

Instrumentation & Process Control
Notes

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SESSION - 2024-25

SEM - 5th

Unit-2

Transducer :- Device which convert mechanical force into electrical signal.

Example - heat, intensity of light, liquid level, humidity and PH value converted into electrical signal.

Advantages of transducer

- (1) Electrical amplification and attenuation can be done easily.
- (2) The mass inertial effect are minimized.
- (3) Effect of friction are minimized.
- (4) Electrical system can be controlled by small power level.
- (5) Electrical output can be easily used, transmitted and processed for the purpose of measurement.

Classification of Transducer :-

- (1) On the basis of transduction form used.
- (2) As primary and secondary transducer.
- (3) As passive and Active transducer.
- (4) As Analog and digital transducer.
- (5) As forward and inverse transducer.

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(1) Principle of Transduction

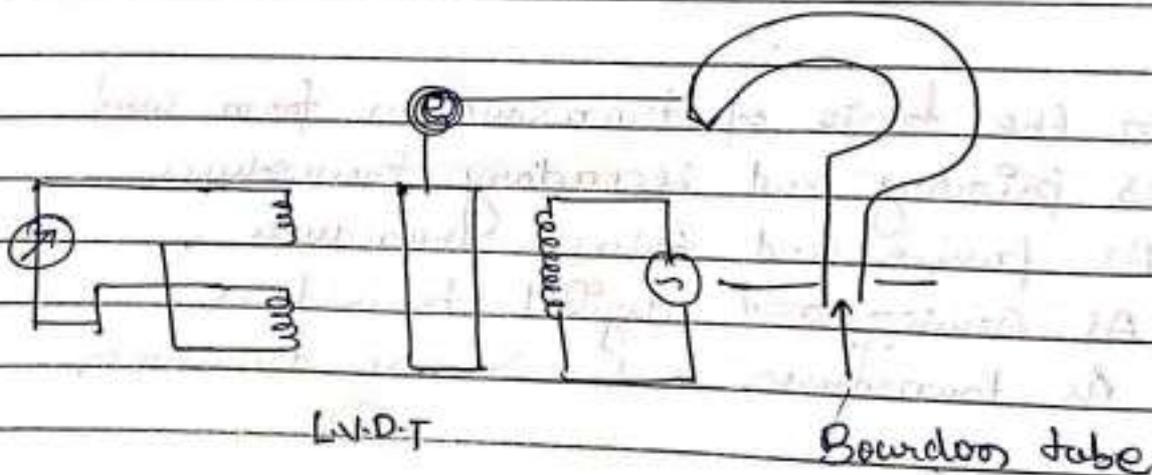
:- Transducers convert the input quantity into resistance, inductance, capacitance, piezo, electric, thermo-electric.

Example R \rightarrow Potentiometer
L \rightarrow Differential transformer
C \rightarrow Variable Capacitor pressure gauge etc.

(2) Primary and Secondary Transducer

:- In any system, if more than two transducers are used, then the transducer which convert physical quantity into physical quantity, that is called primary transducer.

Secondary transducer is which convert physical quantity to electrical quantity.



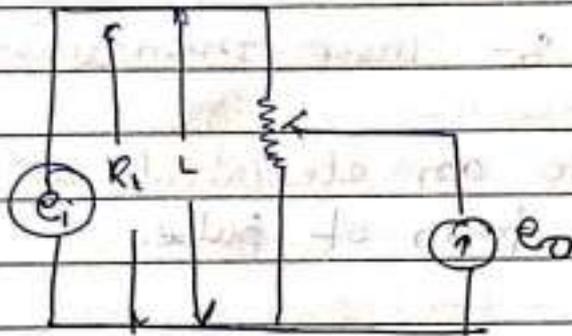
Secondary

primary

③ Passive and Active Transducers :-

Passive transducers :-

- Transducer that require power for transduction
- known as "externally powered transducer".



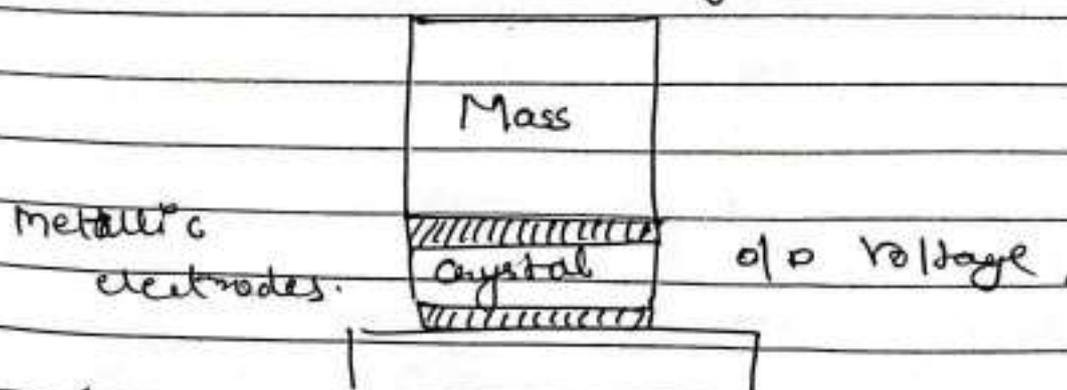
④ Active transducer :-

Active transducers are those which do not required auxiliary power supply to produce their O/P.

ex. Velocity, temperature, light intensity, and force
another examples

→ Tachogenerator, thermo-couple, photovoltaic cell and piezo-electric crystal.

consider piezoelectric crystal



5) Analog and digital transducers

① Analog transducer :- These transducers convert the input quantity into an analog output which is continuous in time.

Example :- Strain gauge, thermo-couple

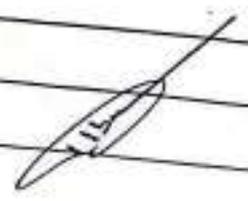
② Digital transducer :- These transducers convert the input quantity into an electrical output which is on in the form of pulse.

Example :- Speed measurement by stroboscope.

6) Transducer and inverse transducer

→ Electrical ← Physical Transducer:

→ Electrical → Physical Inverse Transducer



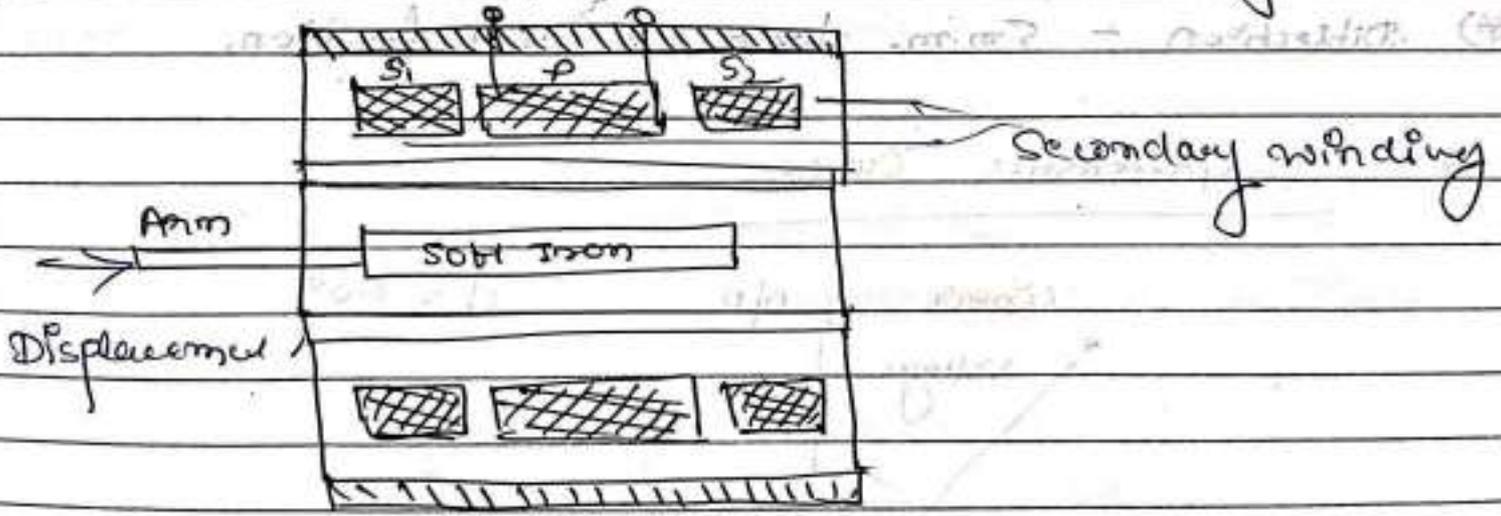
(*) Construction fundamental working principle and Application of :-

- ① L.V.D.T
- ② strain Gauge
- ③ Thermo-couple
- ④ Resistance temperature Detector (RTD)
- ⑤ Thermistor
- ⑥ Piezo-electric
- ⑦ Resistive Inductive and Capacitive
- ⑧ Bourdon tube
- ⑨ Proximity
- ⑩ ultrasonic

① L.V.D.T. → Linear variable differential transducer.

Principle :- Inductive transducer

→ Linear motion into electrical signal

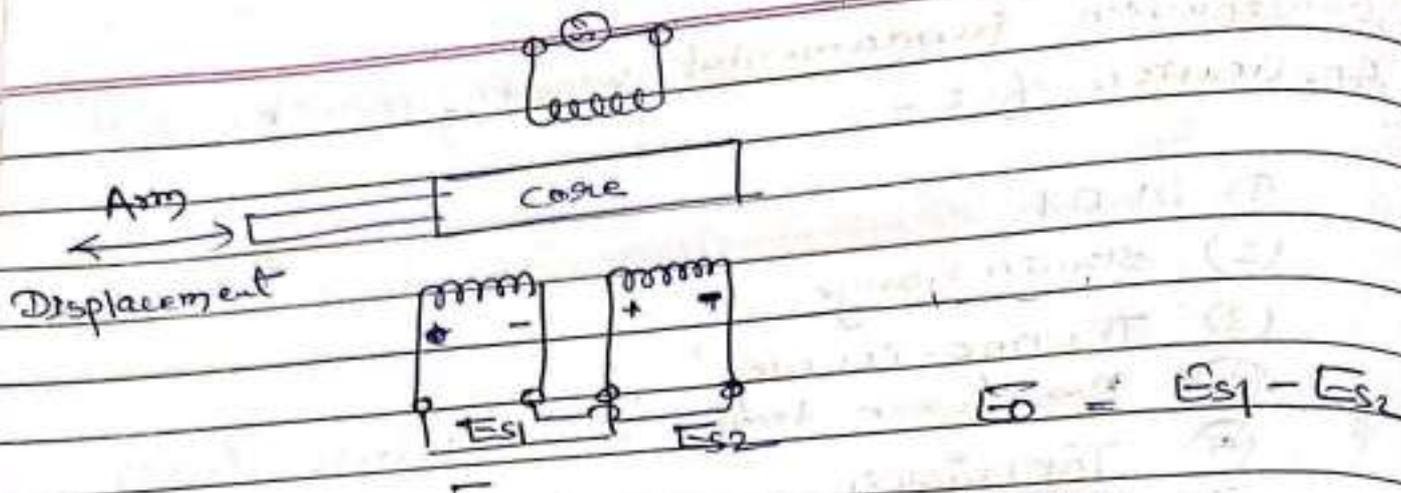


Core :- Soft Iron

Outer section — Stainless steel housing and the end lid provide electrostatic and electro-magnetic shielding.

Signature.....

A.c. excitation



This connection is in series opposition.
If the position of the core is shifted toward left then,

$$E_{s1} > E_{s2}$$

$$E_{op} = E_{s1} - E_{s2}$$

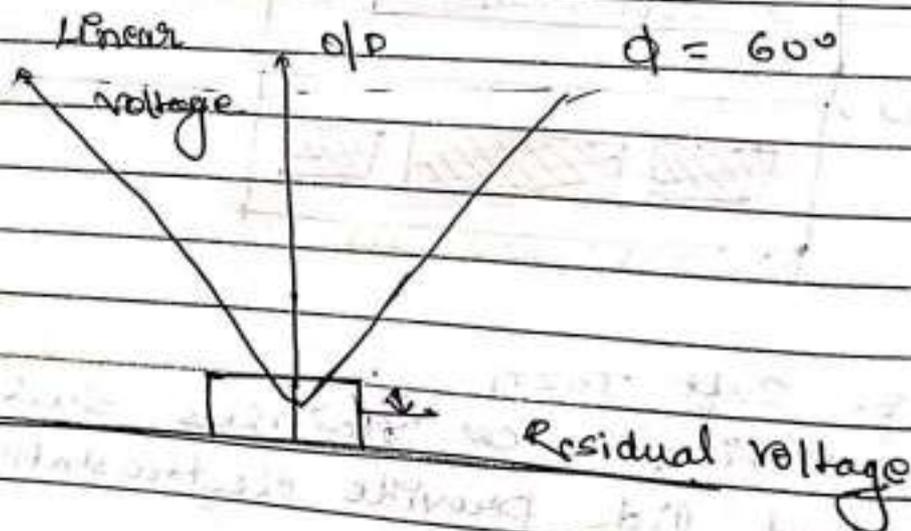
For right shift

$$E_{s2} > E_{s1}$$

$$E_{op} = E_{s1} - E_{s2}$$

(*) Direction - 5 mm. from the null position.

→ Characteristics Curve



Advantages of L.V.D.T.

- ① Large range :- measure displacement upto 125mm to 250mm
- ② Friktion and Electrical Isolation :-
- ③ Low power consumption :- App. 1W.
- ④ Low hysteresis :-
- ⑤ Ruggedness :-
- ⑥ Disadvantages :-

- 1) Large displacement produces small output.
- 2) Transducer function may be affected by vibration.
- 3) They are sensitive to stray magnetic field.

$$\frac{1}{A} = \frac{1}{A}$$

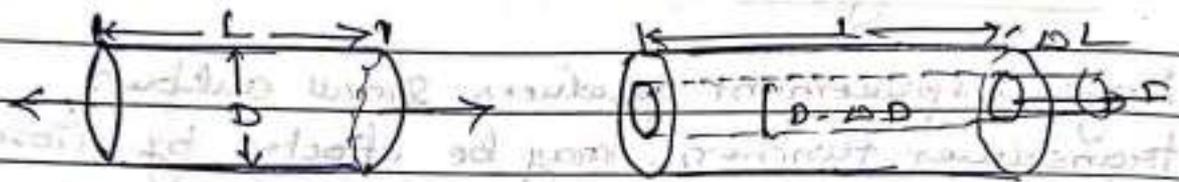
ΔL - change in length
 ΔA - change in area
 ΔR - change in resistance
 $\Delta \rho$ - change in resistivity

Applications → Structural health monitoring of
 Railways & streets monitoring
 Aero space wings, Cable Bridges

Resistive transducer :-

" Strain Gauge "

Q- If a metal conduction is stretched or compressed its resistance changes on account of fact that both length and diameter of conductor changes. Also there is a change in the value of resistivity of the conductor when it is strained and this property is called piezoresistive effect. i.e. it is called piezoresistive transducer.



positive strain or length increases and diameter of conductor decreases.

- Resistance of the conductor also increased.

$$R = \frac{\rho \cdot L}{A}$$

Let tensile stress applied to it,
 then

- ΔL - smallest change length
- ΔA - smallest change in Area
- ΔR - change in resistance
- ΔD - change in diameter

$$R = \frac{\rho \cdot L}{A}$$

Deformation with respect to stress

$$\frac{d}{ds}(R) = \frac{d}{ds}\left(\frac{\rho L}{A}\right)$$

$$\frac{d}{ds}(R) = \frac{\rho}{A} \frac{\partial L}{\partial s} + \frac{L}{A} \frac{\partial \rho}{\partial s} - \frac{\rho L}{A^2} \frac{\partial A}{\partial s} \quad (1)$$

Equation (1) divided by (R)

$$\frac{1}{R} \frac{d}{ds}(R) = \frac{\frac{\rho}{A} \frac{\partial L}{\partial s}}{R} + \frac{\frac{L}{A} \frac{\partial \rho}{\partial s}}{R} - \frac{\frac{\rho L}{A^2} \frac{\partial A}{\partial s}}{R}$$

$$\frac{1}{R} \frac{d}{ds}(R) = \frac{\frac{\rho}{A} \cdot \frac{\partial L}{\partial s}}{\frac{\rho L}{A}} + \frac{\frac{L}{A} \frac{\partial \rho}{\partial s}}{\frac{\rho L}{A}} - \frac{\frac{\rho L}{A^2} \frac{\partial A}{\partial s}}{\frac{\rho L}{A}}$$

$$\Rightarrow \frac{1}{R} \frac{d}{ds}(R) = \frac{1}{L} \frac{\partial L}{\partial s} + \frac{1}{\rho} \frac{\partial \rho}{\partial s} - \frac{1}{A} \frac{\partial A}{\partial s}$$

$$\frac{1}{A} \frac{\partial A}{\partial s}(R) = \frac{1}{L} \frac{\partial L}{\partial s} + \frac{1}{\rho} \frac{\partial \rho}{\partial s} - \frac{1}{A} \frac{\partial A}{\partial s}$$

$\frac{\partial L}{\partial s}$ - per unit change in length.

$\frac{1}{\rho} \frac{\partial \rho}{\partial s}$ = per unit change in resistivity.

$\frac{\partial A}{\partial s}$ - per unit change in Area.

$$A = \frac{\pi D^2}{4}$$

$$\Rightarrow \frac{1}{A} \frac{\partial A}{\partial s} = \frac{1}{\frac{\pi D^2}{4}} \frac{\partial}{\partial s} \left(\frac{\pi D^2}{4} \right)$$

$$= \frac{1}{(\pi D^2)/4} \times \frac{2D \cdot \partial D}{4} \frac{\partial D}{\partial s}$$

$$= \frac{2}{D} \frac{\partial D}{\partial s}$$

Deformation with respect to stress

$$\frac{d}{ds}(R) = \frac{d}{ds} \left(\frac{\rho L}{A} \right)$$

$$\frac{d}{ds}(R) = \frac{\rho}{A} \frac{\partial L}{\partial s} + \frac{L}{A} \frac{\partial \rho}{\partial s} - \frac{\rho L}{A^2} \frac{\partial A}{\partial s} \quad (1)$$

Equation (1) divided by R

$$\frac{1}{R} \frac{d}{ds}(R) = \frac{\frac{\rho}{A} \frac{\partial L}{\partial s}}{\frac{\rho L}{A}} + \frac{\frac{L}{A} \frac{\partial \rho}{\partial s}}{\frac{\rho L}{A}} - \frac{\frac{\rho L}{A^2} \frac{\partial A}{\partial s}}{\frac{\rho L}{A}}$$

$$\frac{1}{R} \frac{d}{ds}(R) = \frac{\frac{\rho}{A} \cdot \frac{\partial L}{\partial s}}{\frac{\rho L}{A}} + \frac{\frac{L}{A} \frac{\partial \rho}{\partial s}}{\frac{\rho L}{A}} - \frac{\frac{\rho L}{A^2} \frac{\partial A}{\partial s}}{\frac{\rho L}{A}}$$

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$$= \frac{2}{D} \frac{\partial D}{\partial s}$$

Deformation with respect to stress

$$\frac{d(R)}{ds} = \frac{d\left(\frac{\rho \cdot L}{A}\right)}{ds}$$

$$\frac{d(R)}{ds} = \frac{\rho}{A} \frac{\partial L}{\partial s} + \frac{L}{A} \frac{\partial \rho}{\partial s} - \frac{\rho L}{A^2} \frac{\partial A}{\partial s} \quad (1)$$

Equation (1) divided by (R)

$$\frac{1}{R} \frac{d(R)}{ds} = \frac{\frac{\rho}{A} \frac{\partial L}{\partial s}}{R} + \frac{L \frac{\partial \rho}{\partial s}}{R} - \frac{\frac{\rho L}{A^2} \frac{\partial A}{\partial s}}{R}$$

$$\frac{1}{R} \frac{\partial(R)}{\partial s} = \frac{\frac{\rho}{A} \cdot \frac{\partial L}{\partial s}}{\frac{\rho L}{A}} + \frac{L \frac{\partial \rho}{\partial s}}{\frac{\rho L}{A}} - \frac{\frac{\rho L}{A^2} \frac{\partial A}{\partial s}}{\frac{\rho L}{A}}$$

$$= \frac{1}{L} \frac{\partial L}{\partial s} + \frac{1}{\rho} \frac{\partial \rho}{\partial s} - \frac{1}{A} \frac{\partial A}{\partial s}$$

$$\frac{1}{A} \frac{\partial A}{\partial s} = \frac{1}{L} \frac{\partial L}{\partial s} + \frac{1}{\rho} \frac{\partial \rho}{\partial s} - \frac{1}{A} \frac{\partial A}{\partial s}$$

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$$= \frac{1}{(\pi D^2)/4} \times \frac{2D \cdot \pi^2}{4} \frac{\partial D}{\partial s}$$

$$= \frac{2}{D} \frac{\partial D}{\partial s}$$

$$\frac{1}{R} \frac{dR}{ds} = \frac{1}{L} \frac{dL}{ds} - \frac{2}{D} \frac{dD}{ds} + \frac{1}{s} \frac{ds}{ds}$$

Poisson ratio $\nu = \frac{\text{Lateral strain}}{\text{Longitudinal strain}} = -\frac{dD/D}{dL/L}$

$$\frac{dD/D}{ds} = -\frac{dL}{L} \times \text{Poisson Ratio}$$

$$= -\frac{dL}{L} \cdot \nu$$

$$\frac{1}{R} \frac{dR}{ds} = \frac{1}{L} \frac{dL}{ds} + \nu \cdot \frac{2}{L} \frac{dL}{ds} + \frac{1}{s} \frac{ds}{ds}$$

Smallest change $\frac{dR}{ds} = \Delta R$

$$\frac{\Delta R}{R} = \frac{\Delta L}{L} + 2\nu \frac{\Delta L}{L} + \frac{\Delta s}{s}$$

Gauge factor $\Rightarrow G_f = \frac{\Delta R/R}{\Delta L/L}$

$$\frac{\Delta R/R}{\Delta L/L} = \frac{\Delta L/L}{\Delta L/L} + \frac{2\nu \Delta L/L}{\Delta L/L} + \frac{\Delta s/s}{\Delta L/L}$$

$$\frac{\Delta R/R}{\Delta L/L} = 1 + 2\nu$$

HOV
neglecting

micro strain = impressed

1 micro strain = 1 mm/m

Material	Gauge factor	Material	Gauge factor
Nickel	-12.1	Platinum	4.8
Manganin	0.47	Carbon	20
KPchrome	2.0	Doped Crystal	100-5000

Signature: _____

Q1 A resistance wire strain gauge uses a soft iron wire of small diameter. The gauge factor is +4.2. Neglecting piezoresistive effect, calculate the poisson ratio.

$$\Rightarrow G_f = +4.2$$

$$G_f = 1 + 2\nu$$

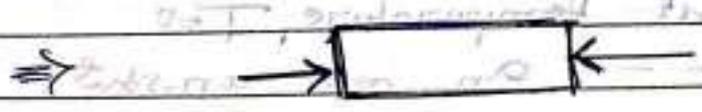
$$4.2 = 1 + 2\nu$$

$$3.2 = 2\nu$$

$$\nu = \frac{3.2}{2}$$

$\nu = 1.6$ poisson Ratio

Q2 A compressive force is applied to a structural member. The strain is 5 micro-strain. Two separate strain gauge are attached to the structural member, one is nickel wire strain gauge having a gauge factor of -12.1 and the other is nichrome wire strain gauge having a gauge factor of 2. Calculate the value of resistance of the gauge after they are strained. The resistance of strain gauge before being strained is 120Ω.



