Chapter 1:
Fundamental of Electrical Energy.

Mechanical Energy (PE, KE) $\Longrightarrow$ Generator $\Longrightarrow$ Electrical Energy

$E_m = P_m \cdot t$

$E_e = P_e \cdot t$

P_e → voltage × current

Generator → DC, AC

DC → V_{DC}, I_{DC} — Thomas Edision

AC → $1\text{-}\phi$, 3ϕ — Tesla

$\underbrace{1\text{-}\phi \quad 3\phi}_{V_{AC},\ I_{AC}}$

* CURRENT

The rate of change of charge is known as current.

$$i = \frac{dq}{dt} \quad , dq \rightarrow \text{charge} \quad , dt \rightarrow \text{time}$$

$$q = n \cdot e$$

$$\text{unit} = \text{Ampere} = C/\text{sec}$$

* VOLTAGE / POTENTIAL DIFFERENCE

Voltage is a measurement between two point of any electrical element i.e it can be also defined as the (pressure due to which electron moves from one point to another point.)

A $\quad q = n \cdot e = \text{columb} \quad$ B

V

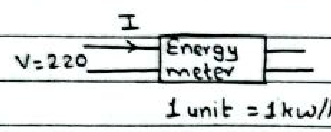
$$\text{Electrical pressure} = v = \frac{dw}{dq} = \frac{1\ \text{Joule}}{1\ \text{columb}} = 1\ \text{volt}.$$

* POWER

The power 'p' is nothing but the time rate of flow of electrical energy which can be written as

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

$P = V \cdot I$



load → Heater, light } 220V

$P = V \cdot I$

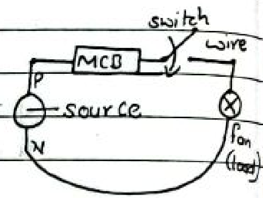
Energy = P.t

Example : heater ⇒ P = 1kW

Energy = P.t = 1kW X 1.hr
= 1kWhr
= 1unit.

* Circuit Variables

1) Source (Battery, Cell, Generator)
2) Load (TV, Heater, freeze, washing machine)
3) Wire (Copper, Aluminium)
4) Safety device (fuse, MCB, MCCB)
5) Controlling unit. (switch, regulator).



* Active and Passive elements

Active elements deliver power to other elements.

e.g: Battery, cell, Generator.
- Voltage source
- Current source

Passive element can't deliver power to other elements, however they can absorb power.

e.g : resistor, inductor, capacitors
↳ Heat form, ↳ magnetic field, ↳ Electric field.

Electrical sources : which supply electrical energy.

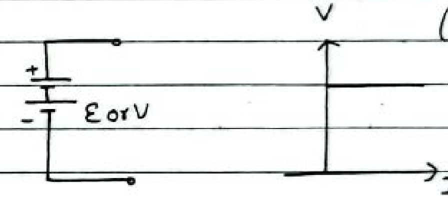
A. Independent source
i) Voltage source
ii) Current source.

i) Voltage source

a) Ideal voltage source

Ideal voltage source is a source which delivers energy with specified terminal voltage, which is independent of the current supplied by the source.

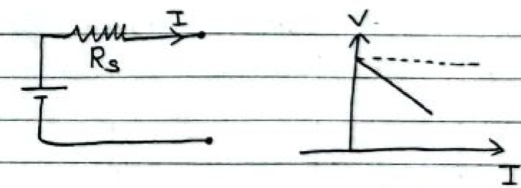
(Graphical representation)



b) Practical Voltage Sources.

All practical voltage source fall short of an ideal source and terminal voltage falls with increase in the current supplied by the sources.

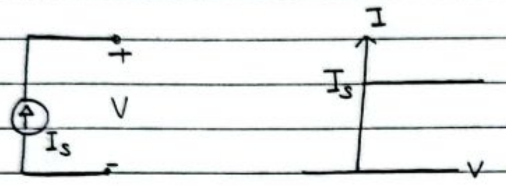
Hence a practical source is represented by voltage source in series with internal resistance 'R_s'.



ii) Current ~~Voltage~~ Source

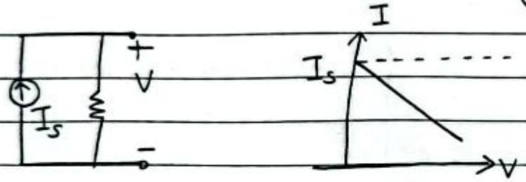
a. Ideal current ~~voltage~~ source.

Ideal current ~~voltage~~ source delivers energy with a specific current which is independent of the voltage at it terminals.



b. Practical Current Source

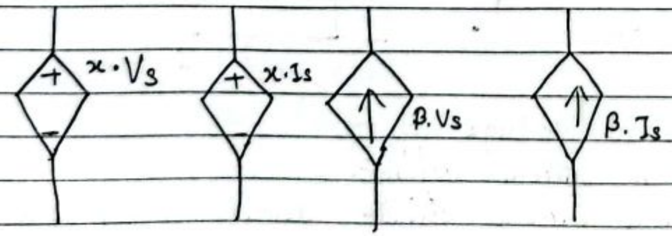
This is represented by the current source I_s in parallel with internal resistance.
In this, current is supplied by the source is decreased with increased in voltage.

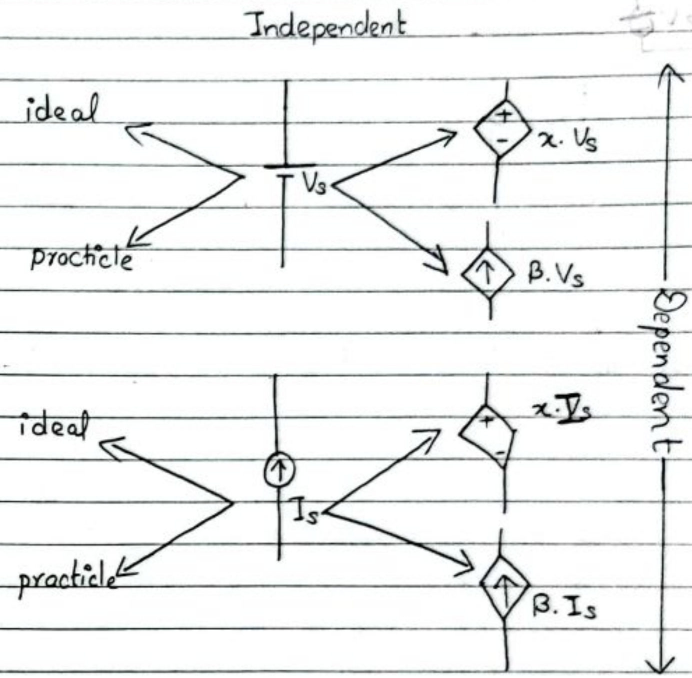


B. Dependent Sources

A dependent source can be represented by diamond shape symbol.
There are four types, which are :

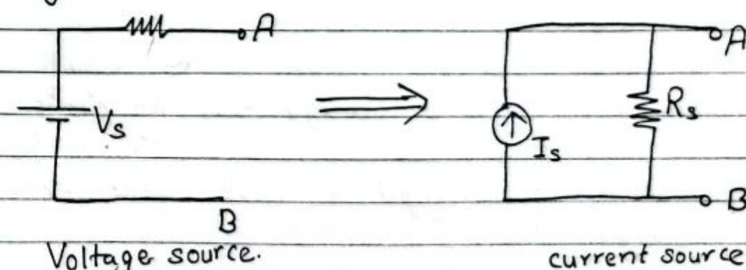
1) Voltage dependent Voltage Source
2) Current dependent Voltage Source
3) Voltage dependent Current Source
4) Current dependent Current Source.





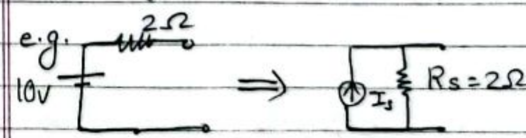
* Source Transformation

1. Voltage source converted to current source.



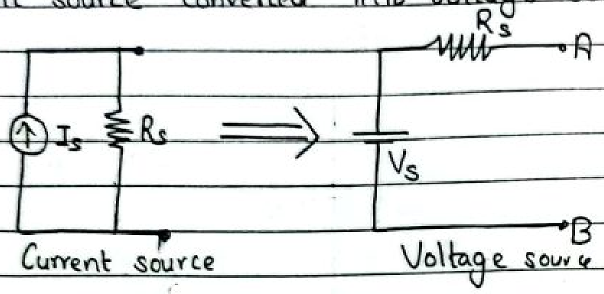
$\boxed{I_s = \frac{V_s}{R_s}}$

e.g.

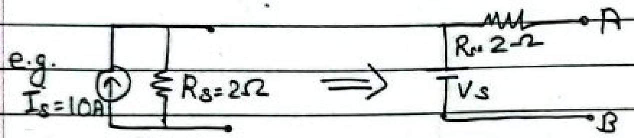


$I_s = \frac{V_s}{R_s} = 5A$ //.

2) Current source converted into Voltage source.



$\boxed{V_S = I_S \times R_S}$

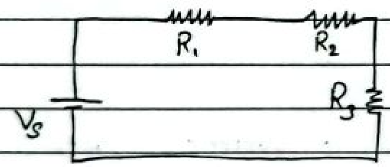


$V_S = I_S \times R_s$
$= 10 \times 2$
$= 20V$

20-January.

* DC Circuits

An electrical circuit is a closed path consisting of active and passive elements all interconnected and current flows in a closed path.



Active element supplies energy to the circuit.
Passive element receives energy from the circuit.

This energy is converted to heat (resistor) or stores it an energy electric field (capacitor) or magnetic field (inductor). Battery is the active element.

Basic Circuit Components:
There are three basic components which are as follows

i) Resistor { it absorbs energy in heat form.
ii) Capacitor }
iii) Inductor } Energy store → magnetic form / → Electric field form.

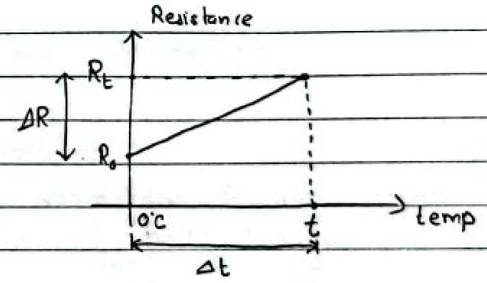
i) Resistor
It is an electric element which opposes the flow of electrons through it.

$R \propto l$ —— (i)

$R \propto \frac{1}{A}$ —— (ii) $\therefore \boxed{R \propto \frac{l}{A}}$

$\therefore R = \frac{\rho \cdot l}{A}$ [(ρ) = resistivity [electrical properties]]

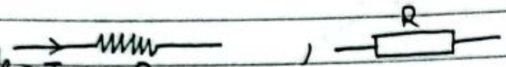
unit of Resistance : (Ω) ohm.
Resistance also depends on heat / temperature.



$\Delta R \propto R_0$ —— (i)
$\Delta R \propto \Delta t$ —— (ii)
$\Delta R \propto \Delta t \, R_0$
$\Delta R = \alpha R_0 \Delta t$
↳ temperature cofficient.

$R_t - R_0 = R_0 \alpha \cdot \Delta t$
$R_t = R_0 + R_0 \alpha \Delta t$
$R_t = R_0 [1 + \alpha \cdot \Delta t]$.

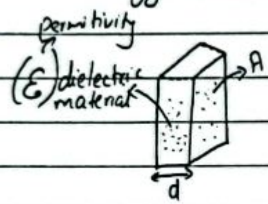
Symbol :



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

ii) Capacitor

Capacitor is a storage element which can store and deliver energy in an electric field.

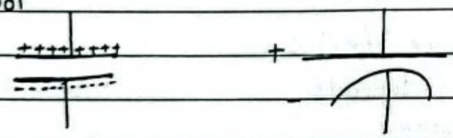


$Q = C \cdot V$

$C = \frac{\epsilon \cdot A}{d}$

unit of capacitance → farad (F)

Symbol

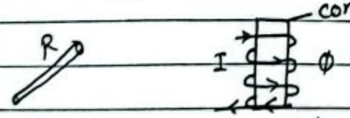


Non-polar capacitor

polar capacitor

iii) Inductor

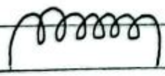
Inductor is a storage element which can store and deliver energy in a magnetic field.



$L = \frac{N \cdot \phi}{I}$ (N → turn, ϕ → weber, I - Ampere)

unit of Inductor : Henry 'H'

Symbol:



$L = \frac{N \cdot \phi}{I}$

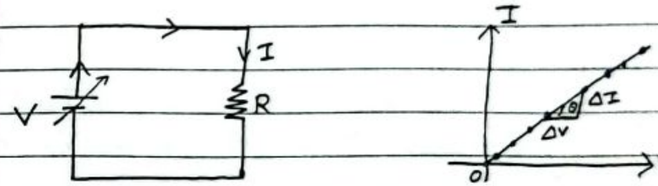
⁂ Ohm's law:

When a voltage is applied to a closed path or circuit it causes a flow of electrons and there exists, current in the circuit. The resistance of the circuit opposes the current flow.

Statement : When the temperature remains constant, current flowing through a conductor is directly proportional to the potential energy difference across the conductor.

i.e. $V \propto I$ (at ~~least~~ constant temperature)

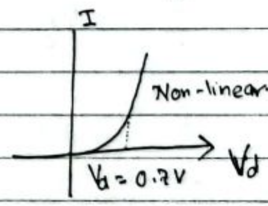
$V = I \cdot R$; where R = proportionality constant
V = Voltage in Volt.
I = current in Ampere.



$\tan\theta = \frac{\Delta I}{\Delta V} = \frac{1}{R}$

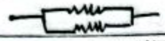
Limitations :

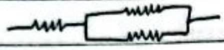
1. It is not applicable to non-metalic conductors.
2. It is not applicable to non-linear devices like zener diode, vaccum tubes etc.
3. It is not applicable if the temperature changes.



Classification of electrical circuits :

→ Series 

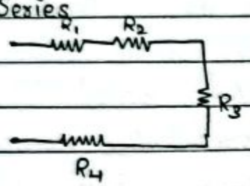
→ Parallel 

→ Series parallel 

→ Mesh Network. 

// Resistor

a) Series

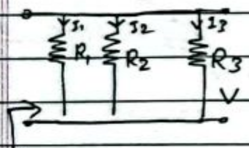


$R_{eq} = R_1 + R_2 + R_3 + R_4 \ldots\ldots$

→ current same $(I_1 = I_2 = I_3 = I_4 \ldots)$

→ Voltage different (V_1, V_2, V_3, V_4)

b) Parallel



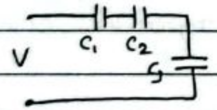
→ current different (I_1, I_2, I_3)

→ Voltage same $(V_1 = V_2 = V_3 = V)$

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

// Capacitor

a) Series



$V = V_1 + V_2 + V_3$ $\quad Q = C \cdot V$

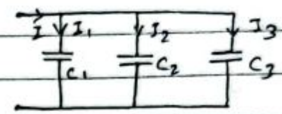
$= \frac{Q_1}{C_1} + \frac{Q_2}{C_2} + \frac{Q_3}{C_3}$ $\quad V = Q/C$

$$\boxed{Q_1 = Q_2 = Q_3 = Q_4}$$

$$V = Q\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right)$$

$$\frac{V}{Q} = \boxed{\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}}$$

b) Parallel



$I = I_1 + I_2 + I_3$, $V = V_1 = V_2 = V_3$

$$\boxed{Q = Q_1 + Q_2 + Q_3}$$

$= C_1 V + C_2 V + C_3 V$

$Q = (C_1 + C_2 + C_3) V$

$\frac{Q}{V} = C_1 + C_2 + C_3$

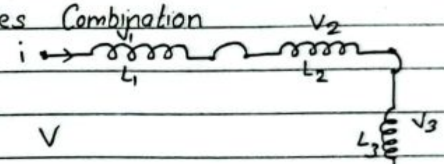
$$\boxed{C_{eq} = C_1 + C_2 + C_3}$$

24th January.

Inductor

It is an electrical device/elements which stores energy in the form of magnetic field.

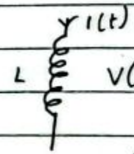
Series Combination



$V = V_1 + V_2 + V_3$

$= L_1 \cdot \frac{di_1}{dt} + L_2 \cdot \frac{di_2}{dt} + L_3 \frac{di_3}{dt}$

$i = i_1 + i_2 + i_3$



$V(t) = L \frac{di(t)}{dt}$

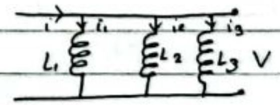
$i(t) = \frac{1}{L} \int V(t) \cdot dt$

$V = (L_1 + L_2 + L_3) \cdot \frac{di}{dt}$

$L_{eq} = L_1 + L_2 + L_3$

$$\boxed{V = L_{eq} \cdot \frac{di}{dt}}$$

Parallel Combination.



$i = i_1 + i_2 + i_3$

$= \frac{1}{L_1} \int V dt + \frac{1}{L_2} \int V dt + \frac{1}{L_3} \int V(t).$

$$i = \left(\frac{1}{L_1}+\frac{1}{L_2}+\frac{1}{L_3}\right)\int V\cdot dt$$

$$i\,\frac{1}{L_{eq}} = \left(\frac{1}{L_1}+\frac{1}{L_2}+\frac{1}{L_3}\right)\int V\cdot dt$$

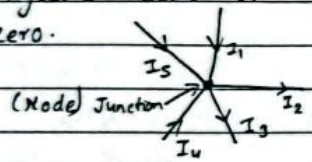
$$\boxed{\frac{1}{L_{eq}} = \frac{1}{L_1}+\frac{1}{L_2}+\frac{1}{L_3}.}$$

$$i = \frac{1}{L_{eq}}\int v(t)$$

Kirchhoff's laws:

a) ~~Voltage~~ Current law (K~~V~~CL)

Algebric sum of the current of at a junction is zero.

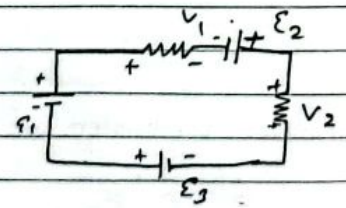


$$I_1 + I_s + I_4 = I_2 + I_3.$$
$$(I_1 + I_s + I_4) - (I_2 + I_3) = 0$$
$$\boxed{\Sigma I = 0} \text{ at junction.}$$

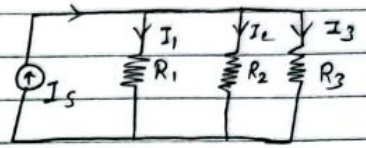
b) Voltage law (KVL).

Algebric ~~to~~ sum of the voltage or emf in a loop or mesh should be zero.

$$\varepsilon_1 - V_1 + \varepsilon_2 - V_2 + \varepsilon_3 = 0$$
$$(\varepsilon_1 + \varepsilon_2 + \varepsilon_3) = (V_1 + V_2)$$
$$\boxed{\Sigma V = 0} \text{ in mesh / loop.}$$



Current Division



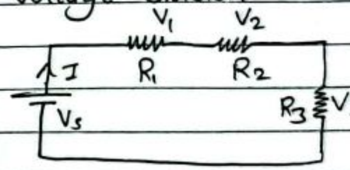
$$I_1 = \frac{1/R_1}{1/R_1 + 1/R_2 + 1/R_3} \times I_s$$

$$I_2 = \frac{1/R_2}{1/R_1 + 1/R_2 + 1/R_3} \times I_s$$

$$I_3 = \frac{1/R_3}{1/R_1 + 1/R_2 + 1/R_3} \times I_s$$

$\boxed{I_s = I_1 + I_2 + I_3}$ KCL

Voltage Division



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

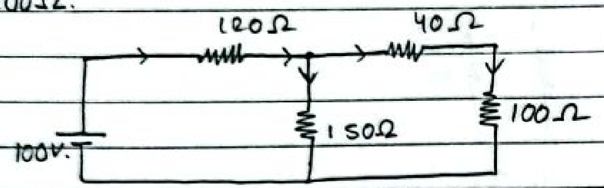
$$V_1 = \frac{R_1}{R_1 + R_2 + R_3} \times V_s$$

$$V_2 = \frac{R_2}{R_1 + R_2 + R_3} \times V_s$$

$$V_3 = \frac{R_3}{R_1 + R_2 + R_3} \times V_s$$

$\boxed{V_s = V_1 + V_2 + V_3}$ KVL.

Q. From the circuit, find the value of current through 100Ω.



$$R_{eq} = \left\{\frac{(40+100)}{150}\right\} + 120$$

$$= (140 // 150) + 120$$

$$= \frac{140 \times 150}{140+150} + 120$$

$$= 72.41 + 120$$

$$= 192.41\ \Omega$$

$$I = \frac{V_s}{R_{eq}}$$

$$= \frac{100}{192.41}$$

$$= 0.51\ A$$

$$I_1 = \frac{1/150}{1/150 + 1/140} \times 0.51$$

$$\boxed{I_1 = 0.246\ A}$$

$$I_2 = I_s - I_1$$

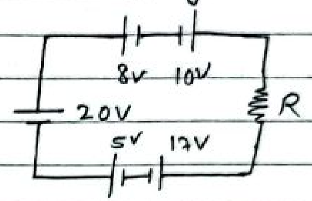
$$= 0.51 - 0.246$$

$$= 0.27\ A$$

$$I_2 = \frac{1/140}{1/150 + 1/140} \times 0.51$$

$$= 0.263A$$

Q. Find the voltage across R in the figure.

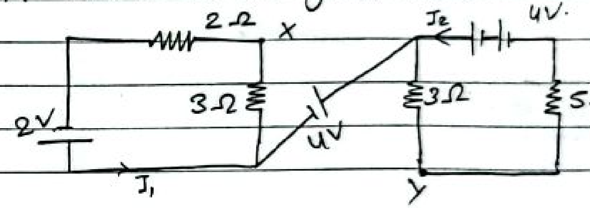


or, $20+5+10 = 8+V_R+17$

or, $35 = 25 + V_R$

$\therefore V_R = 10V$

Q. What is the difference in potential between points X and Y in the given circuit.



$$I_1 = \frac{2}{2+3}$$

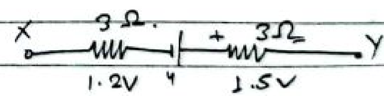
$$I_1 = \frac{2}{5}$$

$$I_1 = 0.4A$$

$$I_2 = \frac{4}{3+5}$$

$$I_2 = \frac{4}{8}$$

$$I_2 = 0.5A$$



$$V_x - 1.2 - 4 + 1.5 - V_y = 0$$

$$V_x - V_y = 1.2 + 4 - 1.5$$

$$\therefore V_x - V_y = 3.7V$$

classmate

Date ____ Page ____

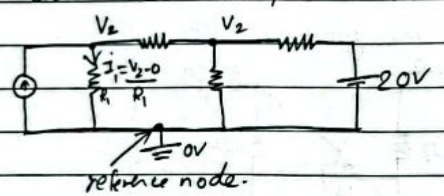
Application of krichhoff's law

a) Nodal Analysis

In nodal analysis we have to use KCL at junction or node.

Rules:

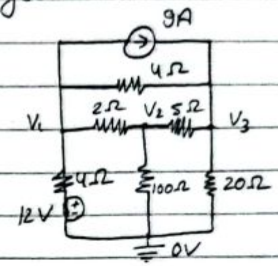
1. Determine node in a circuit.
2. Select a reference node among above nodes.
3. Write down or name other node as unknown node voltage.
4. Write down KCL earthquake at all unknown node

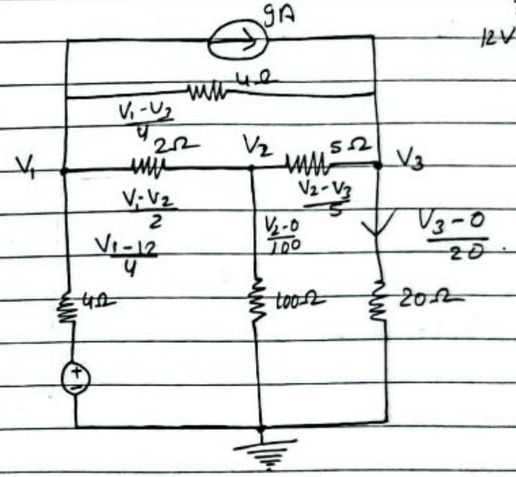


classmate

Date Jan-25

Qn. Calculate the voltage across 5Ω resistor in the newtork given below using Nodal Analysis.





at Node 1 : (KCL)

$$\frac{V_1-12}{4} + \frac{V_1-V_2}{2} + \frac{V_1-V_3}{4} + 9 = 0$$

$$\left(\frac{1}{4}+\frac{1}{2}+\frac{1}{4}\right)V_1 - \frac{12}{4} - \frac{1}{2}V_2 - \frac{1}{4}V_3 + 9 = 0$$

$$\boxed{1 \cdot V_1 - \frac{1}{2}V_2 - \frac{1}{4}V_3 = -6} \quad \cdots\cdots \text{(i)}$$

at Node 2 : (KCl)

$$\frac{V_1-V_2}{2} = \frac{V_2}{100} + \frac{V_2-V_3}{5}$$

$$\frac{1}{2}V_1 - \frac{V_2}{2} - \frac{V_2}{100} - \frac{V_2}{5} + \frac{V_3}{5} = 0$$

$$\frac{1}{2}V_1 - \left(\frac{1}{2}+\frac{1}{100}+\frac{1}{5}\right)V_2 + \frac{1}{5}V_3 = 0$$

$$\frac{1}{2}V_1 - \frac{71}{100}V_2 + \frac{1}{5}V_3 = 0 \quad \text{— (2)}$$

of Node 3:

$$\frac{V_2-V_3}{5}+\frac{V_1-V_3}{4}+9=\frac{V_3}{20}$$

$$\frac{1}{4}V_1+\frac{1}{5}V_2-\left(\frac{1}{5}+\frac{1}{4}+\frac{1}{20}\right)V_3=-9$$

$$\boxed{\frac{1}{4}V_1+\frac{1}{5}V_2-\frac{1}{2}V_3=-9} \quad \ldots\ldots \text{(iii)}$$

$A \cdot x = b$

$$\begin{bmatrix} 1 & -1/2 & -1/4 \\ 1/2 & -71/100 & 1/5 \\ 1/4 & 1/5 & -1/2 \end{bmatrix}\begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix}=\begin{bmatrix} -6 \\ 0 \\ -9 \end{bmatrix}$$

$V_1 = 6.35V$

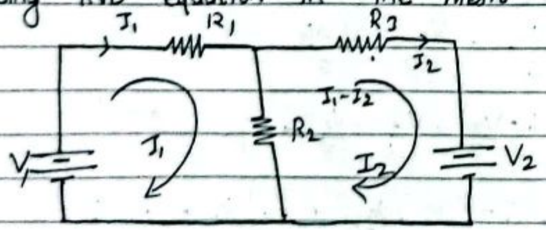
$V_2 = 11.76V$

$V_3 = 25.88V.$

$$I_5 = \frac{V_2-V_3}{5} = \frac{11.76-25.88}{5} = -2.82\ A$$

b) Mesh Analysis:

It is used to ~~just~~ find current in the electric network using KVL equation in the mesh.



