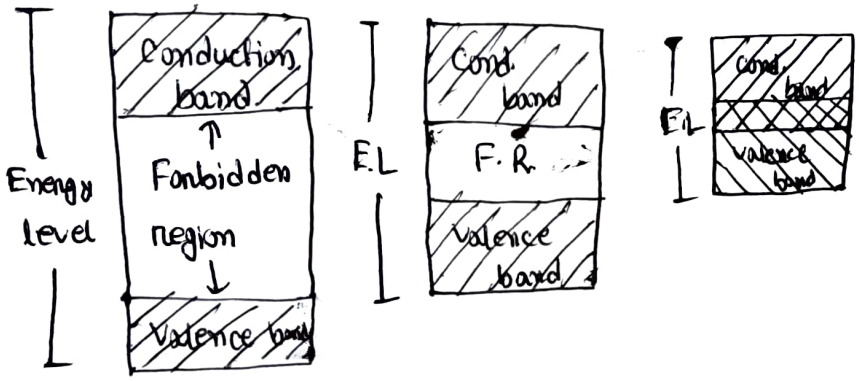
SB 25/06/23

Metal > Semi-conducton > Inducton

Energy band diagram:



(a) Inducton (b) semi-conducton (c) conducton

---

2 types of semi-conducton:

i) Intrinsic (pure semiconducton → found in nature)
E.g., Si, Ge

ii) Extrinsic

Doping:

The process of introducing an impurity to an intrinsic semi-conductor is called doping.

Impurity is of two types:

i) Pentavalent (e.g. Antimony, Arsenic, ~~Phosp~~ Phosphorus)

ii) Trivalent (e.g. Boron, Calcium, Indium)

Extrinsic Semiconductor:

2 types:

i) n type

ii) p type

1) n-type

charge carrier: electron

din: opposite

2) p-type

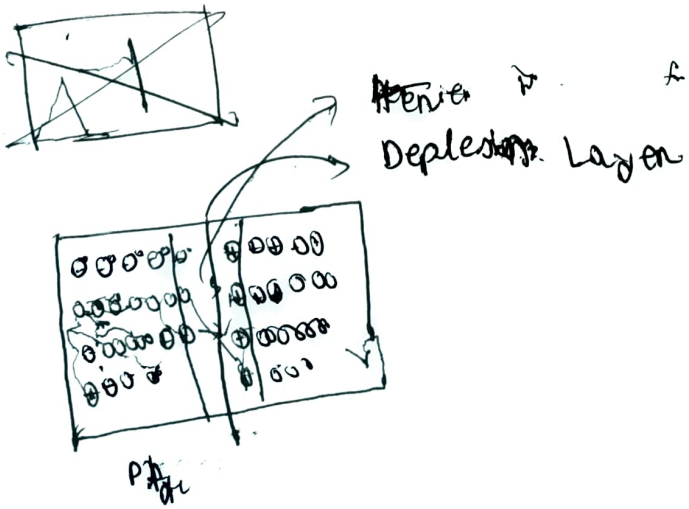
charge carrier: hole

din: current

★ Diode / pn junction diode

3 working

i) No bias



Majority & minority

Charge carrier

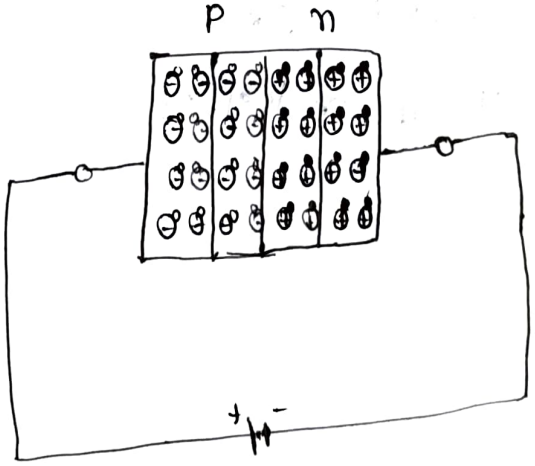
p type : majority : hole

minority : e^-

n type : opposite of p type

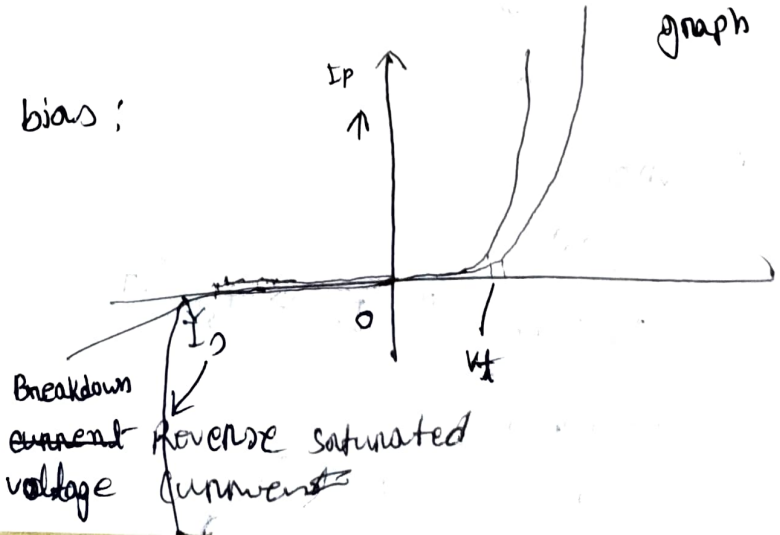
---

ii) Forward bias :



iii) Reverse bias :

V-I characteristic graph of diode



Current ~~law~~ eqn:

$I_D = I_S (e^{V_D/\eta V_T} - 1)$; I_D = Diode current in amperes

I_S = Reverse saturation current

V_D = Voltage across diode

η = Identity ~~for~~ factor

$V_T = \frac{KT}{q}$; V_T = Thermal voltage

K = Boltzmann const.

$= 1.38 \times 10^{-23}\ J K^{-1}$

T = Temp in kelvin

~~V_T = thermal voltage~~

i) when,

$V_D = 0$,

$I_D = I_S e^{V_D/\eta V_T} - I_S$

$= 0$

ii) when

$V_D > 0$,

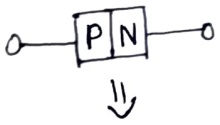
$I_D = I_S e^{V_D/\eta V_T} - I_S \approx I_S e^{V_D/\eta V_T}$

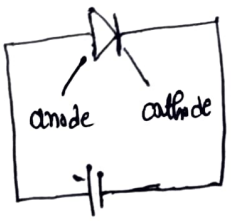
iii) when, $V_D < 0$

$I_D = I_S e^{V_D/\eta V_T} - I_S \approx -I_S$

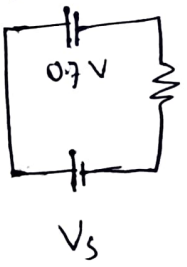
SB

09/07/23





Equivalent circuit (simplified model)



To turn on the diode,

$V_s > Si\ (0.7)$

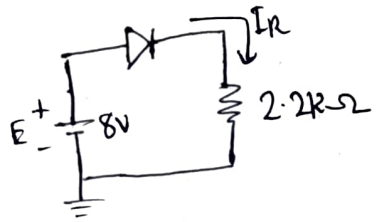
$V_s > Ge\ (0.3)$

Reference books

Electronic Devices And Circuit Theory

– Robert Boylestad

1) Example 2.6

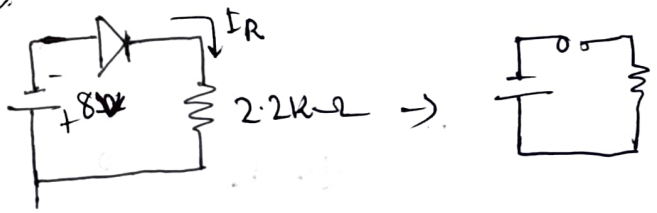


$V_D = ? = 0.7V$

$V_R = 8 - 0.7\ V = 7.3V$

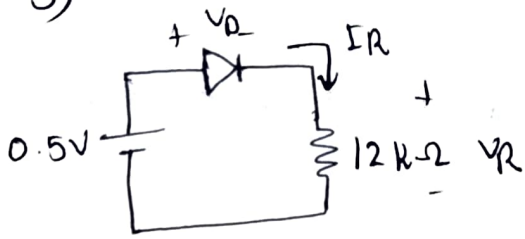
$I_R = \frac{V_R}{R}$

2)



$V_D = 8\ V$

3)