Strain is — 5 micro strain

- ① member Nickel wire strain gauge factor = -12.1
- ② member Nichrome — gauge factor = 2

For member 1

Gauge factor $G_f = \frac{\Delta L/L}{\Delta R/R}$ $G_f = \frac{\Delta R/R}{\Delta L/L}$

$-12.1 = \frac{-5 \times 10^{-6}}{\Delta R/R}$ $\Delta L/L = \text{Strain}$

$\Delta R/R = -5 \times 10^{-6}$

$G_f = \frac{\Delta R/R}{\Delta L/L} \Rightarrow \Delta L/L = \text{Strain}$

$\Delta R/R = G_f \times \text{Strain}$

$\Delta R/R = (-12.1) \times (-5 \times 10^{-6})$

$\Delta R = (-12.1) \times (-5 \times 10^{-6}) \times 120$
 $= 7.26 \text{ m}\Omega$

Similarly for member 2

$\Delta R = 2 \times (-5 \times 10^{-6}) \times 120$
 $= 1.2 \times 10^{-3} \Omega$
 $= 1.2 \text{ m}\Omega$

Resistance Thermometers

∴ The resistance of the conductor is changed when its temperature changes.

$R = R_0 (1 + \alpha_1 T + \alpha_2 T^2 + \dots + \alpha_n T^n + \dots)$

R_0 = Resistance at temperature $T=0$

$\alpha_1, \alpha_2, \alpha_3 \dots \rightarrow$ are constants

material used for is — platinum —

— it can be used for high temperature stability

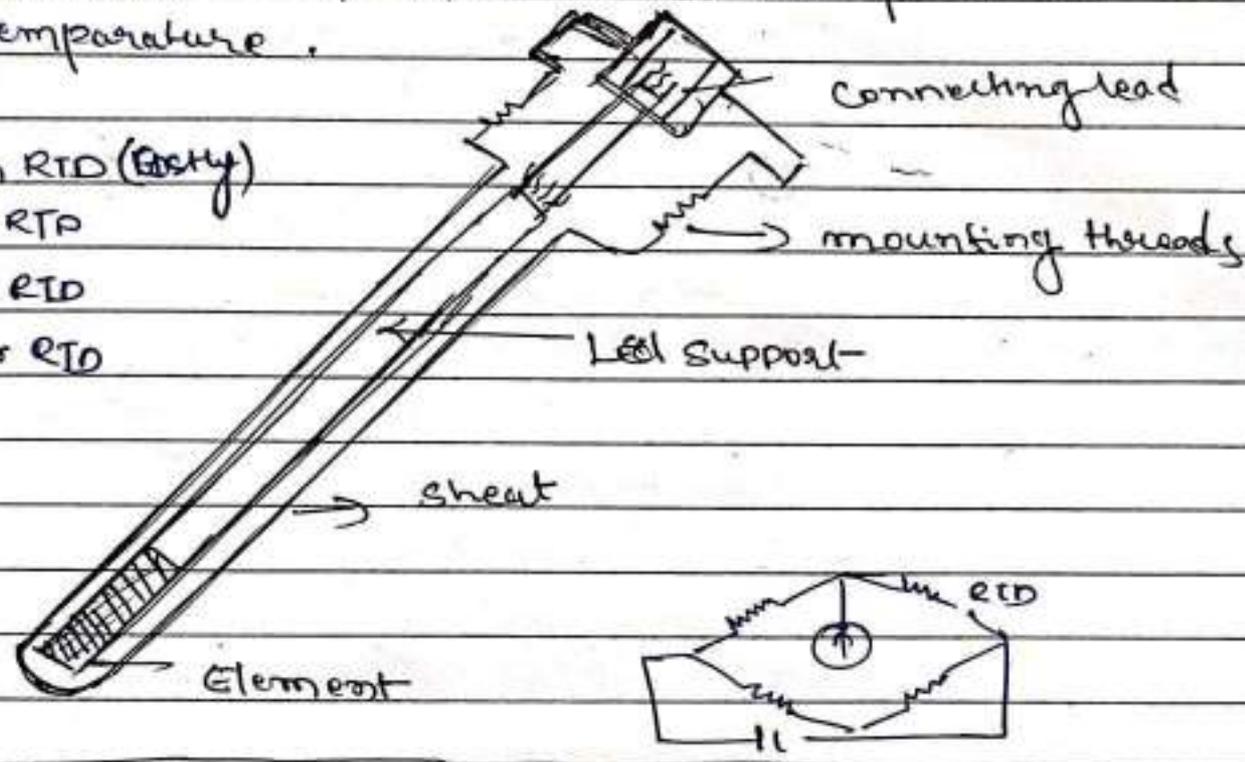
\rightarrow positive coefficient of temperature

Requirement :- to be used as RTD

- ① The changes in resistance of material per unit change in temperature should be as large as possible.
- ② The material should have high value of resistivity so that minimum volume of material is used for the construction of RTD.
- ③ The resistance of material should have a continuous and stable relationship with temperature.

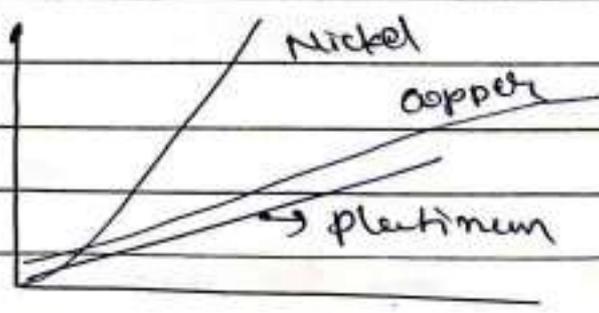
Type- platinum RTD (Best)
 Copper RTD
 Nickel RTD
 Thermistor RTD
 (Cheap)

Advantage* - High Accuracy
 * wide temp.
 * linear response.



RTD material — Platinum, nickel, nickel alloys

Range — 102



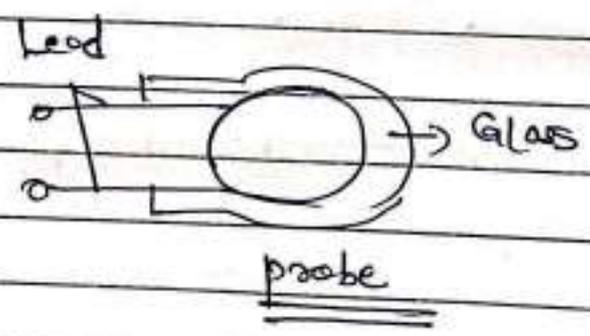
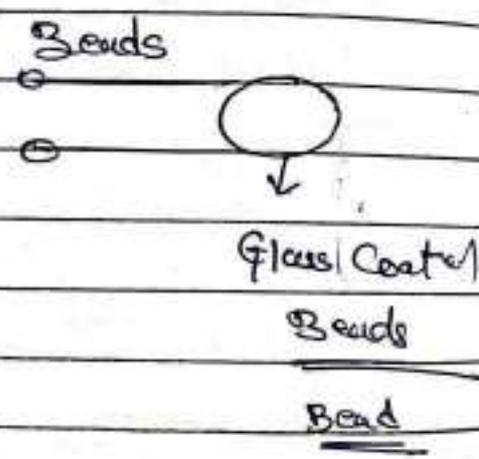
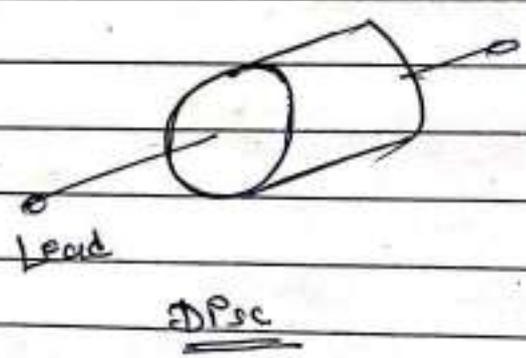
- Disadvantages
- Cost
 - Low current op
 - Fragility
 - Non-linear

Signature.....

Thermistor

Thermal Resistor \rightarrow Thermistor

- \rightarrow made up of semiconductor.
- \rightarrow positive temperature coefficient (Temperature increases Resistance also increases)
But most Thermistors are NTC
- \rightarrow High temperature sensitivity which could not be detected in the RTD.
- \rightarrow Range -150°C to 60°C to -15°C .
- \rightarrow material required :- Magnesium, manganese, Nickel, Cobalt, copper Iron, Uranium
- \rightarrow Size \rightarrow 0.015mm to 1.25mm. (diameter)



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Resistance - Temperature characteristics

$$R_{T_1} = R_{T_2} \exp \left[\beta \left(\frac{1}{T_1} - \frac{1}{T_2} \right) \right]$$

R_{T_1} = resistance of the thermistor at absolute Temp. T_1 °K

$$R_{T_2} = \frac{\beta}{T_2} \quad T_2 \text{°K}$$

β = a constant depending upon the material of thermistor, typically 3500 - 4500°K

material used \rightarrow Platinum commonly

Range - -100°C and 400°C , the thermistor change its resistivity from 10^5 to $10^2 \text{ }\Omega$.

Application of Thermistors

- 1) Measurement of Temperature
- 2) Measurement of thermal conductivity
- 3) Vacuum measurement
- 4) Measurement of composition of gas

Temperature Range

1. °C Celsius $\rightarrow 0^\circ - 100^\circ\text{C}$

2. °F Fahrenheit - $32^\circ\text{F} - 212^\circ\text{F}$

$$C = \frac{5}{9}(F - 32)$$

$$= \frac{212 - 32}{9} = 20$$

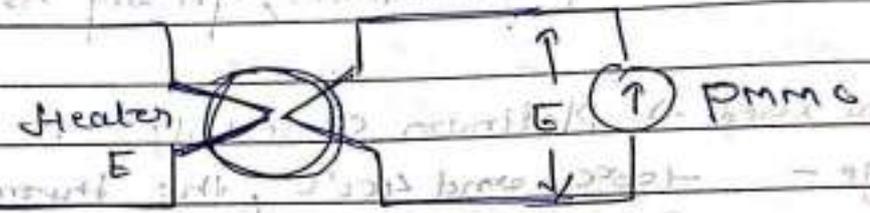
3. °K Kelvin - $273.15\text{K} - 373.15\text{K}$

$$K = C + 273.15$$

Thermocouples

:- When two metals having different work functions are placed together, a voltage is generated at the junction which is nearly proportional to the temperature. This junction is called a thermo-couple.

:- Heat energy is converted into electrical energy.

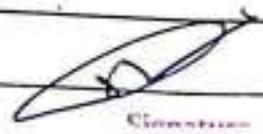
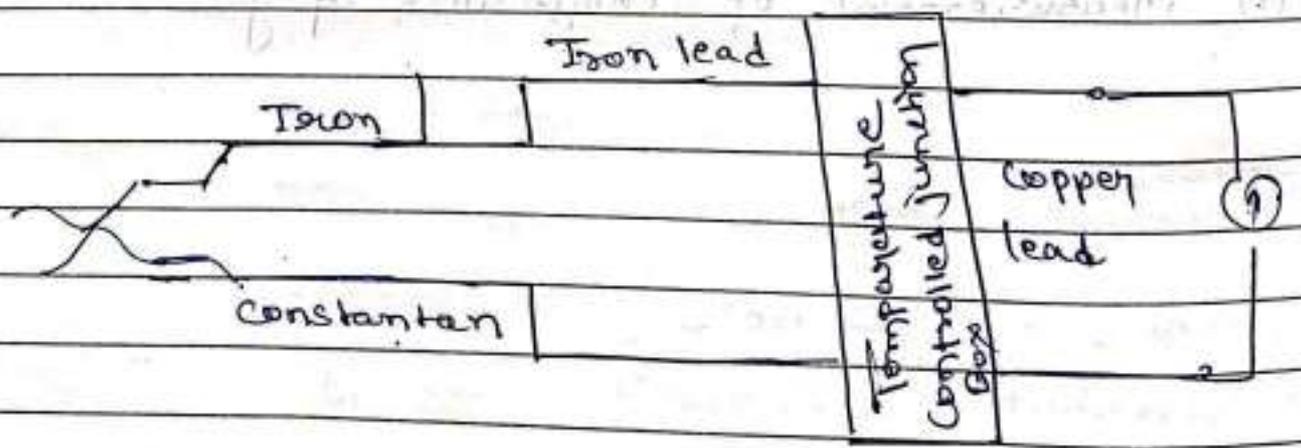


:- suitable for both A.C and D.C application

$$E = a(T_1 - T_2) + b(T_1 - T_2)^2$$

a, b constant depends upon the metal

$\Delta\theta = T_1 - T_2$ temperature difference between the two junction.



Advantages and disadvantages of Thermocouple

Advantages :- 1) Cheaper than resistance thermo-meter
(2) Thermocouple follow the temperature change with a small time lag and

Disadvantages :- ① Lower Accuracy.
② To ensure the long life of thermo-couple, large protection is required.

Piezo-electric Transducer

- A piezo-electric (Transducer) material is one in which an electric potential appear across certain surface of a crystal if the dimension of the crystal are changed by application of mechanical force. This potential is produced by displacement of charge. Its reverse effect is also possible, this effect is known as "piezo-electric effect".

→ Example - Rochelle salts, ammonium dihydrogen phosphate, lithium sulphate, quartz etc

Natural → quartz, ceramics, Rochelle salt

Advantages and disadvantages of Thermocouple

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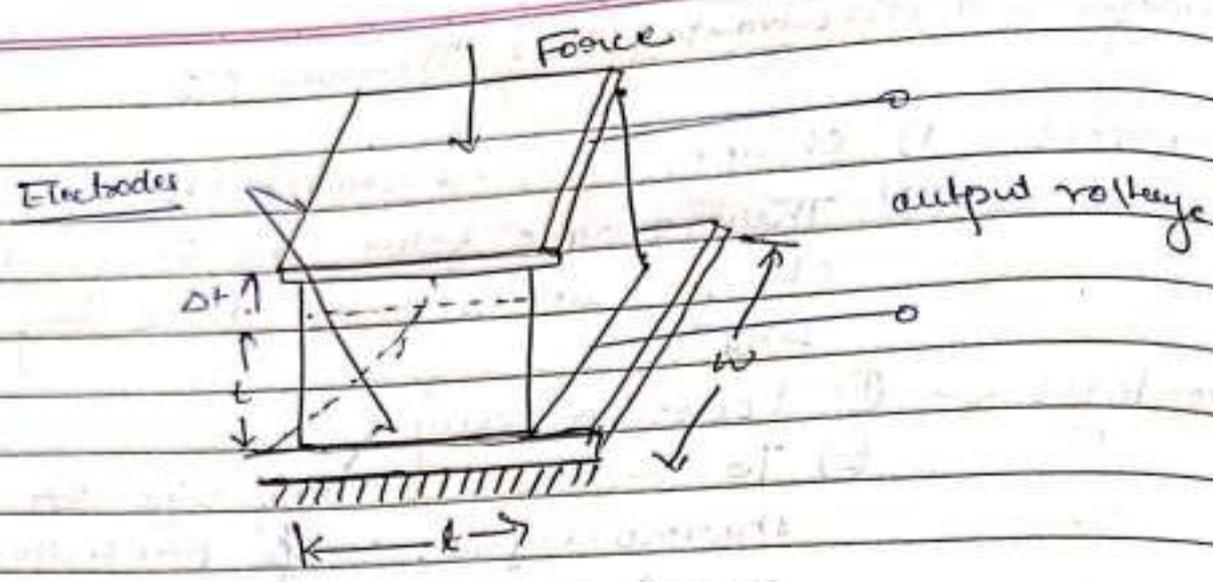
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Piezo-electric Transducers

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→ Example - Rochelle salts, ammonium dihydrogen phosphate, lithium sulphate, quartz etc

Natural → quartz, ceramics, Rochelle salt



charge $Q = d \times F$ Coulomb
 $d =$ Charge sensitivity of crystal (C/N)
 $F =$ Applied Force

Then Force causes change in thickness of crystal

$E = ?$

Young's Modulus $\Rightarrow E = \frac{\text{Stress}}{\text{Strain}} = \frac{F/A}{\Delta t/t}$

$$E = \frac{F \cdot t}{A \cdot \Delta t}$$

Then Force $F = \frac{A \cdot E \cdot \Delta t}{t}$ newton

$A \Rightarrow$ Area of plate $\Rightarrow w \times l$ ($l =$ length)
 $w =$ width

$$Q = d \cdot F$$

$$= d \cdot \frac{A \cdot E \cdot \Delta t}{t}$$

$$Q = \frac{d \cdot w \cdot l \cdot E \cdot \Delta t}{t}$$



The change at the electrodes give rise to an output voltage

$$Q = C_p \cdot E_0$$

$E_0 \rightarrow$ output voltage

$$C_p = \frac{\epsilon_0 \epsilon_r \cdot A}{t}$$

$$E_0 = \frac{Q}{C_p}$$

$$= \frac{d \cdot F}{\epsilon_0 \epsilon_r \cdot A / t}$$

$$E_0 = \frac{d \cdot t}{\epsilon_0 \epsilon_r} \cdot \frac{F}{A}$$

$$E_0 = \frac{d}{\epsilon_0 \epsilon_r} \cdot P \cdot t$$

$P \rightarrow$ pressure = F/A

$g \Rightarrow$ voltage sensitivity $\rightarrow g = \frac{d}{\epsilon_0 \epsilon_r}$

$$E_0 = g \cdot P \cdot t$$

Applied Force depends up on the modulus of elasticity of material.

Example Barium titanate $g = 12 \times 10^{10} \text{ N/m}$

quartz $g = 8.6 \times 10^6 \text{ N/m}$

Capacitive Transducer

$$C = \frac{\epsilon_0 \epsilon_r \cdot A}{d}$$

A = overlapping area of plate, m^2

d = distance between two plates, m

$\epsilon = \epsilon_0 \epsilon_r$ = permittivity of medium F/m

ϵ_r = relative permittivity

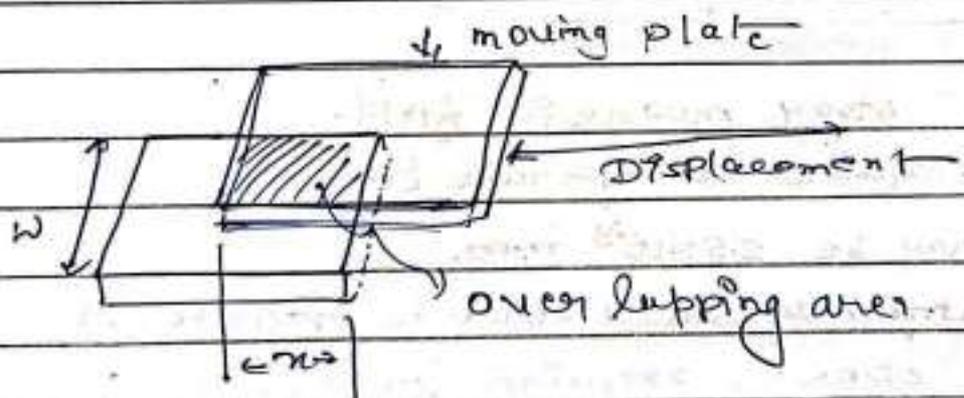
ϵ_0 = permittivity of free space

$$= 8.85 \times 10^{-12} \text{ F/m}$$

Capacitive transducer can be designed by :-

- 1) Changing overlapping area.
- 2) Changing the distance between two plates.
- 3) Changing dielectric constant of medium.

① Transducer using change in area of plates



x = overlapping area of capacitor

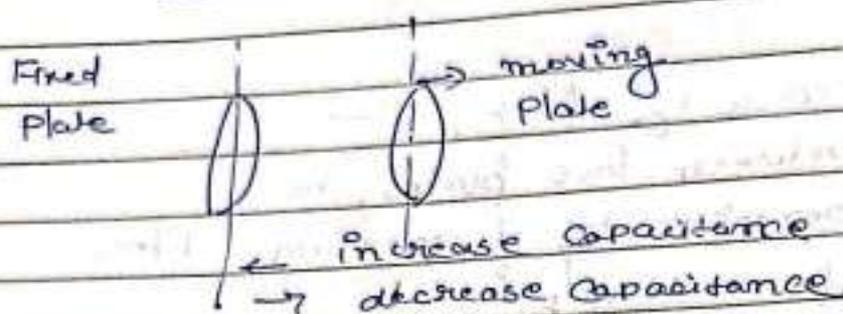
d = displacement between two capacitor

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

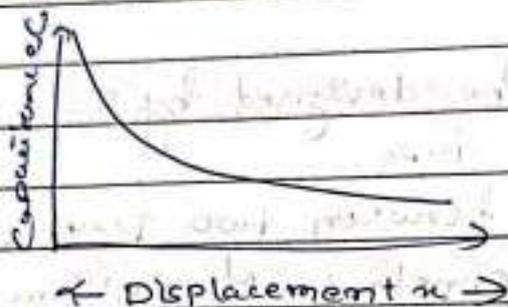
w = width of overlapping plate

$$C = \frac{\epsilon \cdot x \cdot w}{d} \text{ F}$$

② Transducer by using change in distance between plate



Graphical representation



→ It is suitable for measurement small distance.

