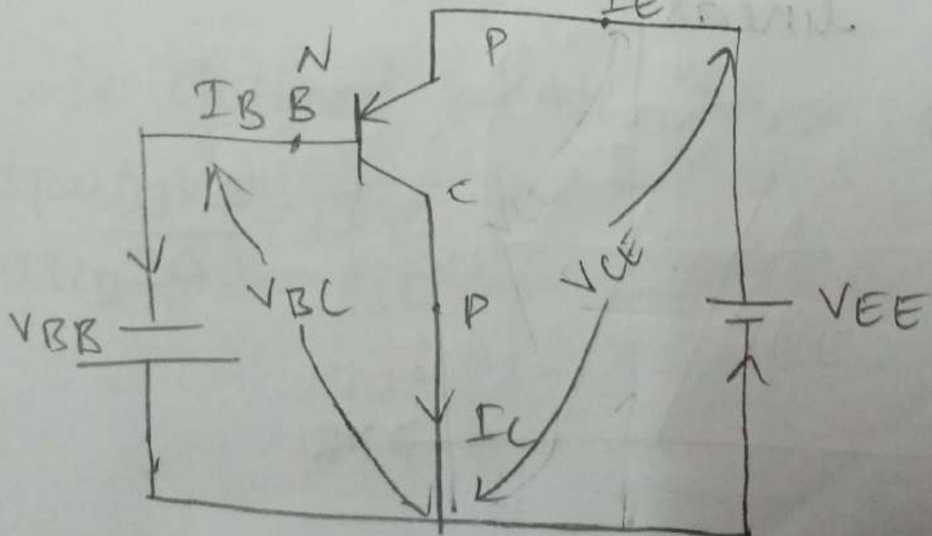
Collector current depends on base amplification factor

$$I_C = \beta I_B$$

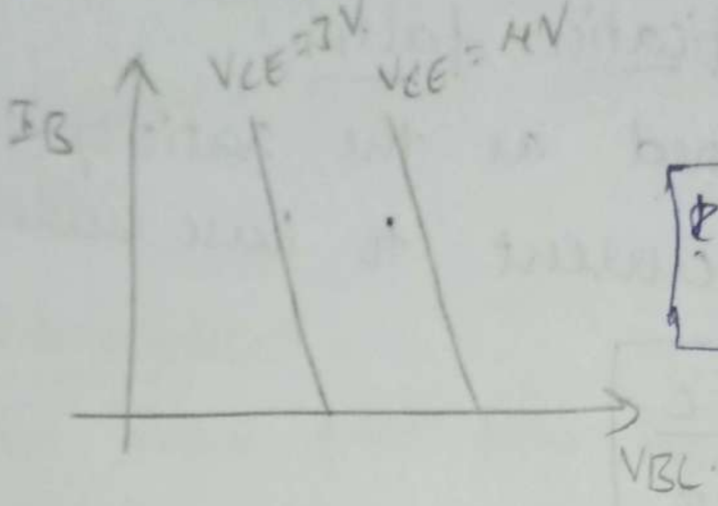
Due to majority carriers there will be leakage current through device I_{CEO}

$$I_C = \beta I_B + I_{CEO}$$

common collector configuration:



Input characteristics:

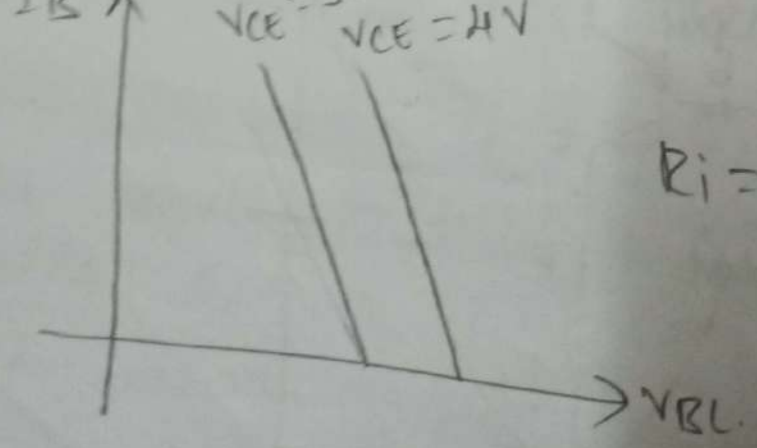


$$R_i = \frac{\Delta V_{BC}}{\Delta I_B}$$

In pnp transistor collector terminal is made common between both input & output known as CC configuration.