$V_D = ? = 0.5\ V$

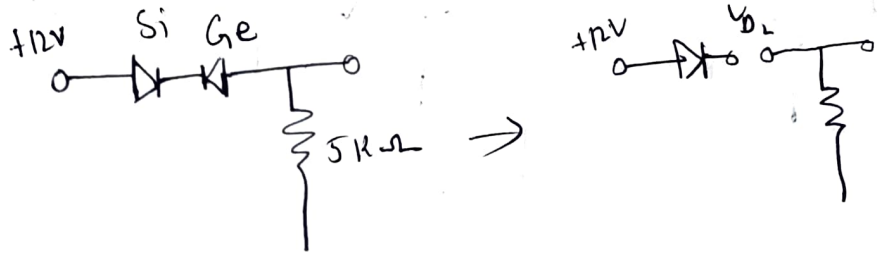
$V_R = ? = 0$

$I_R = ? = 0$

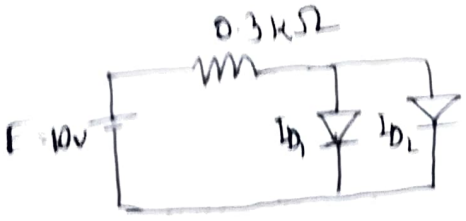
---

4)





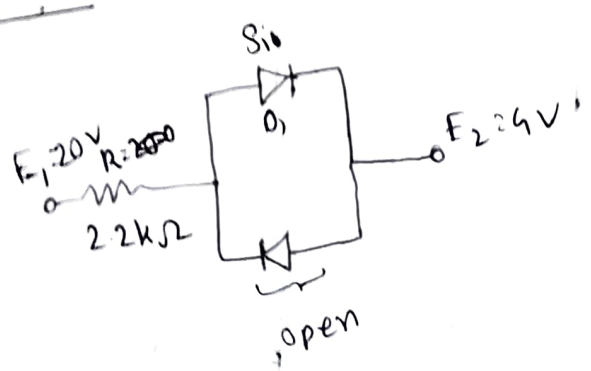
$V_{D_2} = 12,\ I = 0,\ V = 0$



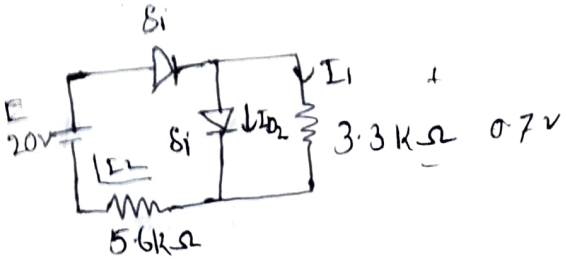
$V_R = 9.3\,V$

I_R :

$I_1 = I_L = \frac{I_R}{2}$



$V_R = 16\,(20-4) - 0.7\,V$



$I_1 = \frac{0.7}{3.3k\Omega}$

$-20 + 0.7 + 0.7 + V_L = 0$

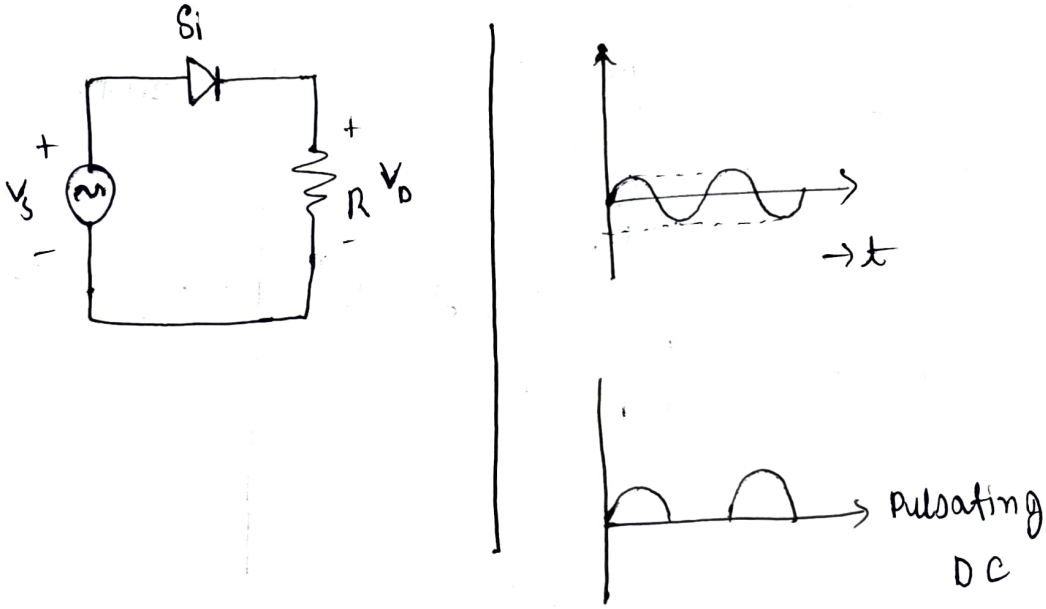
$V_2 = \ldots$

$I_{D_2} = I_2 - I_1$

Diode applications

Half-wave rectifiers:

- A rectifier is an electronic device that converts alternating current to direct current.



Average value :-

$$I_{avg} = I_{dc} = \frac{1}{T}\left[\int_0^{T/2}\left(\frac{v_0(t)}{R}\right)dt + \int_{T/2}^{T} 0\,dt\right]$$

$$= \frac{1}{T}\left[\int_0^{T/2}\frac{V_m \sin\omega t}{R}\,dt\right]$$

$$= \frac{V_m}{RT}\left[-\frac{\cos\omega t}{\omega}\right]_0^{T/2}$$

$$= \frac{V_m}{RT}\left[\frac{-\cos\frac{2\pi}{T}\frac{T}{2} + \cos 0}{\omega}\right]$$

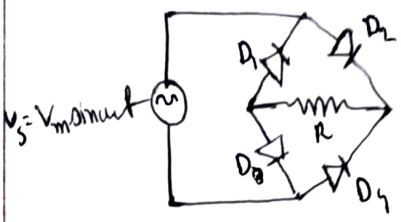
$$= \frac{V_m}{RT} \times \left[\frac{-(-1)}{\omega} + \frac{1}{\omega}\right]$$

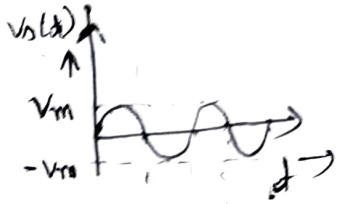
$$= \frac{V_m}{RT} \times \frac{2}{\frac{2\pi}{T}}$$

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

$$= \frac{I_m}{\pi}$$

Full wave bridge rectifier:-

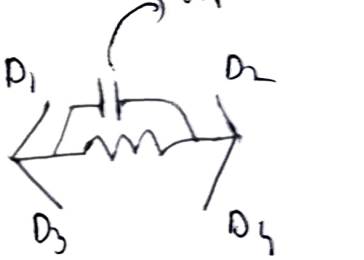








 → not pure DC



using capacitor w/ R

→  → 

RC = T → time constant

time required to discharge

How to make pulsating DC to pure DC

Ans; Capacitor

Average value;

$$I_{avg} = I_{dc} = \frac{1}{T/2}\left[\int_0^{T/2}\left(\frac{V_0(t)}{R}\right)dt\right]$$

$$= \frac{2}{T}\left[\int_0^{T/2}\frac{V_m \sin\omega t}{R}\,dt\right]$$

$$= \frac{2V_m}{RT} \times \frac{2}{\omega}$$

$$= \frac{2V_m}{RT} \times \frac{2}{2\pi/T}$$

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

∴ similarly,

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

Zener diode & voltage regulator/stabilizer

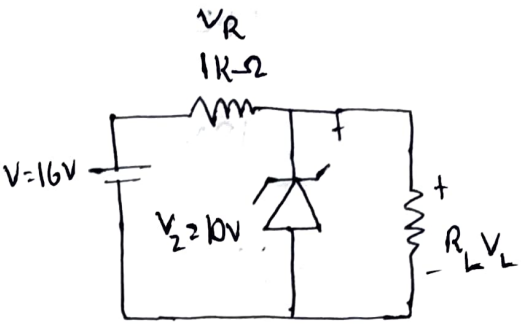
operates in reverse biase condition

SB 13/07/23

Example 2.26

a) Find I_z when, $R_L = 1.2\,k\Omega$

b) Find I_z when, $R_L = 3\,k\Omega$



a) Here,

$$V_L = \frac{1.2}{1+1.2} \times 16\ V$$

$$= 8.73\ V$$

$\therefore V_L < V_z$

$\therefore$ Zener diode is inactive.

$\therefore I_z = 0A$

$\therefore V_R = 16 - 8.73 = 7.27\ V$

b) Here,

$$V_L = \frac{3}{1+3} \times 16 \text{ V}$$

$$= 12\text{V}$$

$\therefore V_L > V_z$

$\therefore$ zener diode is active

Now,

$V_R = 16 - 10\text{V} = 6\text{V}$

$V_L' = 10\text{V}$

$$\therefore I_L' = \frac{V_L'}{R_L} = \frac{10}{3}\text{ k}\Omega = 3.33\text{ mA}$$

$$I_R = \frac{V_R}{R} = \frac{6}{1\text{k}\Omega} = 6\text{mA}$$

$\therefore I_z = I_R - I_L$

SB

16/07/23

Transistor

An electronic device used for amplification.