Advantages of Capacitive transducer

- 1) No effect of stray magnetic field.
- 2) Small power require to operate it.
- 3) resolution may be 2.5×10^{-3} mm.
- 4) It requires extremely small force to operate it, hence small power require for it.

Disadvantages ① - metallic part must be insulated in order to reduce, stray capacitance.

- ② Capacitive transducer shows some times, non-linear behaviour, hence guard ring require.
- ③ Loose cable connecting to source transducer causes error.

Application :- ^① measurement of pressure, force, liquid level.

② measurement of both linear and non-linear displacement.

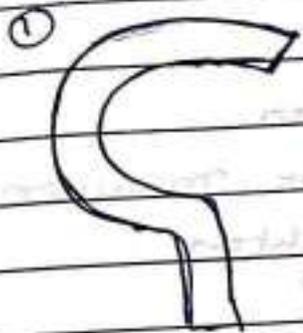
Bourdon Tube

(gas pressure, water pressure, air pressure)

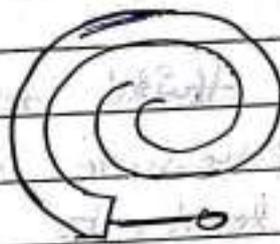
→ Bourdon Tube is used for measurement of pressure
→ used for low pressure to high pressure.

Types of Bourdon Tube :-

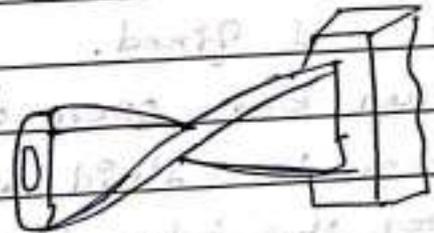
- ① C Type
- ② Spiral
- ③ Twisted tube
- ④ Helical



C Type



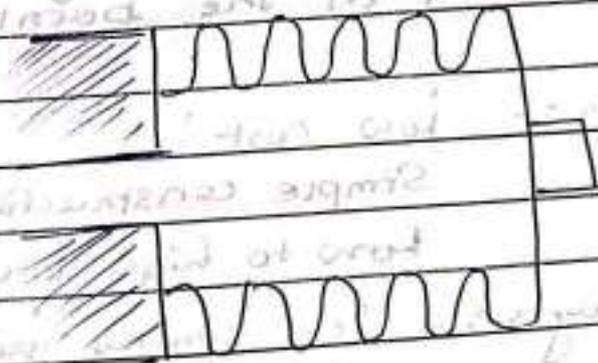
Spiral



Twisted tube

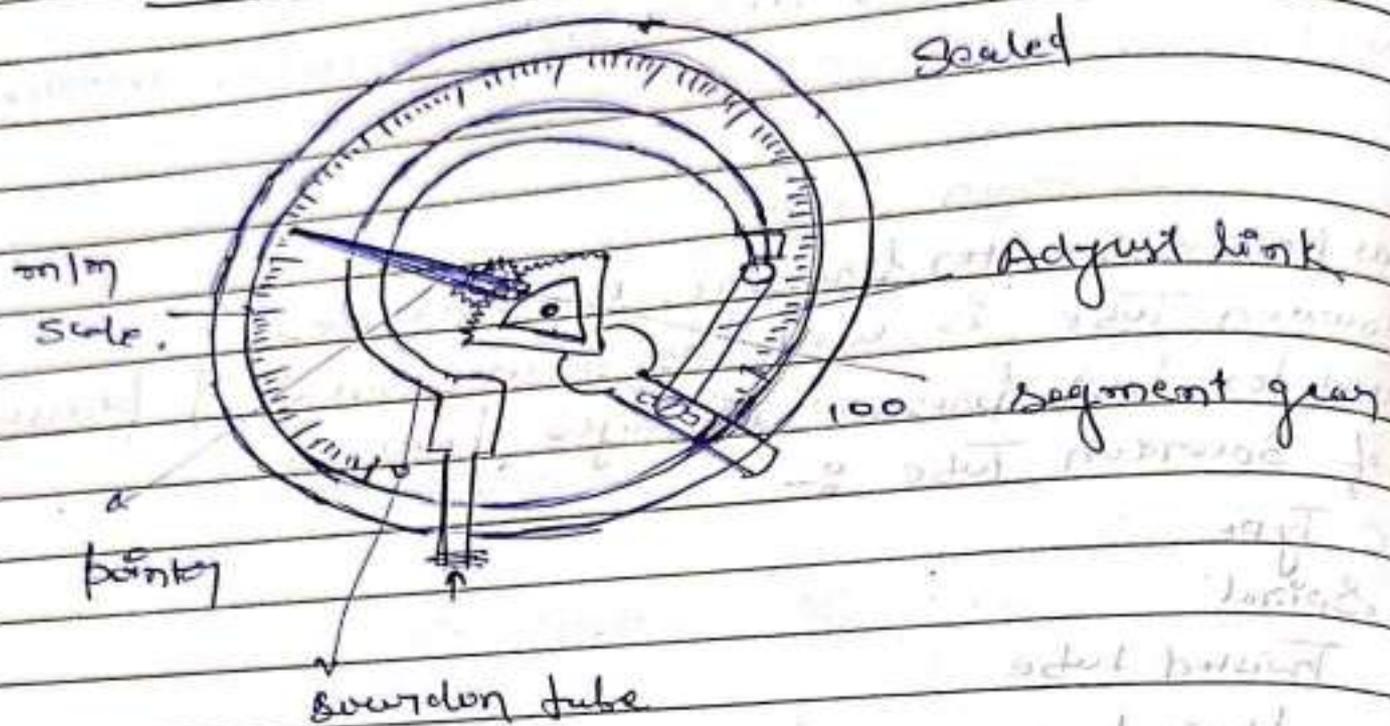


Helical



Bellows

C- Bourdon Tube



- made of - elliptically flattened tube
- one end fixed.
- other end open for the fluid to enter.
- When the fluid, whose pressure is to be measured enter the tube, the tube tends to straighten according to applied pressure.
- This causes moment in free end and amplified with the help of gear mechanism.
- Amplified displacement causes (displacement) deflection in the pointer.

Advantages :-
Low cost
Simple construction
Low to high pressure measurement

Disadvantages :-
Low spring gradient causes
Accuracy problem.

Imp

Proximity Transducer

- used detect the presence of nearby object without any physical contact.
- Emitt \rightarrow Electro-magnetic Radiation
- \rightarrow This electromagnetic radiation, struck the object which is to be detect.

Types - (1) Capacitive proximity / photo electric
 \rightarrow Suitable for plastic target.

(2) Inductive proximity transducer -
always requires metal target.

① Capacitive :-

~~SD~~

Signal conditioning

⇒ The output of first stage transducer will be in a distorted form, which are not suitable for any device, in order to make it usable & satisfactory to drive

The signal conditioning equipment may be required to do linear process like amplification, attenuation, integration, differentiation, addition, & subtraction

Non-linear :- Modulation, demodulation, summing, filtering, clipping and clamping.

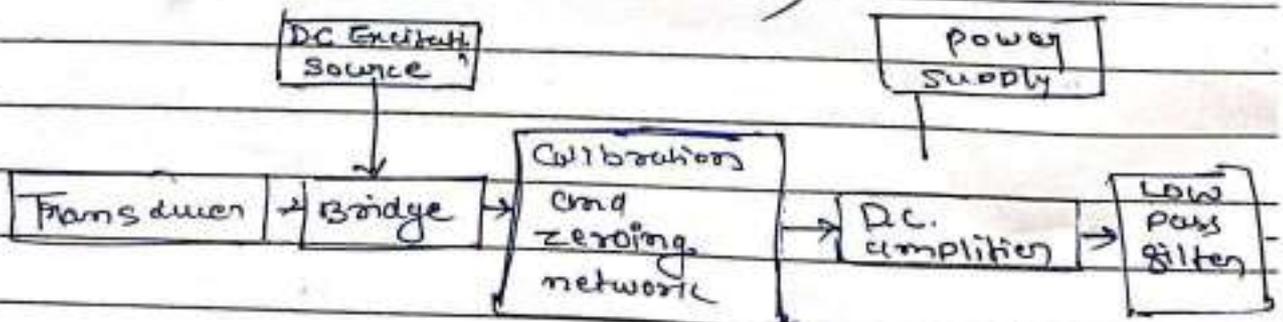
of sig
uses, e.g. - For Pass

Working of signal conditioner for -

- (1) passive transducer - provide supply
- (2) Active transducer - Amplification.

(Passive → strain gauge, potentiometer, resistance thermometer, inductive and capacitive transducer)

(Active → tachogenerator, thermocouple, inductive pickup, piezo electric)



DC for strain gauge,

- (1) Transducer - strain gauge
- (2) Power supply for bridge - DC excitation

(3) Calibration and zeroing network :-

- Calibrate unknown quantity
- The bridge is balance using potentiometer and can be calibrated for unbalance condition.

(4) D.C Amplifier — Amplify low signal

(5) Low pass filter :- Remove high frequency signal, noise, disturbance

Characteristics of D.C. Amplifier

- 1) High common mode rejection ratio.
- 2) High input impedance.
- 3) Good thermal and long term stability.
- 4) It can be easily calibrate for low frequency

Disadvantage

- 1) Suffer from drift.
- 2) unwanted data are also present in signal after using low pass filter.

(3) Calibration and zeroing network :-

- Calibrate unknown quantity
- The bridge is balance using potentiometer and can be calibrated for unbalance condition.

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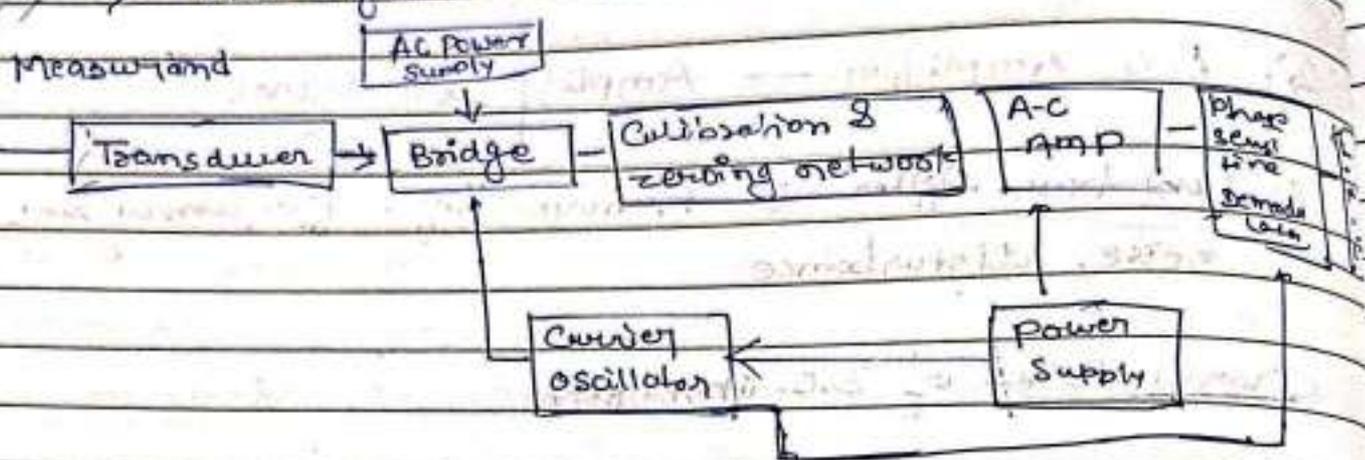
Disadvantage

- 1) Suffer from drift.
- 2) unwanted data are also present in signal after using low pass filter.

A.C. Signal conditioning

→ Main drawback of d.c. signal conditioning is unwanted signal at out data.

→ A.C. signal cond. overcome this.

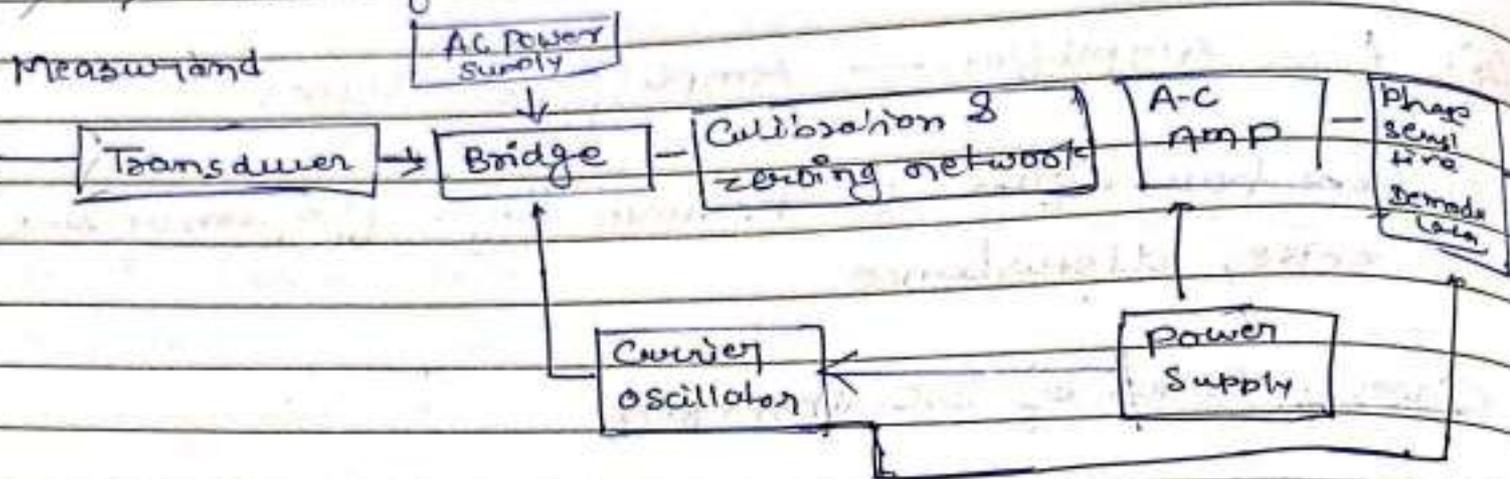


- 1) Carrier frequency range - 20Hz to 200kHz,
These carrier frequency is modulated with bridge output.
 - 2) Calibration and zeroing network - Calibrate it for known signal.
 - 3) Amplify by A.C. amplifier.
 - 4) Phase sensitive demodulation :- Amplified waveform is modulated with the help of phase sensitive demodulation. [The demodulation is phase sensitive so that the polarity of d.c. output indicates the direction of parameter change in bridge o/p.]
- Due to this modulation and demodulation chances of noisy signal is overcome.

A.C. Signal conditioning

→ Main drawback of d.c. signal conditioning is unwanted signal at out data.

→ A.C. signal cond. overcome this.



1) Carrier frequency range - 50 Hz to 200 kHz,
These carrier frequency is modulated with bridge output.

2) Calibration and zeroing network - Calibrate it for known signal.

3) Amplify by A.C. amplifier.

4) Phase Sensitive demodulation :- Amplified wave is modulated with the help of phase sensitive demodulation. [The demodulation is phase sensitive so that the polarity of d.c. output indicates the direction of parameter change in bridge o/p.]

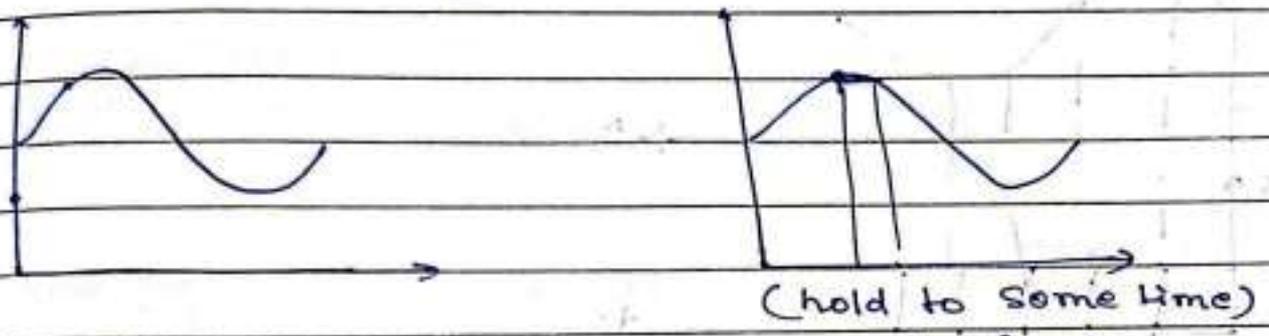
Due to this modulation and demodulation chances of noisy signal is overcome.

DC excitation — strain gauge.

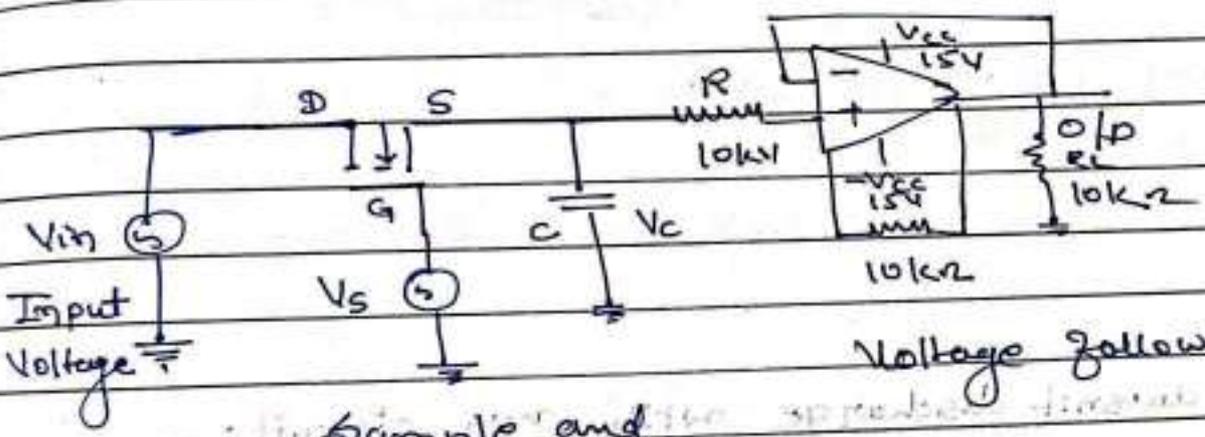
AC excitation — Variable Reluctance transducer.

Sample & hold circuit

— first stage of analog to digital conversion.

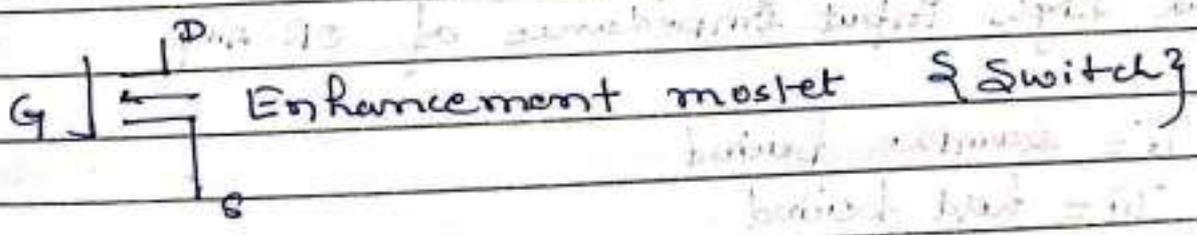


sample an input signal & hold on to its last sampled value until the input is sampled again.