1) Finding mesh in the network.
2) Write down mesh current in each mesh in clockwise direction or anticlockwise direction.
3) Write down KVL equaction in each mesh.

mesh-1 (KVL)

$V_1 - I_1R_1 - (I_1-I_2)R_2 = 0$

$(R_1+R_2)I_1 - R_2I_2 = V_1$

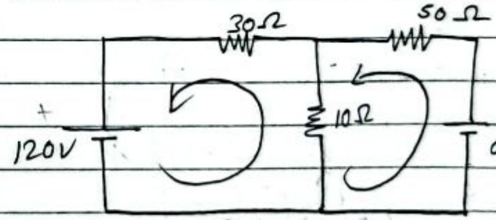
mesh-2 (KVL)

$(I_1-I_2)R_2 - I_2 \cdot R_3 - V_2 = 0$

$(I_1-I_2)R_2 - I_2 \cdot R_3 = V_2$

$$\begin{bmatrix} R_1+R_2 & -R_2 \\ R_2 & -(R_2+R_3) \end{bmatrix}\begin{bmatrix} I_1 \\ I_2 \end{bmatrix}=\begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

Q.NS. Find the mesh current in each branch.



mesh-1:

$120 - I_1 30 = (I_2-I_1)10$

$120 = 10I_2 - 10I_1 - 30I_1$

$120 = 10I_2 - 40I_1$

$-40I_1 + 10I_2 = 120$

$40I_1 - 10I_2 = -120$

mesh-2:

$50I_2 + (I_2-I_1)10 = 60$

$50I_2 + 10I_2 - 10I_1 = 60$

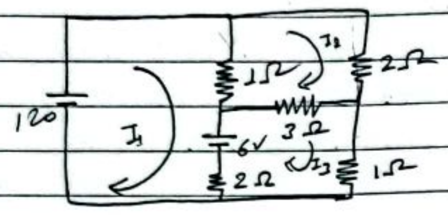
$-10I_1 + 60I_2 = 60$

$-I_1 + 6I_2 = 6.$

$I_1 = 2.86\ A$

$I_2 = 0.52A$

Q.



mesh - 1

$120 = (I_1 - I_2)1 + 6 + (I_1 - I_3).2$

$120 = 3I_1 - I_2 + 6 - 2I_3$

$3I_1 - I_2 - 2I_3 = 114$ .... (i)

mesh-2

$(I_1 - I_2)1 + (I_3 - I_2).3 = 2I_2$

$I_1 - 6I_2 + 3I_3 = 0$ .... (ii)

mesh-3

$6 + (I_1 - I_3)2 = 3(I_3 - I_2) + I_3$

$6 = 2I_1 - 3I_2 + 6I_3$

$-2I_1 - 3I_2 + 6I_3 = 6$ .... (iii)

Matrix:

$$\begin{bmatrix} 3 & -1 & 2 \\ 1 & -6 & 3 \\ -2 & -3 & 6 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 114 \\ 0 \\ 6 \end{bmatrix}$$

$I_1 =$

$I_2 =$

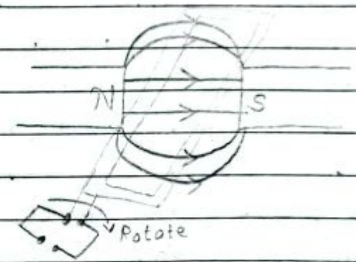
$I_3 =$

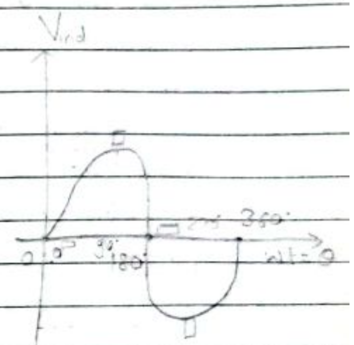
Date 27-Jan.
day Sunday.

Introduction to AC Circuits and parameters.

Rotary electro mechanical generators produce voltage alternating in polarity and reversing positive and negative over time.

Either as a voltage switching polarity or as a current switching direction back and forth, this kind of electricity is known as Alternating current (AC).





$V_{ind} \propto \frac{d\phi}{dt}$.

In the presence of magnetic field when we rotate a coil an emf (voltage) is induced in the coil which is directly proportional to the rate of change of flux.

From graph,

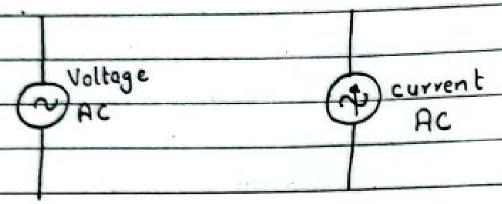
Emf = $Bl\sin\theta$ where, B = Magnetic field density (Tesla)
l = length of conductor.
V = Velocity
θ = angle of rotation.

$E_{max} = BlV$, $\theta = 90°$

$E_{min} = BlV0$, $\theta = 0°$

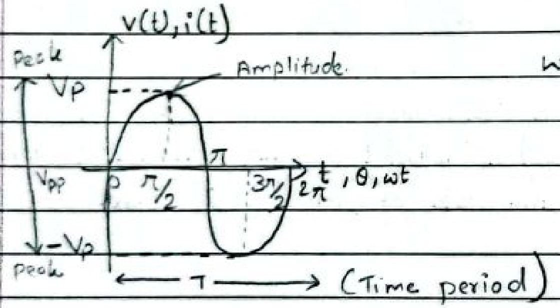
It is Based on Faraday's law of electromagnetic induction.

Symbol :



AC waveform:

When an alternator produces AC voltage the voltage switches polarity over time. When graphed over time the current is traced.
The shape is obtained by plotting the instantaneous values of an alternating quantity such as voltage of current, along the y-axis and time(t) along the x-axis is called wave form.



where,
V_p = peak voltage
V_{pp} = peak to peak voltage.

Amplitude

The maximum positive or negative value attained by alternating quantity in one complete cycle is called amplitude or peak value.
The maximum value of voltage or current is represented by E_m or V_m or V_p and I_m or I_p respectively.

Cycle :

When one set of positive and negative values completes by an alternating quantity or it goes through 360° electrical, it is said to be one complete cycle.

Frequency:

The cycle per second is known as frequency.

$f = \text{cycle}/\text{sec}$, unit = Hz.

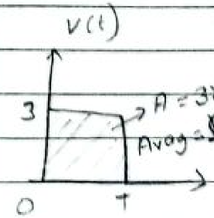
Time Period :

Time taken in seconds by voltage or a current to complete one cycle is called time period.

Average value of a wave form.

The average value of waveform can be found for any wave like sinusoidual, triangular, trapezoidal square or other shape
The average value of a cycle of a waveform is the area under the waveform divided by the length one cycle i.e

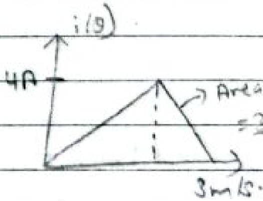
$$V_{avg} = \frac{1}{T}\int_0^T v(t)\cdot dt.$$



$A = 3 \times T$

$Avg = \frac{A}{T} = \frac{3 \times T}{T}$

$= 3$volt



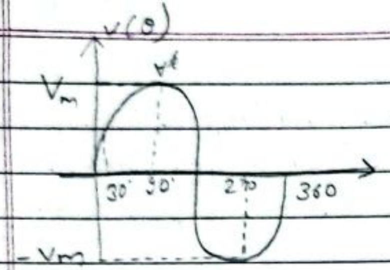
Area $= \frac{b \times h}{2} = \frac{3 \times 10^{-3} \times 4}{2}$

$I_{avg} = \frac{Area}{base}$

$= \frac{3 \times 10^{-3} \times 4}{2 \times 3 \times 10^{-3}}$

$= \frac{2 \times 4A}{2}$

$= 2A$



$V(\theta) = V_m \sin\theta \quad , T = 2\pi$

$V_{avg} = \frac{1}{T}\int_0^T v(t)\cdot dt.$

$= \frac{1}{2\pi}\int_0^{2\pi} V_m \cdot \sin\theta \cdot d\theta.$

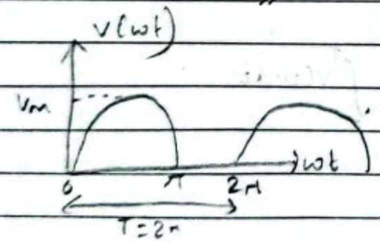
$= \frac{V_m}{2\pi}\left[-\cos\theta\right]_0^{2\pi}$

$= \frac{V_m}{2\pi}\left[-(\cos 2\pi - \cos 0)\right].$

$= \frac{V_m}{2\pi}\left[-(-1+1)\right]$

$= \frac{V_m}{2\pi} \quad -1+1$

$= 0V$



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

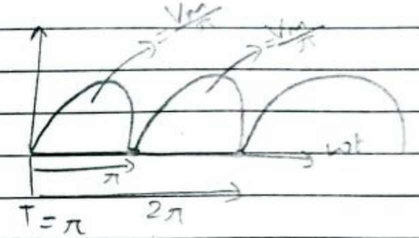
$V_{avg} = \frac{1}{T}\int_0^T v(\omega t) \cdot d(\omega t)$

$= \frac{1}{2\pi}\int_0^{2\pi} V_m \sin(\omega t)\cdot d(\omega t)$

$= \frac{1}{2\pi}\left[\int_0^{\pi} V_m \sin(\omega t)\cdot d\omega t) + \int_{\pi}^{2\pi} 0 \cdot d(\omega t)\right]$

$= \frac{1}{2\pi}\left[V_m\left[-\cos(\omega t)\right]_0^{\pi}\right]$

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



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

$V_{avg} = \frac{1}{T}\int_0^T V(\omega t \cdot d(\omega t)$

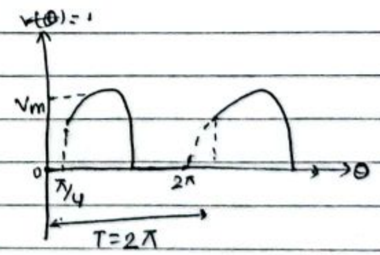
$= \frac{1}{\pi}\int_0^{\pi} V_m \sin(\omega t) d\cdot(\omega t)$

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

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

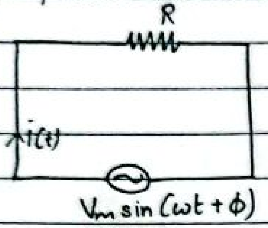
$= \frac{V_m}{\pi}\left[1+1\right]$

$= 2\cdot\left(\frac{V_m}{\pi}\right).$

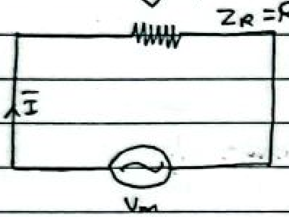


Single phase AC Circuit.

With Resistor



⇓ phasor form



$$\bar{I} = \frac{V_m \angle \phi}{Z_R}$$

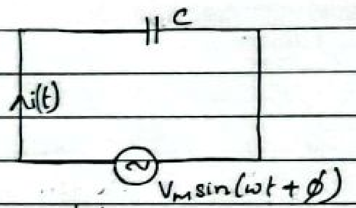
$$\bar{I} = \frac{V_m}{Z_R} \angle \phi$$

$$\bar{I} = I_m \angle \phi$$

$$\therefore I_m = \frac{V_m}{|Z_R|}$$

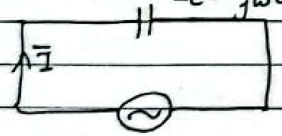
In resistor current and voltage are in same phase.

With capacitance



⇓ phaser form.

$Z_c = \frac{1}{j\omega c} = -j\frac{1}{\omega c}$



$$\bar{I} = \frac{V_m \angle \phi}{Z_c}$$

$$= \frac{V_m \angle \phi}{-j\frac{1}{\omega c}}$$

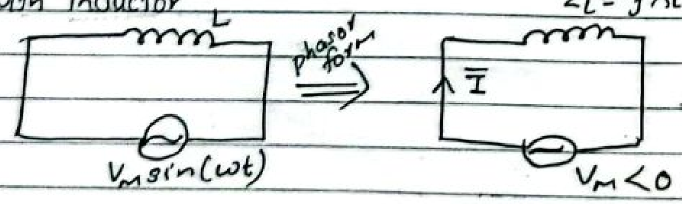
$$= \frac{V_m \angle \phi}{\left|\frac{1}{\omega c}\right| \angle -90^\circ}$$

$$\bar{I} = \frac{V_m}{\left|\frac{1}{\omega c}\right|} \angle +90^\circ$$

In capacitor current leads voltage by 90°.

With inductor

$Z_L = jX_L = j\omega L$



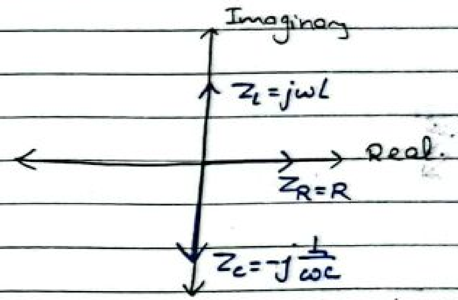
$$\bar{I} = \frac{V_m \angle 0}{Z_L}$$

$$= \frac{V_m \angle 0}{j\omega L}$$

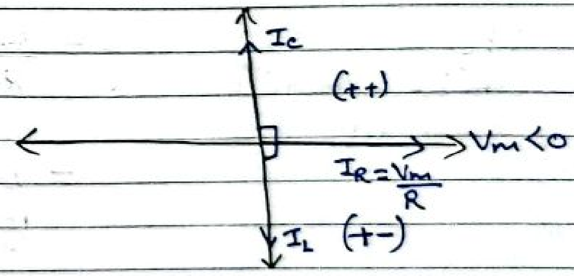
$$= \frac{V_m \angle 0}{|\omega L| \angle 90}$$

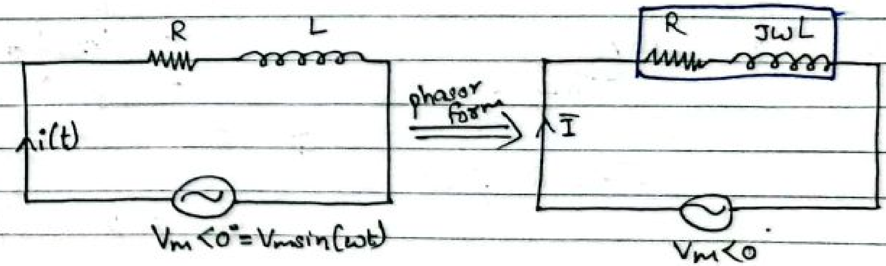
$$\bar{I} = \frac{V_m}{|\omega L|} \angle -90^\circ$$

In inductor current lags voltage by -90°.



Indepance of different Elements.



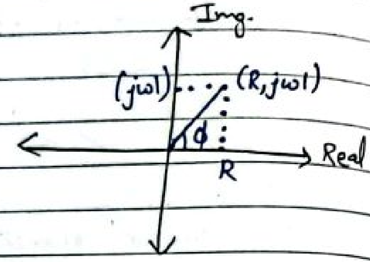


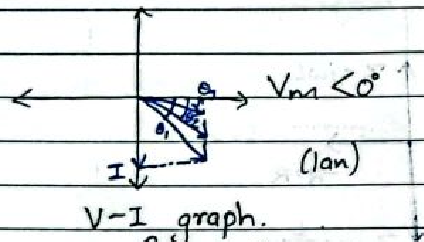
$$Z_T = R + j\omega L \begin{cases} |Z_T| = \sqrt{R^2 + (\omega L)^2} \\ \angle Z_T = \phi = \tan^{-1}\left(\frac{\omega L}{R}\right) \end{cases}$$

$$\bar{I} = \frac{V_m \angle 0}{Z_T}$$

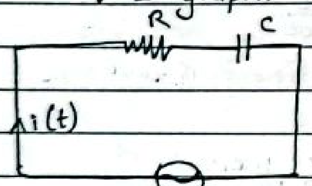
$$\bar{I} = \frac{V_m \angle 0}{R + j\omega L}$$

$$= \frac{V_m \angle 0}{\sqrt{R^2 + (\omega L)^2} \angle \tan^{-1}\left(\frac{\omega L}{R}\right)}$$





V-I graph.



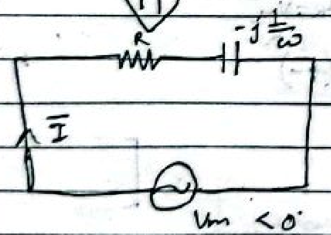
$V_m \angle 0° = V_m \sin(\omega t)$

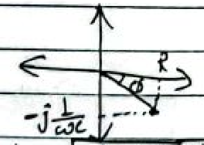
phasor form

$$\bar{I} = \frac{V_m \angle 0}{Z_T}$$

$$\bar{I} = \frac{V_m \angle 0}{R - j\frac{1}{\omega C}}$$

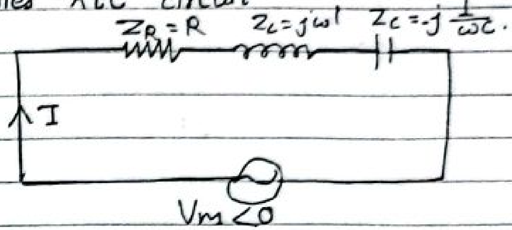
$$= \frac{V_m \angle 0}{\sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2} \angle \tan^{-1}\left(\frac{-1}{\omega R C}\right)}$$





$$Z_T = R - j\frac{1}{\omega C} \begin{cases} |Z_T| = \sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2} \\ \angle Z_T = \phi \tan^{-1}\left(\frac{1}{\omega R C}\right) \end{cases}$$

Series RLC circuit



Series.

$$Z_T = Z_R + Z_L + Z_C$$

In parallel

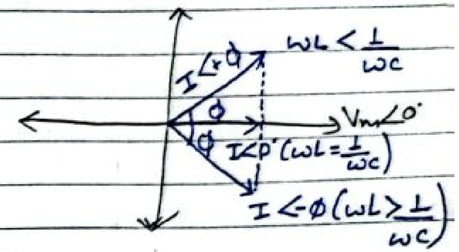
$$\frac{1}{Z_{eq}} = \frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3}.$$

$$Z_T = R + j\omega l - j\frac{1}{\omega C}$$

$$Z_T = \underbrace{R}_{\text{Real}} + j\underbrace{\left(\omega l - \frac{1}{\omega C}\right)}_{\text{imaginary}}$$

if $\omega L > \frac{1}{\omega C}$ ⇒ inductor

if $\omega L < \frac{1}{\omega C}$ ⇒ capacitance.



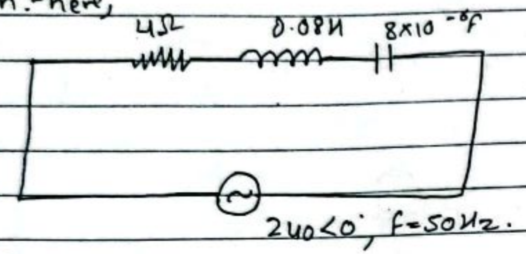
$$\text{Power} = V_{rms} \cdot I_{rms} \cdot \underbrace{\cos\phi}_{\text{power factor}}$$

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

Q. A 240V, 50Hz AC supply is applied to a coil of 0.08H inductance and 4Ω resistance connected in series with the capacitor of 8μF. Calculate.

i) Independence
ii) Circuit current
iii) phase angle between current and voltage.
iv) power factor
v) Voltage across each element.

Soln:- here,



i) $Z_T = Z_R + Z_L + Z_C$

$Z_R = 4\Omega$

$Z_L = j\omega L = j\cdot(2\pi 50)\times 0.08 = 25.12j$

$Z_C = -j\frac{1}{\omega C} = -j\frac{1}{(2\pi 50\times 8\times 10^{-6})} = -398.08j$

$Z_T = 4 + 25.12j - 398.083j$

$Z_T = 4 - 372.969j$

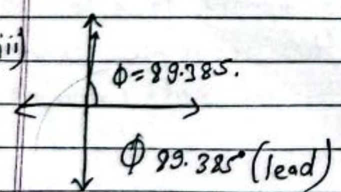
ii) $\bar{I} = \frac{V\angle 0}{Z_T}$

$= \frac{240\angle 0°}{4-372.969j}$

$\bar{I} = 6.9\times 10^{-3} + 0.643i$

$\bar{I} = 0.643\angle 89.385°$ Amp.

iii)



iv. power factor (p.f) $= \cos\phi$

$= \cos(89.385°)$

$= 0.0107.$

v. $\bar{V}_R = \bar{I}.\bar{R}$

$= 0.643\angle 89.385 \times 4$

$= 2.572\angle 89.385.$

$\bar{V}_L = \bar{I}\times Z_L$

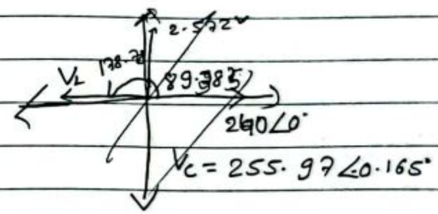
$= 0.643\angle 89.385 \times 25.12j$

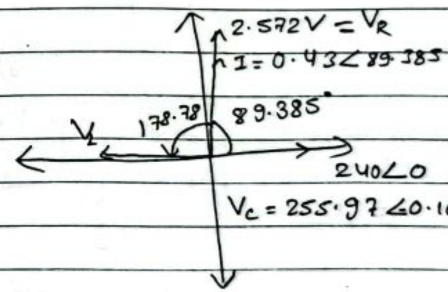
$V_L = 16.15\angle 179.385°$

$\bar{V}_C = \bar{I}\times \bar{Z}_C$

$= 0.643\angle 89.385 \times (-398.089j)$

$= 255.97\angle -0.615°$

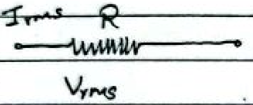




Feb 10

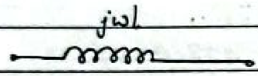
Different types of power.

a. Real power or Active power. (P). $\longrightarrow$ Watt.

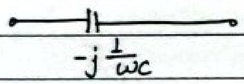


$\Rightarrow P = V_{rms} \cdot I_{rms} \cdot \underbrace{\cos\phi}_{\text{power factor}}$

b. Reactive power (Q) $\longrightarrow$ VAR



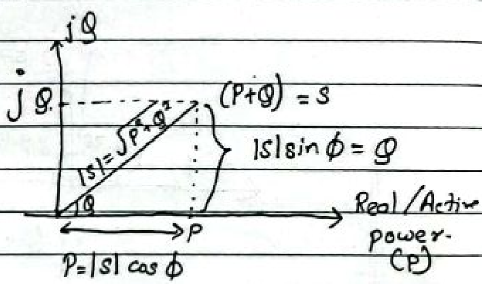
$\Rightarrow Q = V_{rms} I_{rms} \cdot \sin\phi$



c. Apparent Power (S) $\longrightarrow$ (VA)

$S = P + jQ = V_{rms} \cdot I_{rms}$.

$|S| = \sqrt{P^2 + Q^2}$



power phaser diagram

$P = V_{rms} \cdot I_{rms} \cdot \cos\phi$

$= S \cdot \cos\phi$

$= S \cdot (pf)$

$Q = V_{rms} \cdot I_{rms} \cdot \sin\phi$

$\Rightarrow S \cdot \sin\phi$

$\Rightarrow S \cdot \sqrt{1-\cos^2\phi}$

$\Rightarrow S \cdot \sqrt{1-(pf)^2}$

Q. In the network shown in ~~fo~~ figure determine.

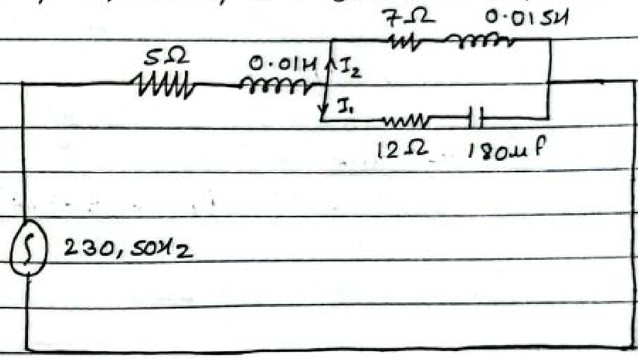
i) Total impedance

ii) The current

iii) The current in each phase

iv) The overall power factor.

v) Volt ampers, active power of reactive power.