One of the most popular transistors is BJT (Bipolar Junction Transistor)

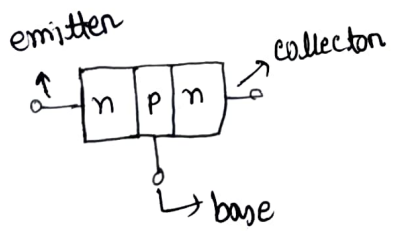
↓ pn junction

↓ Transfer + Resistor

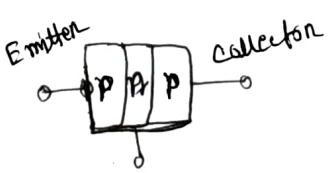
2 types of charge carriers → electron
→ holes

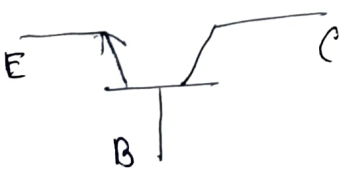
BJT is primarily of 2 types :-

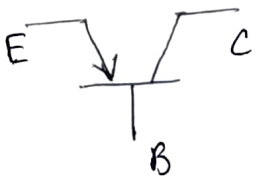
a) npn



b) pnp







Practically npn transistor is used due to the high 'mobility' of electrons as opposed to holes.

Doping :- E > C > B

width :- C > E > B

Modes

Modes of operation:

① Amplifier

② switch ON

③ switch OFF

Configuration

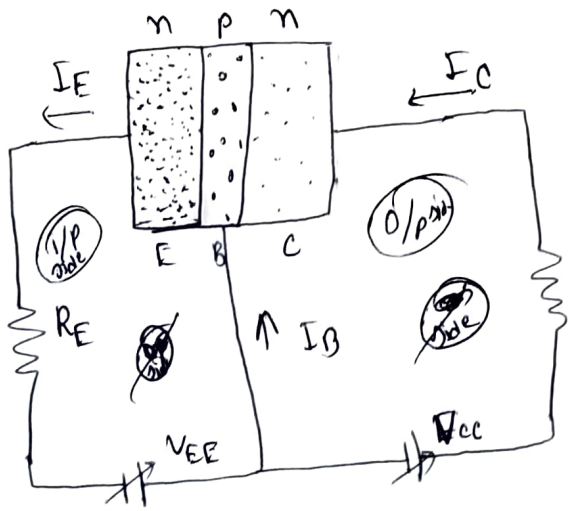
① Common Base

② Common Emitter

③ Common Collector

---

① Common Base



$I_E = I_B + I_C$

For amplification, Base-Emitter junction → Fwd Biased

Collector-Base " → Rev. "

$I_C = \alpha I_E$

$= 0.99 I_E$

$+ I_{CBO}$

I_B is experimentally very low

$\boxed{I_C = \alpha I_E + I_{CBO}}$

I_{CBO} → leakage current

CBO → Open Emitter Collector Base current

Here,

$I_C = \alpha I_E + I_{CBO}$

Since I_{CBO} is very low,

$I_C \approx \alpha I_E$

$\therefore \alpha = \frac{I_C}{I_E}$ $\left[\approx 0.99 ; < 1\right]$

α = common base current (gain / Amplification Factor)

Here,

I_c (o/p current) $\approx$ I_E (i/p current)

Now,

R_{in} → Input resist → low

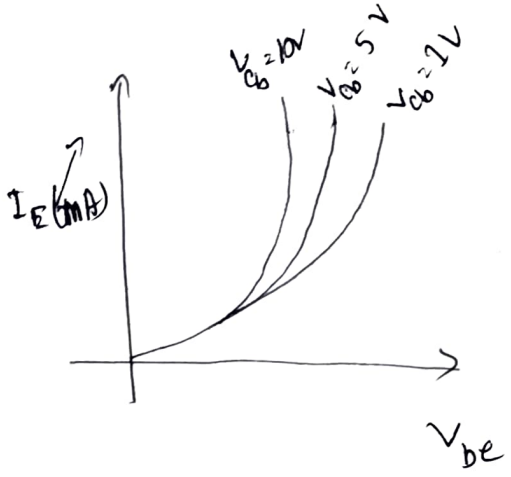
R_{out} → o/p resist → high

V_{bc} ∵ $I_c \times R_{out}$ > $I_E \times R_{in}$ → V_{cb}

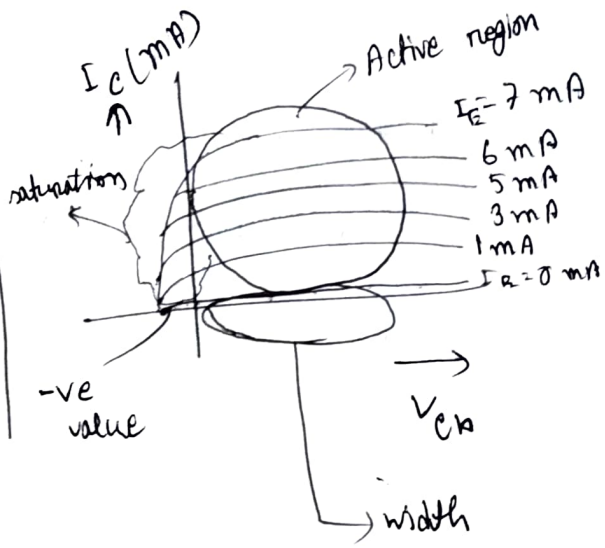
$\therefore A_v = \frac{V_{cb}}{V_{be}} >> 1$

BJT → amplifies voltage, not current } in common Base configuration

Input characteristics



Output characteristics

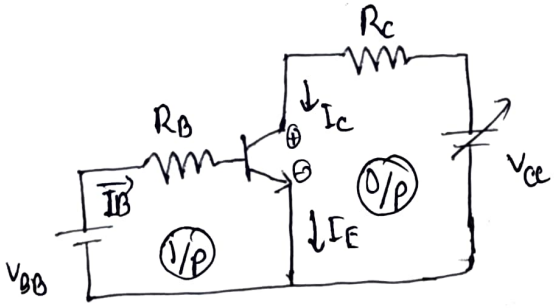


For common base config :

	i/p	o/p
volt.	V_{be}	V_{cb}
curr.	I_E	I_C

SB

Common Emitter Config:



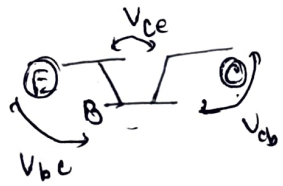
I/P	O/P
V_{be}	V_{cc}
I_B	I_C

For amplification:

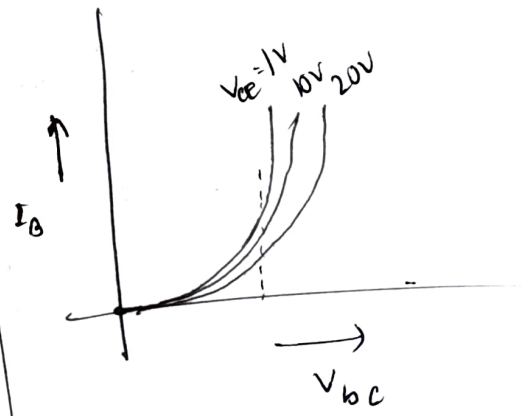
- Collective-base rev biased
- Base Emitter Fwd biased