Input characteristics

Here performance curve is plotted b/w input current I_B against input voltage V_{BC} keeping V_{CE} constant. And now for higher values V_{BC} the graph will be known linear



$$R_i = \frac{\Delta V_{BC}}{\Delta I_B}$$

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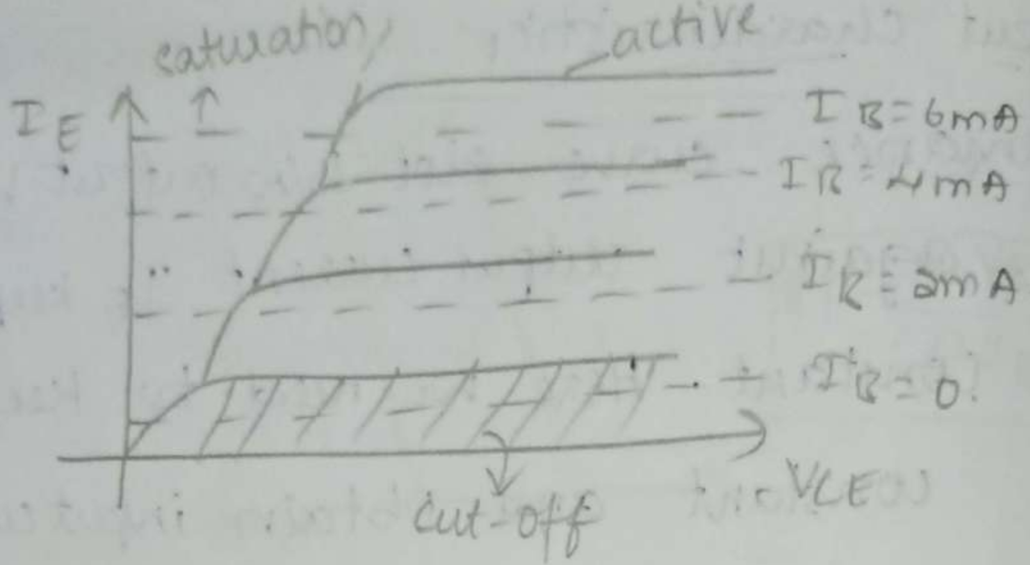
output characteristics:

Performance curve plot b/w output voltage V_{CE} against output current I_E keeping I_B constant. Here we need to keep V_{BC} constant and obtain input current I_B later it is also maintained constant and now output voltage V_{CE} is varied in steps so that for small change input current I_B there will be a large change in output current I_E and here the output characteristics will be same as that of CE configuration.

Output resistance:

$$R_0 = \frac{\Delta V_{CE}}{\Delta I_E}$$

It is defined as the ratio of change in output voltage V_{CE} to change in output current I_E keeping input current I_B constant



Current amplification factor:
It is defined as the ratio of change in emitter current to change in base current known as current amplification factor.

~~In common base configuration the emitter~~

$$\gamma = \frac{I_E}{I_B} \Rightarrow \frac{\Delta I_E}{\Delta I_B}$$

$$\boxed{I_E = \gamma I_B}$$

$$I_E = \gamma I_B + I_{CEO}$$

Q) In common base configuration the emitter current I_E is 1mA & collector current I_C is 0.9mA calculate base current I_B?

$I_E = 1\,mA$, $I_C = 0.9\,mA$

$I_E = I_B + I_C$

$1 = I_B + 0.9$

$$\boxed{I_B = 0.1\,mA}$$

Q) In a common base configuration collector current is 0.95mA and the base current is 0.05mA calculate current amplification factor!