$Z_1 = 5 + j\omega(0.01)$

$= 5 + j(2\pi f(0.01))$

$= 5 + j(2\pi 50 \times 0.01)$

$= 5 + j\pi$

$\therefore Z_1 = 5 + 3.14j$

$Z_2 = 7 + j\omega(0.015)$

$= 7 + j(2\pi f \times 0.015)$

$= 7 + j(2\pi 50 \times 0.015)$

$\therefore Z_2 = 7 + 4.71j$

$Z_3 = 12 - j\dfrac{1}{(2\pi \times 50 \times 180 \times 10^{-6})}$

$= 12 - j17.69$

$\therefore Z_3 = 12 - 17.69j$

i) $Z_{eq} = (Z_2 // Z_3) + Z_1$

$$= \frac{Z_2 \cdot Z_3}{Z_2+Z_3} + Z_1$$

$$= \frac{7+4.71j \cdot 12-17.69j}{7+4.71j + 12-17.69j} + 5+3.14j$$

$$= \frac{-19.7999}{\cancel{19}-12.98j} + 5+3.14j$$

$$= 1.85+\cancel{4.24j} + \cancel{5+3.14j}$$

$$= 6.85 + 7.384$$

$$= (7.65 + 1.68j) + (5+3.14j)$$

$$Z_{eq} = 12.65+4.82j \ \Omega$$

$$I_1 = \frac{V\angle 0}{Z_{eq}}$$

$$I_1 = \frac{230\angle 0}{1265+4.82j}$$

$$I_1 = 16.99 \angle -20.85^\circ \text{ Amp.}$$

$$I_2 = \frac{1/Z_2}{\frac{1}{Z_2} + 1/Z_3} \times I_1$$

$$I_2 = \frac{\frac{1}{Z_2}}{1/Z_2 + \frac{1}{Z_3}} \times I_1$$

$I_3 = I_1 - I_2$

$I_3 = 6.63 \angle 47.4_2$

$$= \frac{Z_3}{Z_2+Z_3} I_1$$

$$= 15.78 \angle -42.37.$$

$\cos\phi = p.f$

$\phi = (0 - (-20.85)) = 20.85$ (lagging)

$p.f = \cos(20.85) = 0.93$

v) Voltampere

$S = V_{rms} \times I_{rms}.$

$= 230 \times 16.99$

$= 3907.7$ VA

$\therefore S = 3.9077$ KVA.

$P = V_{rms} \cdot I_{rms} \cdot \cos\phi$

$= 230 \times 16.99 \times 0.93$

$= 3634.16$ watt

$= 3.634$ kW.

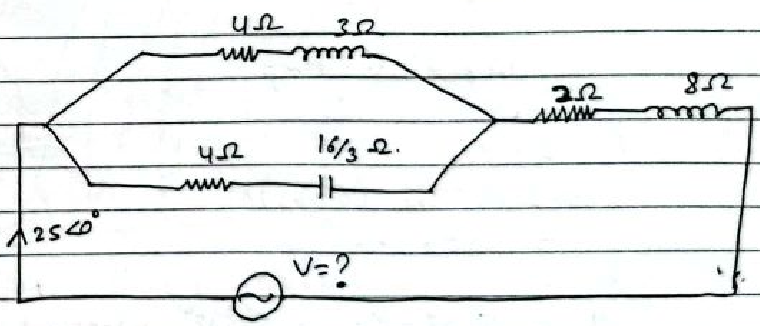
$Q = V_{rms} \cdot I_{rms} \cdot \sin\phi$

$= 230 \times 16.99 \cdot \sin(20.85)$

$= 1390.83$ VAR.

$= 1.390$ kVAR.

Q.N.5



$Z_1 = 4+8j$

$Z_2 = 4-16j$

$Z_3 = 2+8j$

Date:

$$Z_{eq} = (Z_1 // Z_2) + Z_3$$

$$= \frac{Z_1 \times Z_2}{Z_1 + Z_2} + Z_3$$

$$= \frac{(4+3j) \times (4-\frac{16}{3}j)}{(4+3j) + (4-\frac{16}{3}j)} + (2+8j) \qquad = (4+0j) + (2+8j)$$

$$= 1.40 + 4.42j + 2 + 8j$$

$$= 3.40 + 12.42j \qquad = \cancel{20-36} \quad 6+8j$$

$$I_1 = \frac{Z_2}{Z_1+Z_2} \times 25\angle 0$$

$$= \frac{(4-\frac{16}{3}j)}{(4+3j)+(4-\frac{16}{3}j)} \times 25\angle 0$$

$$= 20\angle -36.86 \text{ Amp}$$

$$I_2 = \frac{Z_1}{Z_1+Z_2} \times 25\angle 0$$

$$= \frac{4+3j}{(4+3j)+(4-\frac{16}{3}j)} \times 25\angle 0$$

$$= 15\angle 53.13 \text{ Amp.}$$

$$V = I \cdot Z_{eq}$$

$$= 25\angle 0^\circ \times (6+8j)$$

$$= 250\angle 53.13$$

$$\phi = (53.13 - 0^\circ) = 53.13^\circ \text{ (lagging)}$$

$$p.f = \cos\phi$$

$$= \cos(53.13)$$

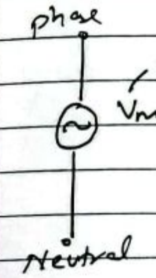
$$p.f = 0.60$$

Date: 15-Feb

1.Q Three Phase AC Circuit Analysis.

→ A three phase supply is a set of three alternating quantities displaced from each other by an angle of 120°. A three phase voltage is shown below.

It consists of three phases – phase A, phase B and phase C. Phase A waveform starts at 0° phase B waveform starts at 120° and phase C waveform at 240°.



amplitude, freq, phase: $V_m \sin(\omega t + \phi)$

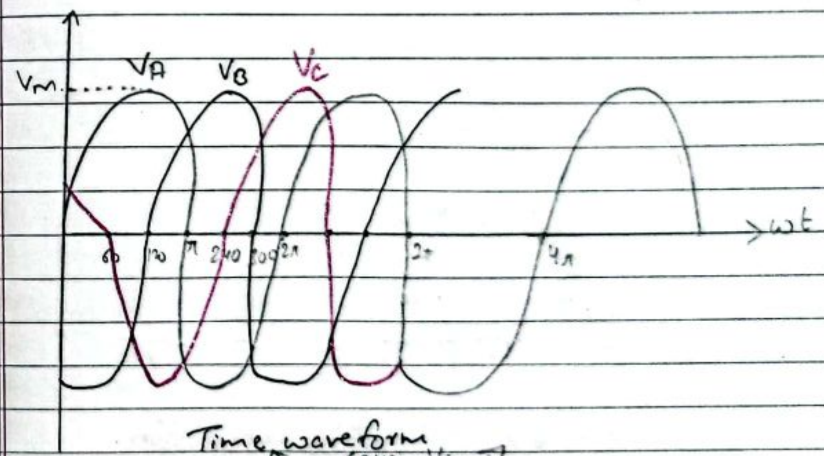
→ $V_m \sin(\omega t + 0^\circ) = V_A = V_{Red}$

$\updownarrow 120^\circ$

→ $V_m \sin(\omega t - 120^\circ) = V_B = V_{yellow}$

$\updownarrow 120^\circ$

→ $V_m \sin(\omega t - 240^\circ) = V_C = V_{Blue}$



Time waveform

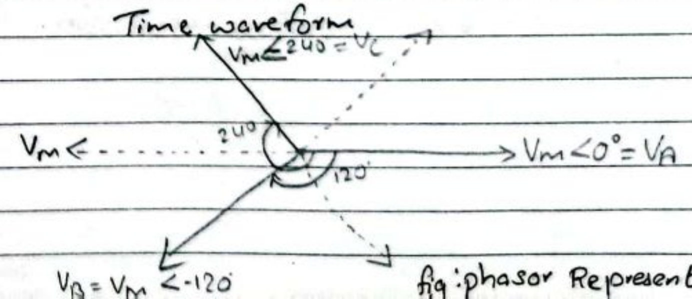
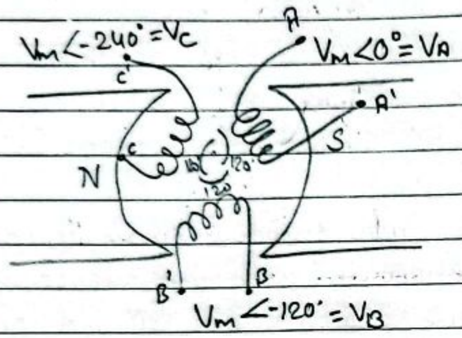
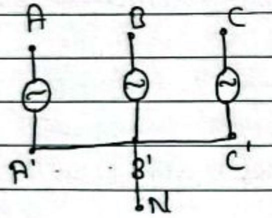


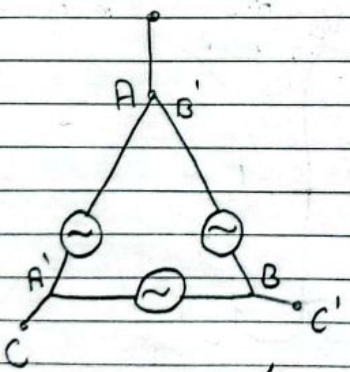
fig: phasor Representation

Generation of 3-ϕ system:





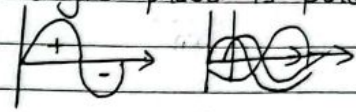
star-Wye = connection



~~str~~ Delta/Ring connection.

Advantages of 3-ϕ system:

→ Three phase system supplies constant voltage where as single phase is pulse setting waveform.



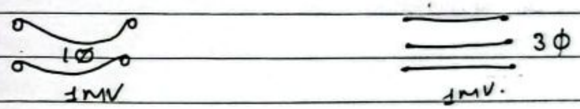
→ The magnitude of 3-ϕ system is 1.5 times higher than 1-ϕ system.

$V_m \longrightarrow 1.5 V_m$

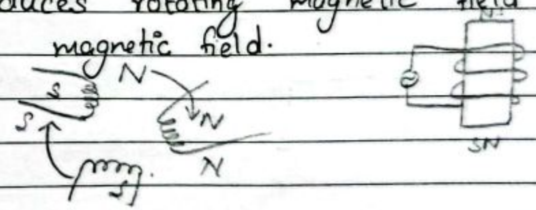
1 − ϕ 3 − ϕ

$P = V_m I_m$

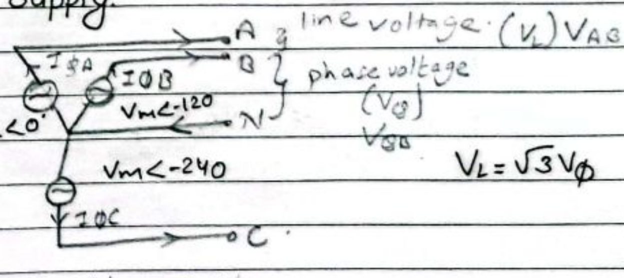
→ Weight of the copper in 3-ϕ system is $\left(\frac{3}{4}\right)^{th}$ time of 1-ϕ.



→ 3-ϕ produces rotating magnetic field whereas 1-ϕ alternating magnetic field.

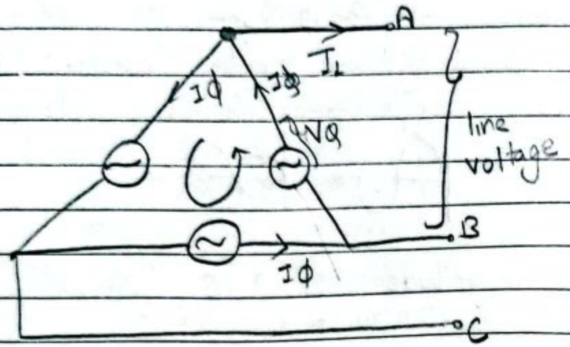


Balanced Supply.



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

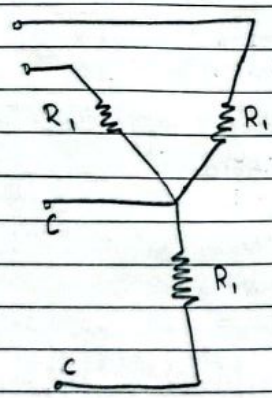
Star-connection



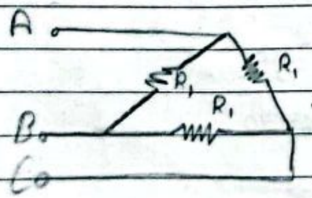
$V\phi = V_{line}$

$I_L = \sqrt{3}\, I\phi$

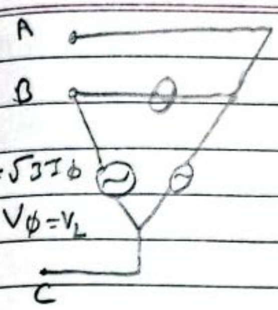
Balanced load



Star connection



Delta - connection



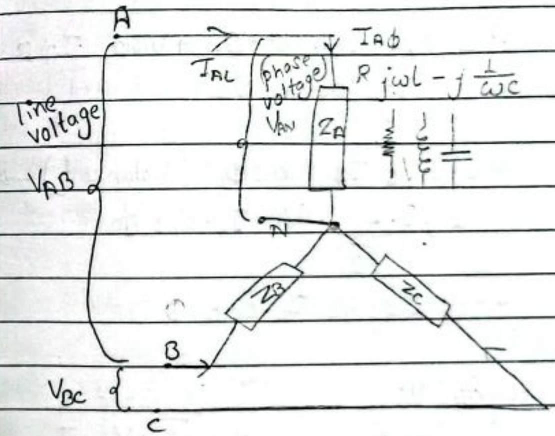
$I_L = \sqrt{3} I\phi$

$V\phi = V_L$

17 feb.

Three phase balanced load

a Start Connection



$I_{LA} = I_{\phi A}$

$I_{LB} = I\phi_B$

$I_{LC} = I\phi_C$

$V_L = \sqrt{3}\, V\phi$

$I_L = I\phi$

line voltage $\left\{ \begin{array}{l} V_{AB} = V_{AN} - V_{BN} \\ V_{BC} = V_{AN} - V_{CN} \\ V_{BC} = V_{BN} - V_{CN} \end{array} \right\}$ phase voltage.

if $Z_A = Z_B = Z_C$ (balanced load)

$Z_A \neq Z_B \neq Z_C$ (Unbalanced load).

$$I_{\phi A} = \frac{V_{\phi A}}{Z_A} = \frac{V_{AN}}{Z_n}$$

$$I_{\phi B} = \frac{V_{\phi B}}{Z_B} = \frac{V_{BN}}{Z_n}$$

$$I_{\phi C} = \frac{V_{\phi C}}{Z_C} = \frac{V_{CN}}{Z_C}$$

$$\therefore I_N = I_{\phi A} + I_{\phi B} + I_{\phi C} = I_{LA} + I_{LB} + I_{LC}$$

if $I_N = 0$ (Balanced load).

Power :

Real power : $P = V_{\phi A} \cdot I_{\phi A} \cdot \cos\theta_A + V_{\phi B} \cdot I_{\phi B} \cdot \cos\theta_B + V_{\phi C} \cdot I_{\phi C} \cdot \cos\theta_C$.

$$P = 3 V_\phi \cdot I_\phi \cdot \cos\phi \text{ (balanced)} \rightarrow \text{watt.}$$

$$= 3 \cdot \frac{1}{\sqrt{3}} \cdot V_L \cdot I_L \cdot \cos\phi$$

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

Reactive Power (Q)

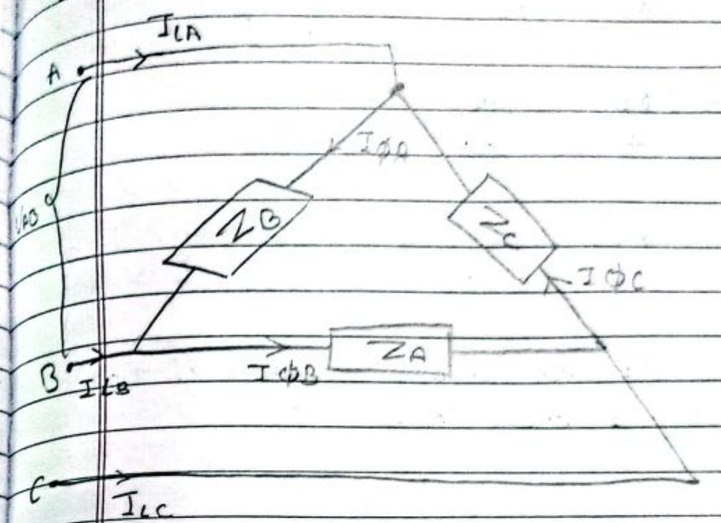
$$Q = 3 V_\phi \cdot I_\phi \sin\phi = \sqrt{3} \cdot V_L \cdot I_L \cdot \sin\phi$$

Apparent Power (S)

$$S = 3 \cdot V_\phi \cdot I_\phi = \sqrt{3} \cdot V_L \cdot I_L$$

$$S = P + jQ$$

b. Delta Connection.



$$I_{LA} + I_{\phi C} = I_{\phi A}$$

line current
$$I_{LA} = I_{\phi A} - I_{\phi C}$$
$$I_{LB} = I_{\phi B} - I_{\phi A}$$
$$I_{LC} = I_{\phi C} - I_{\phi B}$$
phase current

$$V_{AB} = V_{\phi A}$$
$$V_{BC} = V_{\phi B}$$
$$V_{AC} = V_{\phi C}$$
$\rightarrow$ line voltage = phase.

$V_L = V_\phi$ (Balanced)

$I_L = \sqrt{3}\, I_\phi$

if $Z_A = Z_B = Z_C$ (balanced load)

$Z_A \neq Z_B \neq Z_C$ (Unbalanced load)

$$I_{\phi A} = \frac{V_{\phi A}}{Z_A} = \frac{V_{AB}}{Z_A}$$

$$I_{\phi B} = \frac{V_{\phi C}}{Z_B} = \frac{V_{BC}}{Z_B}$$

$$I_{\phi C} = \frac{V_{\phi C}}{Z_C} = \frac{V_{AC}}{Z_C}$$

Real Power (P) $= V_{\phi A} \cdot I_{\phi A} \cdot \cos\theta_A + V_{\phi B} \cdot I_{\phi B} \cdot \cos\theta_B + V_{\phi C} \cdot I_{\phi C} \cdot \cos\theta_C$

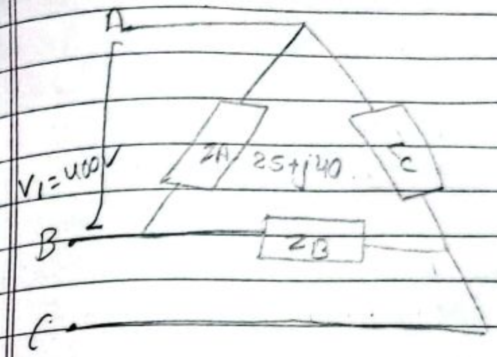
$$P = 3 V_\phi \cdot I_\phi \cdot \cos\phi \quad \text{(balanced)} \rightarrow \text{watt.}$$
$$= 3 \cdot \frac{1}{\sqrt{3}} \cdot V_L \cdot I_L \cdot \cos\phi$$
$$P = \sqrt{3}\, V_L \cdot I_L \cdot \cos\phi$$

Reactive power (Q)
$$Q = 3 V_\phi \cdot I_\phi \sin\phi = \sqrt{3}\, V_L \cdot I_L \cdot \sin\phi$$

Apparent Power (S)
$$S = 3 \cdot V_\phi \cdot I_\phi = \sqrt{3}\, V_L \cdot I_L$$
$$S = P + jQ.$$

Q. A balanced 3-ϕ delta connected load has phase impedance of $(25+j40)\,\Omega$. If 400 V, 3 ϕ supply is connected to this load. find.
i) Phase current
ii) Power supplied to the load.
iii) Reactive of apparent power.

Soln :- here,



$V_{AB} = V_{\phi A} = 400 \angle 0^\circ$
$V_{BC} = V_{\phi B} = 400 \angle -120^\circ$
$V_{AC} = V_{\phi C} = 400 \angle -240^\circ = 400 \angle +120^\circ$.

phase current

$$I_{\phi A} = \frac{V_{\phi A}}{Z_A} = \frac{400\angle 0^\circ}{25+j40} = 8.47 \angle -57.98^\circ$$

$$I_{\phi B} = \frac{V_{\phi B}}{Z_B} = \frac{400\angle -120^\circ}{25+j40} = 8.47 \angle -177.99^\circ$$

$$I_{\phi C} = \frac{V_{\phi C}}{Z_C} = \frac{400\angle -240}{25+j40} = 8.47 \angle 62.00^\circ$$

line current

$I_{LA} = I_{\phi A} - I_{\phi C} = 8.47\angle -57.98 - 8.47\angle 62.0^\circ$
$= 14.66 \angle -87.99^\circ$

$I_{LB} = I_{\phi B} - I_{\phi A} = 8.47 \angle -177.99 - 8.47 \angle -57.98$
$= 14.66 \angle 152.0^\circ$

$I_{LC} = I_{\phi C} - I_{\phi B} = 8.47 \angle 62.0^\circ - 8.47 \angle -177.99$
$= 14.66 \angle 32.005^\circ$

$\theta = 0^\circ - (-57.98^\circ) = 57.98^\circ$ (lagging)

$\theta = -120 - (177.99) = 57.98$

$p.f = \cos\theta = (\cos 57.98)$
$= 0.53.$

$P = 3V_\phi \cdot I_\phi \cdot \cos\phi$
$= 3 \times 400 \cdot 8.47 \cdot 0.53$
$= 5386.92$ watt

$Q = 3 \cdot V_\phi \cdot I_\phi \cdot \sin\phi = 3 \cdot 460 \times 8.47 \times \sin 57.98$
$= 8617.68$ VAR

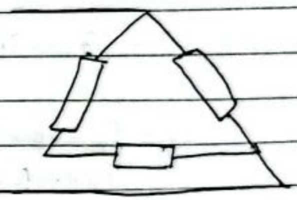
$S = 3V_\phi \cdot I_\phi$
$= 10164VA$

Date 21 Feb

Three Phase AC system.

Qn. A $3-\phi$, Δ-connected load consits of three similar coils each of resistance 50Ω and inductance of 0.3H. The supply is 415V, 50Hz. Calculate
i) The line current
ii) Power factor.
iii) Total active and reactive power when the load is Δ-connected. Draw the phasor diagram.

Soln :- here,



$Z_A = Z_R + Z_L$
$= 50 + j\omega L$
$Z_A = 50 + j(2\pi \times 50) \times 0.3$
$Z_A = 50 + 30\pi j = Z_B = Z_C$

$V_{AB} = 415 \angle 0^\circ = V_{\phi A}$
$V_{BC} = 415 \angle -120^\circ = V_{\phi B}$
$V_{AC} = 415 \angle +120^\circ = V_{\phi C}$

$I_{\phi A} = \dfrac{V_{\phi A}}{Z_A} = \dfrac{415 \angle 0^\circ}{50 + 30\pi j} = 3.88 \angle -62.05^\circ$

$I_{\phi B} = \dfrac{V_{\phi B}}{Z_B} = \dfrac{415 \angle -120^\circ}{50 + 30\pi j} = 3.88 \angle 177.95^\circ$

$I_{\phi C} = \dfrac{V_{\phi C}}{Z_C} = \dfrac{415 \angle +120^\circ}{50 + 30\pi j} = 3.88 \angle 57.95^\circ$

$I_{LA} = I_{\phi A} - I_{\phi C} = 3.88 \angle -62.05 - 3.88 \angle 57.95 = 6.72 \angle -92.05$
$I_{LB} = I_{\phi B} - I_{\phi A} = 6.72 \angle +147.92$
$I_{LC} = I_{\phi C} - I_{\phi B} = 6.72 \angle 27.95^\circ$

$P_A = V_{\phi A} \cdot I_{\phi A} \cdot \cos\phi_A$ | $Q = V_{\phi A} \cdot I_{\phi A} \cdot \sin\phi_A$.

$= 415 \times 3.88 \cos(0-(-62.05))$

$= 754.70$

$P_B = V_{\phi B} \cdot I_{\phi B} \cdot \cos\phi_B$.

$= 415 \times 3.88 \cos(-120-177.95)$

$= \cancel{-1531.82}\ 754.70$

$P_C = V_{\phi C} \cdot I_{\phi C} \cdot \cos\phi_C$.

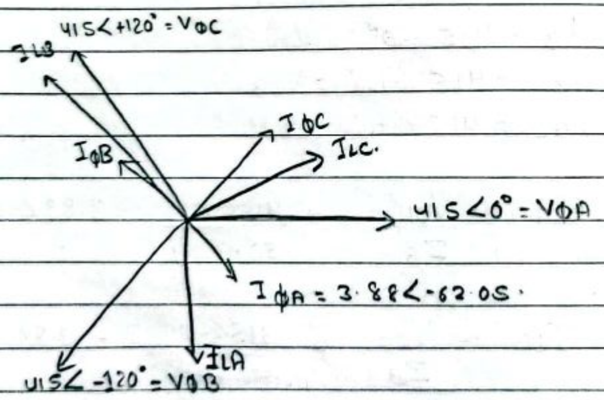
$= 415 \times 3.88 \cdot \cos(120-57.95)$

$= 754.70$

$P_T = P_A + P_B + P_C$.

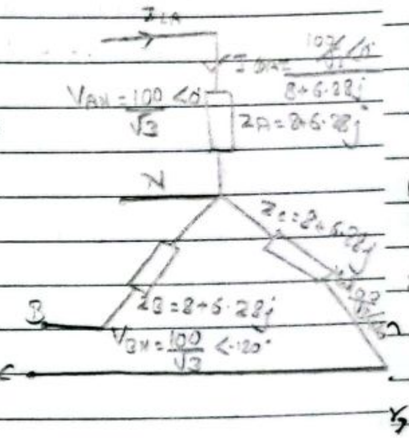
$= 754.70 + \cancel{(-1531.82)}\ 754.70 + 754.70$

$= \cancel{22.41}\ 2264.10$



Q. A 3-φ load consist of three similar inductive coil each of resistance of 8Ω and inductance 20mH. The supply voltage is 100V. 50Hz. Calculate the line current, total power consumed by load in the star connection. And Draw the phasor Diagram.