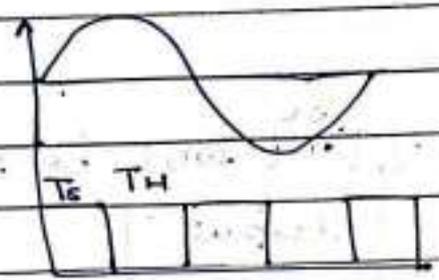


Voltage follower circuit

sample and hold controlled voltage



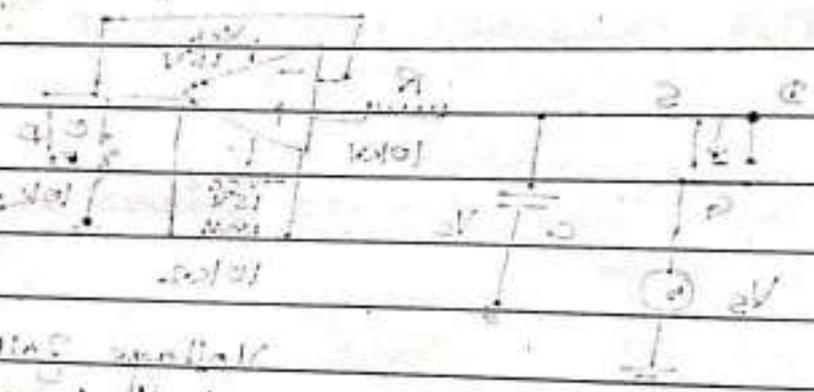
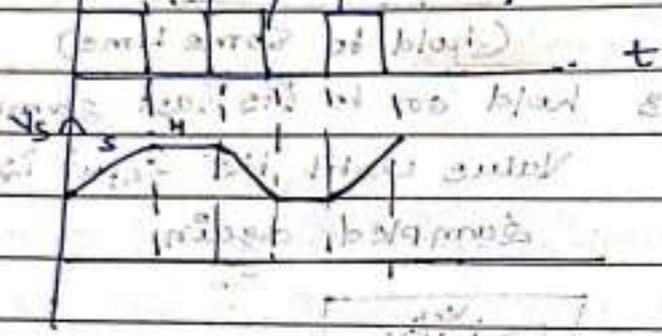
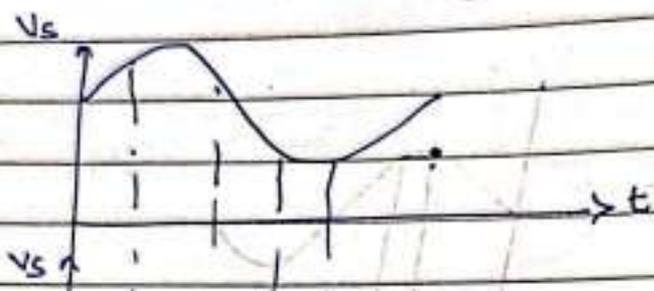
Enhancement mosfet { Switch }



Signature.....

positive $V_s \rightarrow$ Switch closed / on
 Capacitor charges

$V_o = V_c = V_{in}$ (due to voltage follower OP-Amp)



Capacitor doesn't discharge with any circuit: -

No path are available for capacitor to discharge -
 due high input impedance of OP-Amp

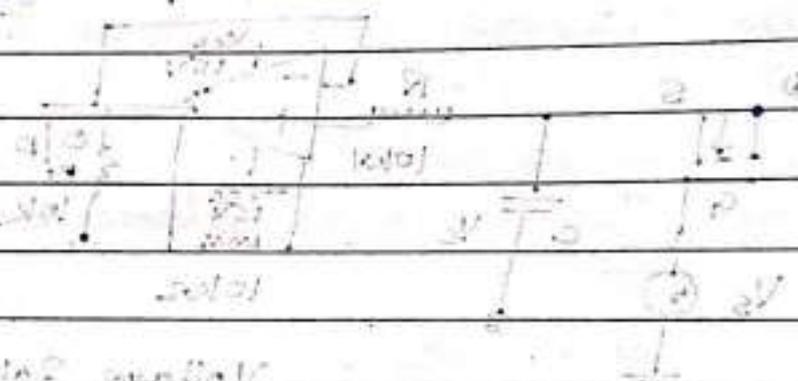
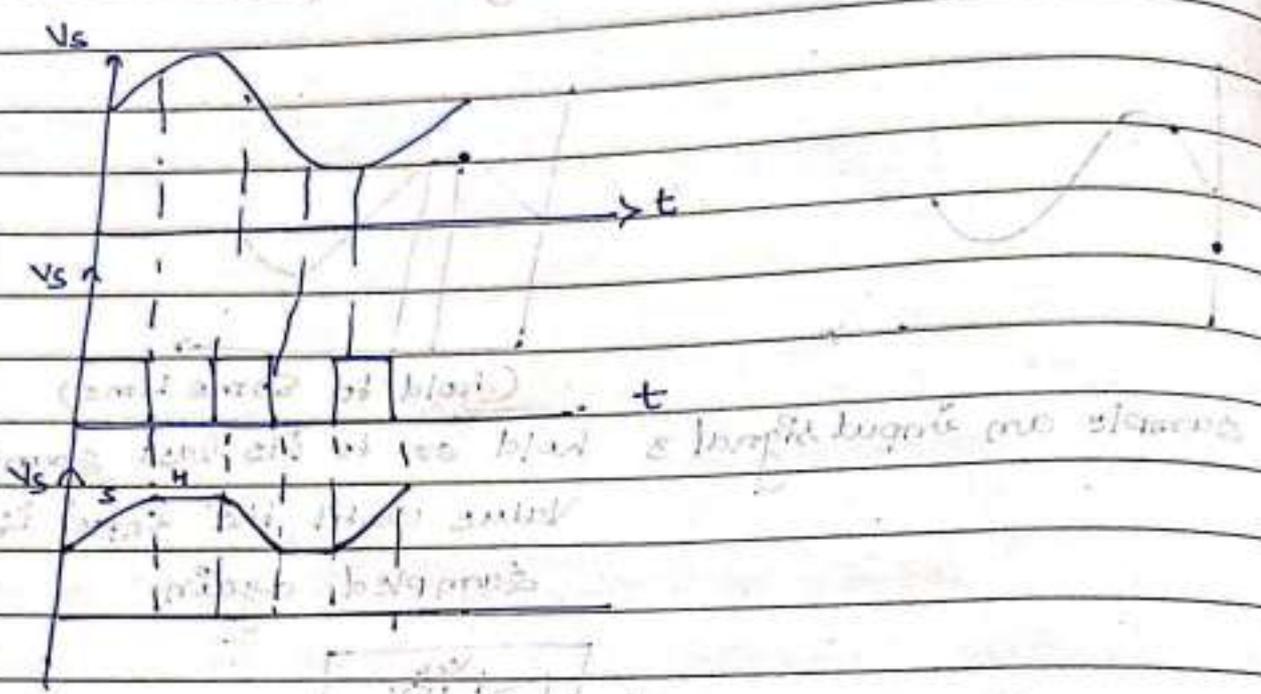
$T_s =$ Sample period

$T_H =$ hold period

frequency of $f_s > f_{in}$ [out will be same as input]
 frequency of input voltage

positive V_s
Capacitor charges

$V_o = V_c = V_{in}$ (due to voltage follower OP-Amp)



Why capacitor doesn't discharge with any circuit: -

(1) No path are available for capacitor to discharge - due high input impedance of OP-Amp

$T_s =$ Sample period

$T_H =$ hold period

frequency of control voltage f_s > frequency of input voltage f_{in} } [out will be same as input] f_o

Signature.....

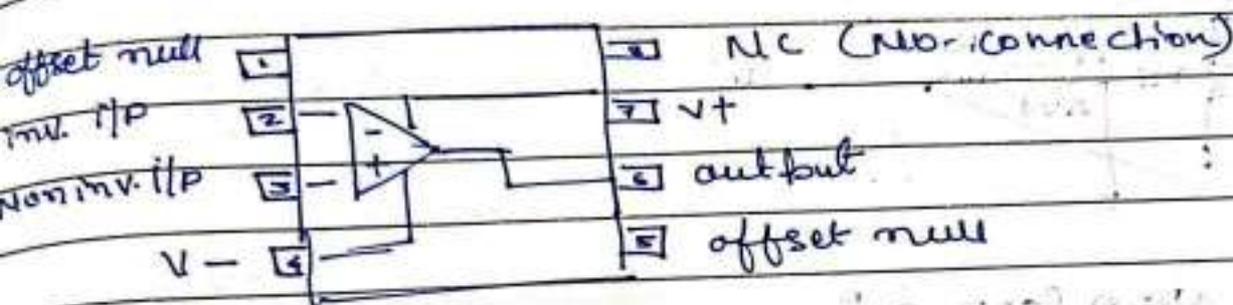
Operational Amplifier

OP-AMP

→ Mostly used for mathematical operation, like - addition, subtraction, multiplication, differentiation, integration, etc.

→ Most common — 741 OP-AMP

→ Type - 2, 1) Inverting (2) Non-inverting

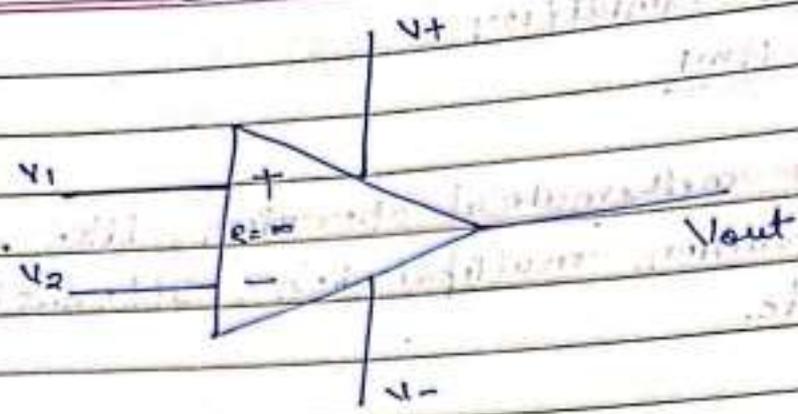


offset effect :- The offset effect are one of the several types of non-ideal behaviour of op-AMP. (pin 1 and 5) null this offset.

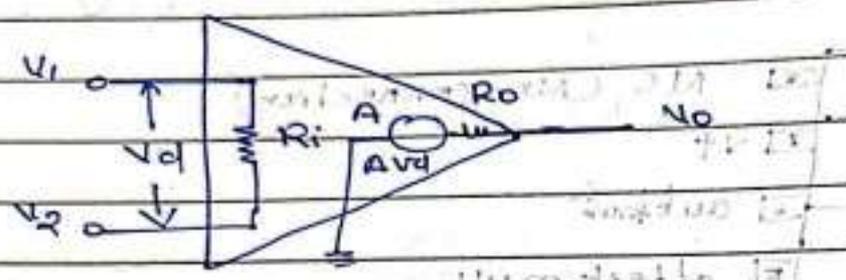
Characteristics of ideal OP-AMP

- ① It should have infinite input impedance.
- ② It should have zero output impedance.
- ③ It should have infinite open loop gain.
- ④ It should have infinite bandwidth, so it can amplify DC signal to highest AC signal.
- ⑤ zero offset voltage unwanted voltage.

OP-AMP

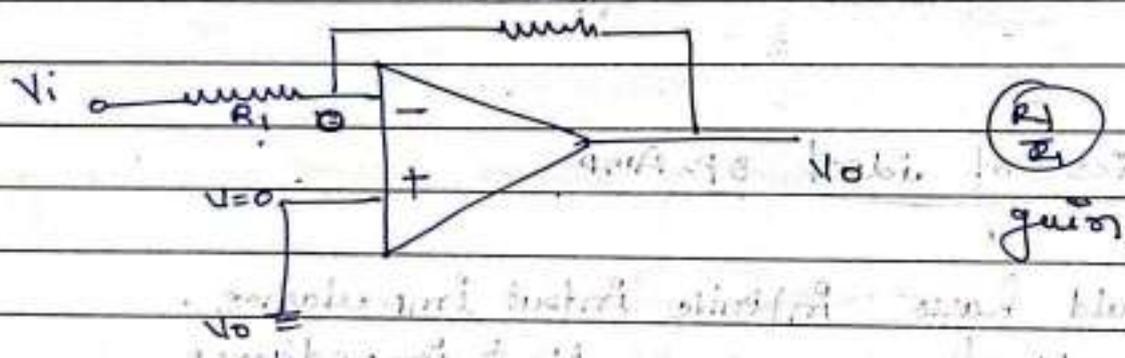


Equivalent circuit of OP-AMP



$A =$ open loop gain

Inverting Amplifier



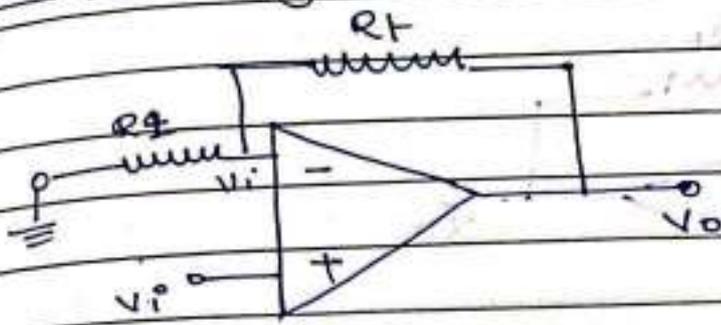
By Virtual ground Concept, both inputs are at 0

$$\frac{V_i - 0}{R_1} + \frac{0 - V_o}{R_f} = 0$$

$$\frac{V_i}{R_1} = \frac{V_o}{R_f}$$

$$V_o = \frac{R_f}{R_1} V_i$$

Non-inverting



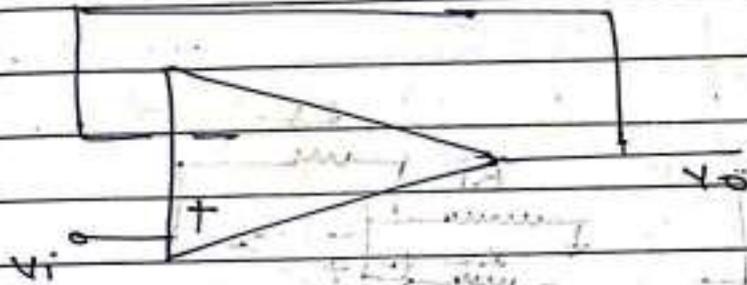
$$0 - V_i^- = \frac{V_i^- - V_o}{R_f} \Rightarrow \frac{V_i^-}{R_f} + \frac{V_i^-}{R_1} = \frac{V_o}{R_f}$$

$$\Rightarrow V_i \left(\frac{1}{R_f} + \frac{1}{R_1} \right) R_f = V_o$$

$$\Rightarrow V_i \left(1 + \frac{R_f}{R_1} \right) = V_o$$

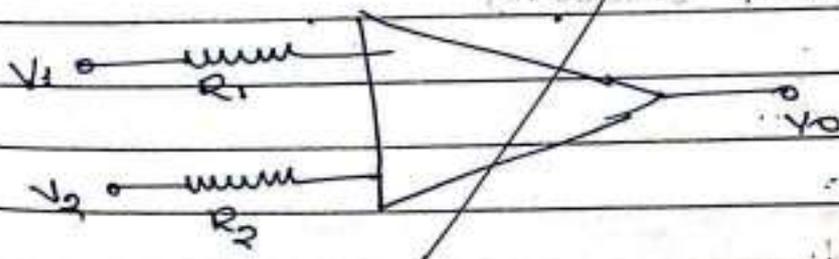
$$V_o = \left(1 + \frac{R_f}{R_1} \right) V_i$$

Voltage follower

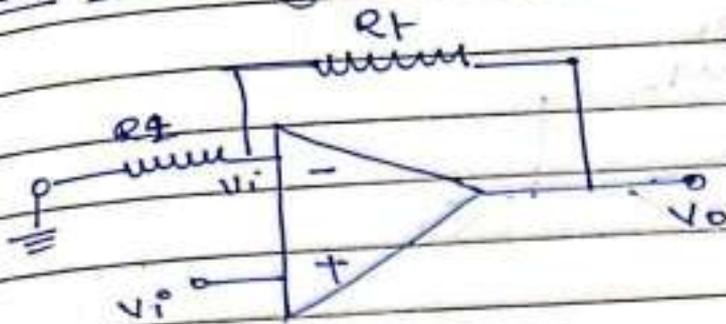


$$c) V_o = V_i$$

Adder - ~~Arithmetic Circuits~~



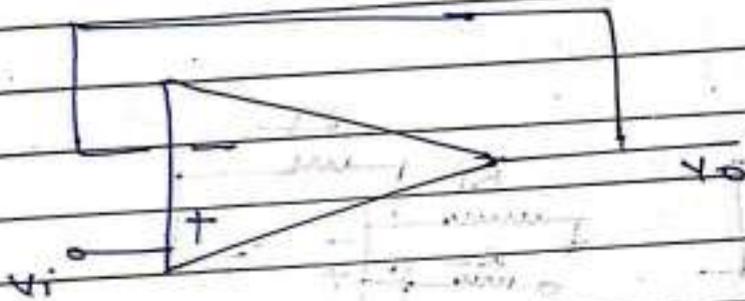
Non-Inverting amplifier



$$0 - v_i = \frac{v_i - v_o}{R_f} \Rightarrow \frac{v_i}{R_f} + \frac{v_i}{R_1} = \frac{v_o}{R_f}$$
$$\Rightarrow v_i \left(\frac{1}{R_f} + \frac{1}{R_1} \right) R_f = v_o$$
$$\Rightarrow v_i \left(1 + \frac{R_f}{R_1} \right) = v_o$$

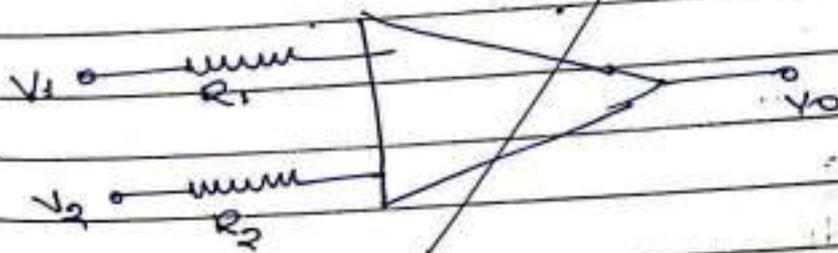
$$v_o = \left(1 + \frac{R_f}{R_1} \right) v_i$$

Voltage follower



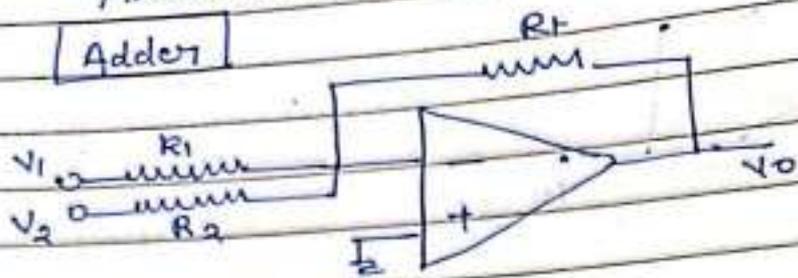
$$v_o = v_i$$

Adder - Arithmetic Circuits



Arithmetic operation

Adder



$$\frac{V_1 - 0}{R_1} + \frac{V_2 - 0}{R_2} = \frac{0 - V_0}{R_f}$$

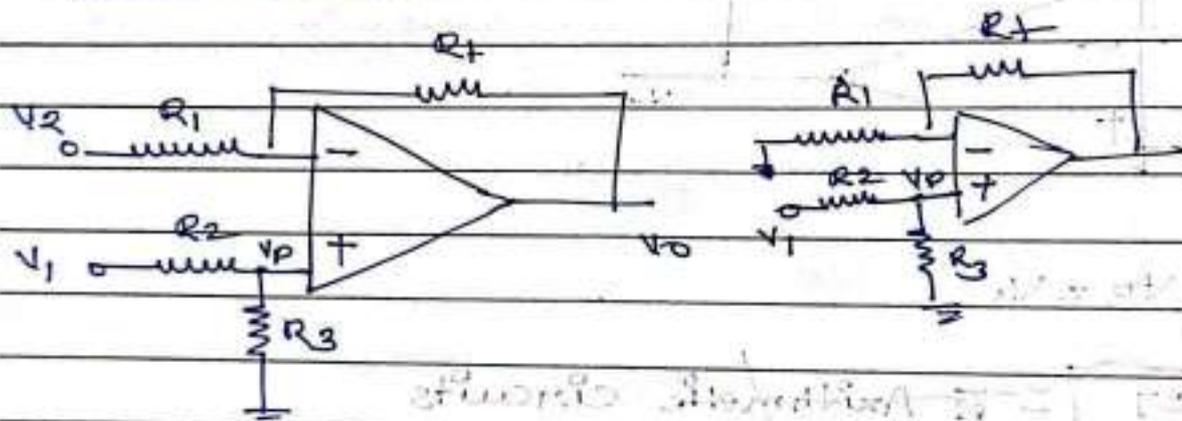
$$\Rightarrow \frac{V_1}{R_1} + \frac{V_2}{R_2} = -\frac{V_0}{R_f}$$

$$R_1 = R_2 = R_f$$

$$\Rightarrow \frac{R_f}{R} (V_1 + V_2) = -V_0$$

$$V_0 = -\frac{R_f}{R} (V_1 + V_2)$$

Subtractor



Applying superposition theorem

$$V_2 = 0$$

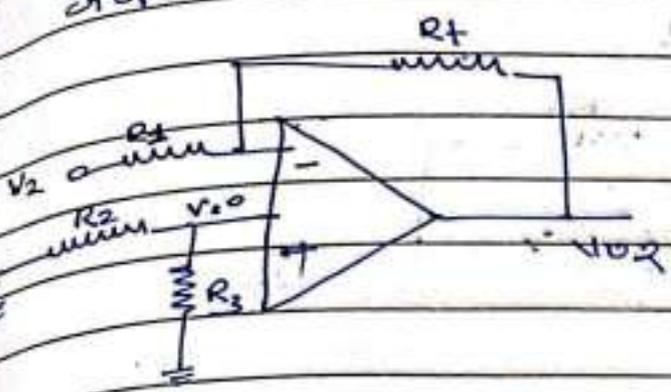
$$V_{o1} = ?$$

$$V_{o1} = \frac{R_3}{R_2 + R_3} \cdot V_1$$

$$V_{o1} = \left(\frac{1 + \frac{R_f}{R_1}}{\frac{R_3}{R_2 + R_3}} \right) V_1$$

Step 2

$V_1 = 0$



$V_{02} = -\frac{R_f}{R_1} V_2$

$V_0 = V_{01} + V_{02}$

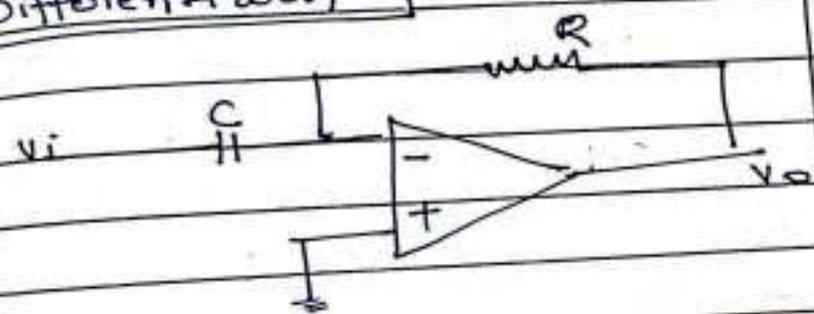
$= \left(1 + \frac{R_f}{R_1}\right) \left(\frac{R_2}{R_2 + R_3}\right) V_1 - \frac{R_f}{R_1} V_2$

$R_f = R_1 = R_2 = R_3 = R$

$= (1+1) \left(\frac{1}{2}\right) V_1 - 1 \cdot V_2$

$V_0 = (V_1 - V_2)$

Differentiator



$C \frac{d(0 - V_i)}{dt} = -\frac{(0 - V_0)}{R}$

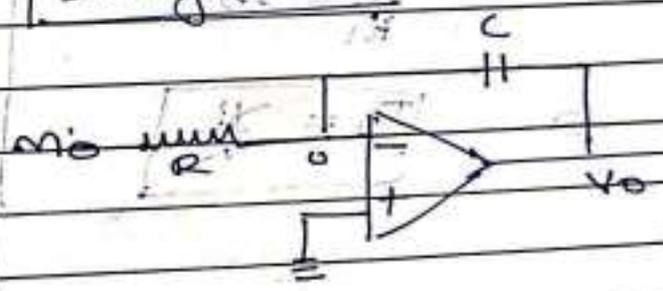
$\Rightarrow -C \cdot \frac{dV_i}{dt} = \frac{V_0}{R}$