$I_C = 0.95\,mA$

$I_B = 0.05\,mA$

$I_E = I_B + I_C$

$= 0.05 + 0.95$

$= 1\,mA$

$\alpha = \dfrac{I_C}{I_E}$

$\alpha = \dfrac{0.95}{1}$

$$\boxed{\alpha = 0.95}$$ ~~mA~~

Q) In a CB configuration the emitter current is 1 mA find collector current when the value of α is 0.92

$I_E = 1mA.$

$\alpha = 0.92.$

$0.92 = \frac{I_C}{1}$

$$\boxed{I_C = 0.92 mA}$$

Relation between α, β, γ:

(i) Relation between α, β:

$\alpha = \frac{I_C}{I_E}$ — (1) $\beta = \frac{I_C}{I_B}$ — (2)

$\Delta I_E = \Delta I_C + \Delta I_B$

$\Delta I_B = \Delta I_E - \Delta I_C$ — (3)

$\beta = \frac{\Delta I_C}{\Delta I_B} = \frac{\Delta I_C}{\Delta I_E - \Delta I_C}$

$$\beta = \frac{\frac{\Delta I_C}{\Delta I_E}}{\frac{\Delta I_E}{\Delta I_E} - \frac{\Delta I_C}{\Delta I_E}} = \frac{\alpha}{1-\alpha}$$

$$\boxed{\beta = \frac{\alpha}{1-\alpha}}$$

$\beta(1-\alpha) = \alpha$.

$\alpha = \beta - \beta\alpha$.

$\alpha + \beta\alpha = \beta$

$\beta = \alpha(1+\beta)$

$$\boxed{\alpha = \frac{\beta}{1+\beta}}$$

Relation between α, β, γ:

(i) Relation between β, γ:

$$\beta = \frac{I_C}{I_B}, \quad \gamma = \frac{I_E}{I_B}$$

$$\Delta I_E = \Delta I_B + \Delta I_C$$

Dividing above equation with I_B, we get

$$\frac{\Delta I_E}{\Delta I_B} = \frac{\Delta I_B}{\Delta I_B} + \frac{\Delta I_C}{\Delta I_B}$$

$$\gamma = 1 + \beta$$

$$\beta = \gamma - 1$$

Relation b/w γ, α:

$$\gamma = \frac{I_E}{I_B}, \quad \alpha = \frac{I_C}{I_E}$$

$$\Delta I_E = \Delta I_B + \Delta I_C$$

$$\Delta I_B = \Delta I_E - \Delta I_C$$

$$\gamma = \frac{\Delta I_E}{\Delta I_E - \Delta I_C}$$

$$\gamma = \frac{\frac{\Delta I_E}{\Delta I_E}}{\frac{\Delta I_E}{\Delta I_E} - \frac{\Delta I_C}{\Delta I_E}}$$

$$\boxed{\gamma = \frac{1}{1-\alpha}}$$

$$\gamma(1-\alpha) = 1$$

$$1 - \alpha = \frac{1}{\gamma}$$

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$$\alpha = 1 - \frac{1}{\gamma}$$

$$\boxed{\alpha = \frac{\gamma - 1}{\gamma}}$$

Expression for CB configuration:-

from CB configuration

$$I_C = \alpha I_E + I_{CBO}$$

$$\boxed{I_C = \left(\frac{\beta}{1+\beta}\right) I_E + I_{CBO}}$$

Expression for CE configuration!

from CB configuration

$$I_C = \alpha I_E + I_{CBO}$$

$$I_E = I_B + I_C$$

$$I_C = \alpha (I_B + I_C) + I_{CBO}$$

$$I_C = \alpha I_B + \alpha I_C + I_{CBO}$$

$$I_C - \alpha I_C = \alpha I_B + I_{CBO}$$

$$I_C(1-\alpha) = \alpha I_B + I_{CBO}$$

$$I_C = \left(\frac{\alpha}{1-\alpha}\right) I_B + \left(\frac{1}{1-\alpha}\right) I_{CBO}$$

$$\boxed{I_C = \beta I_B + \gamma I_{CBO}}$$

Expression ~~CE~~ CC configuration:

from CB configuration

$$I_C = \alpha I_E + I_{CBO}$$

$$I_E = I_B + I_C$$

$$I_E = I_B + \alpha I_E + I_{CBO}$$

$$I_E - \alpha I_E = I_B + I_{CBO}$$

$$I_E(1-\alpha) = I_B + I_{CBO}$$

$$I_E = \frac{1}{1-\alpha} I_B + \frac{1}{1-\alpha} I_{CBO}$$

$$= \gamma I_B + \gamma I_{CBO}$$

$\beta = \frac{\gamma}{\alpha - 1}$

$$\boxed{I_E = (\beta+1) I_B + (\beta+1) I_{CBO}}$$

Q) find the value of β if $\alpha = 0.9$

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.9}{1-0.9} = \frac{0.9}{0.1} = 9.$$