→ Soln:- here,



$Z_A = Z_R + Z_L$

$= 8 + j(2\pi 50) \times 20 \times 10^{-3}$

$= 8 + 6.283j$

$V_{AN} = \frac{100}{\sqrt{3}} \angle 0°$

$V_{BN} = \frac{100}{\sqrt{3}} \angle -120°$

$V_{CN} = \frac{100}{\sqrt{3}} \angle +120°$

$I_{LA} = I_{\phi A} = \frac{100/\sqrt{3} \angle 0}{8+6.28j} = 5.70 \angle -37.78°$

$I_{LB} = I_{\phi B} = \frac{100/\sqrt{3} \angle -120°}{8+6.28j} = 5.70 \angle -157.78°$

$I_{LC} = I_{\phi C} = \frac{100/\sqrt{3} \angle +120°}{8+6.28j} = 5.7 \angle 82.21°$

$P_A = V_{\phi A} \cdot I_{\phi A} \cdot \cos\phi$

$= \frac{100}{\sqrt{3}} \times 5.70 \cdot \cos(0-(-37.78)) = 260.10$ Watt.

$P_B = V_{\phi B} \cdot I_{\phi B} \cdot \cos\phi$

$= \frac{100}{\sqrt{3}} \times 5.70 \cdot \cos(-120-(-157.78)) = 260.10$ Watt.

$P_C = V_{\phi C} \cdot I_{\phi C} \cdot \cos\phi$

$= \frac{100}{\sqrt{3}} \times 5.70 \times \cos(120 - 82.21)$

$= 260.06$ watt.

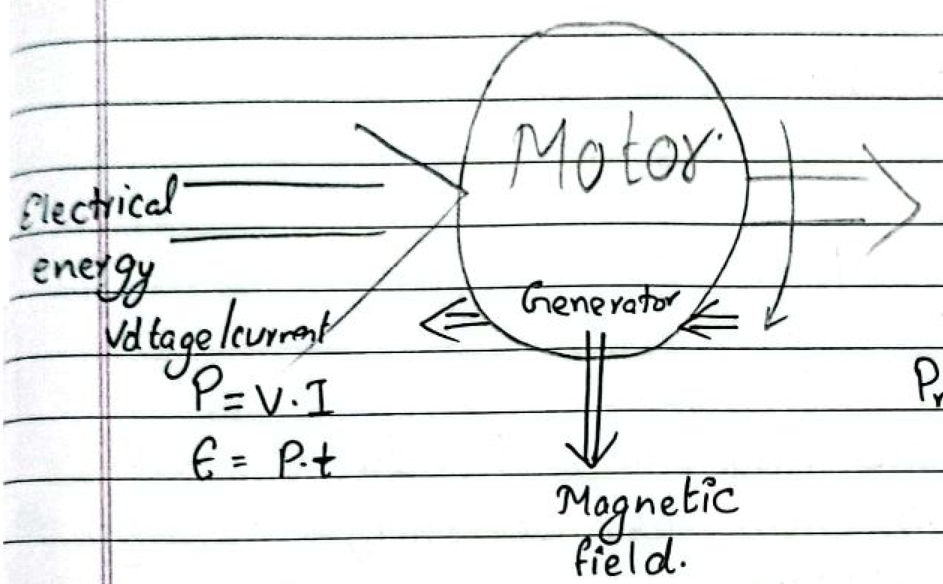
$Q_A = V_{\phi A} \cdot I_{\phi A} \cdot \sin\phi_A$

$= 201.61$ VAR

$S = P_A + j\,Q_A$

$= 260.1 + 201.61j$

ELECTRICAL MACHINES.

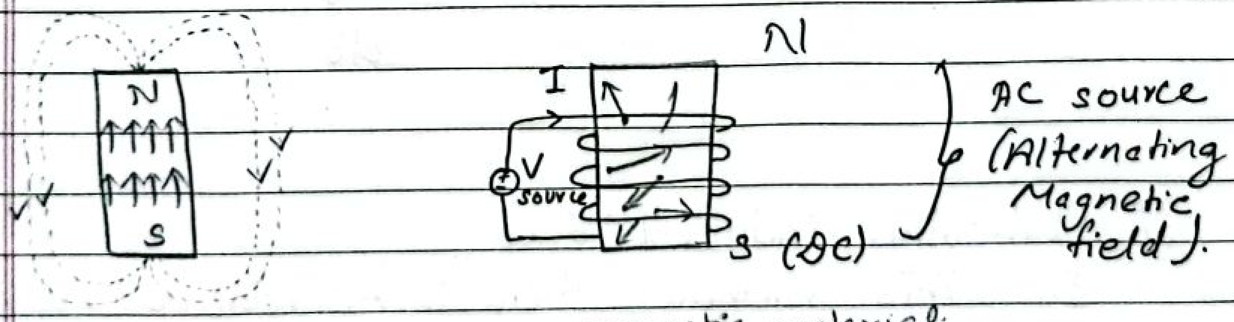


$P = V \cdot I$

$E = P \cdot t$

$P_m = \text{Torque} \times \omega$
$= \text{Torque} \times (2\pi n)$
$= \text{Torque} \left(2\pi \frac{N}{60}\right)$

Magnetic field : Magnetic field is the phenomenon by which energy is converted from one form to another form in Motor, Generator, Transformer.



permanent magnet

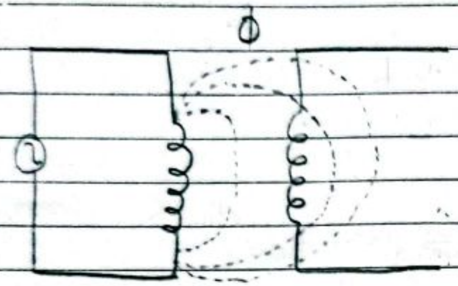
magnetic material

* Faraday's law

In 1821 A.D, Micheal faraday, formulated the basic two laws underlying the phenomenon of electromagnetic induction.

Those two laws are :-

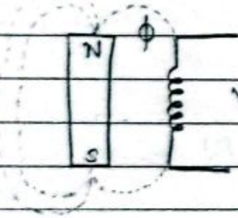
1st law : Whenever the magnitude of magnetic flux linking with a coil changes w.r.t time an emf will be induced in the coil.



$V_{ind} = emf.$

2nd law: The magnitude of induced emf is equal to the rate of change of magnetic flux linkage.

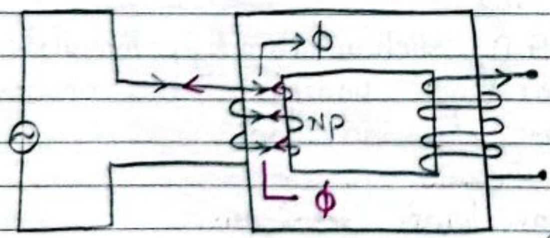
i.e $emf = V_{ind} = -N\dfrac{d\phi}{dt}$



$V_{ind} = emf = -N \cdot \dfrac{d\phi}{dt}$

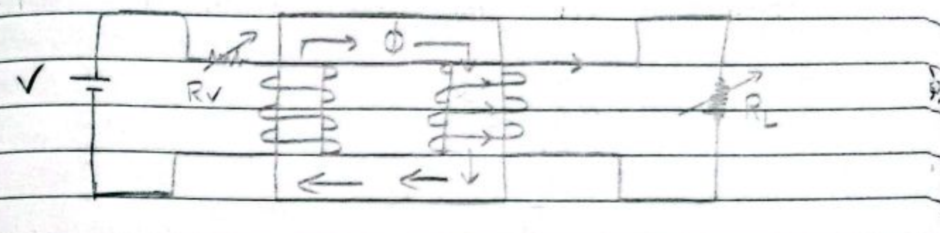
i. Statically induced emf

In this method there is no relative motion between conductor and magnet.



$emf = V_{ind}$

fig. Transformer

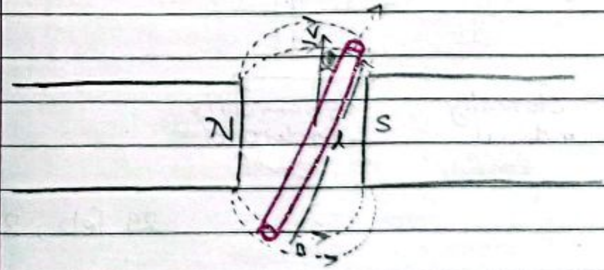


The direction of statically induced emf is given by Lenz's law.

"According to Lenz's law, the statically induced emf will drive the current in such a direction that the magnetic flux due to the induced current will oppose the cause by which emf was induced."

ii) Dynamic induced emf.

In this method there is relative motion between the conductor and the magnet.



$$Emf = V_{ind} = B \cdot l \cdot V \sin\theta$$

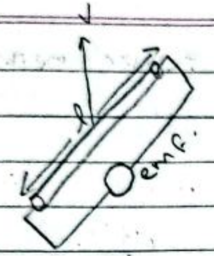
$$\theta = 90^\circ$$

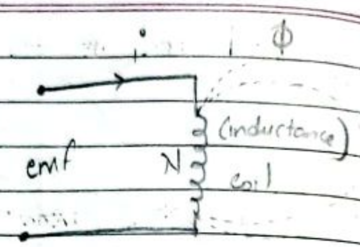
$$V_{ind\,(max)} = B \cdot l \cdot V$$

where, B = magnetic field density

l = length of coil

V = relative velocity of coil.





$L = \frac{N \cdot \phi}{i}$, unit Henry

Now,

$N \cdot \phi = L \cdot i$

Diff both side w.r.t time.

$$\frac{d(N \cdot \phi)}{dt} = \frac{d(Li)}{dt}$$

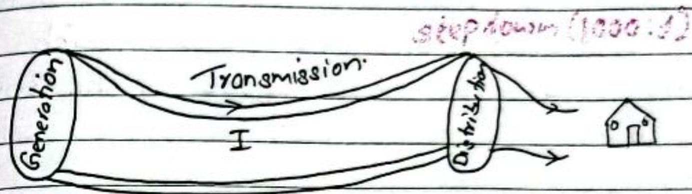
$$N \cdot \frac{d\phi}{dt} = L\frac{di}{dt} + i \cdot \frac{dL}{dt}$$

$$emf = \underbrace{L \cdot \frac{di}{dt}}_{\text{statically induced emf}} + \underbrace{i \cdot \frac{dL}{dt}}_{\text{dynamically induced emf}}$$

29 feb, 2024

Transformer

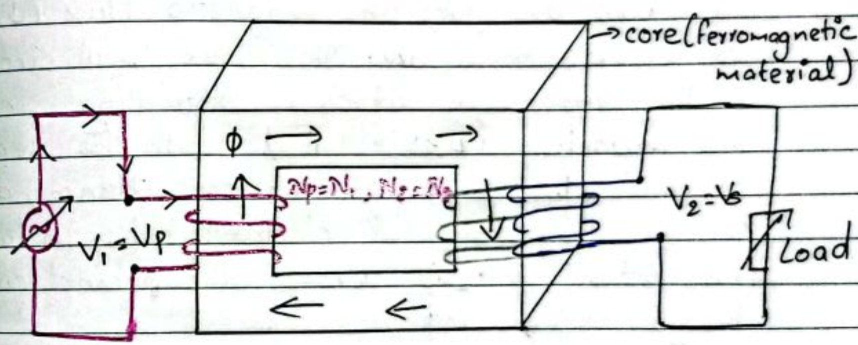
A transformer is a device which is used to step-up voltage than that of generating voltage to achive economical transmission and to step-down those dangerous high voltage level to suitable standard voltgges to achieve softey distribution, it is static device and used to transfer power between two circuits by mutual induction.



step up (1:1000)

$R_{copper} = \frac{S \cdot l}{A}$

Construction



Primary coil ($N_1 = N_p$)

Secondary coil ($N_2 = N_s$)

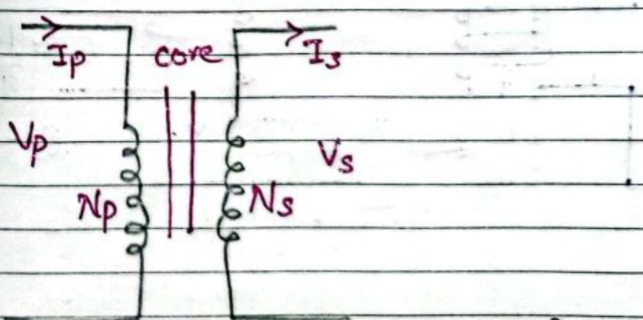
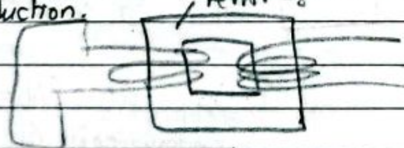


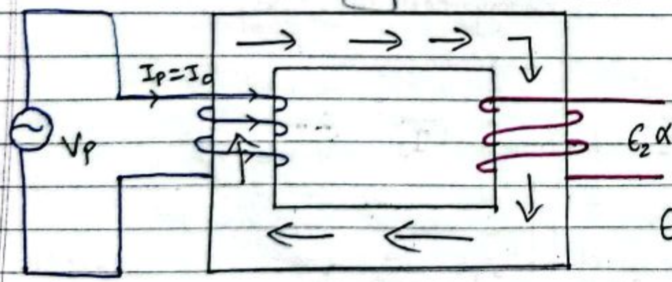
fig: Symbol of Transformer.

Working power principle and emf equation of transformer

Basically a transformer consists of a ferromagnetic core and two separated coils which are wound in the two limbs of the core. The coils made of copper and insulated with insulating materials.

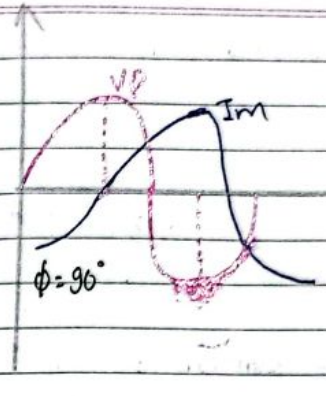
When the coil is supplied by AC voltage the coil will draw some current (say I_0), let us assume that the coil is purely inductive. Hence current lags the voltage by 90°. The wave form of voltage and current are shown below. The core will pass the magnetic flux (ϕ) through its cross-sectional area. This flux will circulates in the ~~cross~~ core which is alternating in nature. The magnetic flux is linked with the second coil on the other limb of the core. Hence, according to Faraday's law of electromagnetic induction, emf (E_2) will induced across the second coil, through mutual induction.

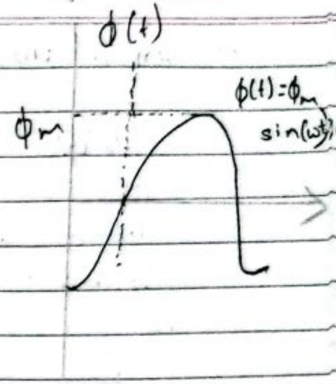




$E_2 \propto \frac{d\phi}{dt}$,

$E_2 = N_2 \frac{d\phi}{dt}$





emf equation:

$$E_2 = -N_2 \cdot \frac{d\,\phi(t)}{dt}$$

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

$$E_2 = -N_2 \cdot \frac{d\ \phi_m \sin(\omega t)}{dt}$$

$$E_2 = -N_2 \cdot \omega \cdot \phi_m \cos(\omega t)$$

$$E_2 = N_2 \cdot \omega \cdot \phi_m \sin(\omega t - 90°)$$

$$E_{2(peak)} = N_2 \omega \cdot \phi_m$$

$$E_{2(rms)} = \frac{E_{2(peak)}}{\sqrt{2}} = \frac{N_2 \cdot \phi \cdot \omega}{\sqrt{2}}$$

$$E_{2(rms)} = \frac{N_2 \cdot \phi\,(2\pi f)}{\sqrt{2}}$$

$$\boxed{E_{2(rms)} = 4.44 F \phi \cdot N_2} \quad \cdots\cdots ①$$

$$E_{1(rms)} = 4.44 f \phi \cdot N_1 \quad \cdots\cdots ②$$

classmate
Date
Page

Turn Ratio (a):

$eq^n ② \div eqn ①$

$$\frac{\mathcal{E}_{1(rms)}}{\mathcal{E}_{2(rms)}} = \frac{N_1}{N_2}$$

$$\frac{\mathcal{E}_1}{\mathcal{E}_2} = \frac{N_1}{N_2} = \text{turn ratio}$$

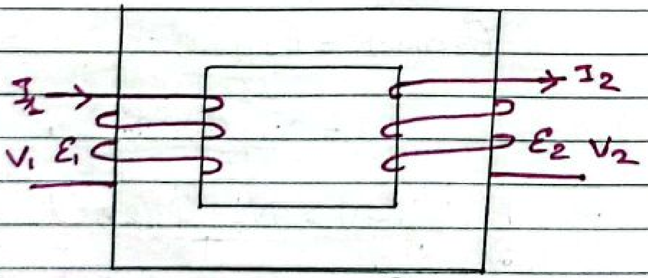
Voltage Transformation ratio (k).

$eq^n ① \div eqn ②$

$$\frac{\mathcal{E}_{2(rms)}}{\mathcal{E}_{1(rms)}} = \frac{N_2}{N_1} = K.$$

$$\therefore \boxed{a = \frac{1}{K}}$$

Current Ratio :



$P_{in} = I_1 \cdot \mathcal{E}_1 = P_{out} = I_2 \cdot \mathcal{E}_2$

(ideal transformer)

classmate
Date
Page

$$\mathcal{E}_1 I_1 = \mathcal{E}_2 \cdot I_2$$

$$\frac{\mathcal{E}_1}{\mathcal{E}_2} = \frac{I_2}{I_1}$$

$$\frac{\mathcal{E}_1}{\mathcal{E}_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1}$$

Different types of transformer.

a) Phase → 1ϕ, $3\text{-}\phi$

b) Core → Rectangular / square, Shell type

c) Application → step up transform, step down transformer, isolation transformer

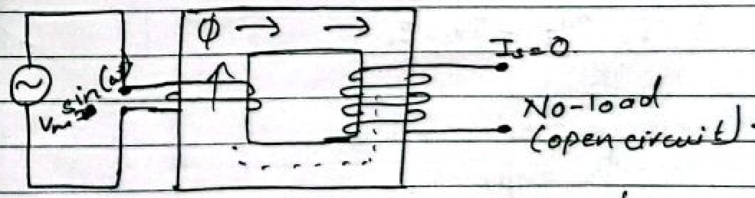
Step up: $N_1 \} \{ N_2$ $N_2 > N_1$

Step down: $N_1 \} \{ N_1$ $N_1 > N_2$.

Isolation: $N_1 \} \{ N_2$

$N_1 = N_2$

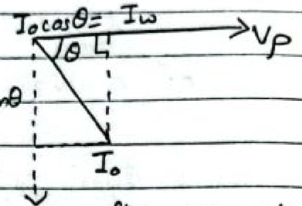
No-load operation of transformer.



(magnetize, no heat)

At no-load, transformer draw some current I_o which is known as no-load primary current.

heat form

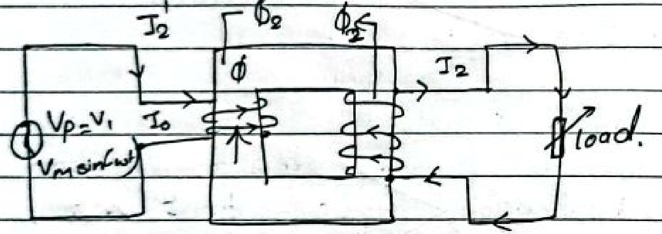


$I_w = I_o \cos\theta$ (loss component)

$I_m = I_o \sin\theta$ (magnetization component) $I_m = I_o \sin\theta$

magnetic flux generate

* Load operation



at No load : $V_2 I_2 = 0$ but input is $V_1 \cdot I_o$ (which is power less at No-load).

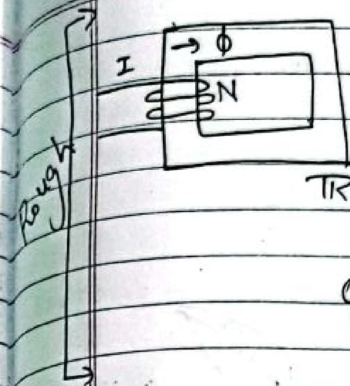
at Load :

$$V_1 \cdot I_2' = V_2 \cdot I_2$$

$$\frac{V_1}{V_2} = \frac{I_2}{I_2'} = \frac{N_1}{N_2}$$

$$\frac{I_2 \cdot N_2}{TR} = \frac{N_1 \cdot I_1}{TR}$$

$$\phi_2 = \phi_2'$$



$V = I \cdot R$

R- Resistance

TR- Reluctance.

$I = V/R = emf/R$

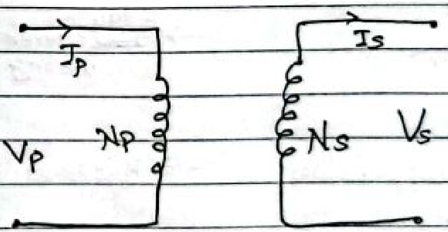
$TR = \frac{l}{\mu A}$ $\quad R = S \cdot l/A$.

$$\phi = flux = \frac{mmf}{TR} = \frac{N \cdot I}{TR}$$

ϕ_2, ϕ_2' are equal and opposite in direction. Hence, the net magnetic flux in the core is always remain constant at any load and is equal to ϕ.

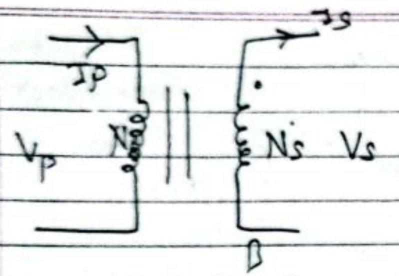
* Ideal Transformer

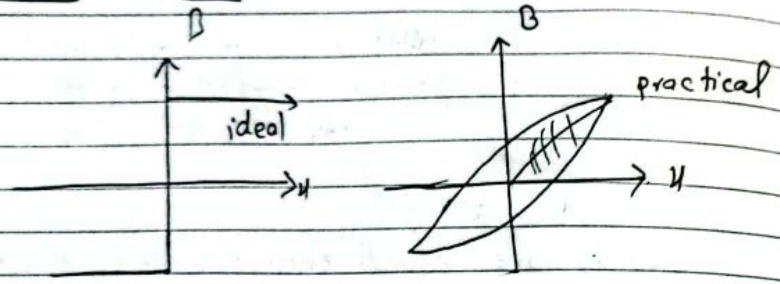
Such type of transformer which has purely inductive windings without any resistance, No magnetic leakage flux and 100% efficient is known as ideal transformer.



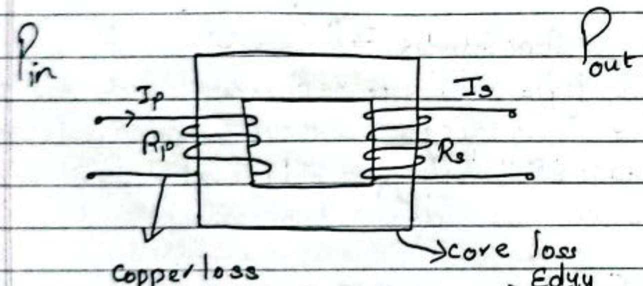
* Practical Transformer.

Such type of transformer which has not purely inductive windings and has resistance, magnetic leakage and not 100% efficient is known as practical / real transformer.





* Losses and efficiency.



→ primary copper loss

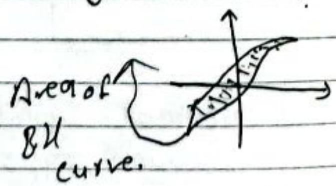
$I_p^2 \cdot R_p$

→ secondary copper loss

$I_p^2 \cdot R_s$.

→ ~~and~~ Edyy current loss
circulating current

→ Hysteresis loss.



$$\eta = \frac{P_{out}}{P_{in}} \times 100\%$$

$$= \frac{P_{out}}{P_{out} + P_{losses}} \times 100\%.$$

$$= \frac{P_{out}}{P_{out} + \underbrace{P_{coreloss}}_{\text{constant}} + \underbrace{P_{copperloss}}_{\text{variable loss}}} \times 100\%.$$

$$= \frac{P_{out}}{P_{out} + P_{const} + I_s^2 \cdot R_{eq}}.$$

$$\eta = \frac{V_s \cdot I_s}{V_s I_s + P_{const} + I_s^2 R_{eq}}.$$

$$\frac{d\eta}{dI_s} = 0 \Rightarrow \text{max}^m \text{ condition}.$$

$$\frac{V_s \cdot I_s (V_s + 0 + 2 \cdot I_s R_{eq}) - (V_s I_s + P_{const} + I_s^2 R_{eq}) V_s}{(V_s \cdot I_s + P_{const} + I_s^2 \cdot R_{eq})^2} = 0$$

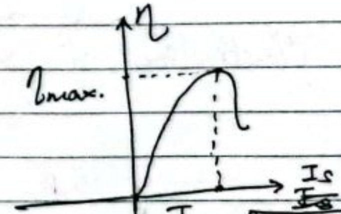
$$V_s I_s + 2 I_s^2 \cdot R_{eq} - V_s \cdot I_s - I_s^2 R_{eq} - P_{const} = 0.$$

$$2 I_s^2 \cdot R_{eq} - I_s^2 R_{eq} - P_{const} = 0.$$

$$I_s^2 R_{eq} = P_{const}.$$

$\cancel{P_{const}}$.

$$P_{copper\ loss} = P_{core}$$



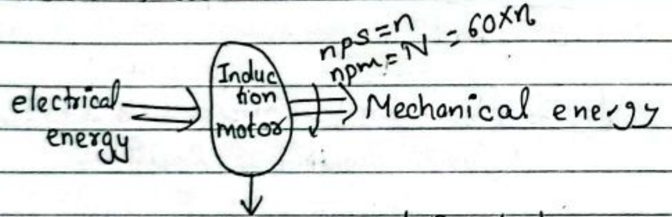
$$I_s = \sqrt{\frac{P_{core}}{R_{eq}}}$$

Date 03-07.