$\Rightarrow -RC \cdot \frac{dV_i}{dt} = V_0$

$RC = 1 \text{ Sec}$

$\Rightarrow V_0 = -\frac{dV_i}{dt}$

Integrator



$\Rightarrow \frac{0 - V_i}{R} = -\left(\frac{d0 - V_0}{dt}\right) C$

$\Rightarrow -\frac{V_i}{R} = +\frac{dV_0}{dt} C$

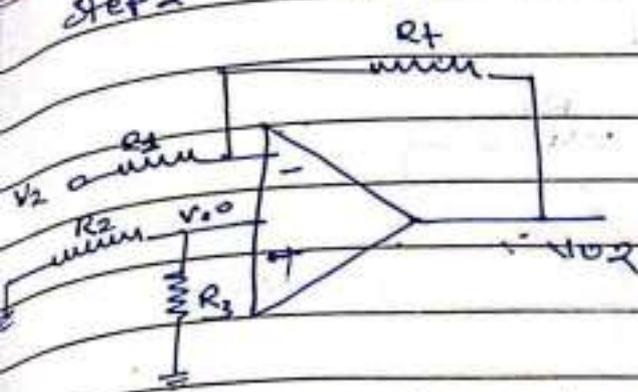
$\Rightarrow \frac{dV_0}{dt} = -\frac{1}{RC} V_i$

$RC = 1$

$V_0 = -\int V_i \cdot dt$

step 2

$V_1 = 0$



$V_{02} = -\frac{R_f}{R_1} V_2$

$V_0 = V_{01} + V_{02}$

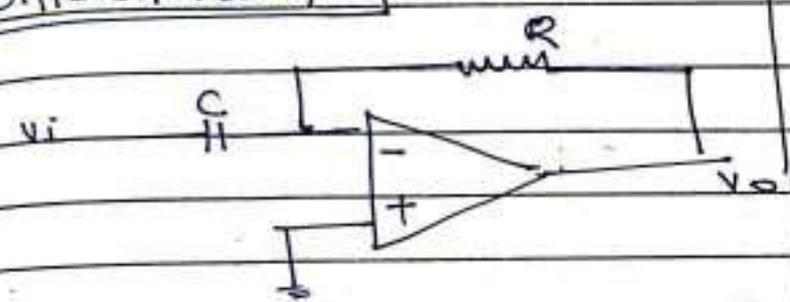
$= \left(1 + \frac{R_f}{R_1}\right) \left(\frac{R_2}{R_2 + R_3}\right) V_1 - \frac{R_f}{R_1} V_2$

$R_f = R_1 = R_2 = R_3 = R$

$= (1+1) \left(\frac{1}{2}\right) V_1 - 1 \cdot V_2 =$

$V_0 = (V_1 - V_2)$

Differentiator



$C \frac{d(0 - V_i)}{dt} = -\frac{(0 - V_0)}{R}$

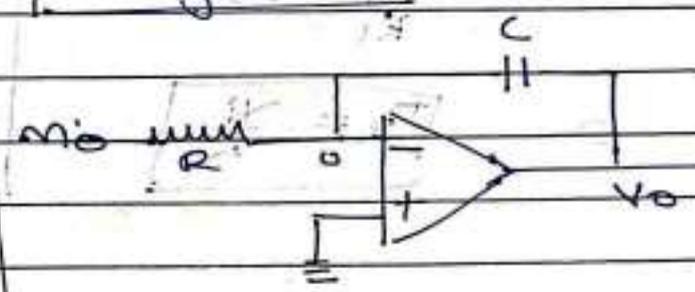
$\Rightarrow -C \cdot \frac{dV_i}{dt} = \frac{V_0}{R}$

$\Rightarrow -RC \cdot \frac{dV_i}{dt} = V_0$

$RC = 1 \text{ Sec}$

$\Rightarrow V_0 = -\frac{dV_i}{dt}$

Integrator



$\Rightarrow \frac{0 - V_i}{R} = -\left(\frac{d(0 - V_0)}{dt}\right) C$

$\Rightarrow -\frac{V_i}{R} = +\frac{dV_0}{dt} C$

$\Rightarrow \frac{dV_0}{dt} = -\frac{1}{RC} V_i$

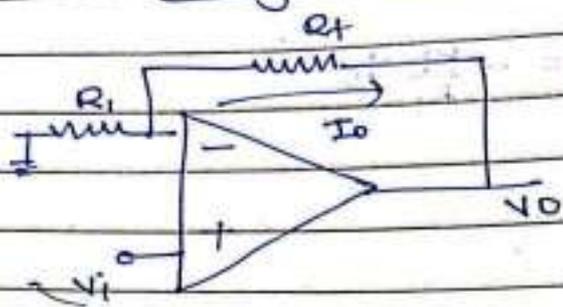
$RC = 1$

$V_0 = -\int V_i \cdot dt$

JW

Convertors

Voltage to current



$$\Rightarrow \frac{Vi - 0}{R_i} = \frac{Vi - V_o}{R_f}$$

$$\Rightarrow \frac{Vi}{R_i} = \frac{Vi - V_o}{R_f}$$

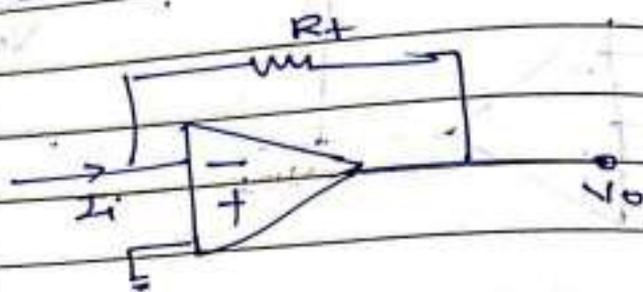
$$\boxed{\frac{Vi - V_o}{R_f} = I_o}$$

output

$$\Rightarrow \frac{Vi}{R_i} = I_o$$

$$\boxed{I_o = \frac{Vi}{R_i}}$$

current to voltage follower



$$\Rightarrow I_i = \frac{V_o}{R_f}$$

$$\Rightarrow \boxed{V_o = R_f \cdot I_i}$$

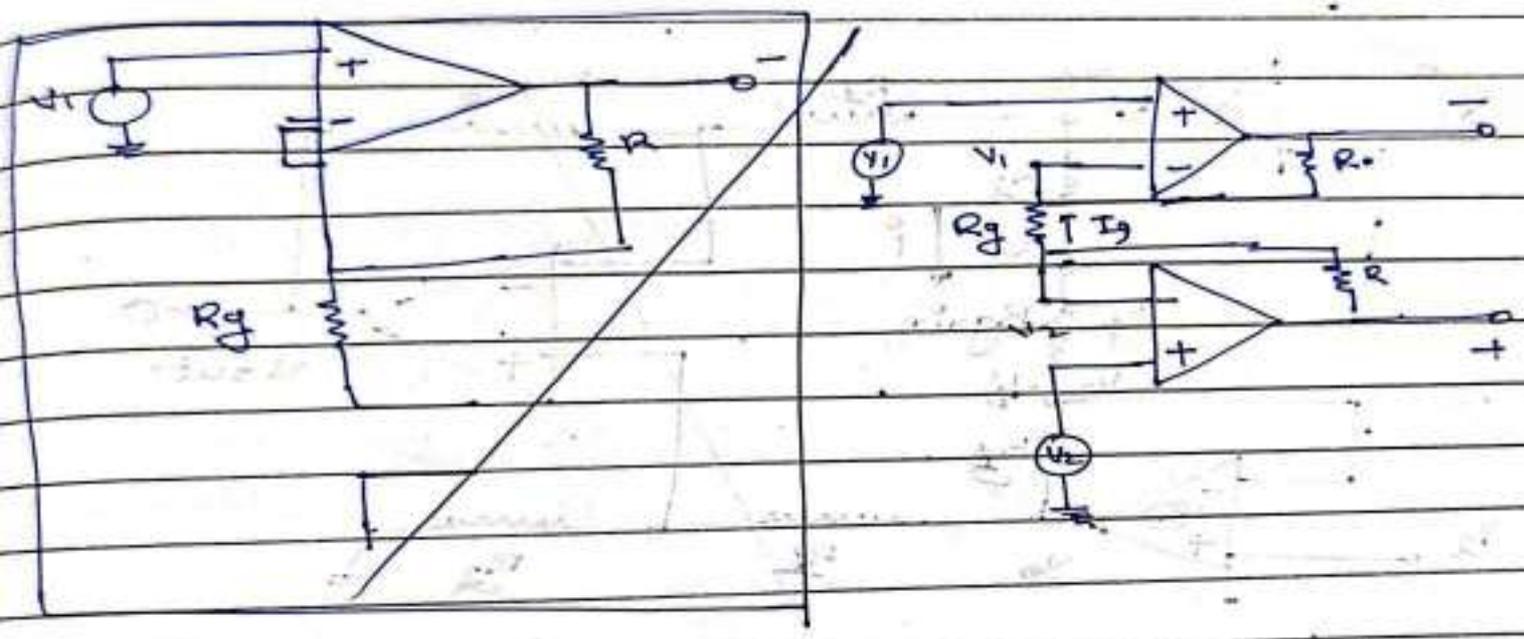
$$R_f = 1$$

$$\boxed{V_o = -I_i}$$

Quantization - on

Instrumentation Amplifier

- Same as differential amplifier with high input impedance.
- High gain.
- High common mode rejection ratio.
- it is close loop device
- consist of two stage amplifier



Input V_1 & V_2 are applied to inverting and non inverting terminal

R - internal resistor
 R_g - gain setting resistor

$$V_1 - V_2 = V_{Rg} = I_g \cdot R_g$$

$$I_{Rg} = \frac{V_1 - V_2}{R_g}$$

$$\frac{V_1 - V_2}{R_4} = \frac{V_A - V_B}{R_4 + 2R_3}$$

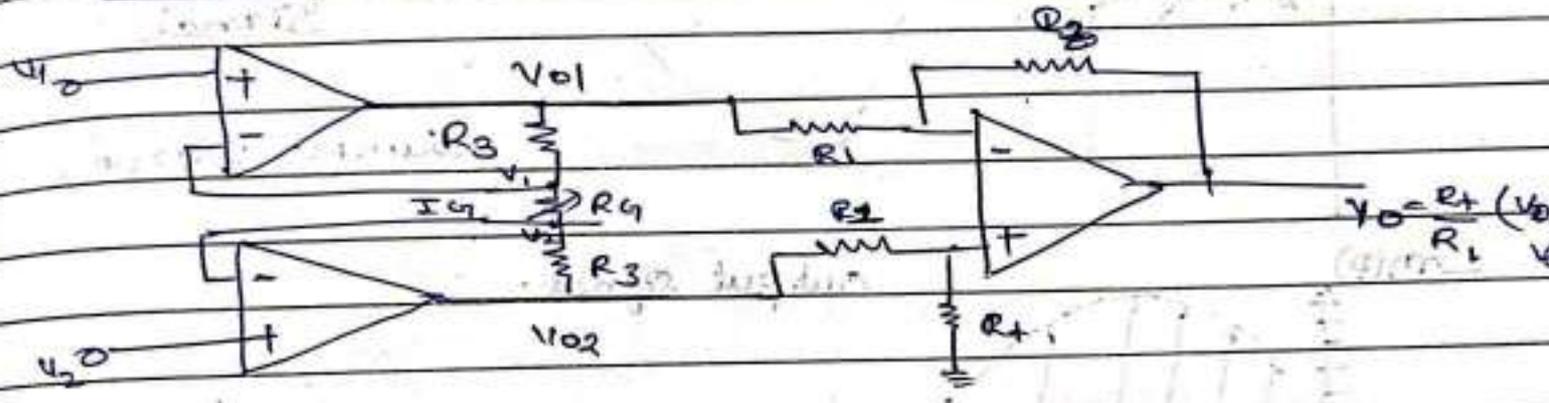
$$(V_A - V_B) = \frac{(R_4 + 2R_3)}{R_4} (V_1 - V_2)$$

$$= \left(1 + \frac{2R_3}{R_4}\right) (V_1 - V_2)$$

$$\Rightarrow V_{out} = \left(\frac{R_2}{R_1}\right) (V_B - V_A)$$

$$V_{out} = \left(\frac{R_2}{R_1}\right) \left(1 + \frac{2R_3}{R_4}\right) (V_2 - V_1)$$

Final derivation of instrumentation amplifier



$$I_G = \frac{V_2 - V_1}{R_4} \quad \text{--- (1)}$$

$$I_G = \frac{V_{01} - V_{02}}{R_3 + R_3 + R_4} = \frac{V_{02} - V_{01}}{R_4 + 2R_3} \quad \text{--- (2)}$$

$$\frac{V_2 - V_1}{R_4} = \frac{V_{02} - V_{01}}{R_4 + 2R_3}$$

$$(V_{02} - V_{01}) = \frac{(R_4 + 2R_3)}{R_4} (V_2 - V_1)$$

$$= \left(1 + \frac{2R_3}{R_4}\right) (V_2 - V_1)$$

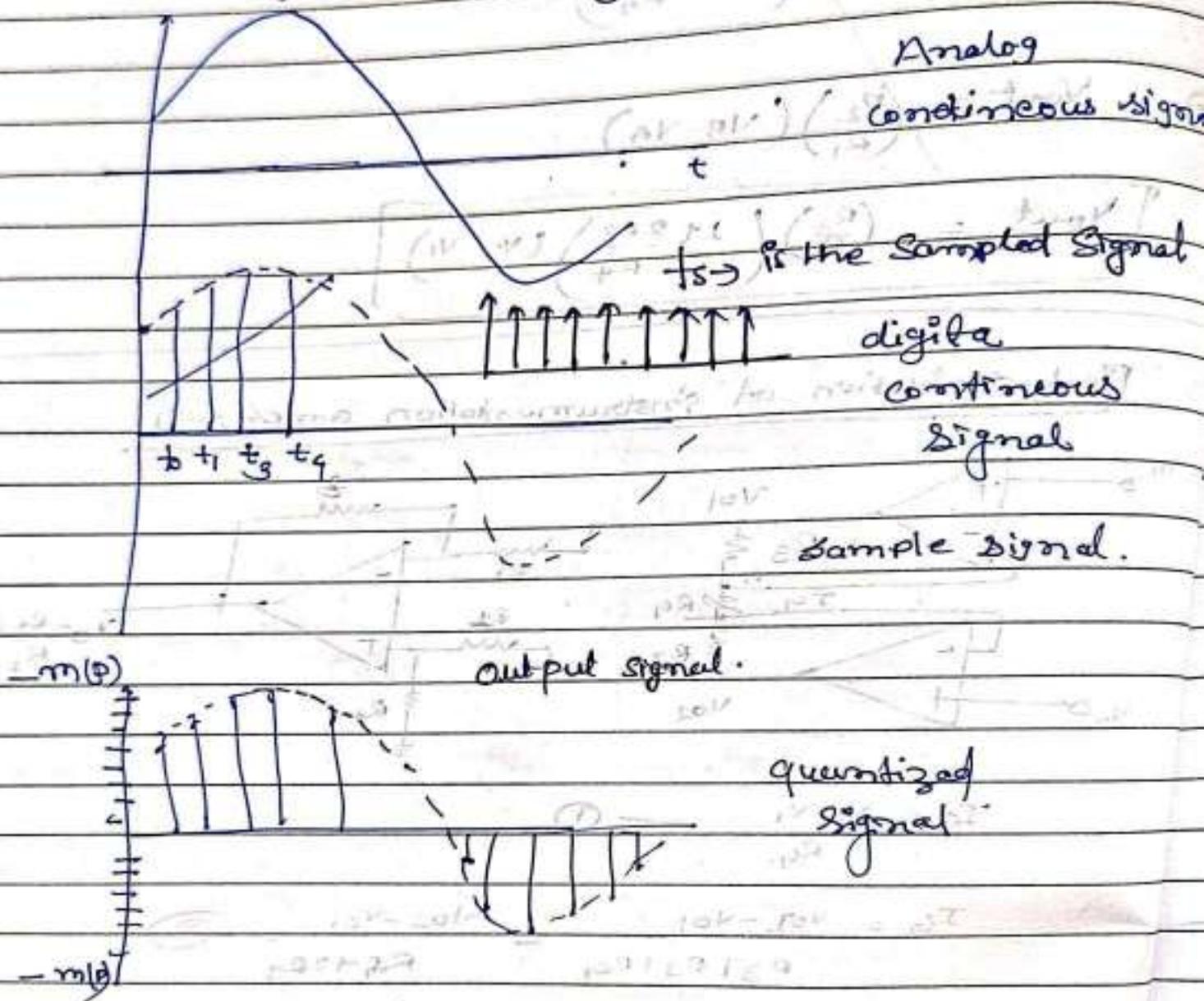
$$V_0 = \left(\frac{R_2}{R_1}\right) \cdot \left(1 + \frac{2R_3}{R_4}\right) (V_2 - V_1)$$

Signature.....

Quantization of Digital Signal

⇒ Rounding of signal, which is obtain from sampler and hold circuit.

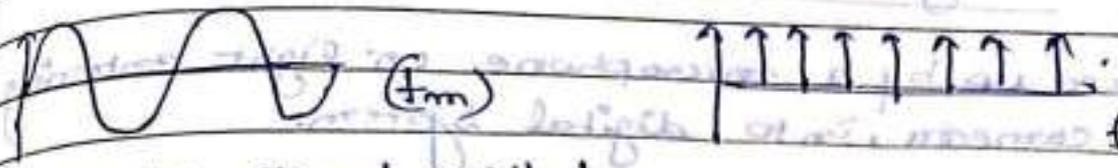
If f is frequency of Analog input signal



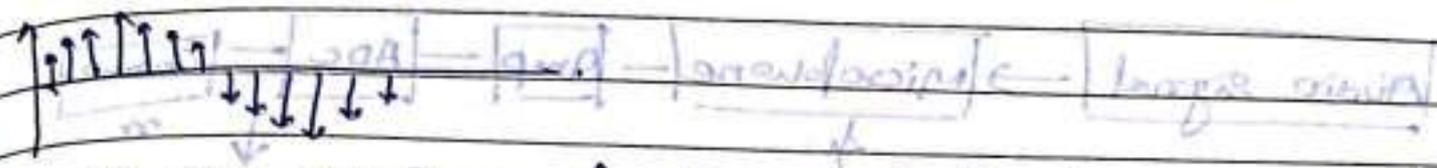
Level between two level = $\frac{\text{Max} - \text{min}}{\text{Total no. level } L}$

Shannon criteria for Sampling

- ① Analog or IP signal
- ② Sampled pulse



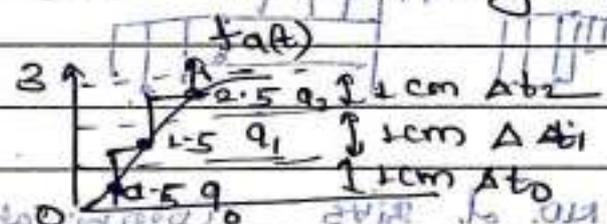
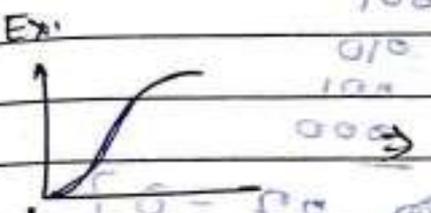
Then OP signal will be -



- ⇒ If the maximum frequency of input analog signal is f_m
- ⇒ Sampled pulse frequency is f_s
- ⇒ Then for getting the wave shape as same as actual input signal

$f_s > 2f_m$, it is Shannon criteria for Sampling

Quantization → is the process of providing level of (Approximate value) of sampled signal.



$f_a(t)$ ⇒ Actual signal.

q_0, q_1, q_2 → level
 $\Delta q_0, \Delta q_1, \Delta q_2$ → Unit Step

Unit Step ⇒ $\frac{\text{Max value signal} - \text{Min value signal}}{\text{Total no of level}}$

⇒ Level ⇒

Quantization Error: It is a difference between Actual signal and Quantized signal

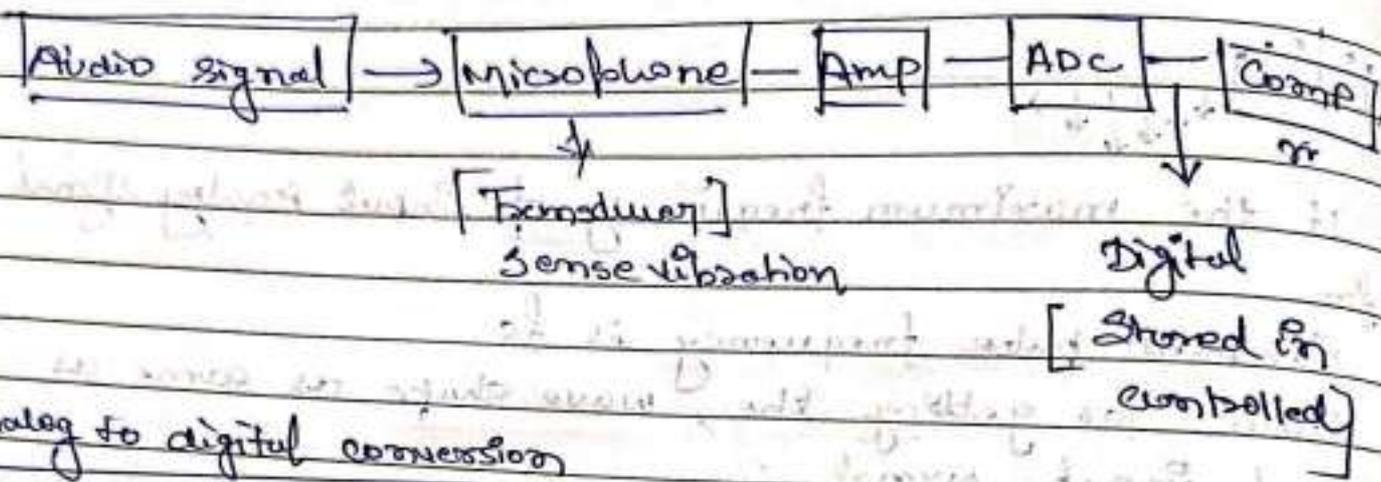
$$Q.E = f_a(t) - f_q(t)$$

Digital to Analog Signal Converter

Analog to Digital Converter

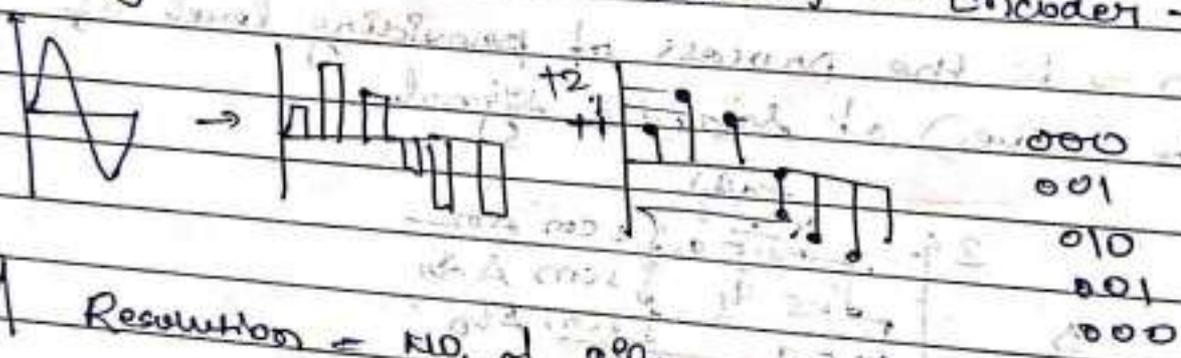
Ex.