Q find the value of α if $\beta = 49$.

$$49 = \frac{\alpha}{1-\alpha}.$$

$$49 - 49\alpha = \alpha.$$

$$49 = 50\alpha.$$

$$\alpha = \frac{49}{50}.$$

$$\alpha = 0.98.$$

Q) find the value of I_C where $\beta = 50$ & $I_B = 20mA$ & take I_{CBO} is $10mA$

~~$= 50 \times 20 +$~~

$$\gamma = 1+\beta = 51$$

$$I_C = \beta I_B + \gamma I_{CBO}$$

$$= (50)(20) + (51)(10)$$

$$= 1000 + 510$$

$$I_C = 1510 mA.$$

Q) find the value of ~~α~~ of a transistor when α is 0.98 calculate the values of β & γ

$$\beta = \frac{\alpha}{1-\alpha}$$

$$= \frac{0.98}{1-0.98} = \frac{0.98}{0.02} = ~~48~~ 49$$

$$\gamma = 1+\beta = 50.$$

$$= ~~49~~.$$

Q) collector current of transistor is 9.945mA emitter current is 10mA & leakage current is ~~5A~~ 5μA. when it is connected in CB configuration α, β, γ.

~~$I_C = 9.$~~

$I_C = 9.945mA$, $I_E = 10mA$.

$I_{CBO} = 5\mu A$.

$$I_C = \left(\frac{\beta}{1+\beta}\right) I_E + I_{CBO}$$

$$9.945 = \left(\frac{\beta}{1+\beta}\right) 10 + 5\times10^{-3}$$

$$9.945 = \frac{10\beta}{1+\beta} + 0.005$$

$$9.940 = \frac{10\beta}{1+\beta}.$$

Q) find the value ~~of~~ ~~α~~ of a transistor when α is 0.98 calculate the values of β & γ

$$\beta = \frac{\alpha}{1-\alpha}$$

$$= \frac{0.98}{1-0.98} = \frac{0.98}{0.02} = 48.49$$

$$\gamma = 1+\beta = 50.$$

$$= ~~49~~.$$

Q) collector current of transistor is 9.945mA emitter current is 10mA & leakage current is ~~5A~~ 5μA. when it is connected in CB configuration α, β, γ.

~~$I_C = 9.$~~

$I_C = 9.945mA$, $I_E = 10mA$.

$I_{CBO} = 5\mu A$.

$$I_C = \left(\frac{\beta}{1+\beta}\right) I_E + I_{CBO}$$

$$9.945 = \left(\frac{\beta}{1+\beta}\right) 10 + 5\times10^{-3}$$

$$9.945 = \frac{10\beta}{1+\beta} + 0.005$$

$$9.940 = \frac{10\beta}{1+\beta}.$$

$$10\beta = 9.940 + 9.940\beta$$

$$0.06\beta = 9.940$$

$$\beta = 165.6$$

$$\beta = \frac{\alpha}{1-\alpha}$$

$$165.6 = \frac{\alpha}{1-\alpha}$$

$$165.6 - 165.6\alpha = \alpha$$

$$166.6\alpha = 165.6$$

$$\alpha = 0.994$$

$$\gamma = 1+\beta = 165.6+1$$

$$= 166$$

Comparision of Transistor:

Configuration	CB	CE	CC
I/p R	less 100 Ω	less 750 Ω	very high 750 kΩ
O/p R	very high 450 kΩ	high 45 kΩ	low 50 Ω
Volt gain	150	500	<1
Applications	radio frequency	Audio frequency	Impedence matching

V_{CEO}: This is the maximum voltage which may be applied across the collector emitter terminal with base open

V_{CBO} (Collector to base voltage): The maximum voltage which may be applied to the collector base terminal with emitter open