Application of Transformer

- It is used by power generation to increase the voltage level.
- It is used in transmission and distribution of power system.
- Transformer are used in audio system to increase or decrease the voltage of electricity before it is sent to speaker.
- Transformer are used in a variety of electronic devices, including computers, TV, radios of cell phones.

Induction Motor



principle is based faraday's law of electromagnetic induction.

$\varepsilon_e = P.t$

$P = V_{AC} \cdot I_{AC}$

1-ϕ 3ϕ

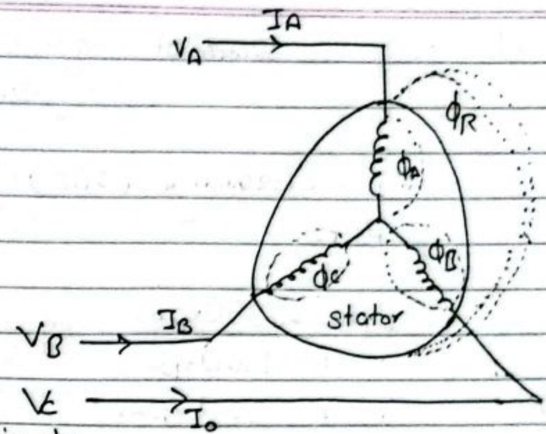
$= P_m \times t$

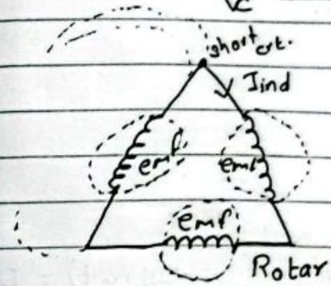
$P_m = \text{Torque} \times \omega$

$= T \times (2\pi n)$

$= T \times \left(2\pi \frac{N}{60}\right)$

Construction of 3-ϕ IM

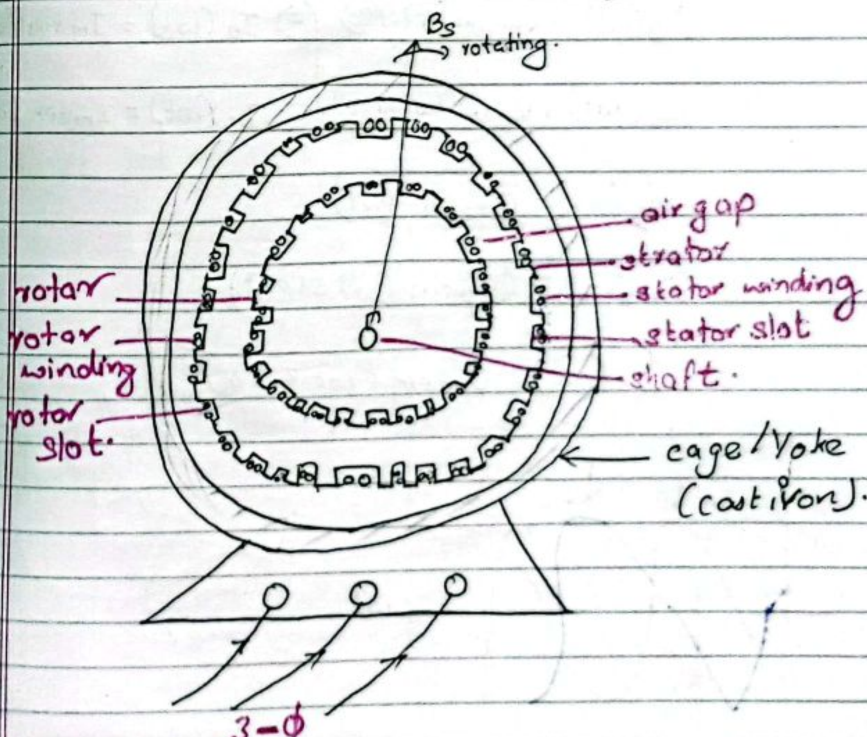




$\text{Torque} = K \cdot (B_S \times B_R)$.

stator magnetic field

Rotor magnetic field.



$N_s = \frac{120f}{P}$ ⇒ speed of magnetic field or Synchronous speed

where, f = frequency (50z)
P = pole

2 pole = 3000 rpm.
4 pole = 1500 rpm
8 pole = 750 rpm

Rotating Magnetic field.

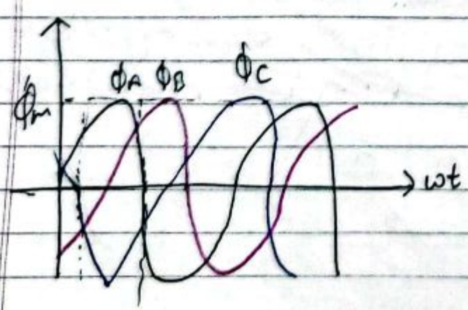
Stator input 3-ϕ

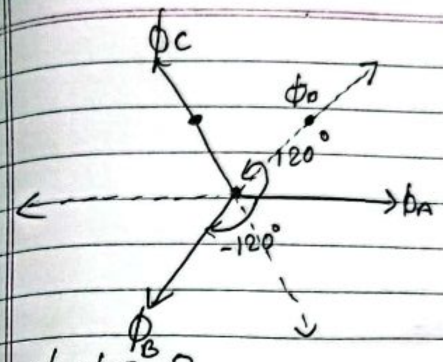
$$\left.\begin{aligned} V_A(\omega t) &= V_m \sin(\omega t) \\ V_B(\omega t) &= V_m \sin(\omega t - 120^\circ) \\ V_C(\omega t) &= V_m \sin(\omega t + 120^\circ) \end{aligned}\right\} \Rightarrow \begin{aligned} I_A(\omega t) &= I_m \sin(\omega t) \\ I_B(\omega t) &= I_m \sin(\omega t - 120^\circ) \\ I_C(\omega t) &= I_m \sin(\omega t + 120^\circ) \end{aligned}$$

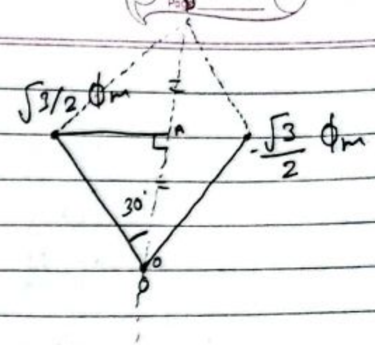
$\phi_A(\omega t) = \phi_m \sin(\omega t)$

$\phi_B(\omega t) = \phi_m \sin(\omega t - 120^\circ)$

$\phi_C(\omega t) = \phi_m \sin(\omega t + 120^\circ)$







at $\omega t = 0$

$\phi_A = 0$ $\quad$ $O_B = 2\,O_A$

$\phi_B = \frac{\sqrt{3}}{2}\phi_m$ $\quad$ $= 3$

$= 1.5$ $\quad$ $\phi_C = \frac{\sqrt{3}}{2}\phi_m$.

$\phi_R = 2\frac{\sqrt{3}}{2}\phi_m \cos 30^\circ$

$= 2 \cdot \frac{\sqrt{3}}{2}\phi_m \times \frac{\sqrt{3}}{2}$

$\phi_R = 1.5\,\phi_m$ //

at $\omega t = 120$

$O_A = \sqrt{3}/2\, \phi_m \cdot \cos 30^\circ$

$O_B = 2 \cdot O_A$

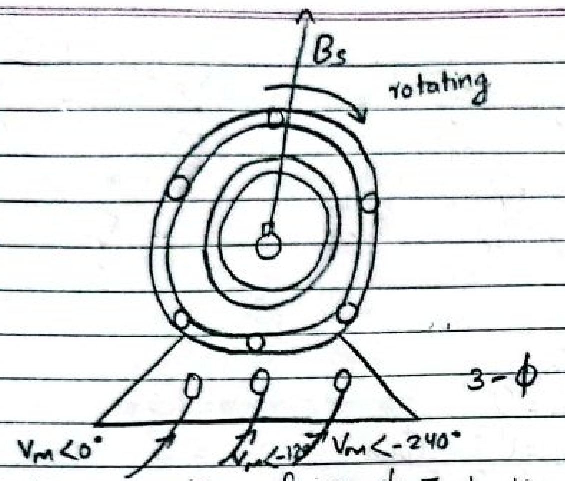
$\phi_R = O \cdot B$

$= 2 \cdot \frac{\sqrt{3}}{2}\phi_m \cdot \cos 30^\circ$

$\phi_R = 1.5\,\phi_m$

Similarly for every ωt : $\phi_R = 1.5\,\phi_m$.

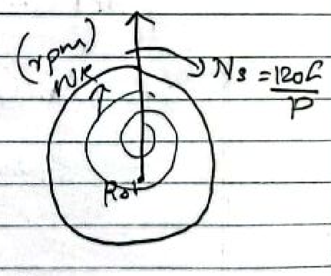
14. March



Working operation of 3-ϕ Induction Motor.

1. When we supply 3-ϕ input to the sator, there is production of rotating magnetic field which cuts the rotor winding and voltage induced in the rotor winding.
2. Due to the fact that rotor windings are short circuted, current will flow in the rotor winding.
3. The rotor current produces another magnetic field.
4. The torque is produced as a result of the interaction of these two magnetic fields i.e.

$$T_{ind} = K \cdot (B_s \times B_R)$$



Slip speed $= N_s - N_R$

$$\text{Slip } (s) = \frac{N_s - N_R}{N_s}$$

$$\text{Slip } (s)\% = \frac{N_s - N_R}{N_s} \times 100\%$$

N_R = Variable (because it depends on load).

Stator frequency.

$$f = \frac{N_s \cdot P}{120} \quad \text{--- (i)}$$

Rotor frequency

$$f_r = \frac{(N_s - N_R) \cdot P}{120} \quad \text{--- (2)}$$

eqn (2) ÷ eqn (1)

$$\frac{f_r}{f} = \left(\frac{N_s - N_R}{N_s}\right) = s$$

$$\boxed{f_r = s.f.}$$

rotor, stator

$$\text{slip} = \frac{N_s - N_R}{N_s}.$$

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

e.g. What will be the speed of rotor if the pole of stator is 6 and frequency 50Hz and rotor frequency is 120 cycle per minute.

Soln :-

$f_r = 120$ cycle/min

$= 120/60$

$= 2Hz.$

$\therefore s = \frac{f_r}{f} = \frac{2}{50} = 0.04$

$N_s = \frac{120 \times 50}{6}$

$= 1000$ ~~RPM~~ rpm.

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

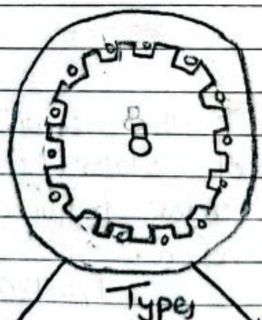
$0.04 = \frac{1000 - N_R}{1000}$

$40 = 1000 - N_R$

$\therefore \boxed{N_R = 960 \text{ rpm}}$

Rotor

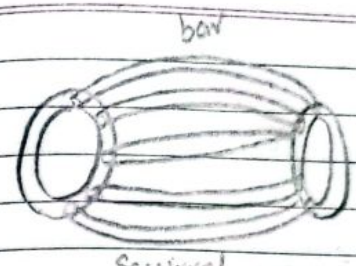
Rotor is a hollow laminated core having slots and copper winding which is mounted on the shaft.

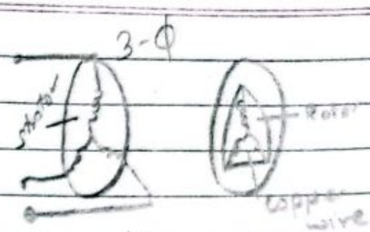


Types

Squirrel cage rotor (In this copper or aluminium bars are placed on the rotor slot).

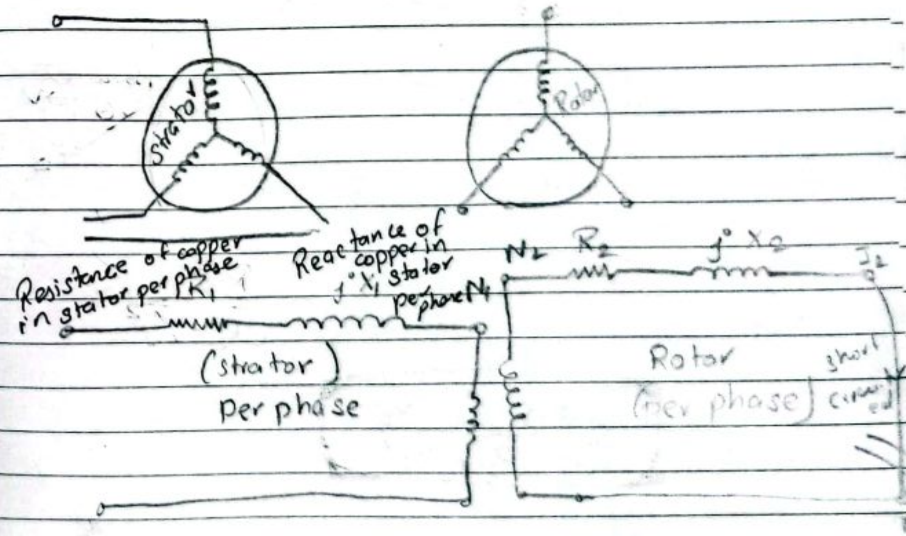
Wound rotor or slip-ring rotor (In this rotor contains windings similar to the stator)





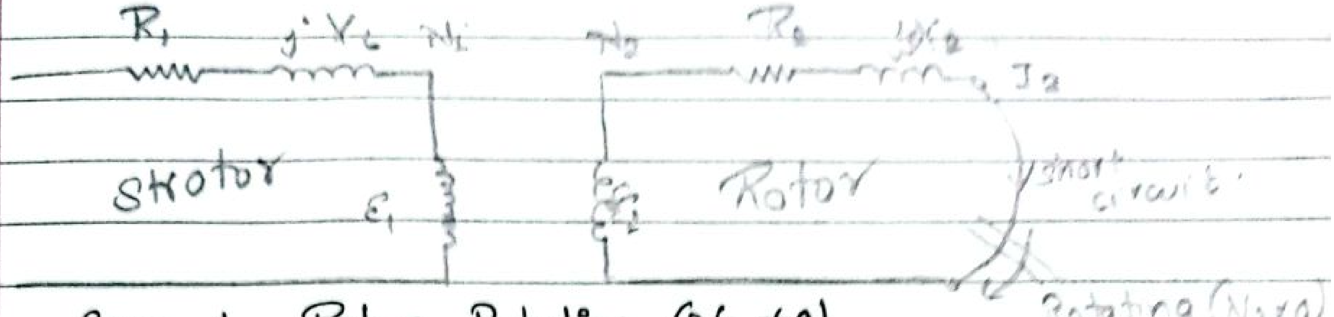
- It is economical & simpler.	It is costly.
- It is rugged, so requires less maintenance.	Needs more maintainance.
- Torque cannot be controlled	Torque can be control by using external resistance.
- Speed cannot be controlled.	Speed can be control by using external resistance

Equivalent Circuit Model of 3-ϕ IM.



Date 16 March

Equivalent circuit Model of IM



Case 1 Rotor Rotating ($N_R \neq 0$)

$$S = \frac{N_S - N_R}{N_S}$$

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

i) Voltage Equation :

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

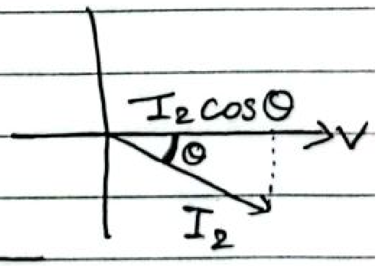
ii) Current equation :

$$I_2 = \frac{S \cdot E_2}{R_2 + j(SX_2)} , \quad |I| = \frac{S \cdot E_2}{\sqrt{R_2^2 + (SX_2)^2}}$$

$$p.f = \cos\theta = \frac{R_2}{\sqrt{R_2^2 + (SX_2)^2}}$$

iii) Torque

$$T = K(B_S \times B_R)$$



$$= K \cdot E_2 \frac{S E_2}{\sqrt{R_2^2 + (SX_2)^2}} \times \frac{R_2}{\sqrt{R_2^2 + (SX_2)^2}}$$

$$\boxed{T_{(\text{rotating})} = \frac{K \cdot S\, E_2^2 \cdot R_2}{R_2^2 + (SX_2)^2}}$$ //

Condition for maximum ~~force~~ torque :

$$\frac{dT}{ds} = 0$$

$$\frac{K \cdot s\, E_2^2 R_2 \,(0 + 2sX_2^2) - (R_2^2 + s^2 X_2)\, K \cdot E_2^2 \cdot R_2}{(R_2^2 + (sX_2)^2)^2} = 0$$

or, $s(2sX_2^2) - (R_2^2 + s^2 X_2^2) = 0$

or, $2s^2 X_2^2 - R_2^2 - s^2 X_2^2 = 0$

or, $S^2 X^2 - R_2^2 = 0$

or, $s^2 = \frac{R_2^2}{X_2^2}$

$\therefore \boxed{s = \frac{R_2}{X_2}}$ $X_2 > R_2$ [So, the value of s is less than 1].

$T_{Rotating} = \frac{K \cdot s\, E_2^2 \cdot R_2}{R_2^2 + s^2 + X_2^2}$

if $R_2^2 >>> (sX_2)^2$, if $R_2^2 <<< (sX_2)^2$

$T_R = \frac{K \cdot s \cdot E_2^2 \cdot R_2}{R_2^2}$, $T_R = \frac{k \cdot s \cdot E_2^2 \cdot R_2}{s^2 X_2^2}$

$\therefore T_R \propto S$ $\therefore T_R \propto \frac{1}{s}$

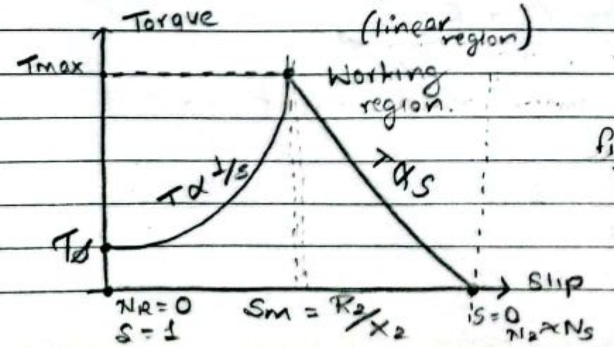
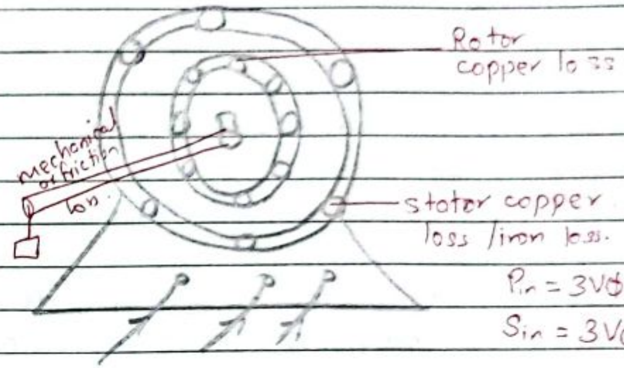


fig: Tourque-Slip X-tics

losses and efficiency:



$P_{in} = 3V_\phi \cdot I_\phi \cdot \cos\phi$ (watt)

$S_{in} = 3V_\phi \cdot I_\phi$ (VA)

$\boxed{P_{in}\,(stator)} - \boxed{\text{Stator loss or iron loss}} = \boxed{P_{in}\ Rotor} - \boxed{\text{Rotor copper loss}} = \boxed{P_{in}\ shaft} - \boxed{\text{Mechanical or friction loss}} = \boxed{P_{mech}\ Power}$

Strator ⟷ Rotor ⟷ $P_{mechanical}$.

$\eta_{Total} = \frac{P_{mech}}{P_{in}(stator)} \times 100\%$

$\eta_{stator} = \frac{P_{in}(rotor)}{P_{in}(stator)} \times 100\%$

$\eta_{rotor} = \frac{P_{in}(shaft)}{P_{in}(rotor)} \times 100\%$.

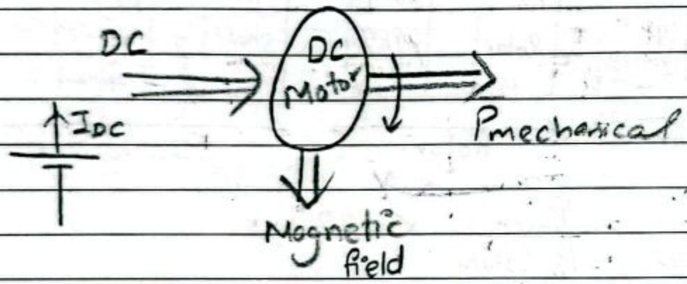
Applications of 3-ϕ IM:

i) Electric train engine
ii) Used as cooling fan.
iii) Printing machines
iv) Rolling mills
v) In water pump motor

vi) In hydrulic for pumping the fluid.
vii) Drilling machine.
viii) Motor or refrigerator /washing machine
ix) Cooler motor
x) Industrial Drives
xi) Agricultural and industrial pump.

Q-3 DC Motor

It is an electro-mechanical devices which converts DC electrical power to mechanical power.



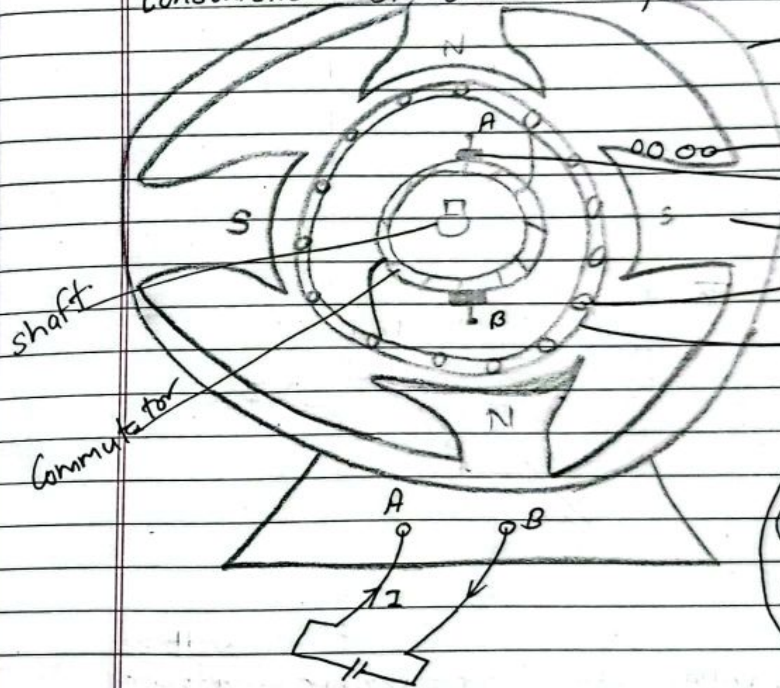
DC Motor Principle :

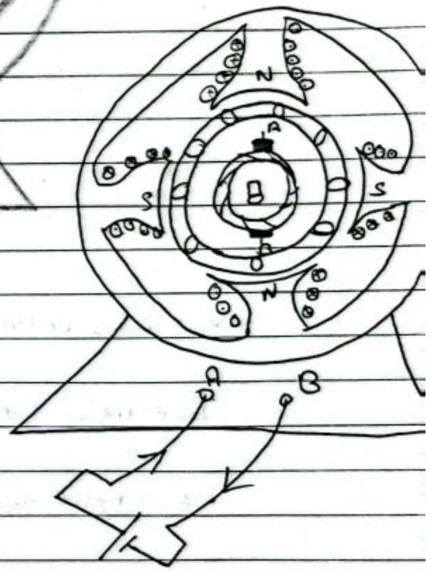
It's action is based on the principle that when a current carrying conductor is placed in a magnetic field, it experiences a mechanical force whose direction is given by Fleming's left hand rule and whose magnitude is given by

$$\boxed{F = BIL \sin\theta}$$

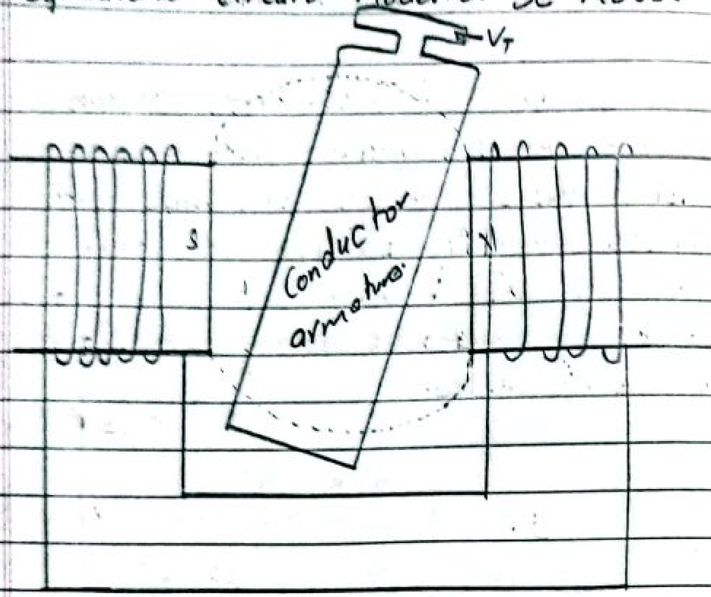
$\theta = 0^\circ$
$F_{min} = 0$
$\theta = 90^\circ$
$F_{max} = BIL$

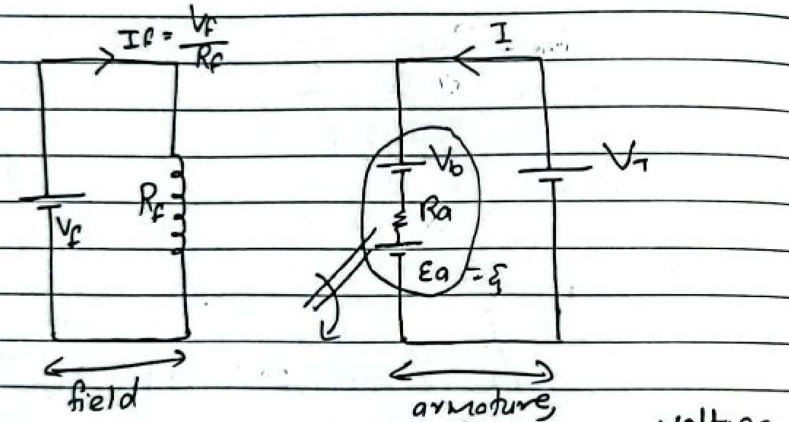
Construction of different parts of DC Motor.