Here,

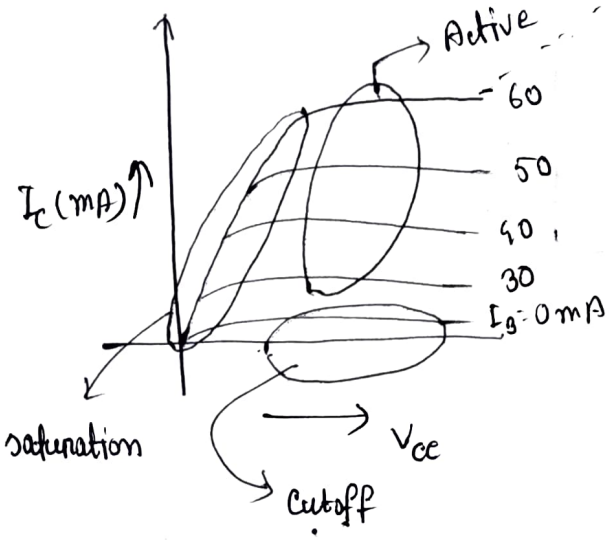
$$V_{ce} = V_{cb} + V_{bc}$$



I/P Characteristics



O/p Characteristics



- angled; increasing

Here,

$V_{ce} = V_{cb} + V_{be}$

if $V_{ce} \uparrow = \uparrow V_{cb} + V_{be}$

$\downarrow$

rev. biased

$\downarrow$

I_C will increase

∴ Current be amplified

For voltage,

$V_{ce} = V_{cb} + V_{be}$

$V_{ce} \gg V_{be}$

∴ Voltage be amplified

Here,

$I_E = I_C + I_B$

Again,

$I_C = \alpha I_E + I_{CBO}$

$= \alpha(I_C + I_B) + I_{CBO}$

$\Rightarrow I_C - \alpha I_C = \alpha I_B + I_{CBO}$

$\Rightarrow I_C(1-\alpha) = \alpha I_B + I_{CBO}$

$\Rightarrow I_C = \frac{\alpha}{1-\alpha} I_B + \frac{1}{1-\alpha} I_{CBO}$

$= \beta I_B + (\beta+1) I_{CBO}$

$= \beta I_B + I_{CEO}$

$\approx \beta I_B$

Let,

$\frac{\alpha}{1-\alpha} = \beta$

$\Rightarrow \frac{\alpha}{1-\alpha} + 1 = \beta + 1$

$\Rightarrow \frac{\alpha + 1 - \alpha}{1-\alpha} = \beta + 1$

$\Rightarrow \frac{1}{1-\alpha} = \beta + 1$

$\therefore \beta = \frac{I_C}{I_B}$

β = Common Emitter Current gain / amplification factor

SB

23/07/23

1) Calculate I_E in a transistor for which $\beta = 50$ & $I_B = 20$ μA.

$I_E = I_C + I_B$

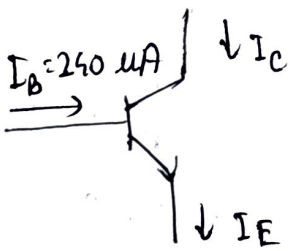
∴ ---

$I_C = \beta I_B + I_{CEO}$ → 0

$= 50 \times 20$

---

2)



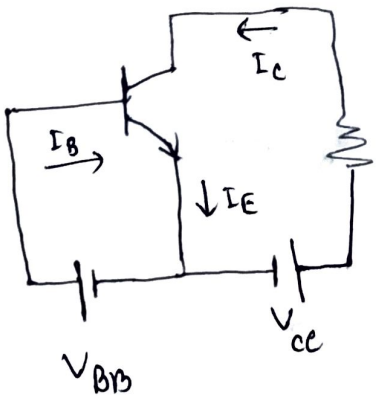
$\beta = 40$

Determine I_C

$I_C = \beta \times I_B$

= ---

3)



$R_C = 1K\Omega$ $V_R = 1V$

Here, $\beta = 95$

$I_B = ?$

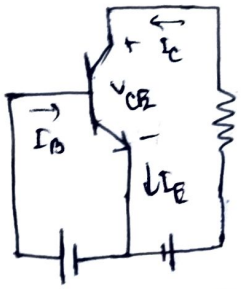
$\beta = \frac{I_C}{I_B} \Rightarrow I_B = \frac{I_C}{\beta}$

$= \cdots$

$I_C = \frac{V_R}{R_C}$

$= \cdots$

Q.



$R_C = 800\ \Omega$

$V_R = 0.5\ V$

$V_{CC} = 8V$

$\alpha = 0.96$

i) Find V_{CE}

ii) Find I_B

$$-8 + 0.5 + V_{CE} = 0$$

$$\therefore V_{CE} = \dots$$

$$\beta = \frac{\alpha}{1-\alpha} = \dots$$

$$I_C = \frac{V_R}{R_C}$$

5.

For an npn BJT, when a voltage of 5V is applied between collector and base, keeping the emitter disconnected, a current of 0.2 μA flows in this state. Consequently, the 5V source is connected to the collector & emitter keeping the base disconnect Now, a current of 20 μA flows. The collector curren is found to be 1 mA. Find:

a) α b) I_E c) I_B

$I_{CBO} = 0.2$ μA

$I_{CEO} = 20$ μA

$I_{CEO} = \frac{I_{CBO}}{1-\alpha}$

$I_C = \alpha I_E + I_{CBO}$

$I_E = I_C + I_B$

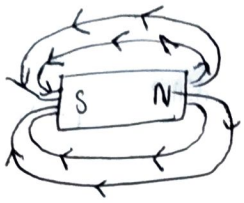
Electrical Machines

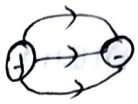
~~Electrical~~

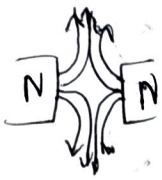
Basic Electrical Technology - Vol - 02 | Ref. Book

- B.L Theraja

Induction Motor







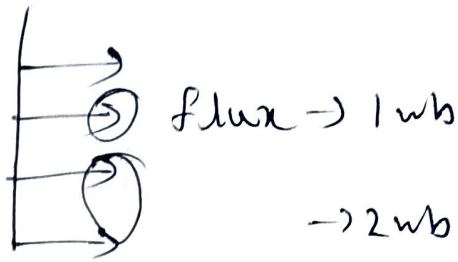
Electromagnet

Magnetic Flux:

- The amount of magnetic field lines passing through a given closed coil.

Symbol → ϕ

Unit → weber (wb)



✱ Faraday's Laws of Electromagnetic Induction:

1) whenever a conducton is placed in a varying magnetic field, an electromotive force is induced. If the conducton ~~curre~~ circuit is closed, an induced current flows through the circuit.



2) The induced emf in the coil is directly proportional to the rate of change of flux.

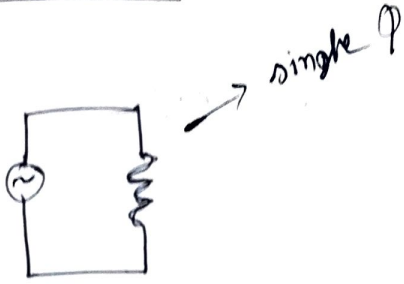
$$E \propto \frac{d\phi}{dt}$$

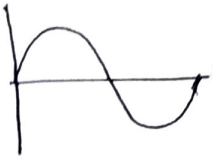
$$\Rightarrow E = N \frac{d\phi}{dt}. \rightarrow \text{incomplete}$$

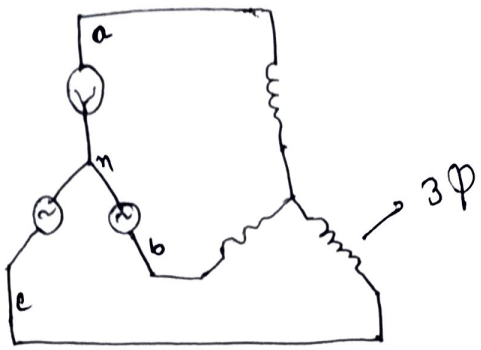
3) Lenz's law

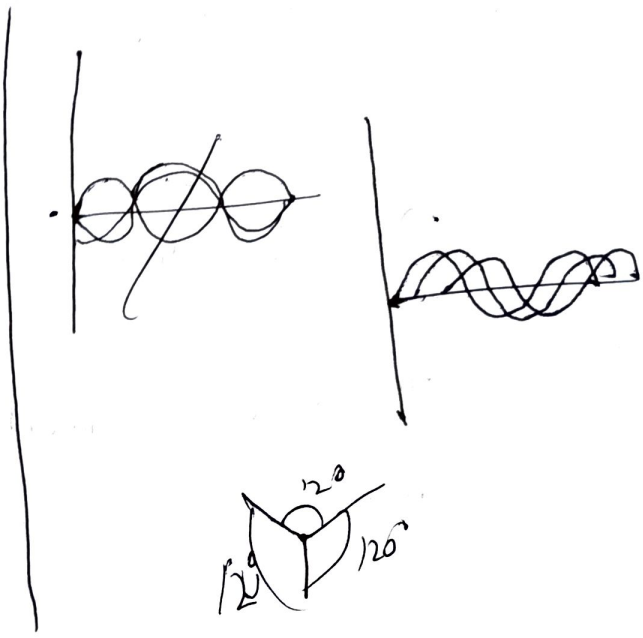
The induced current will flow in such a direction so that

3φ Circuit









Two types of 3φ circuit :