→ Sound picked up by a microphone or light entering a digital camera, into digital system:



Analog to digital conversion

Analog → Δ/H — Quantization — Encoder — Digital



Resolution = NO. of bits combination $2^n = 8$

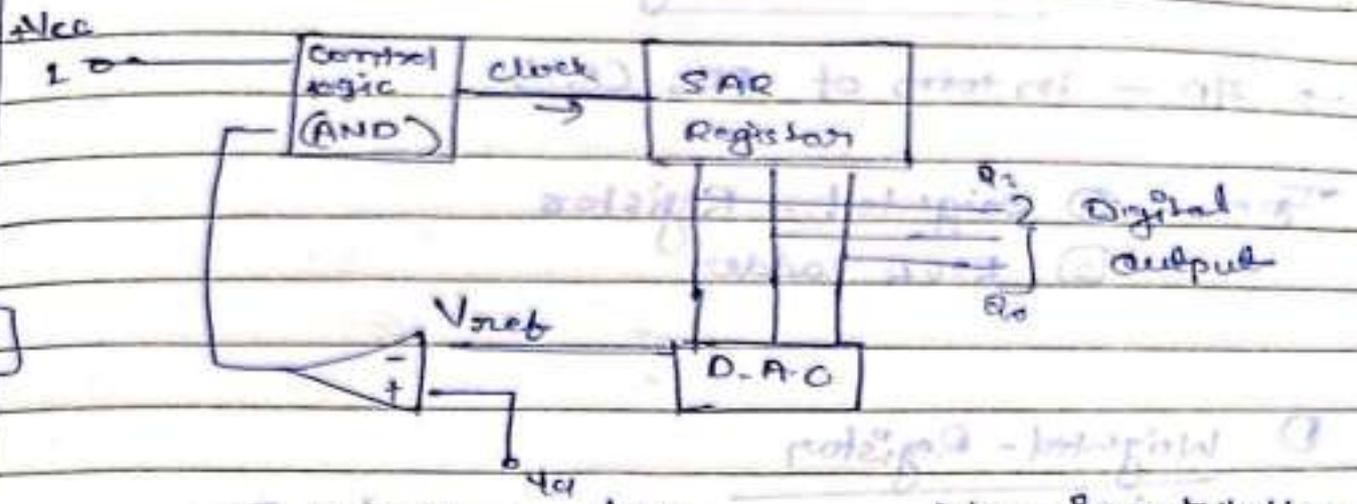
Resolution \Rightarrow Full Scale Range - Min. Scale Range

2^n

Analog to digital converter

- ① Counter Type
- ② Successive Approximation Type

① Successive Approximation

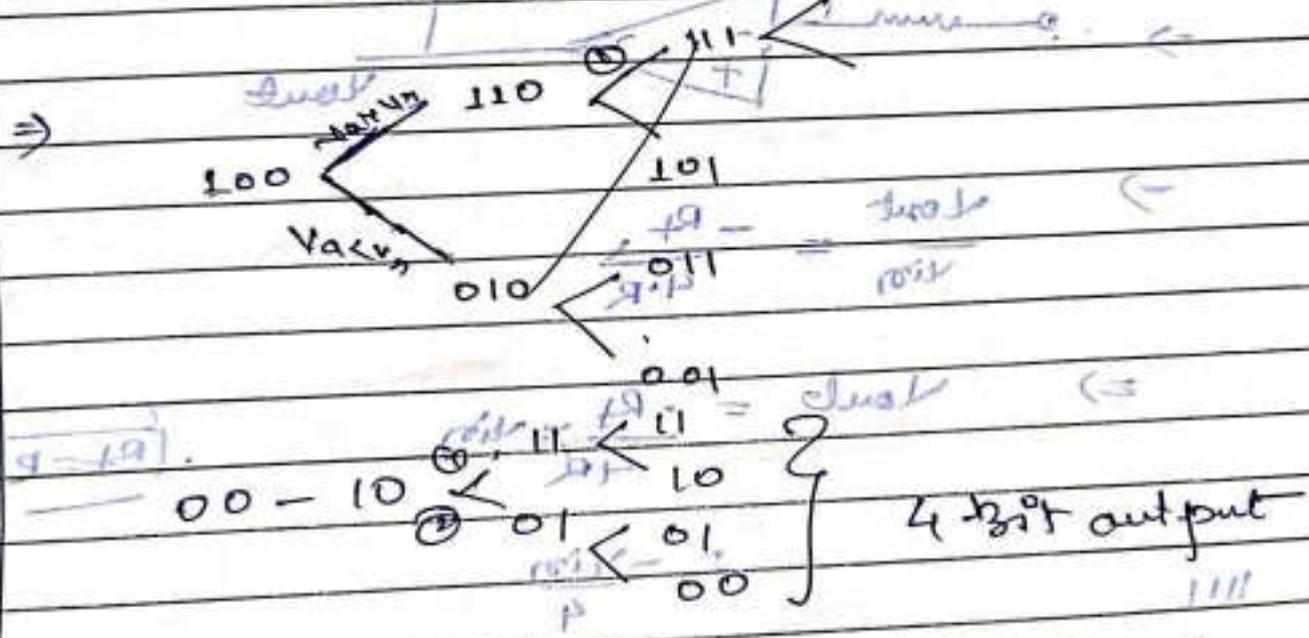


$V_a > V_{ref} = \text{High}$
 $V_a < V_{ref} = \text{Low}$

$V_a = \text{Input voltage}$

SAR Successive Approximation Register

SAR \Rightarrow 000, OP of OP-AMP - High, OP of AND - High
 \Rightarrow 100 $\Rightarrow V_a > V_{ref} = \text{High}$
 $V_a < V_{ref} = \text{Low}$



$$V_{out} = \frac{V_{ref}}{2^4} (1111) = \frac{V_{ref}}{16} (15) = \frac{15}{16} V_{ref}$$

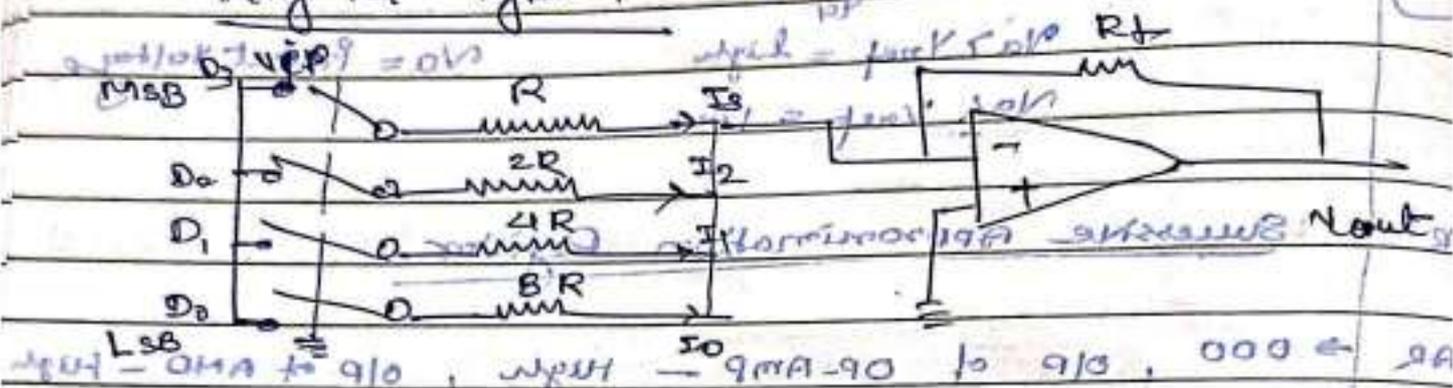
Signature.....

Digital to Analog

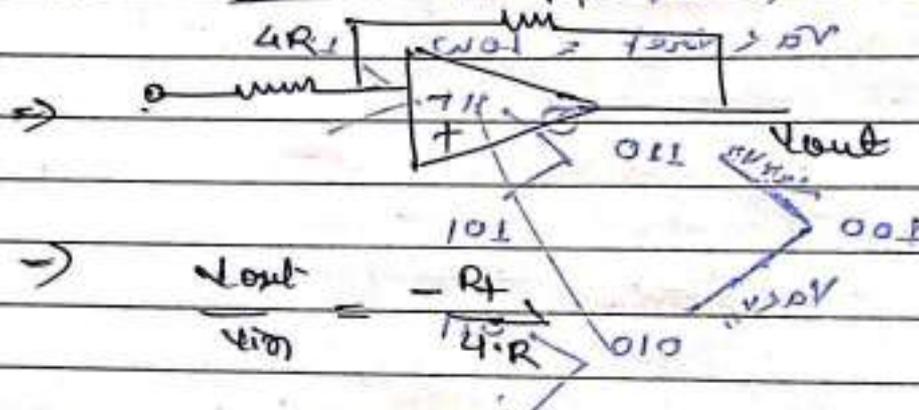
→ IP - in form of bits (0,1) →

- Types -
- ① Weighted - Resistor
 - ② R-2R ladder

① Weighted - Resistor



① Example → 0010



$$V_{out} = -\frac{R_f}{R} \times V_{in}$$

$$V_{out} = -\frac{R_f}{4R} \times V_{in}$$

Input output

$$I = I_0 + I_1 + I_2 + I_3$$

= X

$$V_{out} = -R_f \left[\frac{V_{in}(D_0)}{8R} + \frac{V_{in}(D_1)}{4R} + \frac{V_{in}(D_2)}{2R} + \frac{V_{in}(D_3)}{R} \right]$$

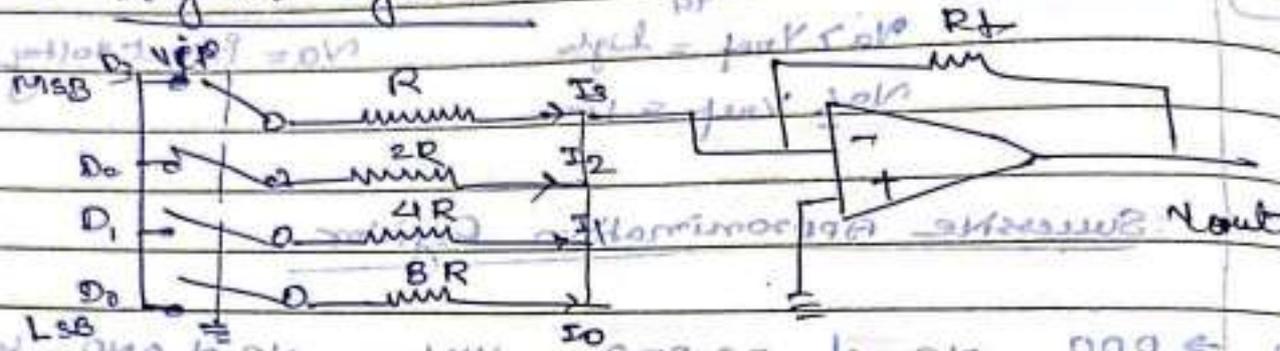
$$R_f = R$$

Digital to Analog

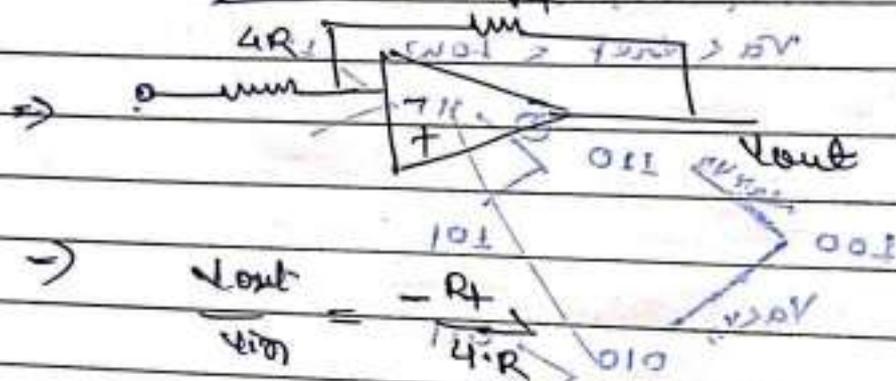
→ IP - in terms of bits (0,1)

- Types -
- ① Weighted - Registers
 - ② R-2R ladder

① Weighted - Register



① Example → 0010



$$\frac{V_{out}}{V_{in}} = -\frac{R_f}{4 \cdot R}$$

$$\Rightarrow V_{out} = \frac{R_f}{4R} \times V_{in}$$

$$I = I_0 + I_1 + I_2 + I_3$$

$$= X$$

$$V_{out} = -R_f \left[\frac{V_{in}(D_0)}{8R} + \frac{V_{in}(D_1)}{4R} + \frac{V_{in}(D_2)}{2R} + \frac{V_{in}(D_3)}{R} \right]$$

$$R_f = R$$

$$V_{out} = -V_{ip} \left[\frac{D_0}{2} + \frac{D_1}{4} + \frac{D_2}{2} + D_3 \right]$$

$D_3 D_2 D_1 D_0$
1010

$$= - \left[\frac{1}{8} + 0 + \frac{1}{2} + 0 \right] V_{ip}$$

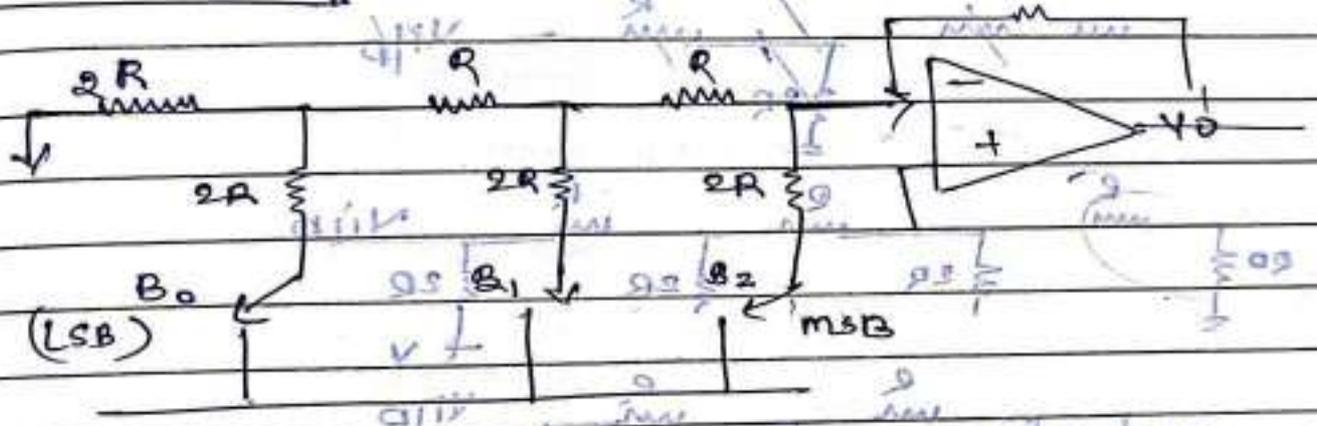
$$= - \left[\frac{1}{8} + \frac{1}{2} \right] V_{ip} \Rightarrow \frac{5}{8} V_{ip}$$

$D_3 D_2 D_1 D_0$
1010

$$V_{out} = -V_{ip} [0 + \frac{1}{4} + 0 + 1]$$

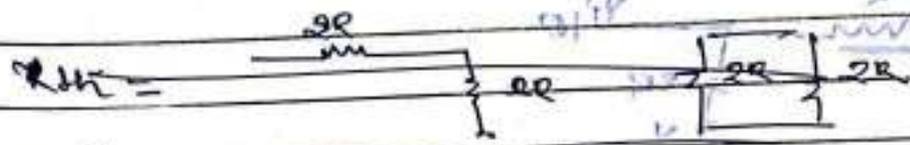
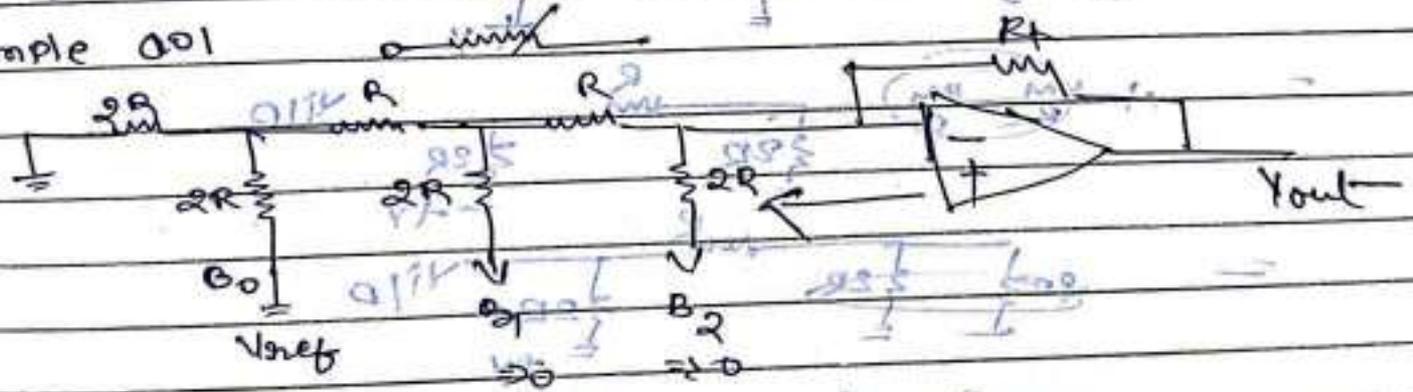
$$V_{out} = \frac{5}{4} - V_{ip}$$

② R-2R Ladder



V_{ref}

Example 001



$$R_{in} = R$$

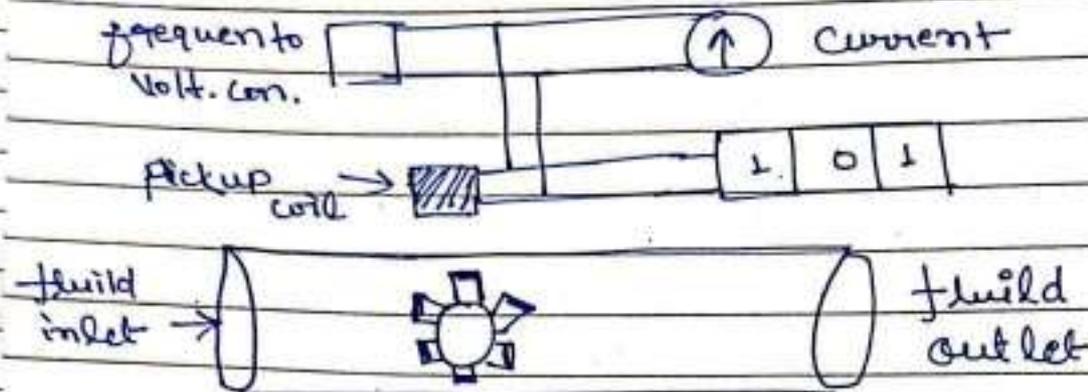
Measurement of Non-Electrical Quantity

Types — ① Turbine flowmeter

② Electro-magnetic flowmeter

③ Hot wire Anemometer

④ Ultrasonic flowmeter

(1) Flow Measurement(1) Turbine Meter

- Parts →
- ① Pipe, which fluid velocity is to be measured.
 - ② Hydrodynamically supported rotor, sealed with magnet.
 - ③ Pickup coil.
 - ④ Frequency to Voltage Converter.

Working :- ① Turbine flow meters are volumetric flow meters are available in wide range.

② Output is usually in digital form.

③ A hydrodynamically supported rotor is kept in the meter.

④ Blade of rotor are sealed with magnet when rotor rotates it magnetic field also start to rotate.

⑤ This rotate magnetic field cut the pickup coil conductor and e.m.f. induced in it.

⑥ This generated e.m.f. is in pulse form which display by Digital meter.

Advantages

- ① NO. voltage drop.
- ② good accuracy.
- ③ output is directly in digital form
- ④ The pulse output may be summed by counter without errors.