Equivalent circuit Model of DC Motor.





V_f = field voltage $\quad$ V_T = terminal ~~velocity~~ voltage

I_f = field current $\quad$ V_b = brush voltage drop

R_f = field resistance $\quad$ R_a = armature resistance

(E_a, E_b = Back emf)

Back emf or armature Voltage (E_a, E_b)

When the armature of a DC motor rotates under the influence of the driving torque, the armature conductors move through the magnetic field and hence emf is induced in them as in a generator. The induced emf acts in opposite direction to the applied voltage V_T and is known as back emf i.e E_b.

$$E_a = \frac{d\phi}{dt} \quad \text{where, } d\phi = P.\phi \quad (P = \text{pole},\ \phi = \text{flux})$$

$$dt = 60/N \text{ (rpm)}$$

$$E_a = \frac{P.\phi}{60/N} = \frac{P.\phi.N}{60}$$

where,
P = pole
ϕ = flux
N = no. of revolution per min (rpm).

if there are Z no. of conductor

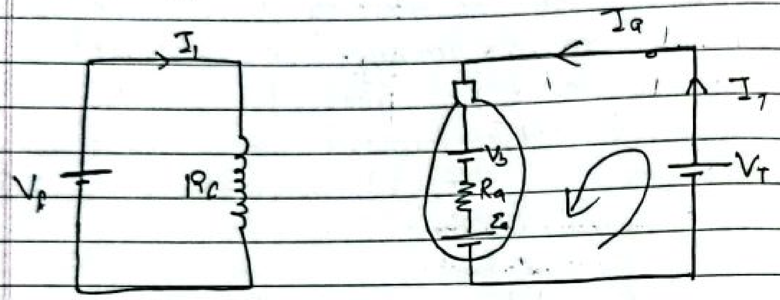
$$E_a = \frac{P.\phi.N}{60} \times (Z)$$

Lap winding: $E_a = \frac{P.\phi.N}{60} \times \left(\frac{Z}{P}\right)$

Wave winding: $E_a = \frac{P.\phi.N}{60} \times \left(\frac{Z}{2}\right)$

Different type of DC Motor.

a Separately Excited DC Motor.



$V_f = I_f R_f$

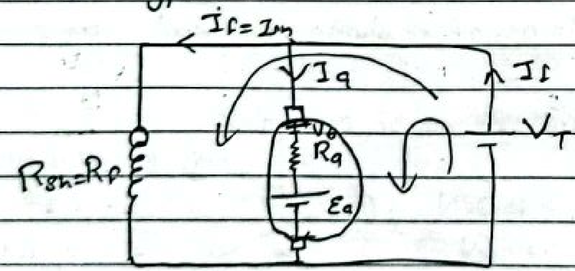
$I_T = I_a$ (KCL)

$I_f = \frac{V_f}{R_f}$

$V_T = \underbrace{V_b}_{\text{brush voltage}} + \underbrace{I_a R_a}_{\text{armature copper voltage drop}} + \underbrace{E_a}_{\text{armature or back emf}}$

b. Self Excited DC Motor.

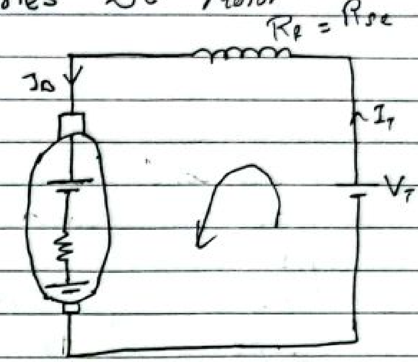
i) Shunt type: DC Motor.



$I_T = I_{sh} + I_a$

$V_T = V_b + I_a R_a + E_a$

ii) Series DC Motor

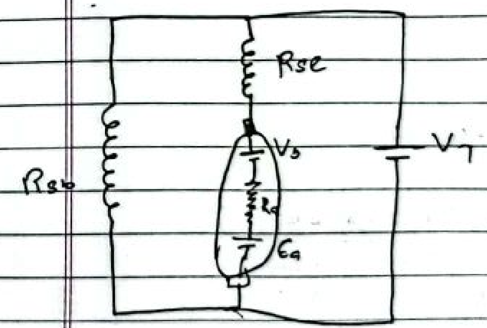


$I_T = I_{se} = I_a$

$V_T = I_{se} \cdot R_{se} + V_b + I_a R_a + E_a$.

iii) Compound type. DC motor.

1) long shunt :

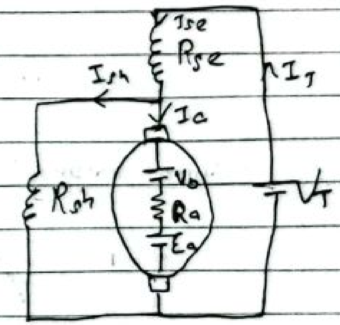


Current $\begin{cases} I_a = I_{se} \\ I_T = I_{se} + I_{sh} \end{cases}$

$V_T = I_{se} R_{se} + V_b + I_a R_a + E_a$

$V_T = I_{sh} \cdot R_{sh}$.

Short shunt



$I_T = I_{se}$

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

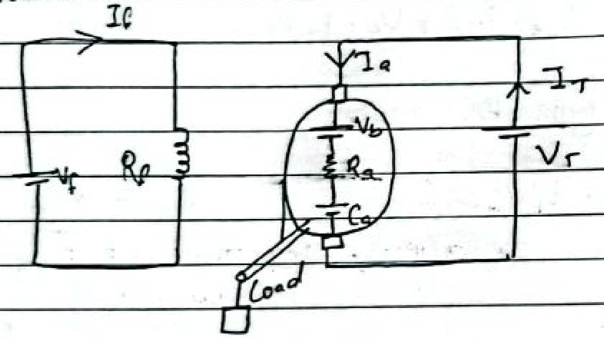
$V_T = I_{se} R_{se} + V_b + I_a R_a + E_a$

$V_T = I_{se} \cdot R_{se} + I_{sh} \cdot R_{sh}$

Torque of DC Motor

Toque is produced around the circumference of rotor starts rotating in the conductors which lie near the surface of the rotor at a common radius from its centre.

In motor torque is transsferred to the shaft of the rotor and drives the material load.



$V_T = V_b + I_aR_a + E_a$, $I_T = I_a$

multiplying with I_T

$$V_T \cdot I_T = \underbrace{I_T \cdot V_b}_{\text{power in brush (sparking)}} + \underbrace{I_a^2 \cdot R_a}_{\text{armature copper loss}} + \underbrace{I_a \cdot E_a}_{\text{armature power}}$$

P_{in}

if there is no mechanical loss.

$P_m = T \cdot \omega$ ---- (1)

$P_{armature} = I_a \cdot E_a$

$T\omega = I_a \cdot E_a$

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

$E_a = \frac{\phi \cdot P \cdot N}{60} \left(\frac{Z}{A}\right)$

A → 2 (wave), P (lap)

$T = \frac{\phi \cdot P \cdot N}{60} \times \left(\frac{Z}{A}\right) \times \frac{I_a}{2\pi N/60}$

$T = \frac{\phi \cdot P}{2\pi} \left(\frac{Z}{A}\right) \times I_a$

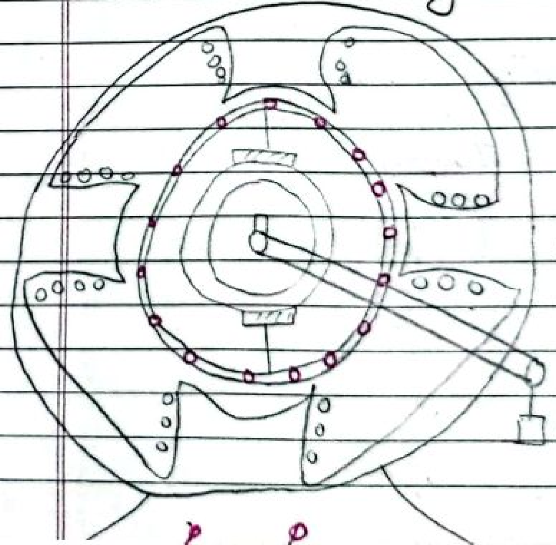
$T = \frac{\phi \cdot P}{2\pi} \left(\frac{Z}{A}\right) \times I_a$

$\boxed{T \propto \phi \cdot I_a}$

Torque is directly proportion to ϕ of armature current.

21 March.

Loses and efficiency of DC Motor.



⇒

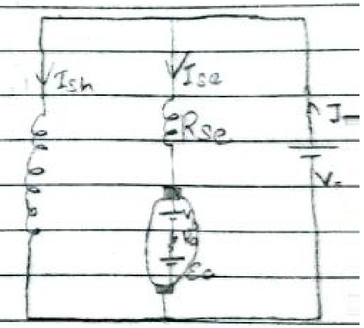


Fig Equivalent Circuit Model of long shunt compound DC Motor

There are three different types of losses.

i) Copper loss
→ Armature copper loss $(I_a^2 \cdot R_a)$
→ Series copper loss $(I_{se}^2 \cdot R_{se})$
→ Shunt copper loss $(I_{sh}^2 \cdot R_{sh})$.

ii) Magnetic loss / Iron loss / core loss / constant loss
→ Hysteresis Loss
→ Eddy current Loss.

iii) Mechanical loss
→ frictional loss.
→ Windage loss.

$$\eta = \frac{P_{mechanical}}{P_{input}} \times 100\%$$

If there is no friction loss.

$P_{mech} = P_a = E_a \cdot I_a$

$$\eta = \frac{P_a}{P_{in}} \times 100\%$$
$$= \frac{P_a}{P_a + P_{losses}} \times 100\%.$$

Applications of DC Motor

i) Shunt DC Motor
→ where we need constant speed at no-load or full motor.
e.g: Lathes, drills, boring mills, spinning machines.

ii) Series DC Motor
→ where we need variable speed i.e speed is low and torque is high at starting and high speed and low torque.
eg: Electric traction train, cranes, elevators, air compressor, vaccum cleaner.

iii) Compound DC Motor.
→ They are used rarely in industry but if used they provide constant speed and high torque.
eg: Presses, shears, etc.

* Synchronous Generator

In industry and generation houses uses 99% of the Mega-watt synchronous generator as a turbine. It provides frequency regulation and voltage regulation. Synchronous generator are used as voltage control in powe stations

Synchronous generator have mainly three parts i.e.

a) Stator: It contains various part which ~~ind~~

There are three different types of losses.

i) Copper loss
→ Armature copper loss $(I_a^2 \cdot R_a)$
→ Series copper loss $(I_{se}^2 \cdot R_{se})$
→ Shunt copper loss $(I_{sh}^2 \cdot R_{sh})$.

ii) Magnetic loss / Iron loss / core loss / constant loss
→ Hysteresis loss
→ Eddy current loss.

iii) Mechanical loss
→ frictional loss.
→ Windage loss.

$$\eta = \frac{P_{mechanical}}{P_{input}} \times 100\%$$

If there is no friction loss.
$P_{mech} = P_a = E_a \cdot I_a$

$$\eta = \frac{P_a}{P_{in}} \times 100\%$$
$$= \frac{P_a}{P_a + P_{losses}} \times 100\%.$$

Applications of DC Motor.

i) Shunt DC Motor
→ where we need constant speed at no-load or full motor.
e.g: Lathes, drills, boring mills, spinning machines.

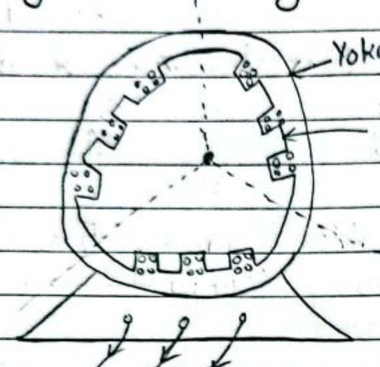
ii) Series DC Motor
→ where we need variable speed i.e speed is low and torque is high at starting and high speed and low torque.
eg: Electric traction train, cranes, elevators, air compressor, vaccum cleaner.

iii) Compound DC Motor.
→ They are used rarely in industry but if used they provide constant speed and high torque.
eg: Presses, shears, etc.

* Synchronous Generator
In industry and generation houses uses 99% of the Mega-watt synchronous generator as a turbine. It provides frequency regulation and voltage regulation. Synchronous generator are used as voltage control in power stations

Synchronous generator have mainly three parts i.e.
a) Stator: It contains various part which ~~ind~~

include the frame, stator core, stator windings and cooling arrangements.



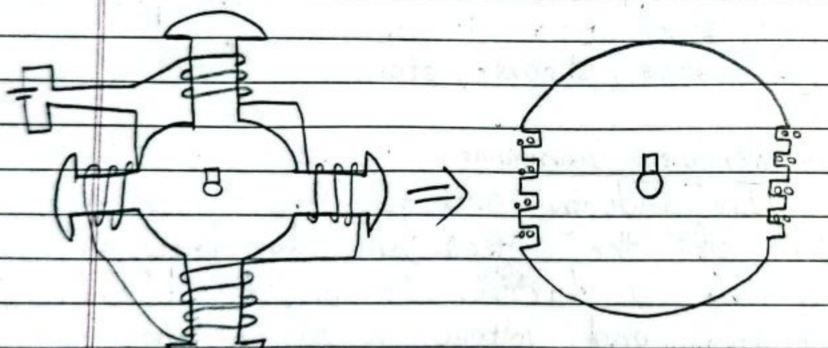
$N_s = \frac{120f}{P}$

if $f = 50Hz$, $P = 2$ pole

$N_s = \frac{120 \times 50}{2}$

electrical power generator (3-ϕ)

Rotor: It has exactly same rotor of IM but it has the rotating part with number of magnetic poles excited by DC source.

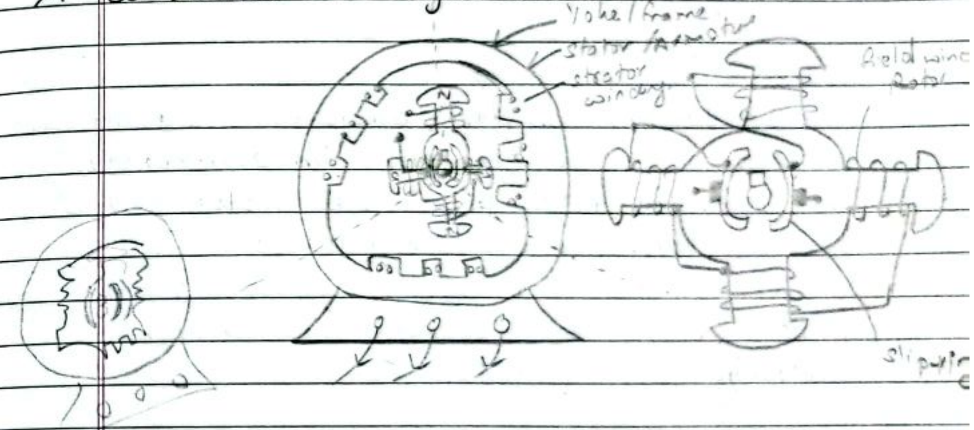


c) Excitor

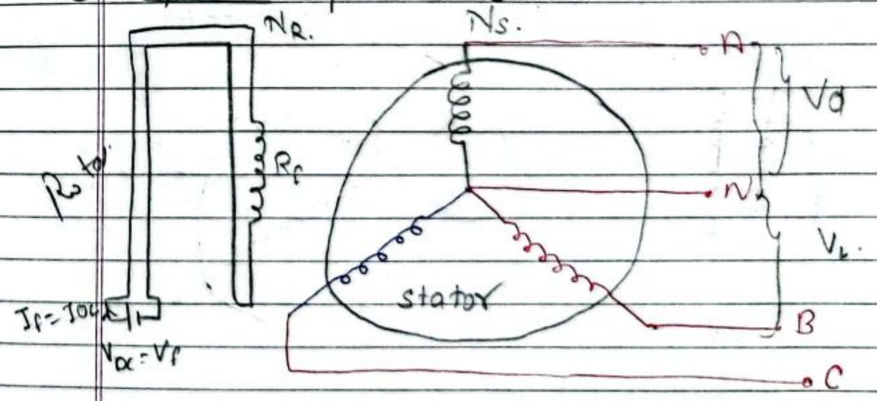
Excitor is a self excited DC generator mounded on the shaft of the generator or alternator. This provides DC current required to magnetize the magnetic poles of the rotor.

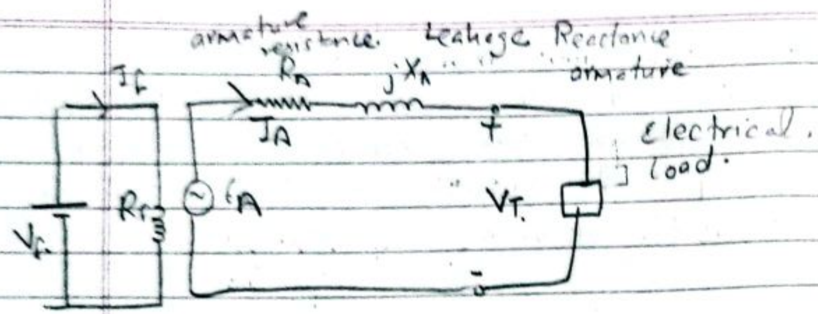
The DC current generated by the excitor is fed to the field winding of the alternator through the slip-ring and carbon-brush.

* Construction of Synchronous Generator.



~~Equation~~ Equivalent Circuit Model.





$$E_A = I_A R_A + I_A jX_A + V_T$$

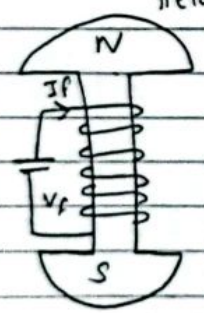
March. 23

Synchronous Generator

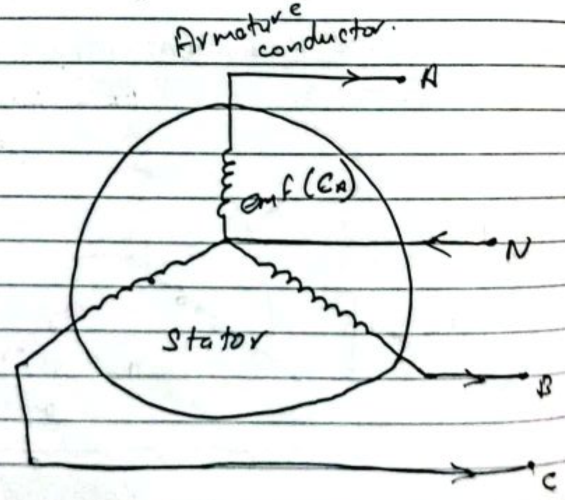
Working principle and emf equation.

It works on the principle of electromagnetic induction like DC generator. In synchronous generator, the field poles are rotating and armatur conductor (stator conductors) are stationary but in ~~Eth~~ DC generator, the field poles are stationary and armature conductors are rotating.

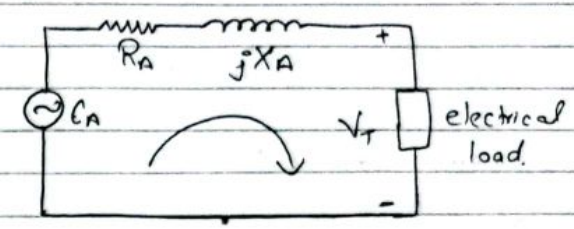
field.



Rotor.



Circuit diagram per phase.



$$\underbrace{E_A}_{\text{emf armature}} = \underbrace{I_a . R_a}_{\text{armature Resistance voltage}} + \underbrace{j\, I_a X_a}_{\text{leakage reactance voltage drop}} + \underbrace{V_T}_{\text{Terminal voltage}}$$

Average value of emf (E_A) $= \dfrac{d\phi}{dt}$

$$d\phi = P.\phi$$

$$dt = \frac{1}{n} - \text{rps}$$

$$= \frac{1}{N/60} - \text{rpm}$$

$$E_A = \frac{\phi . P}{60/N}$$

$$\boxed{E_a = \frac{\phi . PN}{60}}$$

$$E_A = \frac{\phi P}{60} \times \frac{120 f}{P}$$

$E_A = 2\phi . f$ (Avg. Value per conductor.)

if there are Z no. of conductor

$E_A = 2 \cdot \phi \cdot f \cdot Z$

where,

$Z = 2T$ [T = No. of turn of conductor.

$\boxed{E_A = 4 \cdot \phi \cdot f \cdot T}$

RMS value of S.G.

Rms value of S.G $E_{rms} = 4.44\ \phi f T$

$\boxed{E_{rms} = 4.44\ \phi f T}$

Application of Synchronous Generator

- Synchronous machines are used in modern societies like industry, commercial, agriculture and domestic sectors.
- SG usually operate together, forming a large power system supplying electrical energy to the loads or consumers
- SG are built in large unit's their rating ranging from 10 to 100 of mega watts.
- Smaller synchronous machines are sometimes used for (private generation) and as standy by units, with disel engines or gas turbines as prime mover.

- large unit of 10 to 100 megawatt
- small SG are used in private generation
- large power system supply electric energy
- used in modern society like industry, commercial, agriculture etc

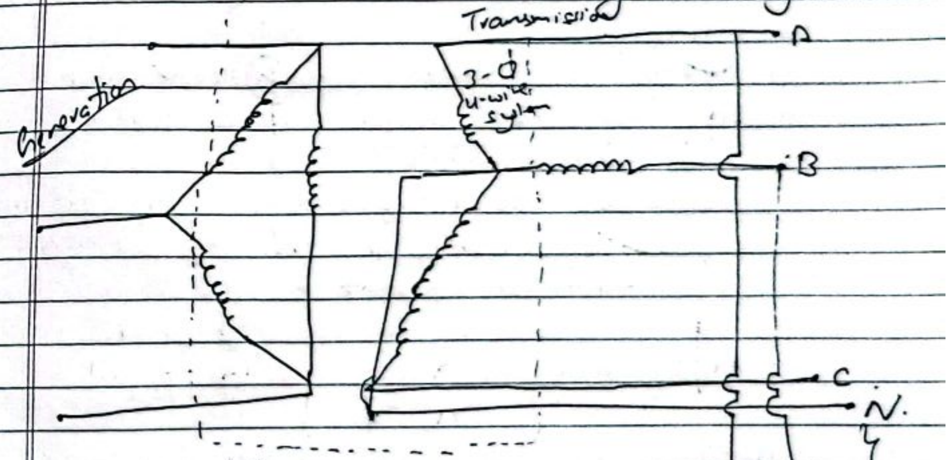
CHAPTER-4

Electrical Installation (10 mark).

Consumer Power Supply System.

Components of Power system.

NEA.
- → Generation (where electricity is generated)
- → Transmission (By which electricity is carried from one place to another place)-
- → Distribution (to the consumers provided by the electricity authority).



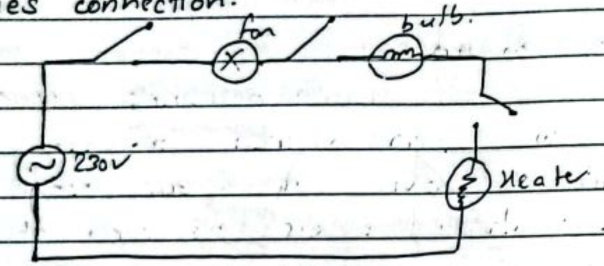
3-ϕ Delta/Star
Distribution transformer.
11KV/400V

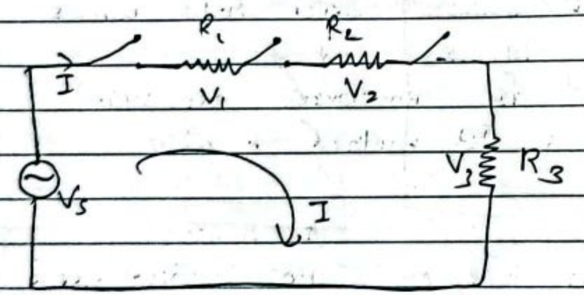
Electrical wiring Components:

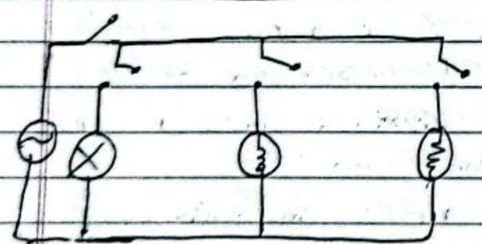
Electrical writing is generally refers to insultated conductor used to carry current and associated device. Domestic electric appliances like lights, [illegible], fans, washing machines, water pumps etc are connected to the supply through insulated wire which are controlled by switches. The wiring diagram gives the connections of different appliances to the supply within a house or building.

Different types of wiring method:

a) Series connection.







Types of wiring based on Consumers.

i) Domestic Wiring

ii) Commercial Wiring.

iii) Industrial wiring.

Types of wiring based on material used.

i) Cleat wiring

In this types of wiring, wood or plastic cleats are fixed to walls or ceilings at regular intervals i.e 0.6m between each other.

- PVC insulated cabels are taken through the holes of each cleat.
- Cleat support and hold wires
- This is less costly.
- Used for temporary installation.
- It is old method of wiring.

ii) CTS wiring or TRS wiring.