1) Balanced

- Phase diff between each phase is 120°
- magnitude of the phase are equal

ii) unbalanced

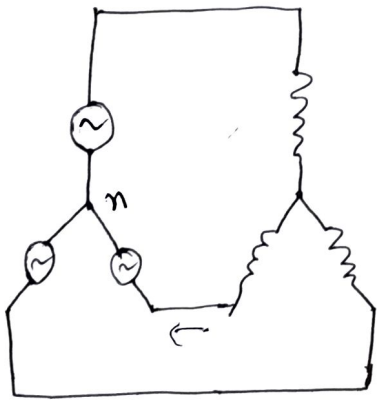
Induction motor

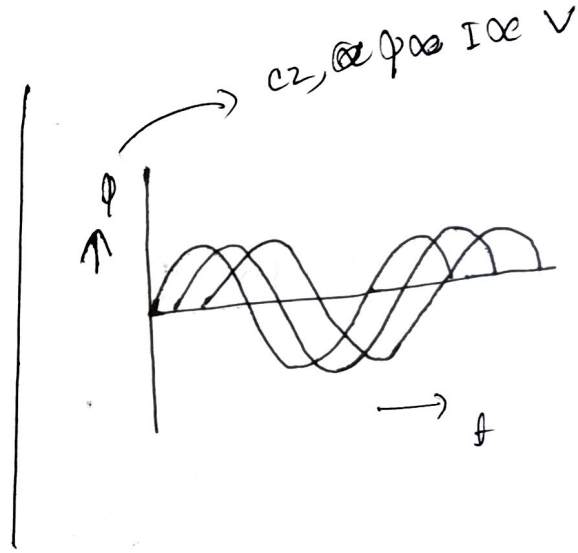
Has two parts → stator, rotor

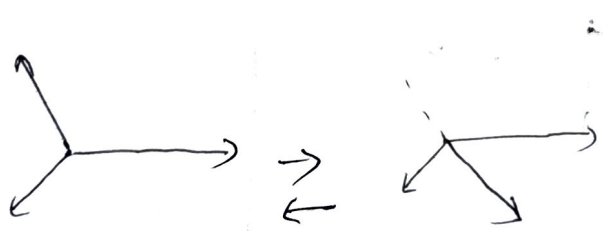
is self starting

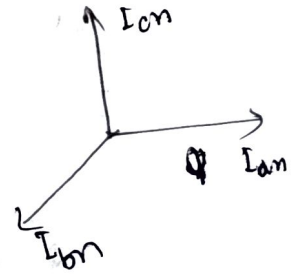
—

★ How the rotor of an induction motor rotates?

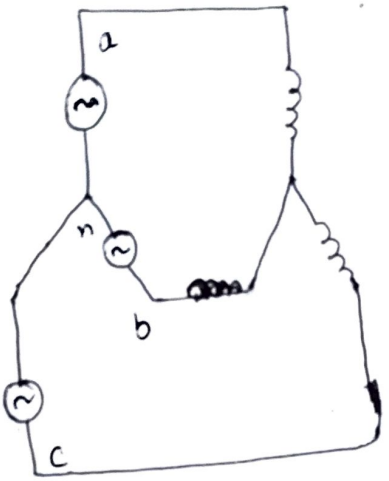


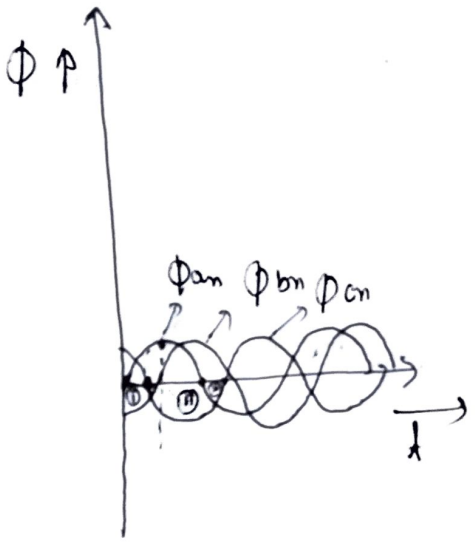




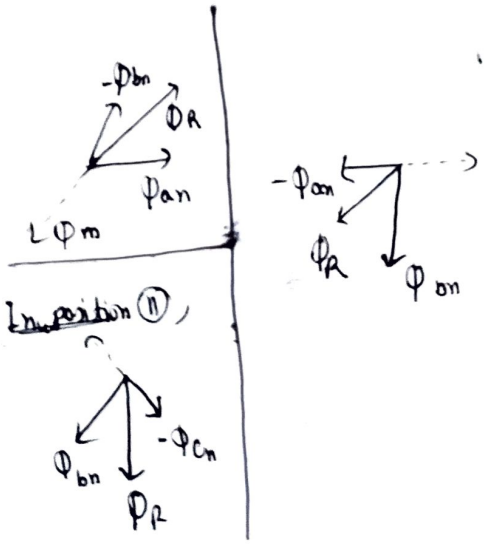


Why rotor in induction motor rotates?

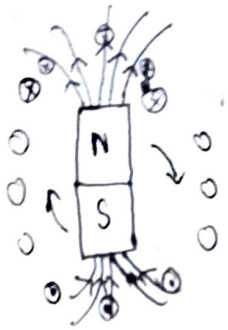




In position (I),



From pos (I), (II) & (III) it is evident that the resultant flux Φ_R is rotating which indicate a Rotating magnetic Field (RMF)



⊙ → current going out inward

⊗ → current going in ~~inward~~

- Suppose RMF is rotating clockwise.

- Now, rotor seems to rotate anticlockwise with respect to the RMF

- Induced current is produced where direction is found from FRH rule.

- Now, mag flux is produced in the conductor which produces a rpaltion as a result Rotor rotates

→ Direction found by FLH rule.

Synchronous speed

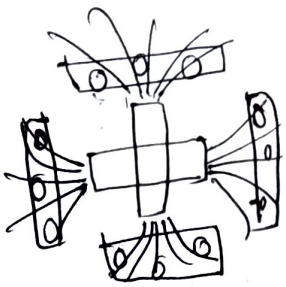
The rotating speed of RMF is called synchronous speed. It is expressed in RPM.

Notation → N_s

$$N_s = \frac{120\,F}{P}$$

F → Frequency of AC supply voltage

P → No of poles



Rotor speed → N

$N < N_s$; can't be $N = N_s$ as relative motion would cease to exist.

Slip :

The diff between rotor & RMF speed is called slip.

$$\text{Slip} = N_s - N$$

It is often expressed as % slip.

$$\% \text{ Slip} = \frac{N_s - N}{N_s} \times 100$$

↳ It indicates how slow the motor is compared to the RMF

S depends on load

load ↑ S ↑

load ↓ S ↓

Supply volt. in stator $\longrightarrow V \longrightarrow$ Frequency $\longrightarrow F$

$$\phi \propto I \propto V$$

$$\downarrow \quad \downarrow \quad \downarrow$$

$$F \quad F \quad F$$

Initially the Frequency of ϕ through the rotor $\rightarrow f$

$\therefore$ The freq of induced current $\longrightarrow F$

We know,

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

$$\Rightarrow F = \frac{N_s P}{120}$$

$\therefore N_s \uparrow f \uparrow$

When rotor starts moving,

Rotor speed $\rightarrow N$

$\therefore$ The freq of ϕ through rotor,

$$f' = \frac{(N_s - N)P}{120}$$

$\therefore$ The freq of induced current through rotor $\rightarrow f'$

A 4 pole 3 ϕ induction motor operates from a supply voltage whose frequency is 50 Hz. Calculate:

(i) The speed at which the magnetic field of the stator is rotating. → 2K

(ii)