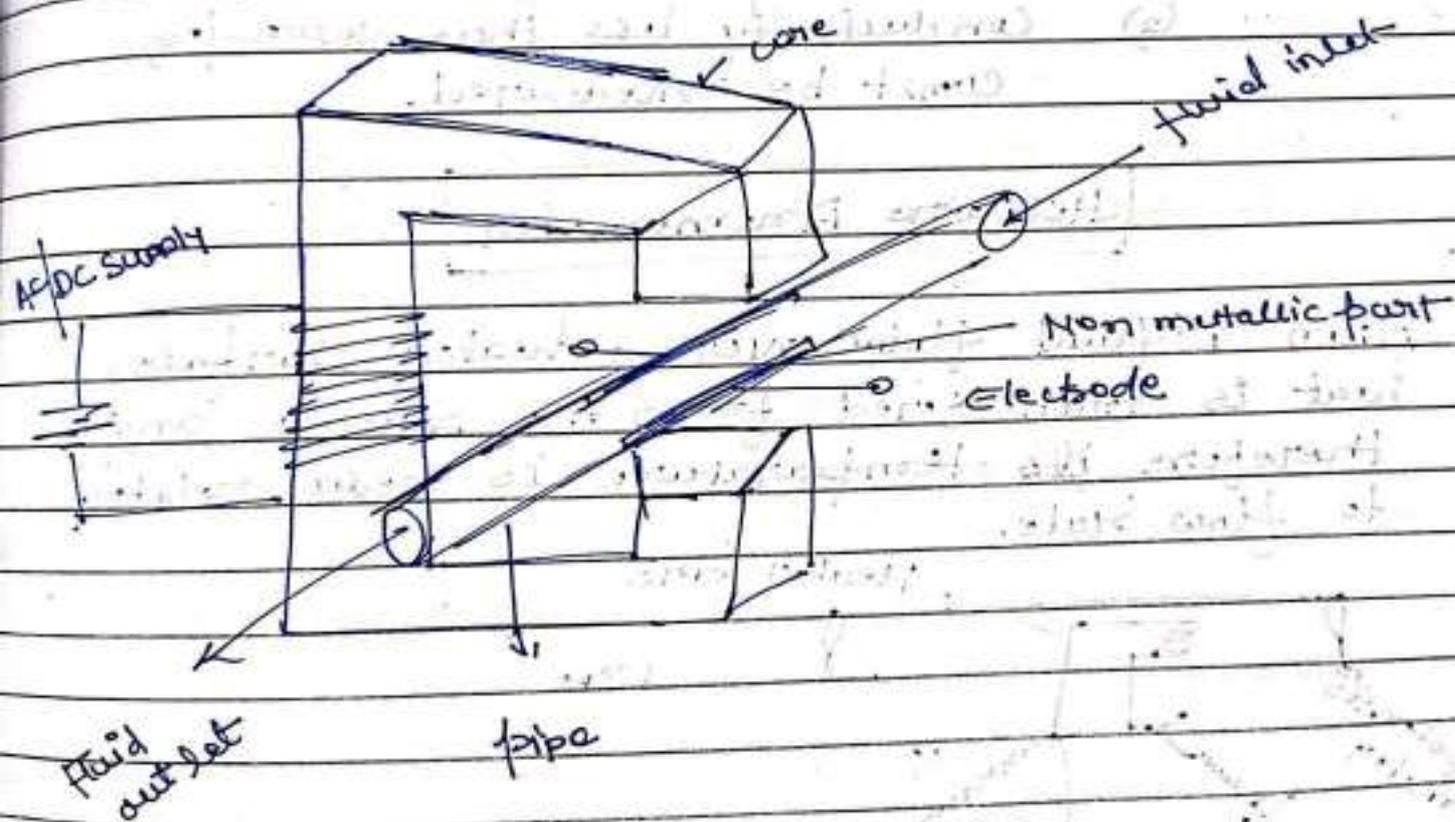
The error is approximately $\pm 0.5\%$

Disadvantages

- ① Low accuracy for low volume of fluid.
- ② Error due to excessive frictional torque, also due to wear and corrosion of bearing.

③

Electromagnetic flow meter



① Suitable for conducting liquid.

② $E = B \cdot l \cdot v$ Volt

$B =$ Flux density wb/m^2

$l =$ length of conductor = diameter of pipe

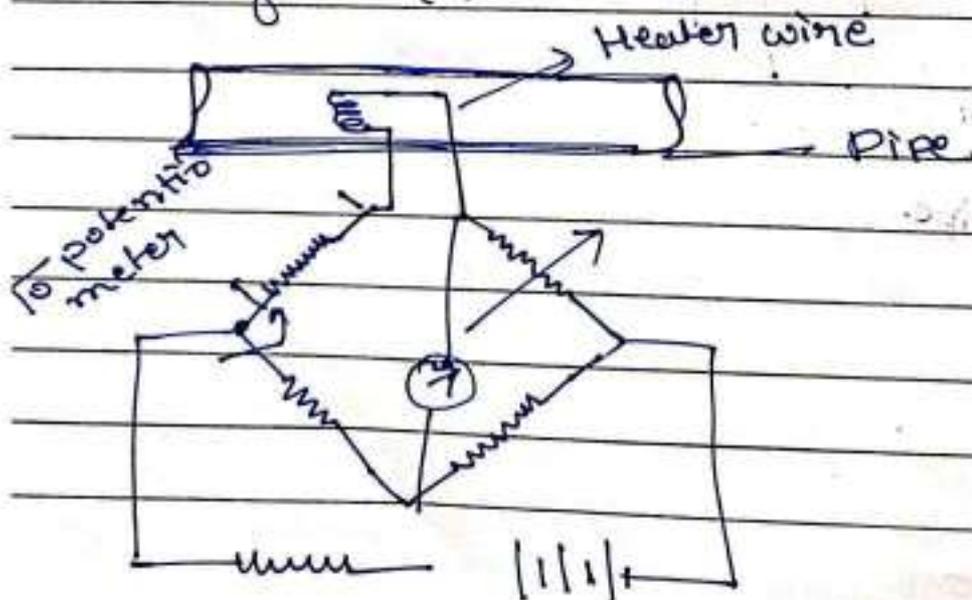
$v =$ Velocity of conductor flow, m/s

Advantages :- (1) output is linear function of i/p
(2) output is unaffected by change in liquid characteristics such as velocity, viscosity, pressure, temperature.
(3) No pressure drop due to absence of obstruction.

Disadvantages :- (1) The operating cost are high due to it heavy slurries are handled.
(2) conductivity less than $10 \text{ cm} / \text{m}$ can't be measured.

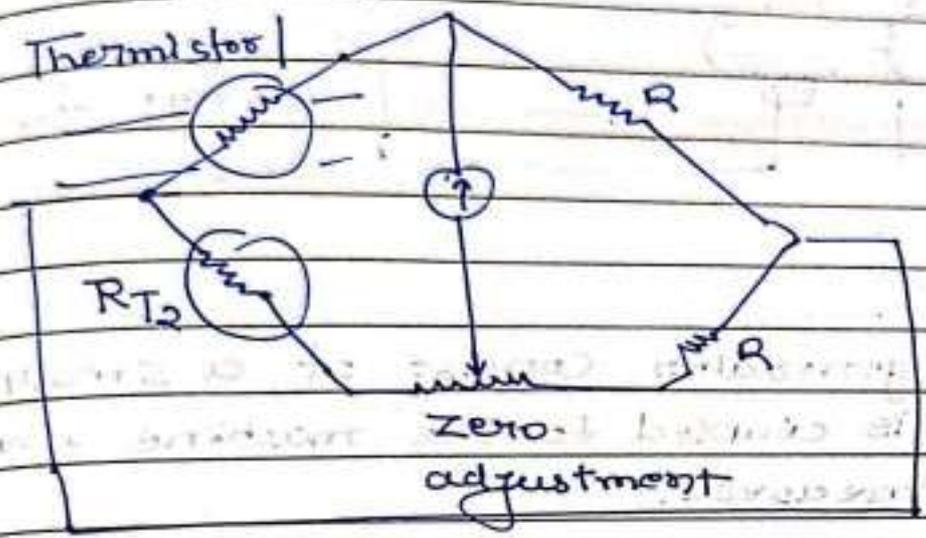
Hot wire Anemometer

→ When a fluid flows over a heated surface, heat is transferred from the surface and therefore its temperature is directly related to flow rate.



- ① In a hot wire anemometer, heat is supplied electrically to a fine wire placed in the flow stream.
- ② The temperature of wire is determined by measuring its resistance with a wheatstone bridge.

Flowmeter using Thermistor

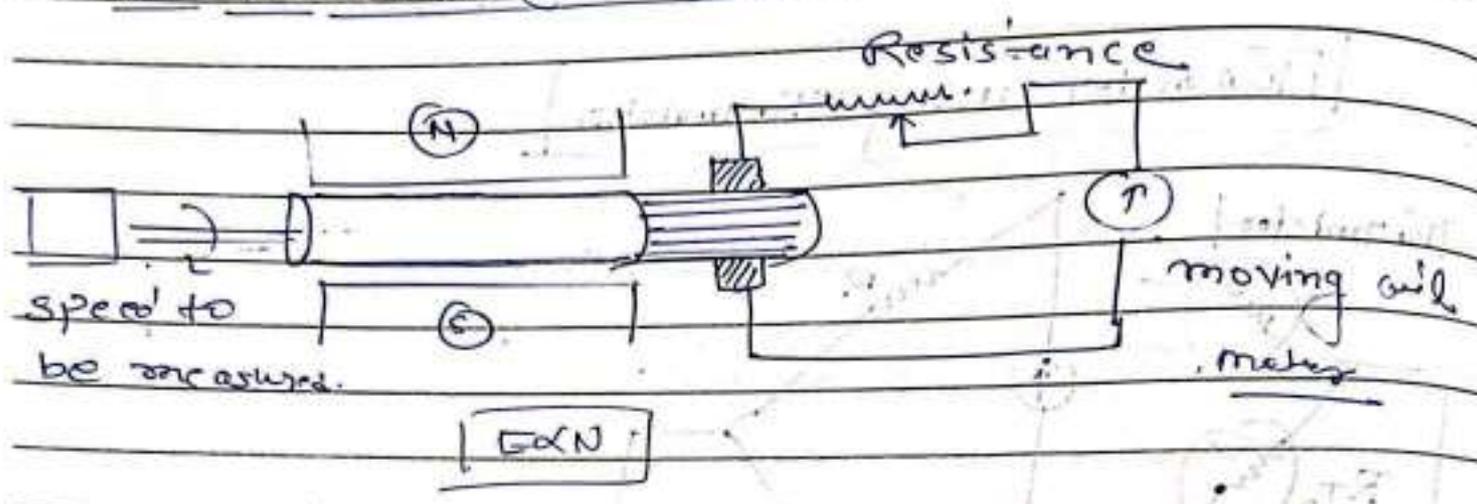


- Two thermistor connected on arms of bridge.
- one thermistor is sealed, other is opened, and
- and mounted on small pipe.
- Temp kept some amount, at initially
- air flow → Temp ↓
- Resistance of Thermistor ↓ ↑
- The amount of cooling is proportional to the rate of flow of air

Measurement of Speed

- Tachometer :- (1) D.C. Tachometer generator
 (2) A.C. Tachometer generator

D.C. Tachometer generator :-



→ D.C. Tachometer generator consist of a small armature which is coupled to the machine whose speed is to be measured.

→ Armature revolves in the field of permanent magnet.

→ E.M.F. generated in it.

$$E \propto N \cdot \Phi$$

$\Phi \rightarrow$ kept constant

$$E \propto N$$

Speed is converted into G.M.F.

→ E.M.F. is measured with the help of P.M.M.C.

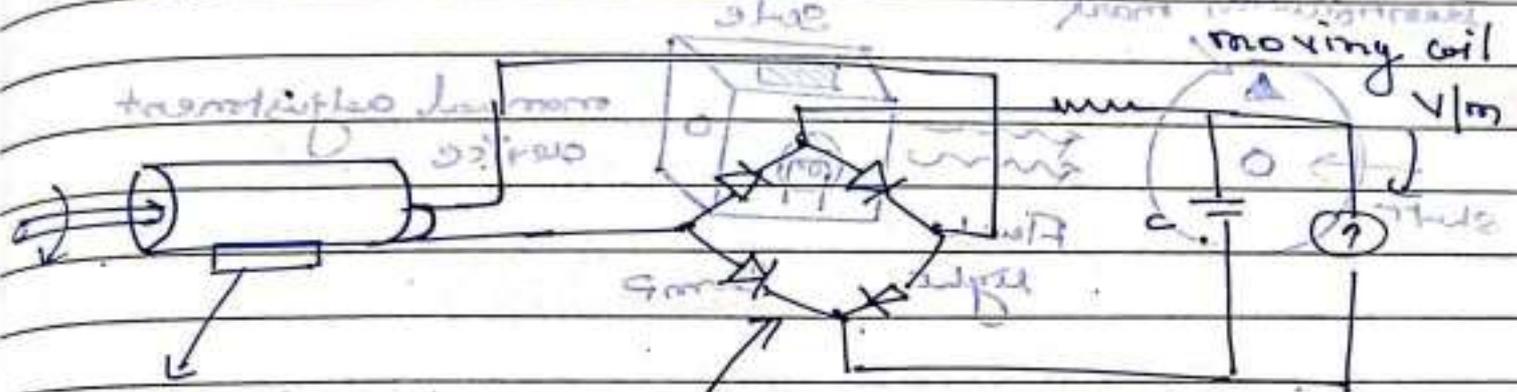
→ Limiting Resistor is added in the measuring circuit.

- Advantages :- (1) Direction of rotation & Polarity of
 (2) O/P is 10 mV/rpm and O/P can be measured by simple v/m

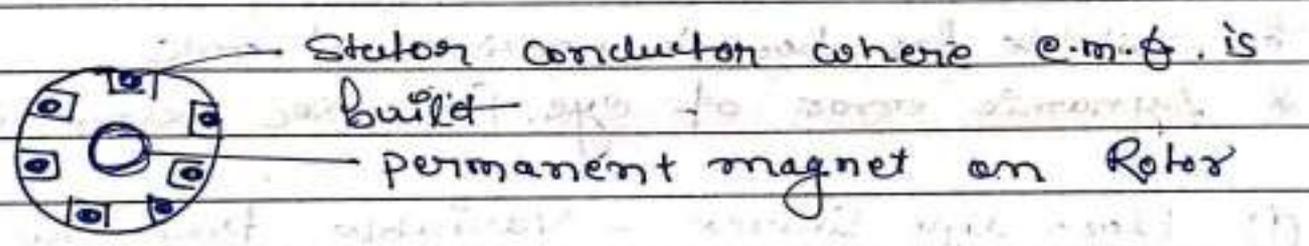
Disadvantages :- (1) Brush produces maintenance prob lem.

(2) A.C. Tachometer Generator

- This tachometer generator has stator magnet.
- The coil is wound on rotor, hence commutator & brushes are not required.
- Rotation of mag. causes e.m.f. in stator coil.
- Amplitude and frequency are proportional to speed of rotation.



Permanent mag. AC gen. Rectifier Smoothing circuit



Advantages — NO. brush.

Disadvantages — (1) If the output voltage is low, then it is very difficult to smooth out the ripple in output voltage waveforms.

At high speed of frequency ↑, then imp. of tachog. is ↑, which causes voltage drop.

Signature: [Handwritten Signature]

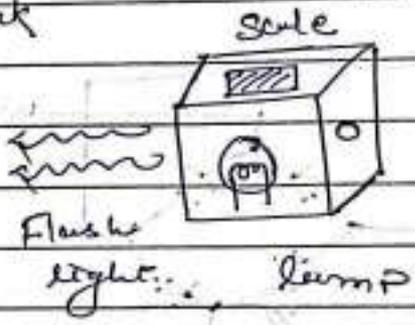
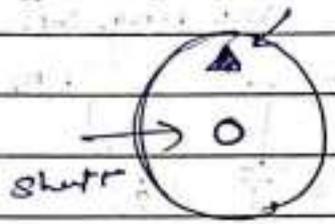
Stroboscopic Tachometer

→ Used for speed measurement of any object without contact.

→ Parts

- (1) Xenon Lamp
- (2) Handle
- (3) Fine adjust knob } adjust light-flash rate
- (4) Coarse adjust knob }
- (5) Display unit [LED Display]
- (6) Supply - rechargeable battery

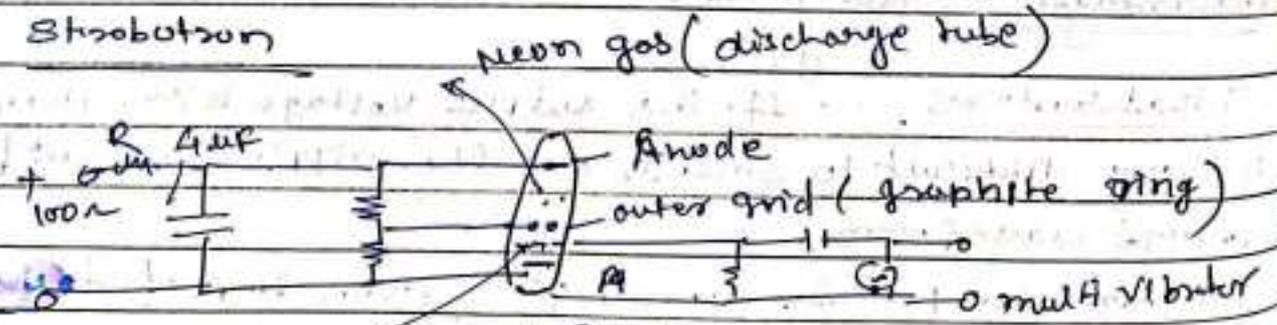
Identification mark



→ If the frequency of flash light and identification marks are same (object which speed is to be measured) then it will be final speed of machine.

- * Suitable for periodic motions of rotic
- * Dynamic errors of eye. [1/16 sec same image for ...]

- (1) Flash light source - Variable frequency oscillator
- (2) Stroboscopy

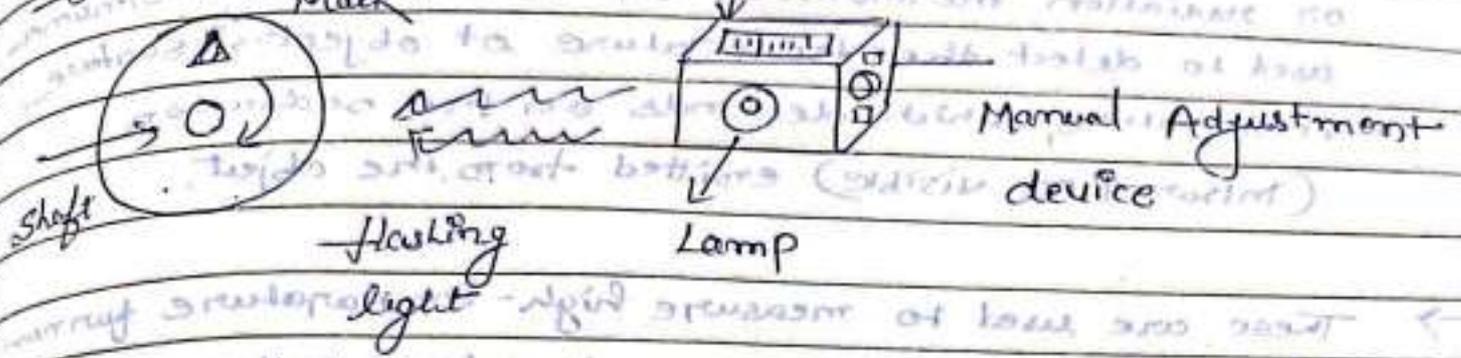


Inner grid wire
 Cathode (Cesium comp)

Signature: _____

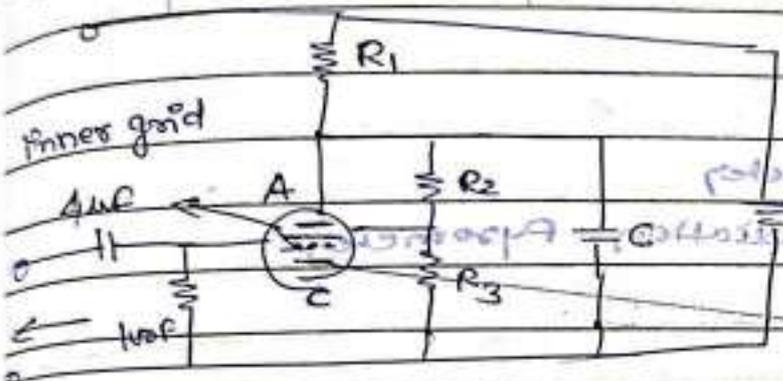
Digital Laser Tachometer

Diagram



Working

→ These device can measure the rotational speed of shaft and convert it into digital form.



Multivibrator

- Neon gas - discharge tube,
- Discharge tube - Anode Cathod & inner grid & outer grid
- potential difference is between two grid causes conduction start. [This can occur due to multivibrator oscillator]
- Then discharge start due to ionization of neon gas. [Flash light]
- during discharge when flash light started, then capacitor discharge through (R2, R3 and R1). Hence large voltage drop occur in R1, in this stage Anode potential drop, so initial ionization and flash light stop. Then oscillator again give pulse to the Anode, and capacitor again charge

Max flash rate - 300 per second.

Signature

Demit Guru

Temperature measurement read logic

→ Pyrometer also is known as an infrared thermometer or radiation thermometer or non-contact thermometer used to detect the temperature of object's surface (Infrared or visible) emitted from the object.

→ These are used to measure high-temperature furnaces.

→ These device can measure the temperature very accurately, precisely, more visually and quickly.

→ Types of Pyrometer

(1) Optical Pyrometer

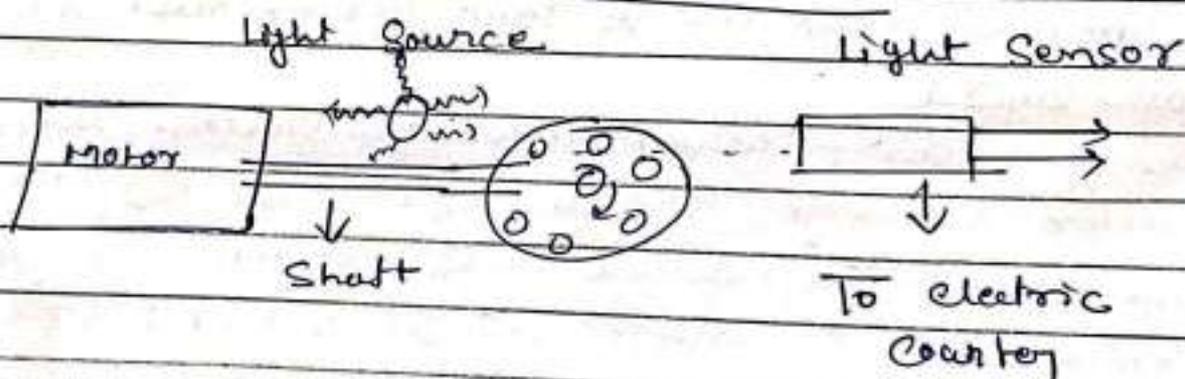
(2) Infrared / Radiation Pyrometer

Digital tachogenerator

→ Photo-electric type

→ Inductive Type

① Photo-electric Type Tacho-generator



- The disc has a number of equidistance holes on its periphery.
- At one side of the disc a light source is fixed and at the other side of the disc, and on line with the light source, a light sensor such a photo-tube.
- When the opaque portion of the disc is between the light source and light sensor, the latter is unilluminated and produces no o/p.
- When a hole appears between the two, the light falling upon the sensor produces o/p.
- The frequency at which these pulses are produced depends upon the number of holes in the disc and its speed of rotation.
- Holes are fixed and \therefore o/p becomes a function of rotation.