- This type of wiring is also used for house wiring and is quite cheap.
- Cab tyre sheathed (CTS) wire or Tough rubber sheathed (TRS) wire is normally used as conductor for this wiring.
- This wires are run on the teak wooden battens which are fixed on the wall or ceiling by means of screws and wooden plugs.

iii) Batten wiring

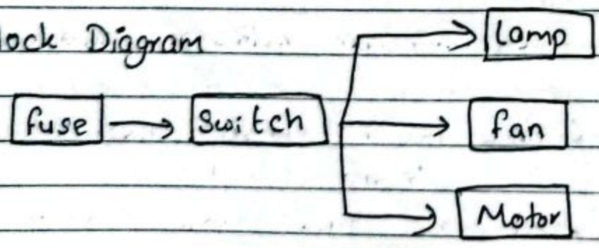
- In this, insulated wires are run through the straight teak wooden battens
- The wooden battens are fixed on the ceiling or walls by plugs and screw.
- This system takes less time to instal.
- These are mainly used for indoor installation.

iv) Conduit wiring.

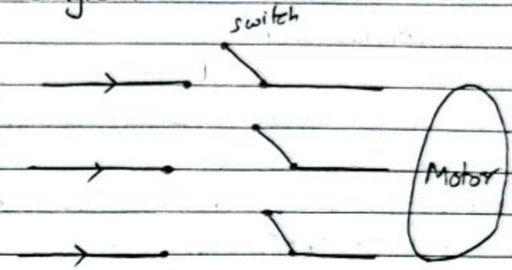
- In this wiring, pvc cables are taken through either PVC conducit pipes or through steel conducit pipes.
- This conduit wiring can be either surface conducit wiring or concealed conducit wiring
- If the conduicts are run inside the surface of the walls or ceilings, they should be covered with plastering, it is called ~~conduict~~ concealed wiring.
- Surface conducit wiring is used in industries to connect heavy motors or load.
- Concealed wiring is the most popular in residential buildings.
- This method is the safest method of wiring and also looks clean and neat.

⇒ Electrical Wiring Representation

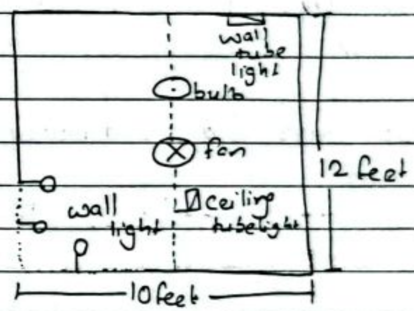
a) Block Diagram



b) Line Diagram



c) Circuit Diagram



⇒ Wiring Accessories

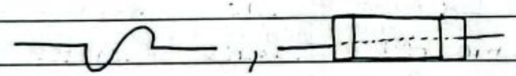
i) Switch
ii) Socket
iii) lamp holder
iv) plugs
v) fuse
vi) MCB / MCCB
vii) Distribution Boards
viii) Wires and Cables.
ix) PVC Pipes
x) Led Bulbs / Tubelight.

⇒ Protective Devices, their constructions and sizing.

i) fuse : fuse is a device used to protect the circuits and equipments against overload and short circuits.

- fuse element materials have low melting point and high conductivity.
- fuse operation is based on the heating effect of the current ∵ when flow through element.
- Its rating can start from few mA (milliampere) to several kA (kiloampere)
- different types of fuse are used in application nowadays.
  i.e - Rewirable fuse
  - Cartridge fuse
  - High Rupturing capacity fuse.

Symbol of fuse are



fuse factor = $\dfrac{\text{Rated minimum fusing factor}}{\text{Current rating}}$

→ 1.25 for class P

→ 1.25 and 1.5 for class Q → Q_1, Q_2

→ 1.5 and 2.5 for class R

Eg: What is the minimum rated current of the 20A P class fuse that will be operated?

$1.25 = \dfrac{\text{Rated min}^m\text{ fusing factor}}{20\text{ A}}$

Rated min^m fusing factor = 25A

Safety Devices.

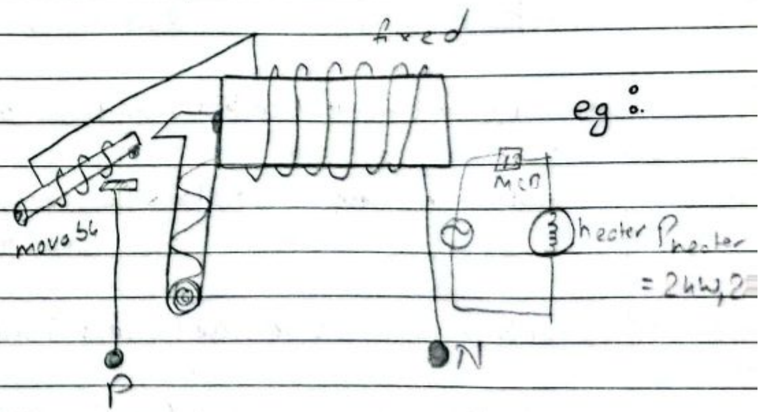
a. fuse

b. MCB

MCB stands for Miniature Circuit Breaker. It is an electromechanical devices which can turn a circuit ON and OFF wherever, there is a fault in the circuit, it automatically operates to turn off the circuit. Generally MCB provides short-circuit protection to a circuit. It senses the overcurrent in the circuit caused by short circuit and trips the circuit.

An MCB consists of two contacts, one is moving contact and the other is fixed contact when the circuit current becomes abnormally high, the movable contact separated from fixed contact to make the circuit open and disconnect it from the supply mains. The MCB come in various poles like single-pole, double pole and 3-pole.

eg:



- MCB rated current not more than 100A.
- MCB of different current rating are available

i.e. 6, 10, 13, 16, 20, 25, 40, 50, 63, 80 and 100A.

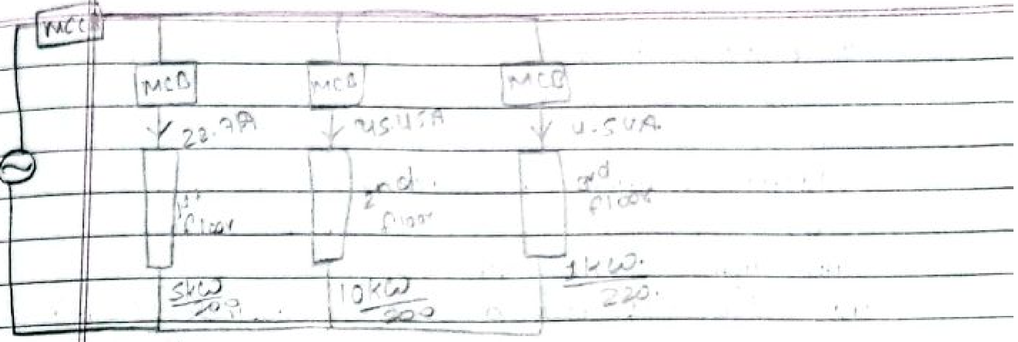
c) MCCB

MCCB stands for Molded Case Circuit Breaker. MCCBs are the protecting devices having trip circuit thermal or thermomagnetic or electronic type. The MCCBs provide protection against overcurrent due to short circuit, earth fault, under voltage, etc.

It is used to protect the loads over 100A and motor protection circuit. It also available in ~~sig~~ single pole, double-pole and triple pole versions. (also on 4-pole).

Differences between MCB and MCCB.

MCB	MCCB
- Type of switch which protects the system from overloaded current.	Protects the equipments from over temperature and fault current.
- Miniature Circuit Breaker	Molded Case Circuit Breaker
- Available in single, two and 3-pole version.	Available in single, two, three and four pole version.
- Current rating up to 100A	Current rating from 10-200amp
- Cannot be control remotely	- Can be control remotely.
- Used for domestic purpose like house wiring.	Used commercially and in industries.



Wires and cables.

Conductors: A conductor has many free electrons so is good at transferring electrical current.

e.g : Copper - high conductivity
- Easily soldered
- Heavier of more expensive than aluminum
- Copper wire is used in house wiring.

Aluminum: It has 60% conductivity than copper.
- Cheap and lighter than copper.
- Used for small loads which takes less amount of current.

Using these ~~wires~~ conductors and PVC insulators wires and cables are made.

Wires:
- Domestic of small industry wiring.

Cables:
- small and big industries.

- distribution lines.
- Transmission lines.

Different types of wires:

Six types of wires:

a) Vulcanised indian rubber wire (V.I.R)
b) Tough rubber sheathed wire (T.R.S)
c) Poly Vinyl chloride Wire (P.V.C).
d) lead alloy sheathed wire.
e) weather proof wires.
f) flexible wires.

Different types of Cables

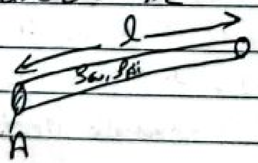
The type of cables basically decided based on the voltage level for which it is manufactured and material used for the insultion such as paper, cotton, rubber, etc. The classification of cables according to the voltage level is,

- Law Tension Cables (L.T cables)
- Medium of High Tension Cables (H.T cables).

Determination of a size of a cable or wire:

The current carrying capacity of any conductor depends directly on its length and inversly on its cross-sectional area. i.e

$$R \propto \frac{l}{A}$$

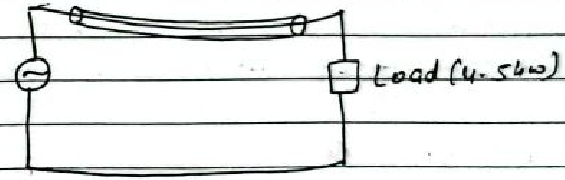


$$R = \rho \frac{l}{A}$$

According to IEEE standard of any point below power supply terminal and instollation of load voltage drop should not increase about 2.5% of the supply voltage.

Moreover for given load except the known current, there should be 20% extra scope of current for additional load for future emergency needs.

e.g: for electrical wiring installation in a building, Total load is 4.5KW and supply voltage is 220V. find the most suitable size of cable for energy meter to subcircuit.



$P_T = 4.5 \times 10^3$ watt.

20% of $P_T = \frac{20}{100} \times 4500 = 900$ watt.

$P_{Total} = 4500 + 900 = 5400$ watt.

$P_T = V_T \cdot I_T = 5400$

$I_T = \frac{5400}{220} = 25.54A$.

for 24.54A copper size size should be 4.5 mm². ~~size~~ (Table).

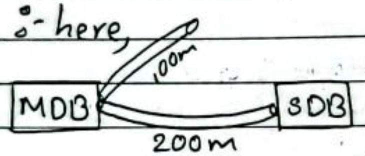
Eg: Determine the size of a copper cable for MDB to SDB require to carry the maximum current of 60A. It is given that length of cable are 200m and 100m, the permissible voltage drop is 2% of the supply voltage. The supply system is single phase whose voltage is 220V. Rating of copper is given below.

area of conductor (mm^2)	1.5	2.5	4	6	10	16	25	35
Current reading.	21	27	36	45	60	77	99	120

50	95	120	150
145	175	240	276.

$\rho = 1.68 \times 10^{-8}$

Soln :- here,



$V_{drop} = 2\%$ of 220

$= \frac{2}{100} \times 220$

$= 4.4V.$

$V_d = I_{wire} \times R_{wire}.$

$4.4 = 60 \times \frac{\rho . l}{A}$

$A = \frac{60 \times 1.68 \times 10^{-8} \times 200}{4.4}$

$A = 4.58 \times 10^{-5} m^2$

$= 4.58 \times 10^{-5} (1000)^2$

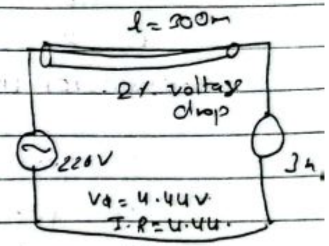
$= 45.81 mm^2.$

$V_d = I_{wire} \times R_{wire}.$

$4.4 = 60 \times \frac{\rho . l}{A}$

$\therefore A = \frac{\cancel{4.58}}{2.29} \times 10^{-5} m^2 \; (1000)^2$

$A = 22.9 mm^2.$



→ $I_{motor} = \frac{2238}{220} = 10.17A.$

$3hp = 3 \times 746$ watt

$= 2238$ watt.

$I \cdot \frac{\rho . l}{A} = 4.44$

$A = \frac{10.17 \times 1.68 \times 10^{-8} \times 300}{4.4}$

$A = 11.64 mm^2$

Earthing for electrical Equipment and Appliances.

Equipment earthing is a connection done through a metal link between the body of any electrical appliances, or neutral point, as the case may be, to the deeper ground soil. The metal link is normally of MS flat, GI wire which should be penetrated to the ground earth grid.

Earthing is important because it provides
→ Safety of person
→ Safety of equipments

→ Prevent at least minimize damage to equipment as a result of flow of heavy currents.
→ Improve the reliability of the power system.

Classification of Earthing

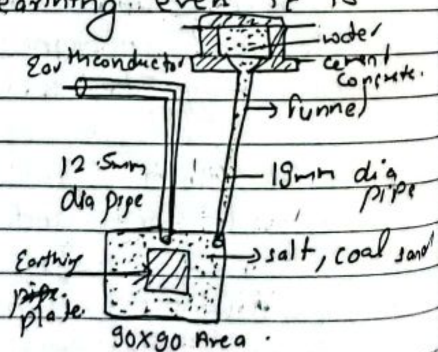
→ System earthing (Connection between part of a plant in operating system like LV neutral of a power transformer winding)

→ Equipment Earthing (Safety grounding) connection of bodies of equipment (like electric motor body, transformer, Switchgear box, Circuit breakers, etc) to earth.

Types of earthing:

a) Plate Type Earthing.

The earthing system, where copper or galvanized iron plate is used to connect all the earthing conductors to the earth is called plate type earthing. Generally, the plate is placed vertically at a dept not less than 3 meters or 10 feet from the ground level. Plate earthing is complex installation than rod earthing even it is most costly too.



It's advantages.

The main advantage of plate ~~everythin~~ earthing is, it can carry a very high current than rod earthing. Also it provides a very good conductivity between earthing conduct and the ground.

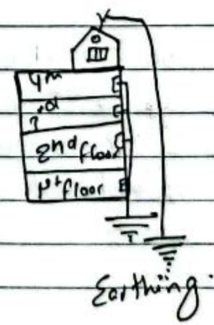
It's disadvantage.

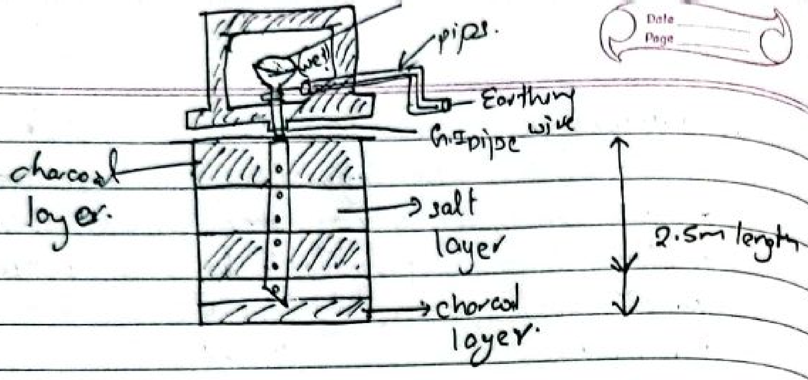
→ It has high installation cost.
→ It is more complicated than rod earthing.

2nd April

b. Rod Type earthing. / Pipe type earthing.

Pipe earthing is the process of using a metallic conductor to establish an establish on electrical connection between two points in an electrical system. It's also known as "grounding" or "earth bonding". The most common type of pipe earthing metal pipes filled with concrete or other conductive materials that are burried in the ground. These pipes are then connected to a ground rod which is usually made of copper or another metal alloy.





Electric shock and its Hazards.

Electric shock may be defined as dangerous event or conditions due to direct or indirect electrical contact with energized conductor or equipment and from which a person may sustain electrical injury from shock, damage to workplace environment, damage to property or both.

One can get shock by direct contact to the parts of installation.

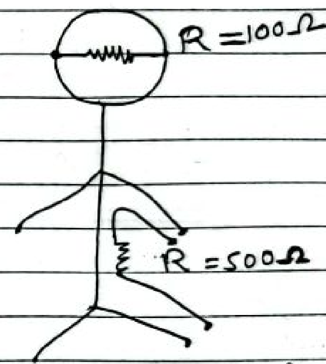
The effect of electrical current through the human body vary according to

- The voltage level.
- The time of current flow.
- The value of the current.
- frequency of the network.
- Path of the current.
- The ability of the person to electrical installation with voltage up to 50V, in dry place and up to 25V in wet or humid place (AC) and up to 120V DC are considered safe in what concerns direct and indirect contact.

More dangerous DC of same level of voltage or current.

AC (50Hz)	DC (mA)	Effects.
0.5 - 1.5	0 - 4	perception
1 - 3	4 - 15	Surprise
3 - 22	15 - 80	Reflex action
22 - 40	80 - 160	Muscular contraction
41 - 100	160 - 300	Respiratory Block
more than 100	more than 300	Usually fatal

Resistance of body depends on various factors like Humid or wet skin, weight, sex, age and the path of the current through human body it passes.



The harardous of electrical shock are as follows.

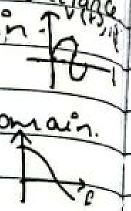
→ loose of motion control → Burns
→ Respiratory arrest → cardiac arrest
→ Pain
→ Physical fatigue.
→ Burn
→ cardiac arrest.

Chapter 3

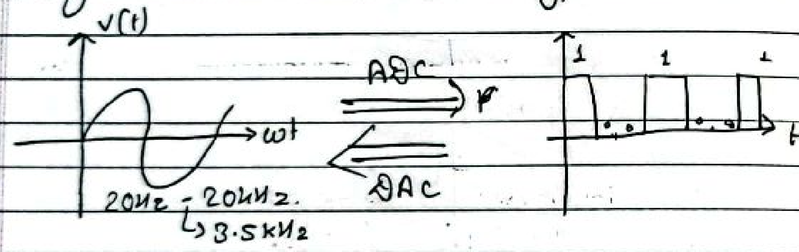
Introduction to Electronics Engineering (14 marks)

Electronics comprises the physics engineering, technology and applications that deals with emission, flow and control of electronics in vaccum matter. This distinguishes it from classical electrical engineering as it uses active devices to control electron flow by amplifilication rather than just passive effect such as resistance, capacitance and inductance.

Electrical Signals → Time domain
Electrical Signals → frequency domain



Signals are of different types i.e



Analog signal — Digital signal.

ADC = Analog to Digital Converter.
DAC = Digital to Analog converter.
→ electronic components.
↓
Semiconductor devices.

Semiconductor Devices:

The materials that are neither conductor nor insulator with energy gap of about 1eV (electron Volt) are called semiconductors.

Most common materials commercially used as semi-condutors are ~~given~~ germonium (Ge) and Silicon (Si) because their property to withstand high temperature. That means there will be no significant change in their energy gap with change in temperature.

$$E_g = 1.210 - 3.60 \times 10^{-4} \times T\,eV \quad (\text{for Si})$$

$$E_g = 0.735 - 2.23 \times 10^{-4} \times T\,eV \quad (\text{for Ge})$$

where, T = absolute temperature in k at room temp of 300°k

$$E_g \approx 1.1eV \quad (\text{for Si})$$
$$E_g \approx 0.72eV \quad (\text{for Ge})$$

At room temperature resistivity of semiconductor are in between insulator and conductors. Semiconductors show negative coefficient of resistivity. i.e. resistance decreases with increase in temperature.

Both Si and Ge are elements of IV-group i.e both elements have four Valence electrons.

Both form the covalent ~~both~~ bond with the neighbouring atom. At absolute zero temperature both behave like an insulator i.e the valence band is full while conduction band is empty but as the temperature is raised more and more covalent bonds break and electrons are set free and jump to the conduction band.

Intrinsic Semiconductor

As per theory of semiconductor, semiconductor in its pure form is called as intrinsic semiconductor. In pure semiconductor number of electrons (n) is equal to number of holes (p) and thus conductivity is very low as valence electrons are co-valent bond.

In this case we can write $n=p=n_i$ where n_i is called intrinsic concentration. It can be shown as

$$n_i = n_o T^{2/3} . e^{V_G/2V_T} \quad \text{where;}$$

n_o = constant

T = absolute temperature

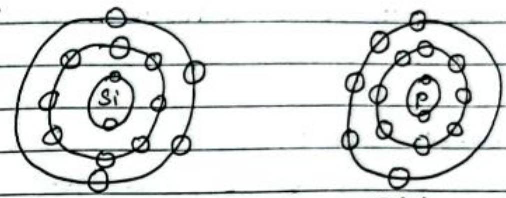
V_G = Band gap of semiconductor

V_T = Thermal voltage.

Extrinsic Semiconductors

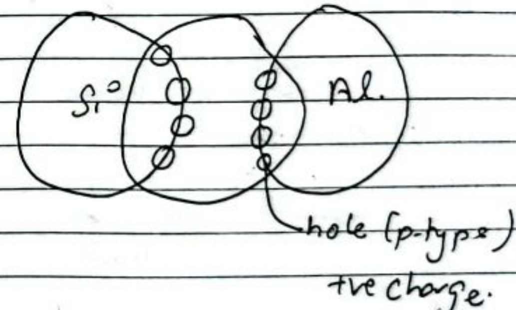
As per theory of semiconductor, impure semiconductors are called extrinsic semiconductors. Extrinsic semiconductors is formed by adding a small amount of impurity which is known as doping. Depending on the type of impurity we have two types of semiconductor i.e N-type and p-type.

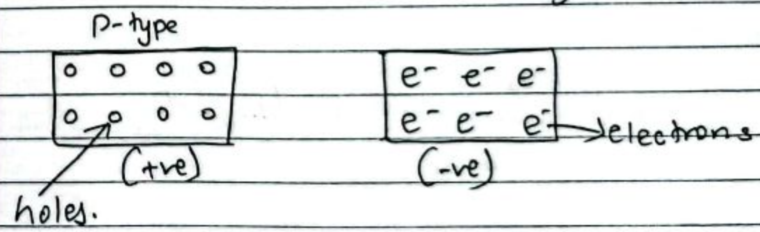
N type



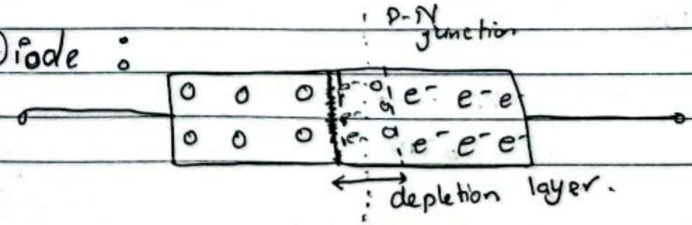
Doping: N-type (-ve charge)

P-type



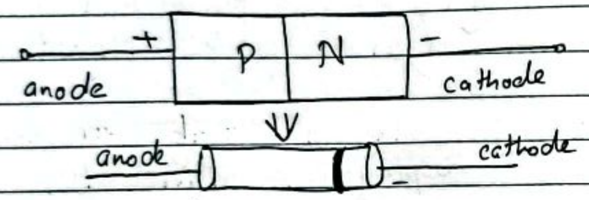


Diode :

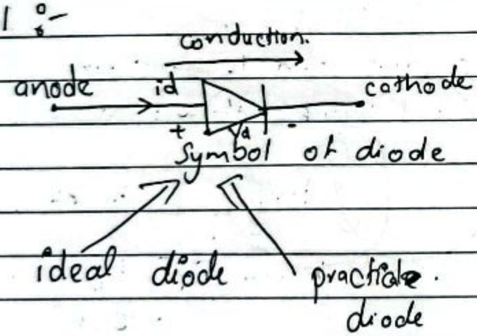


A diode is defined as a two terminal electronics components that only conductors current in one direction (So long as it operated within a specified voltage level.

An ideal diode will have zero resistance in one direction and infinite resistance in the reverse direction.

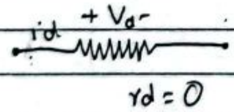


Symbol :-



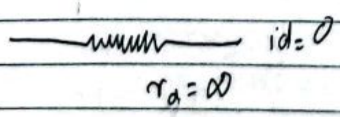
Ideal.

i) Conduction.



$i_d = \frac{V_d}{r_d} = \infty$.

ii) Reverse



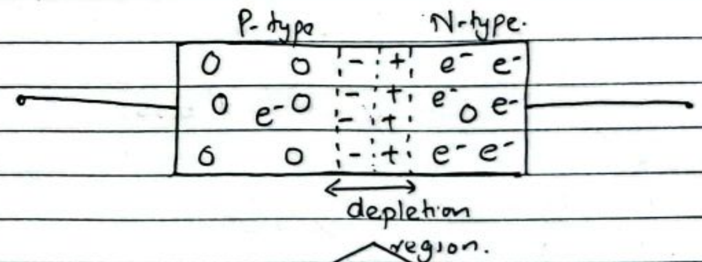
for practical diode

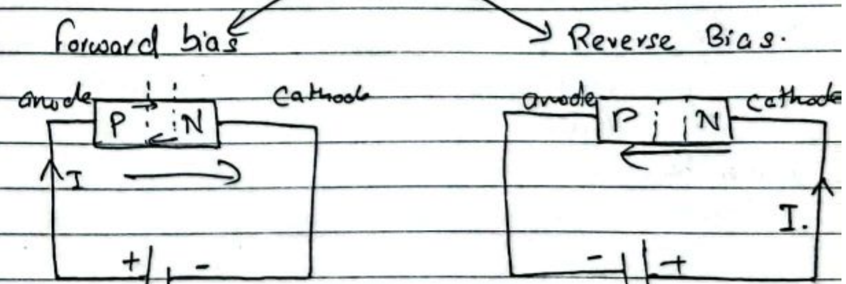
i) Conduction $r_d \neq 0$ (min m)
ii) Reverse $r_d \neq \infty$ (high)

6-April.

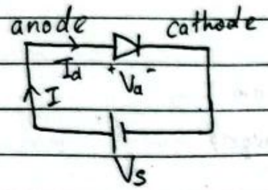
✱ Working principle of Diode.