(I) → ~~2000~~ 1500

(II) → $0.04 = \frac{N_s - N}{N_s} \times 100$

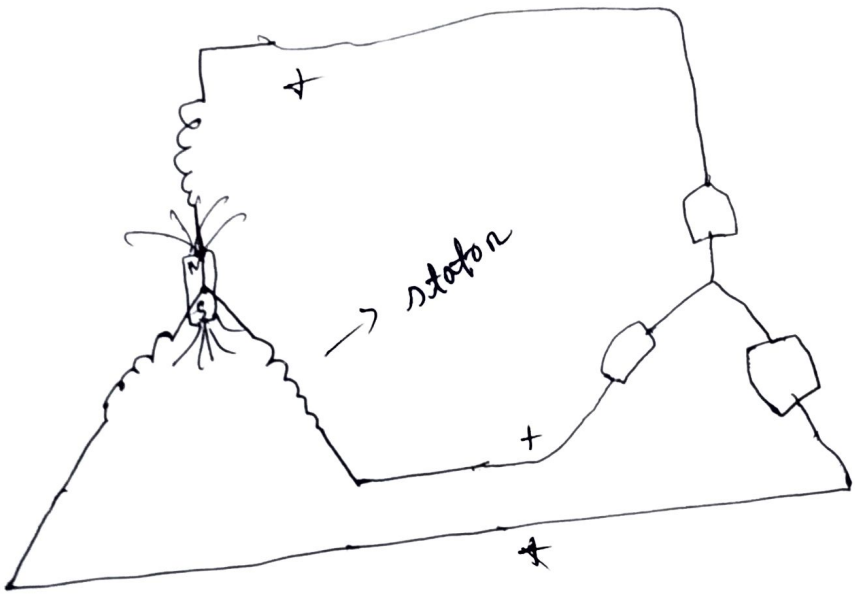
$N = ~~1000.2~~ \; 1499.4$

(III) ~~f'~~ : ~~0.10~~ 0.015

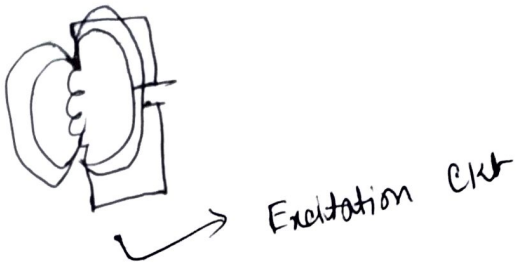
(IV) 50 H_z

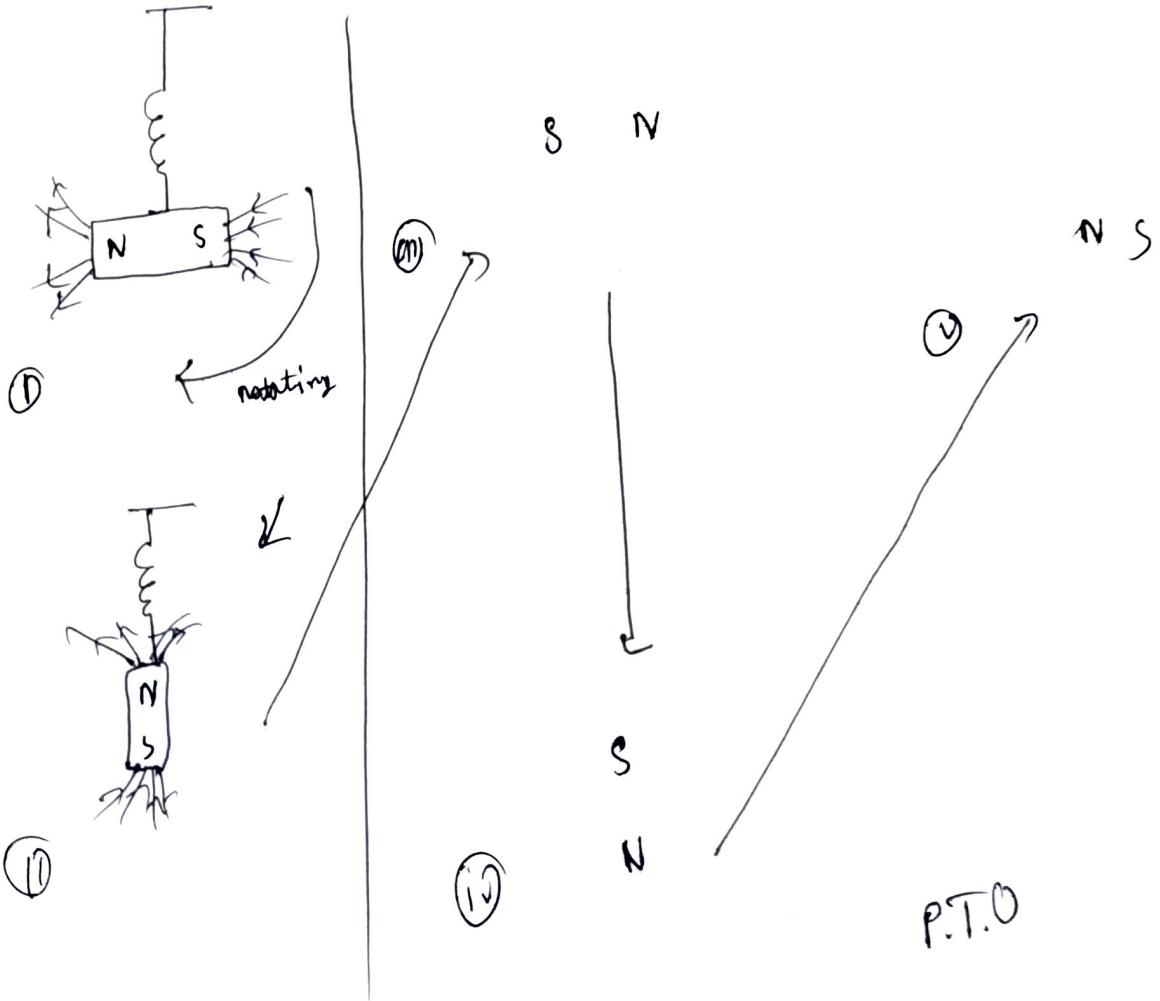
Alternator / AC generator / Synchronous generator :

- Two parts → Stator / Armature
  → Rotor

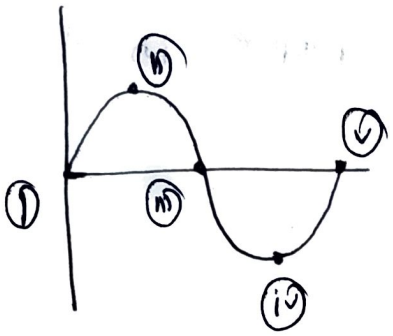


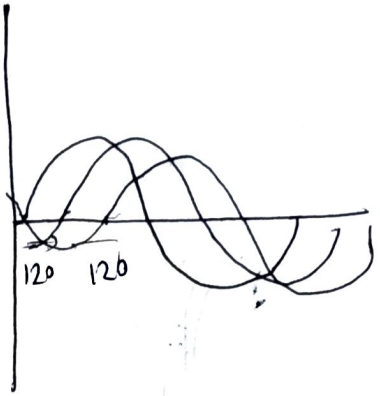
Rotor has a excitation circuit connected to it → its purpose is to create an EMF





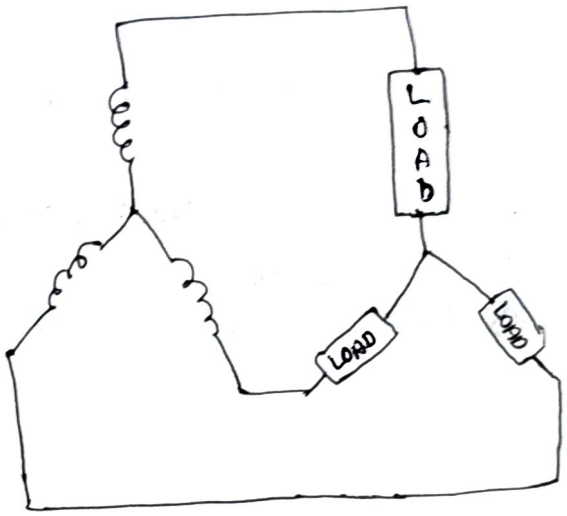
P.T.O


I
II
III
IV
V

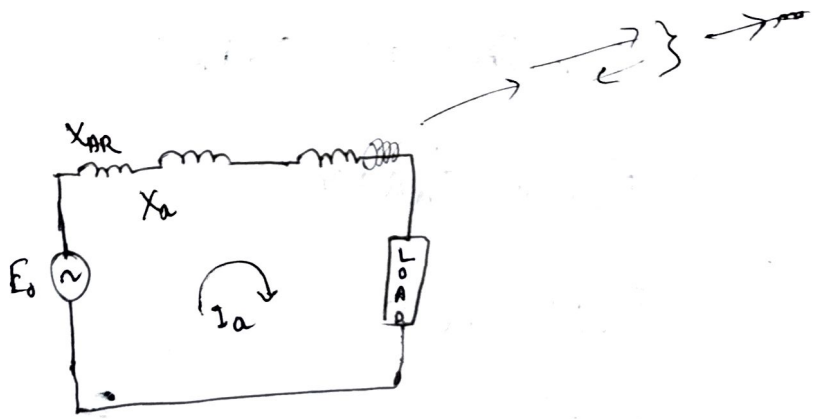

120
120

SB 03/08/23

Terminal voltage



To find the terminal voltage across the load, we conduct per phase analysis.



Armature reaction:

The current induced in the stator creates flux of its own which opposes the flux created by the excitation circuit which ultimately reduces the EMF we indicate this reduction by voltage drop across an inductor X_{AR}.

Now,

$$\vec{E_0} = \vec{I_a} j X_{AR} + \vec{I_a} j X_a + \vec{I} R_a + \vec{V}$$

$$= \vec{I_a} j (X_{AR} + X_a) + \vec{I_a} R_a + \vec{V}$$

$$= \vec{I_a} j X_s + \vec{I_a} R + \vec{V}$$

$$= \vec{I_a} (j X_s + R_a) + \vec{V}$$

$$= \vec{I_a} \vec{Z_s} + \vec{V}$$

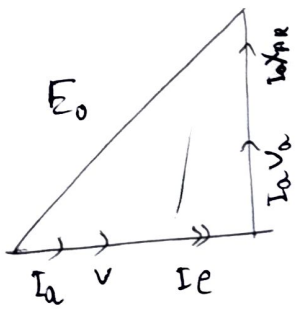
$$\therefore \vec{V_t} = \vec{E_0} - \vec{I} \vec{Z_s}$$

$$\vec{Z} = R + jX_L - jX_C$$

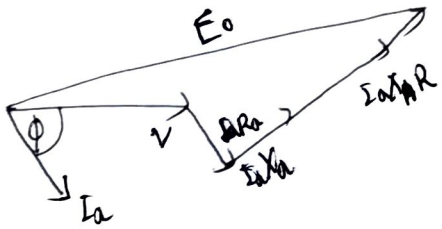
* Phasor / vector diagrams of a loaded Alternator:

Load is of 3 types: Resistive
Inductive
Capacitive

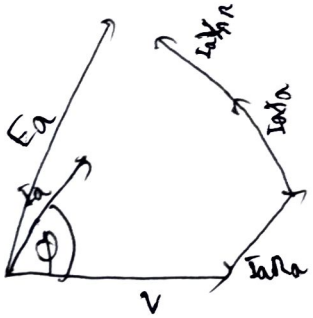
i) Resistive load:



ii) Inductive load:



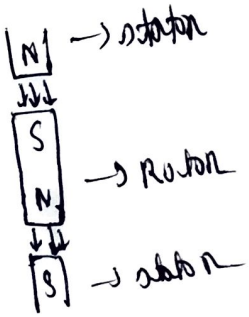
iii) Capacitive load:



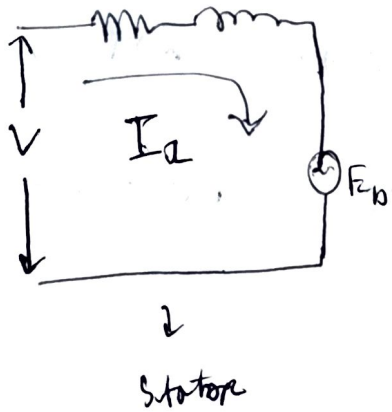
Synchronous motor:

Operating principle:

- 3 ϕ supply provided to stator → RMF is generated
- The rotor is moved using a DC motor to rotate at synchronous speed.
- There is an excitation ckt on the rotor which is then turned on.
- The RMF in stator & magnetic field in rotor get locked with each other. The DC motor is then detached.
- Now, the motor rotates at synchronous (const) speed.



Equiv. ckt per phase



Stator

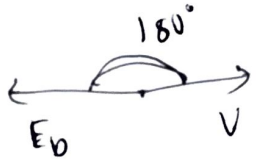


Rotor

Synchronous Motor with different excitation

Unloaded:

- IF $|\vec{E_b}| = |\vec{V}|$ (Normal excitation)



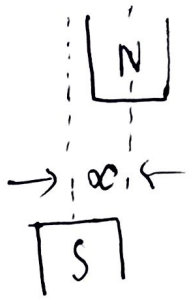
SB 10/08/2023

~~Excitations~~

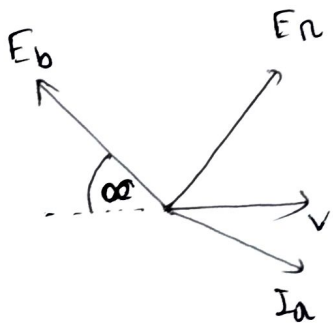
Synchronous motor with different excitations:

Loaded motor:

Normal excitation:



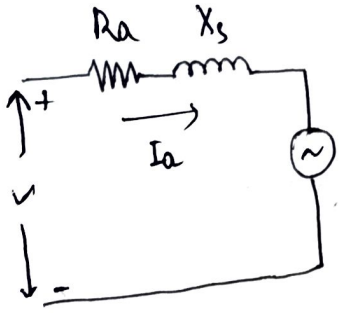
* α → load angle



$|\vec{E_b}| = |\vec{V}|$

- I_a lags V by ϕ, so motor behaves like an inductive load

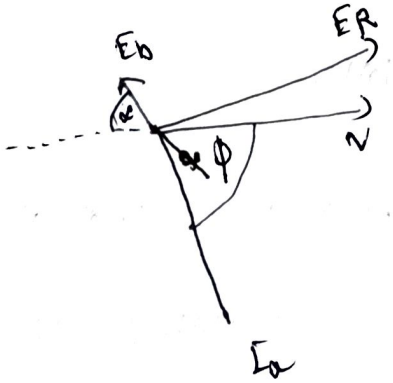
Equiv. ckt per phase:



$R_a \approx 0$

~~Under~~ Under excitation:

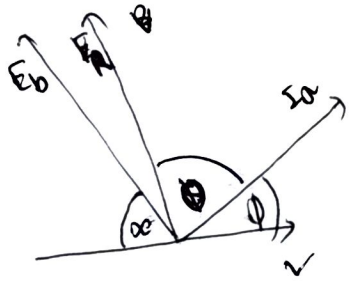
- $|\vec{E_b}| < |\vec{V}|$ $\quad \theta \approx 90°$



Loaded motor:

Over excitation:

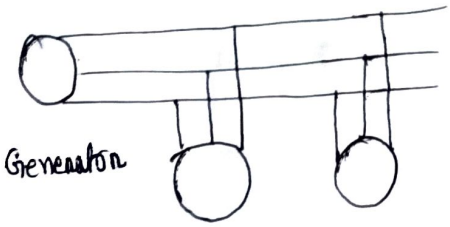
- $|\vec{E_0}| > |\vec{V}|$ $\quad \theta \simeq 90°$



— syn. motor acts capacitive load

Application:

- Power factor connection:
  - Practically all loads are inductive.
  - Synchronous motor operating as a capacitive load is connected parallely to an inductive load to improve the power factor.

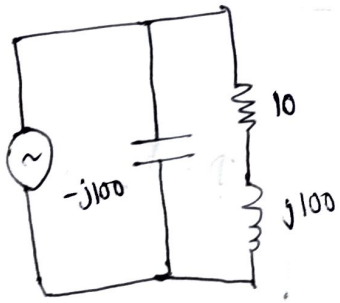


Inductive load

sync. motor

How syn. motor acts as a syn. capacit

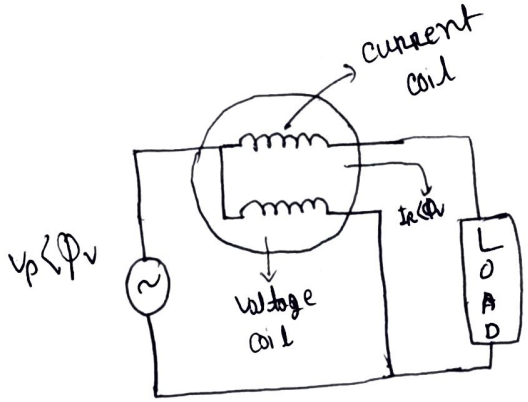
Sync. capacitor



Electrical instruments:

- Wattmeter :-

A device which measures real power in a circuit.

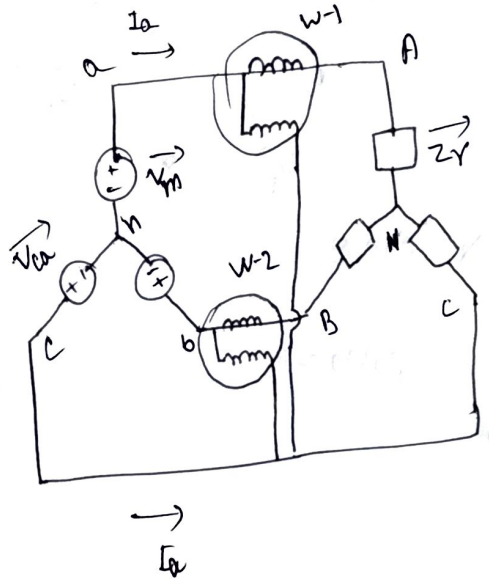


$$W = I_{rms} V_{rms} \cos\phi \qquad \therefore \phi = \phi_V - \phi_I$$

$$= I_p V_p \cos\phi$$

$$= I_L V_L \cos\phi$$

-2. Wall-meter method for measuring real power in a 3-phase balanced circuit:



W-1

Curr → I_a
Vol → V_{ac}

$W_1 = V_{AC} I_a \cos\phi_1$

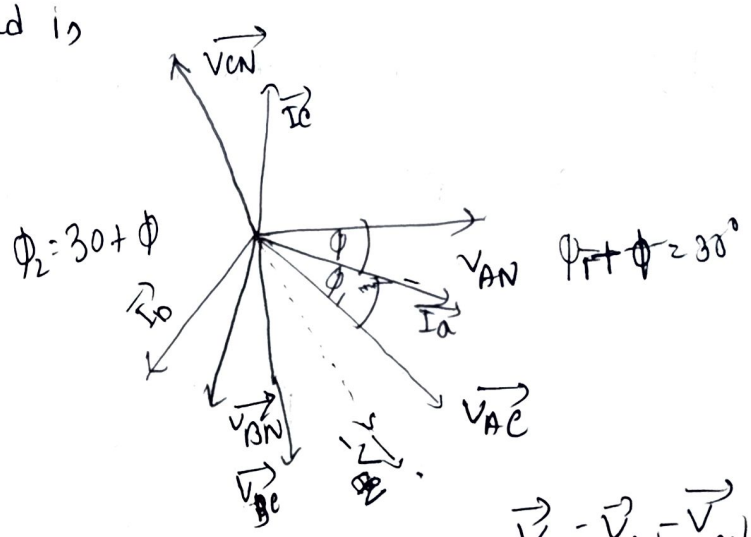
W-2

Curr → I_b
Vol → V_{BC}

$W_2 = V_{BC} I_b \cos\phi_2$

$= V_L I_L \cos(\phi + 30^\circ)$ [from next page]