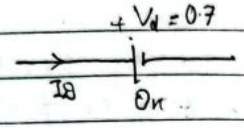
Its principle depends on the interactions of n-type and p-type semi conductors. An n-type semiconductor has plenty of free electrons and very few numbers of holes. In other word, we can say that the concentration of free electrons is high and that of holes in an n-type semiconductor. free electrons in n-type semiconductor are refered as majority charge carrier, and ~~hold~~ holes in the n-type semiconductor are referred as minority charge carrier.





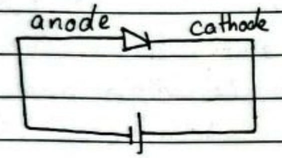
F.

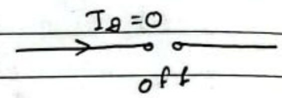




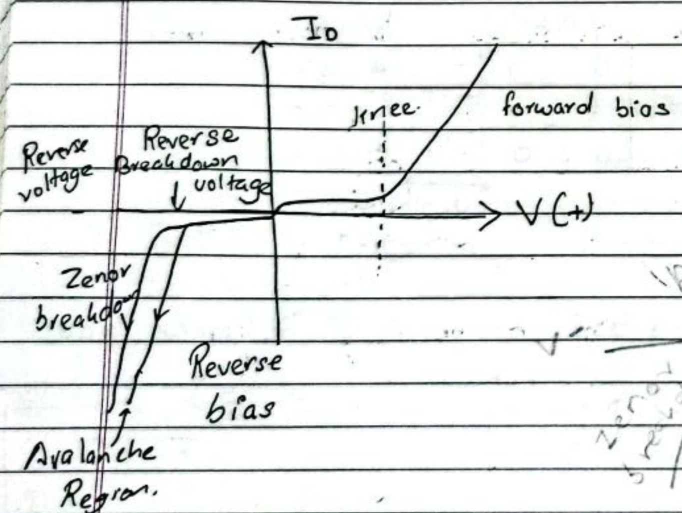
if $V_D > 0$ (forward bias) $\rightarrow$ Ideal
if $V_D > 0.7V$ (Si) } Non-ideal.
$> 0.3V$ (Ge)

R.

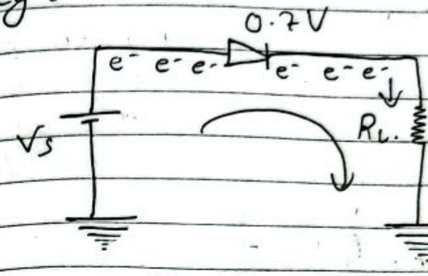




if $V_D < 0$ (Reverse bias) $\rightarrow$ Ideal.
if $V_D < 0.7V \rightarrow$ practical.



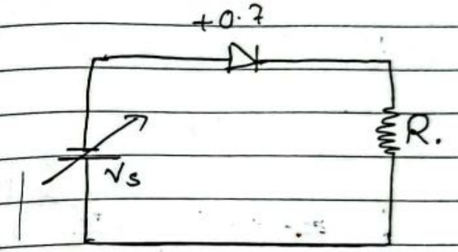
Eg: forward.



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

$V_s = 0.7 + IR.$

Eg: Reverse.

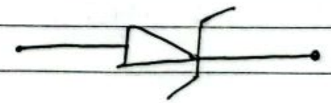


$V_s < 5$

$V_s < 5$

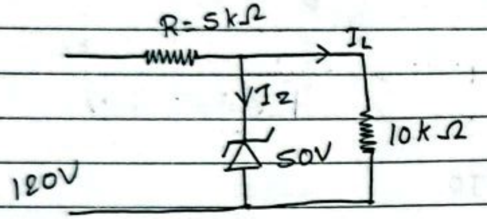
Under reverse bias voltage junction barrier tends to increase with increase in bias voltage

Zener diode is basically like an ordinary P.N junction diode but normally operates reverse biased conditions. But ordinary P-N junction diode connected in reverse biased condition is not used as Zener diode practically. A zener diode is a specially designed, highly doped P-N junction diode.



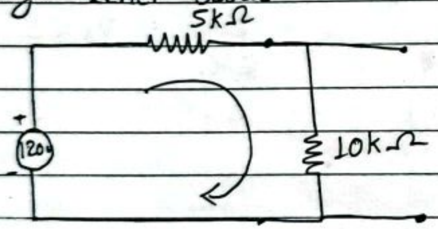
Zener diode symbol.

Eg: for the circuit shown below, find i) Output V
ii) Voltage drop across series resistance.
iii) The current through zener diode.



Soln :- here,

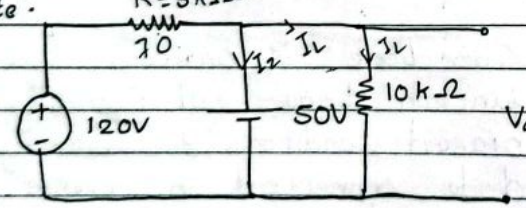
Removing zener diode



$\frac{10}{10+5} \times 120$

$= 80V$

Zener diode acts as voltage source because it is 'on state'.



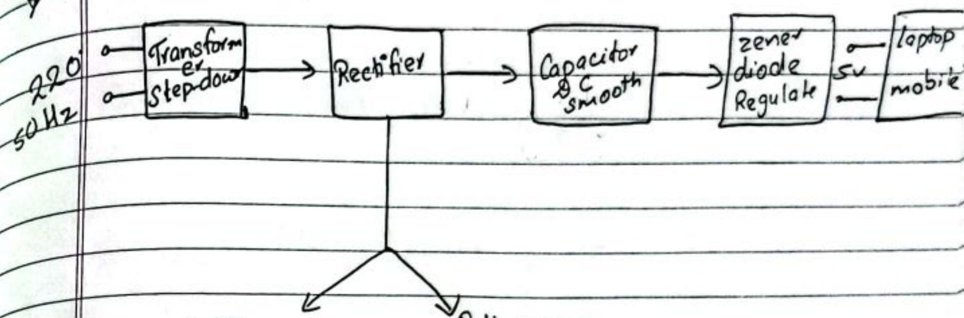
$I = \frac{70}{5000} = \cancel{35mA}\ 14mA.$

$I_L = \frac{50}{10000} = 5mA.$

$I_z + I = I_L$

$I_z = -I_L + I = -5 + 14 = +9mA$

Application of Diode.

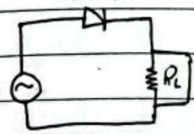


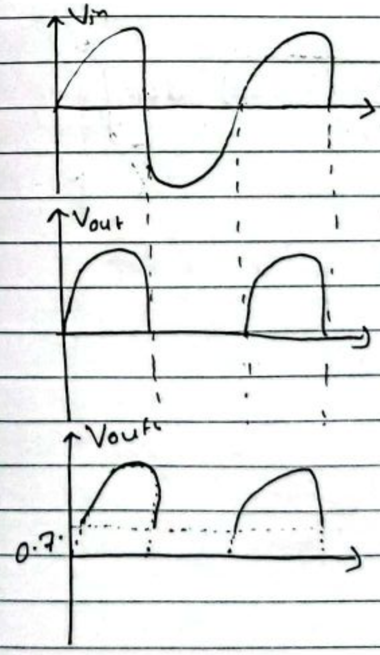
Half wave rectifier

Full wave rectifier.

- center tapped transformer
- Bride Rectifier.

Diode





Half wave rectifier (Ideal)

Half wave rectifier (practical)

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

$$V_{avg} = \frac{1}{T}\int_0^T v(t)\cdot dt$$

$$V_{rms} = \sqrt{\frac{1}{T}\int_0^T (v(t))^2 \cdot dt}$$

$$V_{avg} = \frac{1}{2\pi}\int_0^{2\pi} V_m \sin(\omega t)\cdot d(\omega t)$$

$$= \frac{V_m}{2\pi}\left[\int_0^{2\pi} \sin(\omega t)\cdot d(\omega t)\right]$$

$$= \frac{2 \times V_m}{2\pi}$$

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

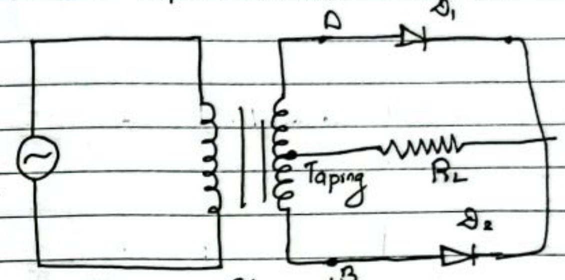
$$= \sqrt{\frac{V_m^2}{2\pi}\left[\int_0^{\pi} \sin(\omega t)^2 \cdot d\omega t\right]}$$

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

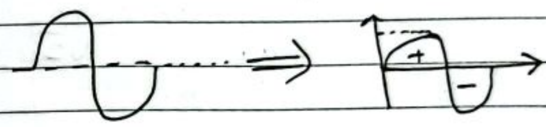
Rectifier :

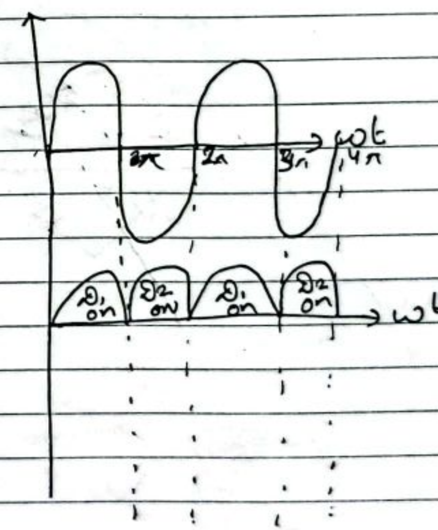
a) half-wave Rectifier
b) full-wave rectifier.

i) Center Toped full-wave rectifier



Step-down.





$$V_{avg} = \frac{1}{T}\int_0^T V(t)\,dt$$

$$V_{rms} = \sqrt{\frac{1}{T}\int_0^T v^2(t)\,.dt}.$$

$T = \pi$

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

$$= \frac{1}{\pi}\int_0^{\pi} V_m \sin(\omega t)\cdot d(\omega t)$$

$$= \frac{V_m}{\pi}\left[\int_0^{\pi} \sin(\omega t)\cdot d(\omega t)\right]$$

$$= \frac{2V_m}{\pi}$$

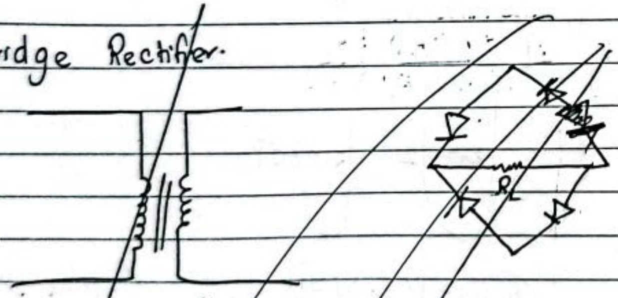
$$= \sqrt{\frac{1}{\pi}\int_0^{\pi} V_m \sin(\omega t)^2\, d\omega t}$$

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

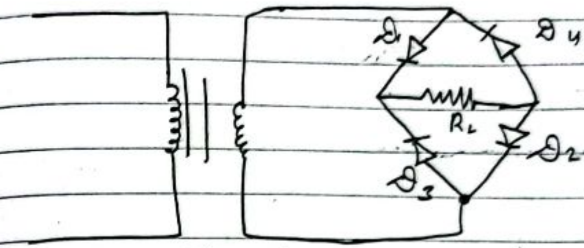
$$= \sqrt{\frac{V_m^2}{\pi}\cdot\frac{\pi}{2}}$$

$$= \frac{V_m}{\sqrt{2}}$$

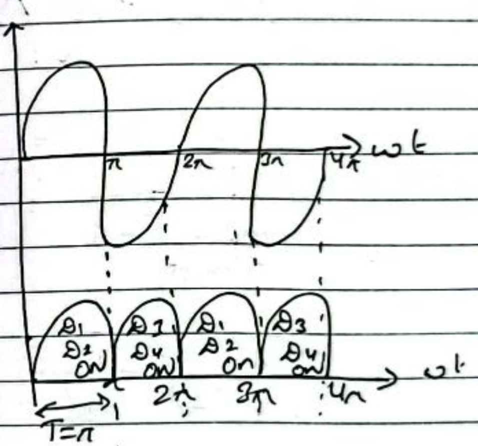
~~ii) Bridge Rectifier.~~



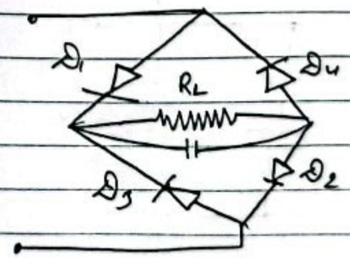
ii) Bridge Rectifier.



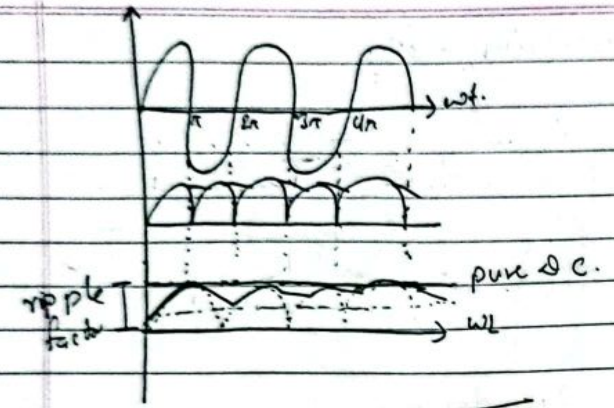
step-down



Capacitor :



full wave and half wave rectifier with a capacitor-input filter is used to smooth the wave form of output voltage. The value of capacitor depends on the level of output voltage.



Ripple factor = $\sqrt{\left(\frac{V_{rms}}{V_{dc}}\right)^2 - 1}$.

half wave

$r = \sqrt{\left(\frac{V_m/2}{V_m/\pi}\right)^2 - 1}$

$= \sqrt{\left(\pi/2\right)^2 - 1}$

$= 1.21$

full wave

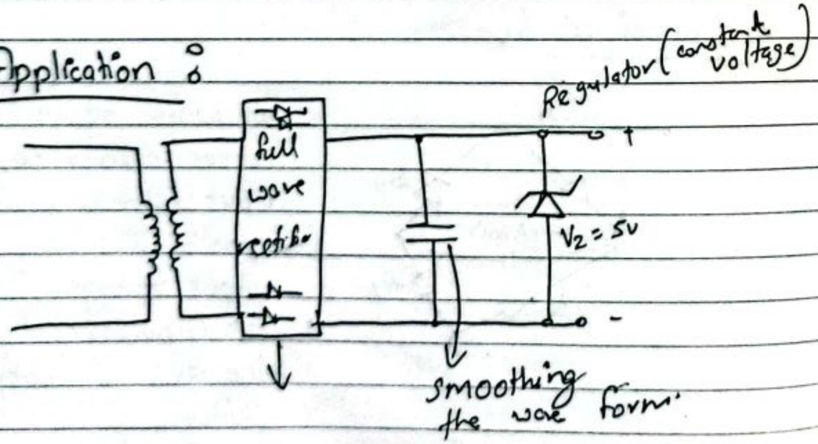
$r = \sqrt{\left(\frac{V_m/\sqrt{2}}{2V_m/\pi}\right)^2 - 1}$

$= \sqrt{\left(\frac{\pi}{2\sqrt{2}}\right)^2 - 1}$

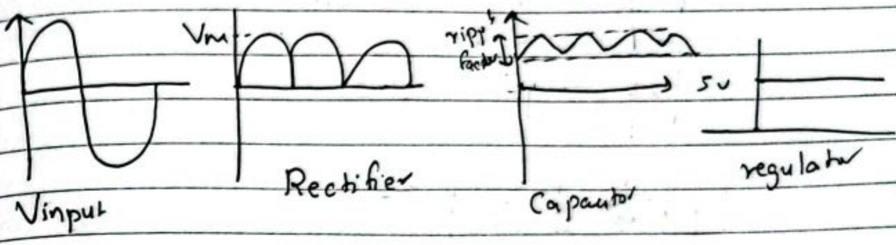
$= 0.48$

less ripple factor = better one.

Application :



$V_{avg} = 0$ $V_{avg} = \frac{2V_m}{\pi}$



Continued. ....

imp De-Morgans Theorem.

There are two laws given by him that are as follows :-

⟹ 1^{st} law : $\overline{A+B} = \overline{A} \cdot \overline{B}$

Proof :

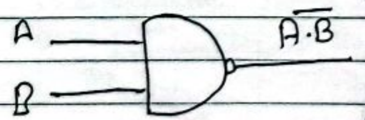
A	B	$\overline{A}$	$\overline{B}$	$\overline{A+B}$	$\overline{A} \cdot \overline{B}$
0	0	1	1	1	1
0	1	1	0	0	0
1	0	0	1	0	0
1	1	0	0.	0	0

⟹ 2^{nd} law : $\overline{A \cdot B} = \overline{A} + \overline{B}$

Proof :

A	B	$\overline{A}$	$\overline{B}$	$\overline{A \cdot B}$	$\overline{A} + \overline{B}$
0	0	1	1	1	1
0	1	1	0	1	1
1	0	0	1	1	1
0	0	0	0	0	0.

NAND Gate :

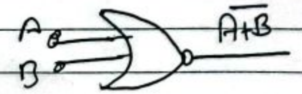


$= \overline{A} + \overline{B}$

Universal Gate.

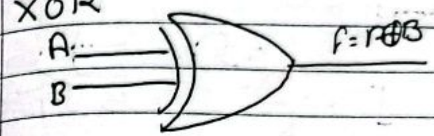
De-Morgans Theorem

NOR Gate :



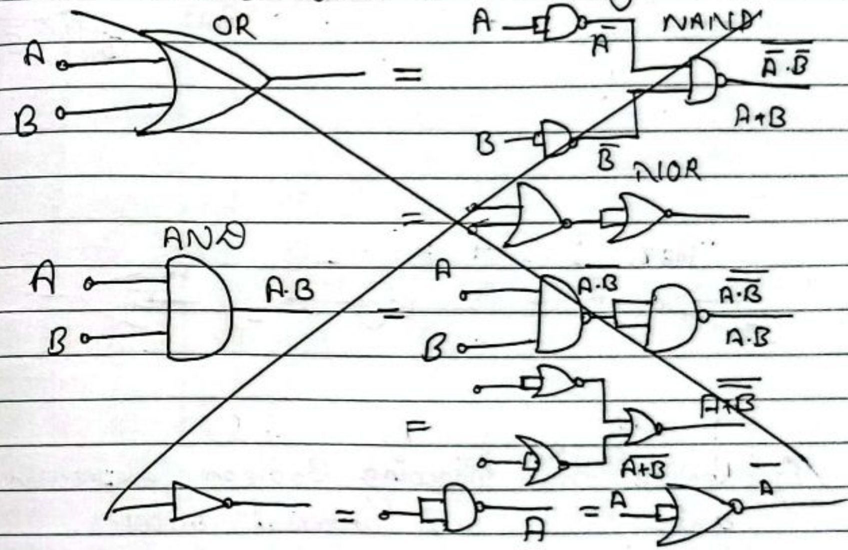
$= \overline{A} - \overline{B}$

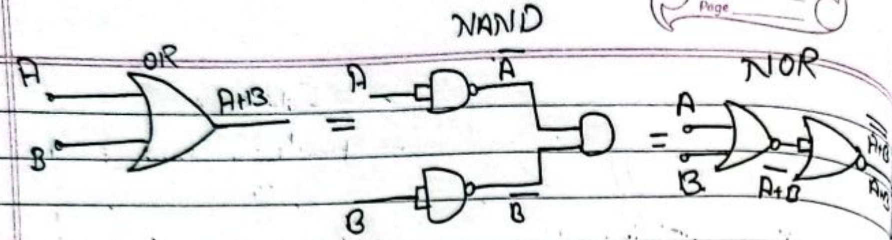
XOR

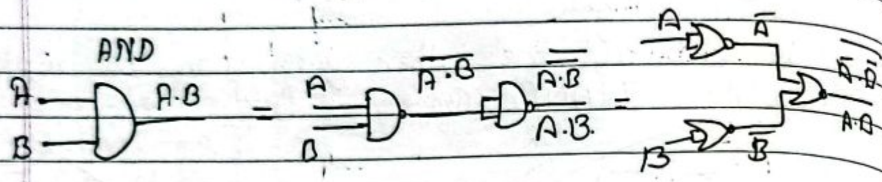


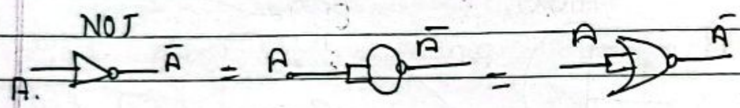
Why NAND Gate and NOR Gate are called universal gate.?

→ Because all the other gate can be replaced with NAND Gate or NOR gate i.e



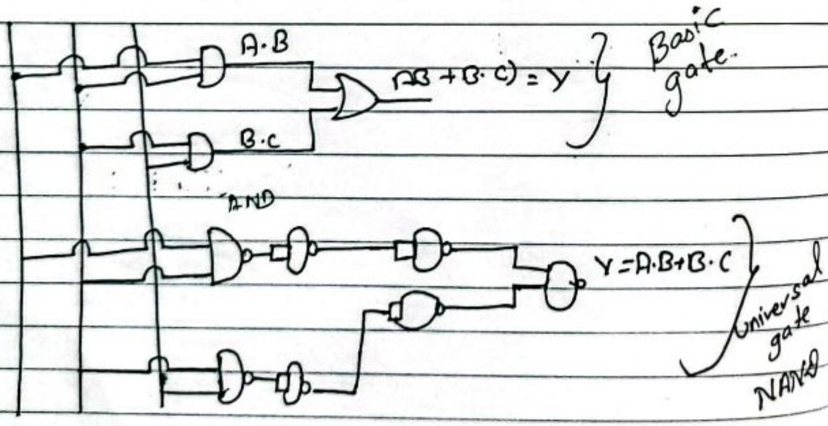






Eg. Realize the following Boolean expression using basic gates and universal gates.

$Y = (A.B) + (B.C)$



Representation of Boolean Expression:

The relationship between boolean expression variables and output variable is called Boolean expression. the Boolean expression can be represented in two different forms, they are;

i) Sum of products (SOP) form

ii) Product of sums (POS) form.

Eg:

A	B	C	Y
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	0
1	1	1.	1.

1 = SOP

SOP

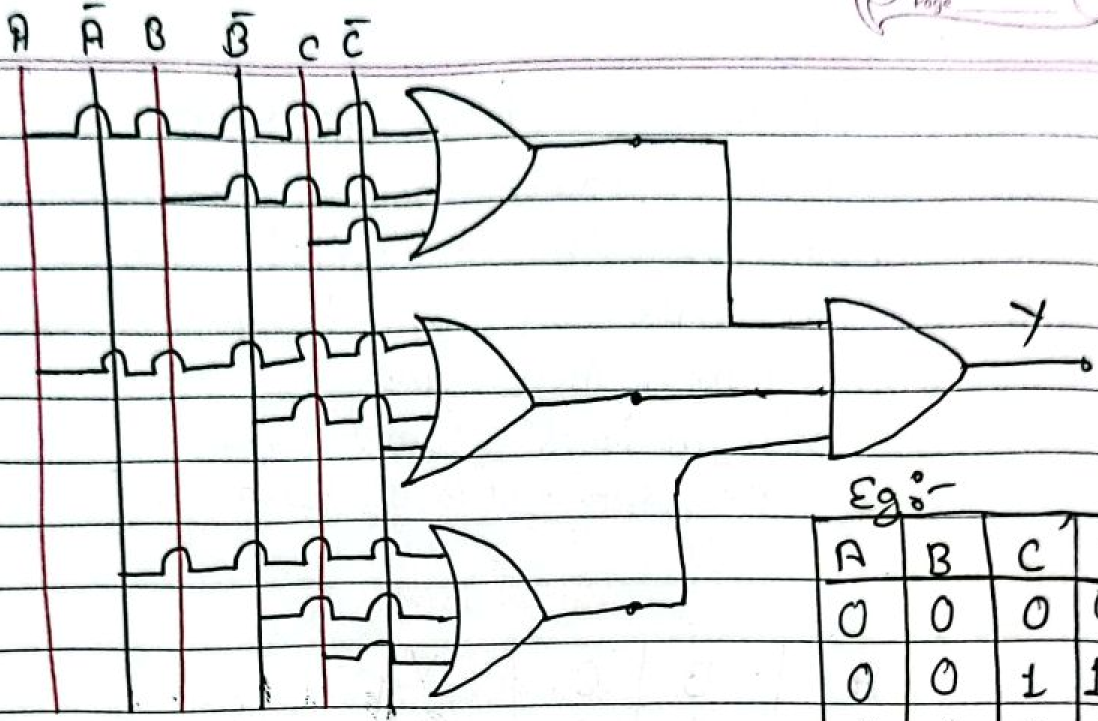
$Y = \bar{A}\cdot\bar{B}\cdot C + \bar{A}\cdot B\cdot\bar{C} + A\cdot\bar{B}\cdot\bar{C} + A\cdot\bar{B}\cdot C + A\cdot B\cdot C$

~~POS.~~

~~$Y = \bar{A}\cdot B\cdot\bar{C} + \bar{A}\cdot B\cdot C$~~ -

POS

$Y = (A+B+C) \cdot (A+\bar{B}+\bar{C}) \cdot (\bar{A}+\bar{B}+C)$



Eg:-

A	B	C	Y
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	0
1	0	0	0
1	0	1	1
1	1	0	1
1	1	1	1

SOP

$$Y = \bar{A}\cdot\bar{B}\cdot C + \bar{A}\cdot B\cdot\bar{C} + A\cdot\bar{B}\cdot C + A\cdot B\cdot C$$
$$+ ABC$$

POS

$$Y = (A+B+C)\cdot(A+\bar{B}+\bar{C})\cdot(\bar{A}+B+C)$$