Let the load is inductive



$\vec{V}_{AC} = \vec{V}_{AN} - \vec{V}_{CN}$

$\vec{V}_{BC} = \vec{V}_{BN} - \vec{V}_{CN}$

line voltage & phase voltage have a phase diff of 30°

Now,

$$W_1 + W_2 = V_L I_L \cos(30 - \phi) + V_L I_L \cos(30 + \phi)$$

$$= V_L I_L \times 2 \cos\left(\frac{30 - \phi + 30 + \phi}{2}\right) \cos\left(\frac{30 - \phi - 30 - \phi}{2}\right)$$

$$= 2 V_L I_L \cos 30 \cos(-\phi) = 2 V_L I_L \frac{\sqrt{3}}{2} \cos\phi$$

$$= \sqrt{3}\, V_L I_L \cos\phi$$

Advantage of three-phase sys

- wire require : 3-phase → 1x ~~single phase~~ → 1.7x

Ⓐ YY YΔ ΔY ΔΔ

First two's math probs

Y-Y → aka line to line

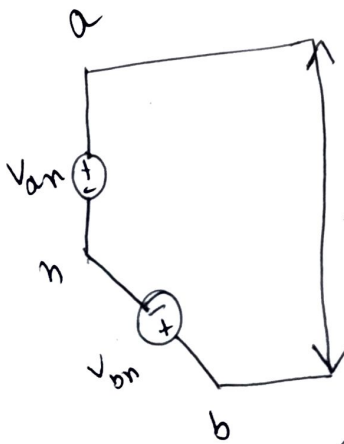
aka phase to neutral

phase vol

V_{an}, V_{bn}, V_{cn}

Line vol

V_{ab}, V_{bc}, V_{ca}



$-V_{an} + V_{ab} + V_{bn} = 0$

$\Rightarrow V_{ab} = V_{an} - V_{bn}$

$V_{ab} = \dots$

$= \sqrt{3}\, V_p \angle -30°$

$|V_{ab}| = \sqrt{3}\, V_p$

for abc sequence

$V_{an} = V_p \angle 0°$

$V_{bn} = V_p \angle -120$

$V_{cn} = V_p \angle +120$

Y Y connection এর ক্ষেত্রে phase to line voltage এর সম্পর্ক

Example 2

---

line current

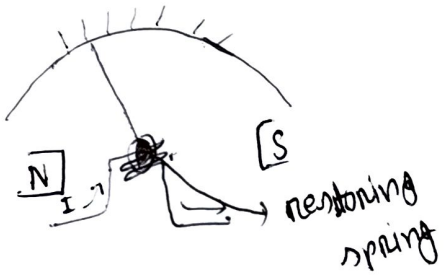
$$I_a = \frac{V_{an}}{Z}$$

SB 17/08

- Basic meter / Galvanometer / PMMC (Permanent Magnet moving coil) meter:

- PMMC meter is an electrical instrument used for detecting the presence of current/voltage

- Basic construction:

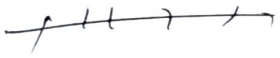


$\tau \propto \phi \times I$

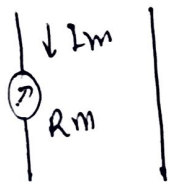
↓

deflection

- The deflection is proportional to the amount of current flown



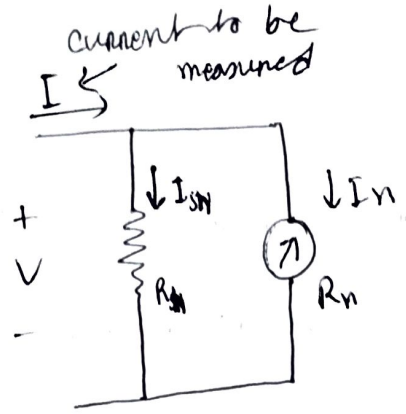
- Symbol



I_m = Full scale deflection current

R_m = Internal resistance

DC Ammeter:



$$I = I_{sh} + I_m$$

Now,

$$R_{sh} I_{sh} = R_m I_m$$

$$\Rightarrow R_{sh} (I - I_m) = R_m I_m$$

$$\Rightarrow R_{sh} = \frac{R_m I_m}{I - I_m} = \frac{R_m}{\frac{I}{I_m} - 1} = \frac{R_m}{m - 1}$$

multiplying factor

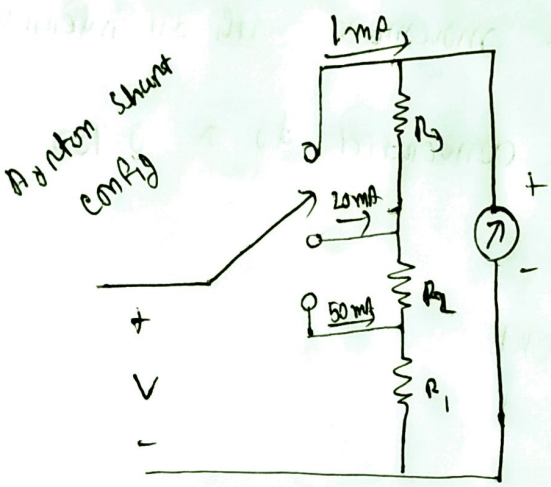
$$\Rightarrow m = \frac{I}{I_m}$$

Problem:

A 1mA PMMC meter movement with an internal resistance of 100Ω is to be converted to a 0-100 mA range ammeter.

Design the ammeter ckt.

Multi range ammeter :



3 ranges
0-1
0-20
0-50
} mA

Prob; Design an Ayrton shunt to provide an ammeter with a current range of 0-1 mA, 0-10 mA and 0-50 mA. A PMMC movement with internal resistance of 100 Ω & full scale current of 50 μA is used.

For 0-1 mA,

$(R_1 + R_2 + R_3) \times (10^{-3} - 50 \times 10^{-6})$

$= 100 \times 50 \times 10^{-6}$

$\Rightarrow R_1 + R_2 + R_3 = 5.26\ \Omega$ —— (1)

For 0-10 mA

$(R_1 + R_2)(10 \times 10^{-3} - 50 \times 10^{-6}) = (R_3 + 100) \times (50 \times 10^{-6})$

$\Rightarrow (5.26 - R_3) \times 0.0095 = R_3 \times 50 \times 10^{-6} + 50 \times 10^{-4}$

$\Rightarrow R_3 = 4.7\ \Omega$

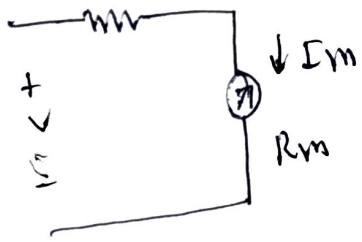
Now for 0-50 mA,

$R_1(50 \times 10^{-3} - 50 \times 10^{-6}) = (R_2 + R_3 + 100) \times 50 \times 10^{-6})$

$\therefore R_2 = 0.45$

$\therefore R_1 = 0.11\ \Omega$

DC volt meter



Here,

$V = I_m (R_s + R_m)$

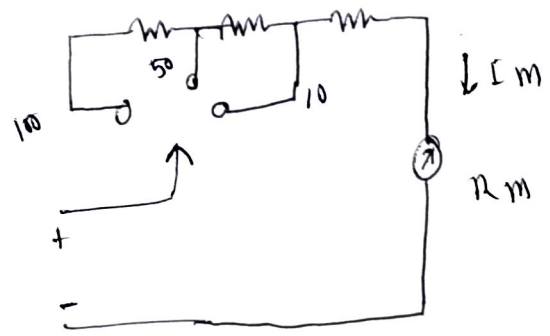
$R_s = \frac{V - I_m R_m}{I_m}$

$= \frac{\frac{V}{I_m R_m} - 1}{\frac{1}{R_m}} = (m-1) R_m$

$= \frac{1}{R_m} V$

Multirange voltmeter

- Problm: convert a PMMC meter movement with an internal resistance of 50 Ω. A full scale deflection current of 2 mA into a multirange dc voltmeter with voltage ranges of 0-10 V, 0-50 V, & 0-100 V



For 0 - 10 V,

$$R_1 = \frac{10 - I_m R_m}{I_m}$$

0 - 50 V,

$$R_1 + R_2 = \frac{50 - I_m R_m}{I_m}$$

For 0 - 100 V,

$$R_1 + R_2 + R_3 = \frac{100 - I_m R_m}{I_m}$$

$$R_3 = \frac{V - I_m R_m}{I_m}$$