Advantages → ① Direct digital o/p is generated hence no Analog to digital converter is used.

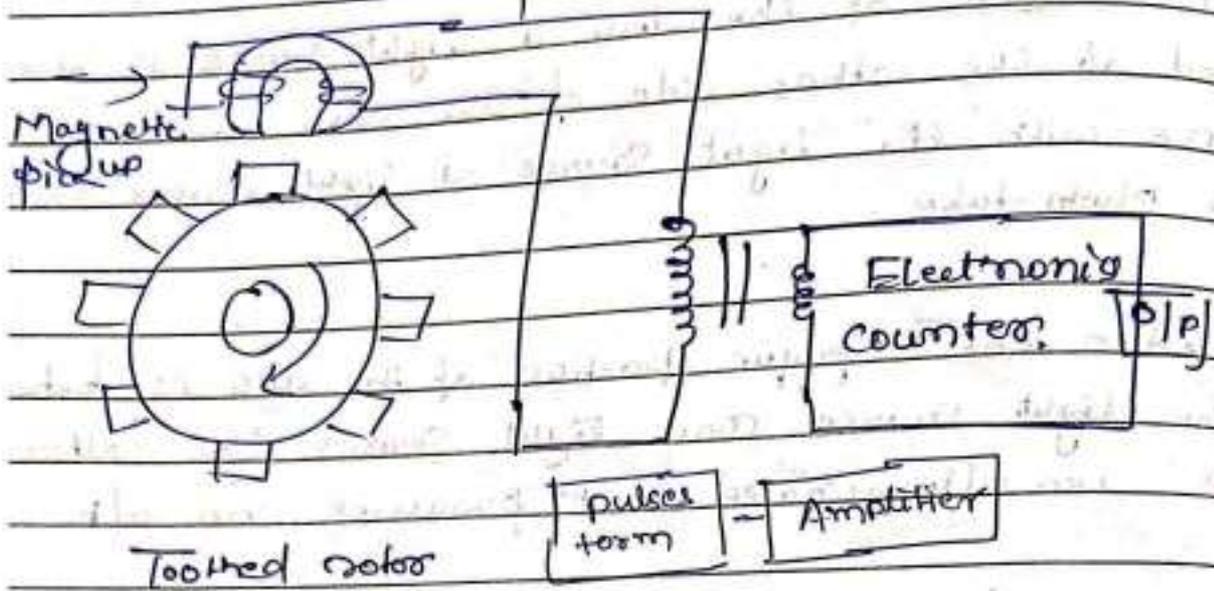
② The pulse amplitude are constant. This simplifies the electronics circuitry.

Disadvantages → The life time of the light source is 50,000 Hr. than replacement requires.

②

② Inductive type

① Tooth rotor of Variable Inductance Tachometer



1) Magnetic pickup coil. \rightarrow permanent magnet + coil

2) Toothed rotor \rightarrow [metallic toothed rotor]

जब Rotor की tooth, permanent magnet, up पर
Magnetic pickup coil से pass करती है, तब फो to
No. of flux change से होता, जिससे, Magnetic
pick-up coil में Faraday's Law Satic field से होता
है, और pulse generated होता है।

then it will send to the amplifier and after
the amplification, it pass to display from
filter.

Speed (n) = pulses per second

$$= \frac{P}{T} \text{ rps}$$

$$= \frac{P \times 60}{T} \text{ rpm}$$

Advantages

- ① Simple and rugged construction
- ② Maintenance free.
- ③ It is easy to calibrate.

Disadvantages

→ Losses in the flux in air gap.

Example A variable reluctance type tachometer has 60 rotor teeth. The counter record speed 3600 counts per second. Determine speed in r.p.m.

$$\text{Speed} = \frac{\text{pulse per second}}{\text{Total NO of teeth}} \times 60$$

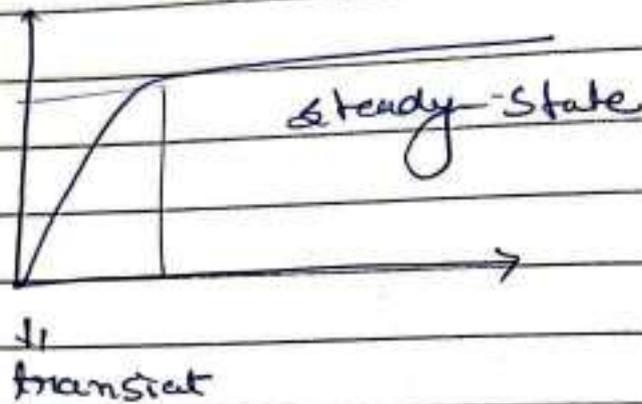
$$= \frac{3600}{60} \times 60$$

$$= 3600 \text{ rpm}$$

Unit-01

Dynamic characteristics

→ A sensor may be characterized with a time-dependent characteristics, which is called a dynamic characteristics



Example - When we start some gadget to start it's may take some to start (this time warm up)

⊗ The warm up time for a sensor can be very short or considerably long depends upon the sensor working and character environment

dynamic

Sensor input output characteristics can also be describing using constant coefficient linear diff. equation

Equation are following :-

(1) $s(t) = a_1 s(t) + a_0$ — Zero order function

(2) $a_1 \frac{d}{dt} s(t) + a_0 s(t) = s(t)$ → first order system

(3) $a_2 \frac{d^2}{dt^2} s(t) + a_1 \frac{d}{dt} s(t) + a_0 s(t) = s(t)$ ⇒ store - 2 energy

Date: _____ GENIUS

Unit-05 Basic control system Laplace Transformation

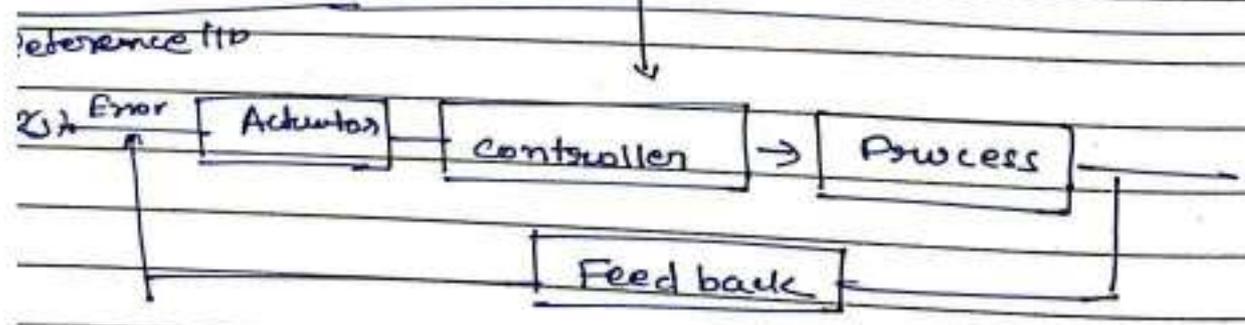
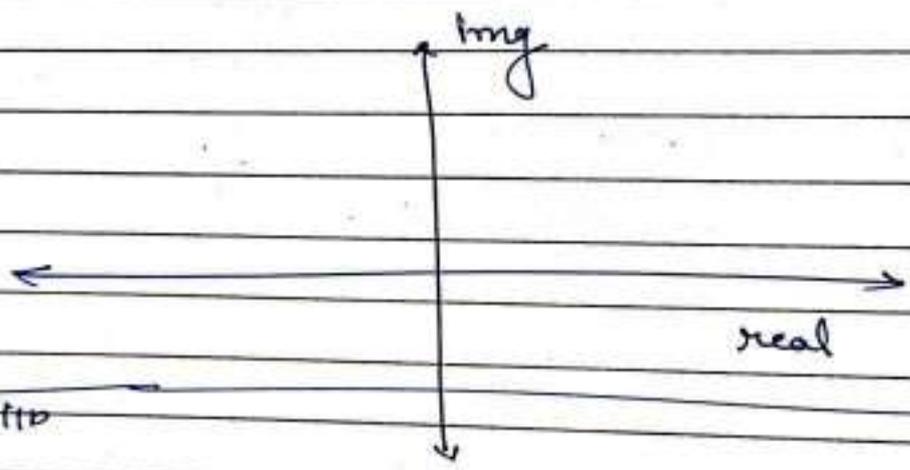
Laplace Transformation is the method of, conversion of function from time domain to frequency domain.

$$f(t) \longleftrightarrow R(s)$$

Eg. Lucknow \rightarrow Kanpur
2 hours | 90 km

Application - Engineering, Control System, Scientist

$s \rightarrow$ Plane (frequency)
 $s \rightarrow \sigma + j\omega$
 $\sigma \rightarrow$ Real
 $j\omega \rightarrow$ imaginary axis



Generalised diagram of control system

① $f(t) = 1$

$$L(1) = \int_0^{\infty} e^{-st} \cdot 1 \cdot dt$$

$$= \left[\frac{e^{-st}}{-s} \right]_0^{\infty}$$

$$= \left[\frac{e^{-\infty}}{-s} - \frac{e^0}{-s} \right]$$

$$L(1) = \frac{1}{s}$$

②

$L(e^{at}) = ?$

$$= \int_0^{\infty} e^{at} \cdot e^{-st} dt$$

$$= \int_0^{\infty} e^{-(s-a)t} dt$$

$$= \left[\frac{e^{-(s-a)t}}{-(s-a)} \right]_0^{\infty}$$

$$L(e^{at}) = \frac{1}{(s-a)}$$

Similarly $e^{-at} = \frac{1}{(s+a)}$

(3) $\mathcal{L}\{\sin at\} =$

$$\mathcal{L}\{\sin at\} =$$

$$e^{j\theta} = \cos \theta + j \sin \theta$$

$$e^{jat} = \cos at + j \sin at$$

$$e^{-jat} = \cos at - j \sin at$$

$$\frac{e^{jat} - e^{-jat}}{2} = \frac{\cos at + j \sin at - \cos at + j \sin at}{2}$$

$$\frac{e^{jat} - e^{-jat}}{2} = \frac{j \sin at}{1}$$

$$\sin at = \frac{1}{2j} [e^{jat} - e^{-jat}]$$

$$\mathcal{L}\{\sin at\} = \frac{1}{2j} [e^{jat} - e^{-jat}]$$

$$= \left[\frac{1}{s-j} - \frac{1}{s+j} \right] \frac{1}{2j}$$

$$= \left[\frac{s+a - s+a}{s^2+a^2} \right] \frac{1}{2j}$$

$$= \frac{2aj}{(s^2+a^2) \times 2j}$$

$$= \boxed{\frac{a}{s^2+a^2}}$$

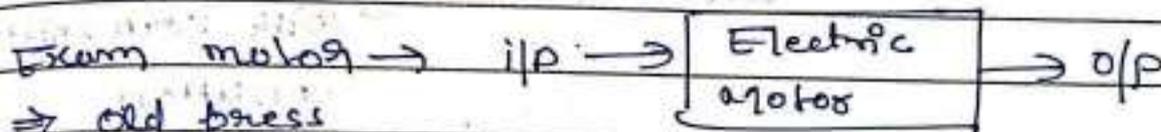
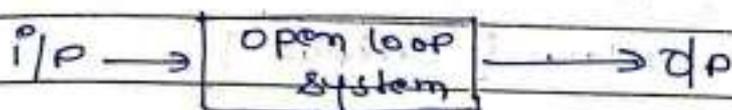
Similarly $\mathcal{L}\{\cos at\} = \frac{s}{s^2+a^2}$

Control System

A system which consist of number of component conncted together to perform a specific function in which the output is controlled by input.

- Types —
- ① open loop system
 - ② close loop system

① open loop system



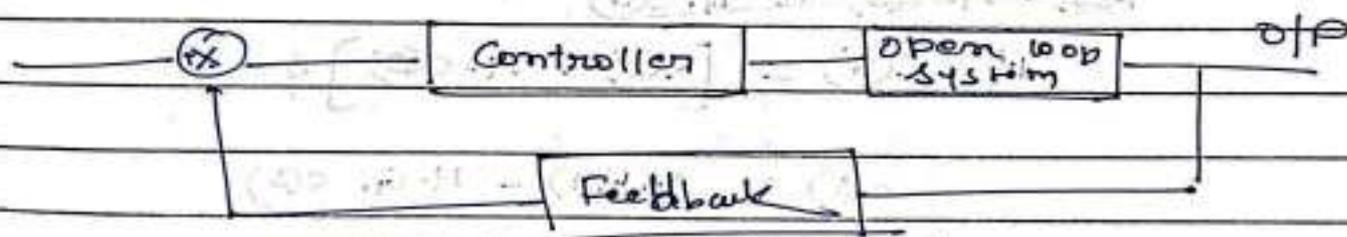
⇒ old press

⇒ water heater | Traffic light | Heavy load

Advantages —

- Simple & Economical
- Easier to construct
- Stable

② close loop system



Advantages —

- 1) Accurate
- 2) less Affected by Noise

Disadvantages — ① Complex & Costlier

② Feedback reduces the over all gain of the system

③ Stability main problem

- Example →
1. Aircraft guided System
 2. Fully automatic machine
 3. Tracking the traffic density, and open the light.

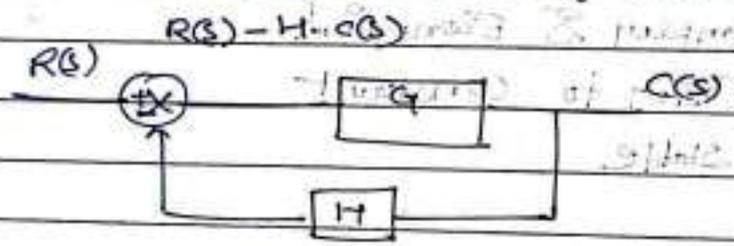
Transfer Function

→ Ratio of Laplace transform of output to the Laplace transformation of input.

$$T.F = \frac{\text{Laplace [output]}}{\text{Laplace [input]}}$$

with zero initial condition.

For close loop transfer function



$$R(s) - H \cdot C(s) = G \cdot C(s)$$

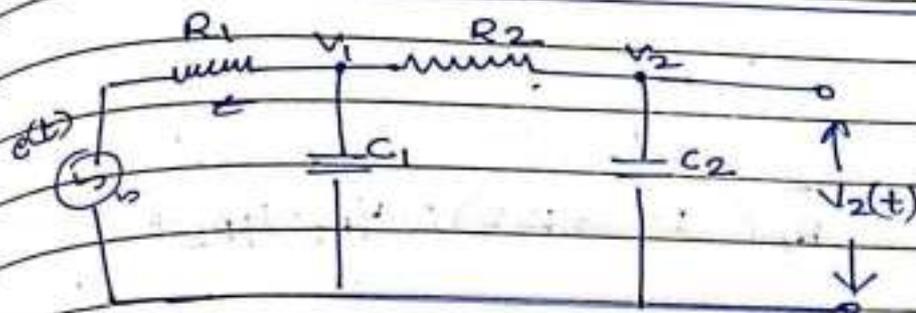
$$R \cdot C(s) = [R(s) - H \cdot C(s)] G$$

$$C(s) = G \cdot R(s) - H \cdot G \cdot C(s)$$

$$[1 + G \cdot H] C(s) = G \cdot R(s)$$

$$\frac{C(s)}{R(s)} = \frac{G}{1 + GH}$$

Pole and zero concept of T.F



Node ①

$$\Rightarrow \frac{V_1(t) - e(t)}{R_1} + C_1 \frac{dV_1(t)}{dt} + \frac{V_1(t) - V_2(t)}{R_2} = 0$$

$$\Rightarrow \frac{V_1(s) - E(s)}{R_1} + C_1 s \cdot V_1(s) + \frac{V_1(s) - V_2(s)}{R_2} = 0$$

$$\Rightarrow V_1(s) \left[\frac{1}{R_1} + C_1 s + \frac{1}{R_2} \right] - \frac{E(s)}{R_1} - \frac{V_2(s)}{R_2} = 0$$

$$\Rightarrow V_1(s) \left[\frac{1}{R_1} + C_1 s + \frac{1}{R_2} \right] = \frac{E(s)}{R_1} + \frac{V_2(s)}{R_2} \quad \text{--- (1)}$$

Node ②

$$\frac{V_2(t) - V_1(t)}{R_2} + C_2 \frac{dV_2}{dt} = 0$$

$$\frac{V_2(s) - V_1(s)}{R_2} + s \cdot C_2 \cdot V_2(s) = 0$$

$$V_2(s) \left[\frac{1}{R_2} + C_2 s \right] = \frac{V_1(s)}{R_2}$$

$$V_1(s) = R_2 \cdot V_2(s) \left[\frac{1}{R_2} + C_2 s \right]$$

$$V_1(s) = V_2(s) \left[1 + R_2 C_2 s \right] \quad \text{--- (2)}$$

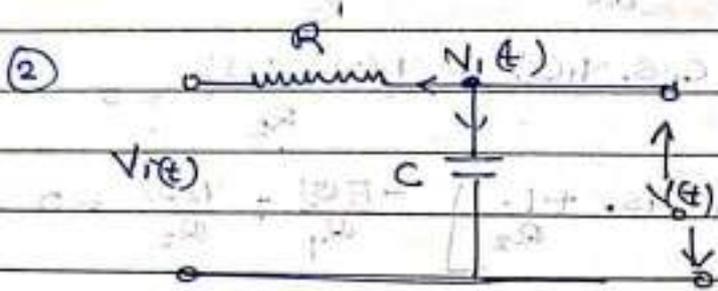
$V_1(s) \rightarrow$ (1)

$$V_2(s) \left[1 + R_2 C_2 s \right] \left[\frac{1}{R_1} + C_1 s + \frac{1}{R_2} \right] = \frac{E(s)}{R_1} + \frac{V_2(s)}{R_2}$$

$$\Rightarrow V_2(s) \left[R_2 (1 + R_2 C_2 s) \left(\frac{1}{R_1} + C_1 s + \frac{1}{R_2} \right) - \frac{1}{R_2} \right] = \frac{E(s)}{R_1}$$

$$\Rightarrow \frac{V_2(s)}{E(s)} = \frac{R_1 (1 + C_2 R_2 s) \left(\frac{1}{R_1} + C_1 s + \frac{1}{R_2} \right) - \frac{1}{R_2}}{R_1 (1 + C_2 R_2 s) \left(\frac{1}{R_1} - \frac{1}{R_2} + \right)}$$

$$= \frac{R_1 \left[(1 + C_2 R_2 s) \left(\frac{1}{R_1} + C_1 s + \frac{1}{R_2} \right) - \frac{1}{R_2} \right]}{R_1 \left[(1 + C_2 R_2 s) \left(\frac{1}{R_1} + C_1 s + \frac{1}{R_2} \right) - \frac{1}{R_2} \right]}$$



$$\frac{V_o(t) - V_i(t)}{R} + C \cdot \frac{dV_o(t)}{dt} = 0$$

$$\Rightarrow \frac{V_o(s) - V_i(s)}{R} + C \cdot s \cdot V_o(s) = 0$$

$$\Rightarrow \frac{V_o(s)}{R} - \frac{V_i(s)}{R} + C \cdot s \cdot V_o(s) = 0$$

$$\Rightarrow \left(\frac{1 + R \cdot C \cdot s}{R} \right) \cdot V_o(s) = \frac{V_i(s)}{R}$$

$$\Rightarrow \frac{(1 + R \cdot C \cdot s) \cdot V_o(s)}{R} = \frac{V_i(s)}{R}$$

$$\Rightarrow \frac{V_o(s)}{V_i(s)} = \frac{1}{1 + R \cdot C \cdot s}$$

$$\text{T.F.} = \frac{1}{1 + R \cdot C \cdot s}$$

Pole and Zero Concept of T.F.

zero \rightarrow it is the value of (s) [frequency] for which numerator of the Transfer function become zero.

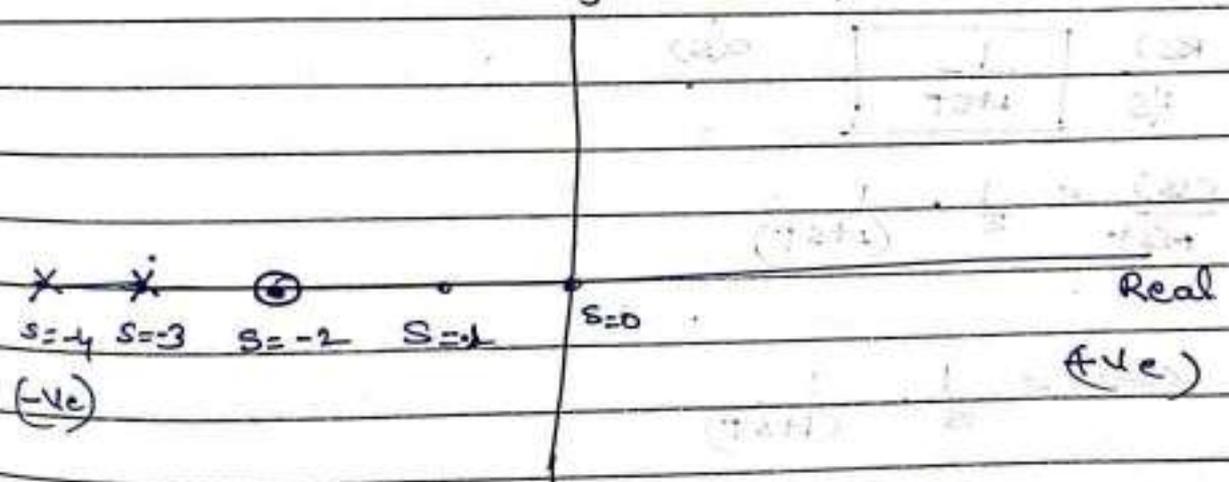
poles \rightarrow It is the value of (s) [frequency] for which the denominator of the Transfer function become ∞ or 0.

$$T.F. = \frac{(s+2)}{(s+3)(s+4)}$$

Zeros $\rightarrow (s+2) = 0$
 $s = -2$

poles $\rightarrow (s+3)(s+4) = 0$
 $s = -3$
 $s = -4$

Pole zero diagram \rightarrow which locate the position $j\omega$ of poles & zeros



Ex \Rightarrow T.F. For n no. of pole

$$T.F. = \frac{(s-z_1)(s-z_2)(s-z_3) \dots (s-z_n)}{(s-p_1)(s-p_2)(s-p_3) \dots (s-p_n)}$$

Zeros $\rightarrow z_1, z_2, z_3$

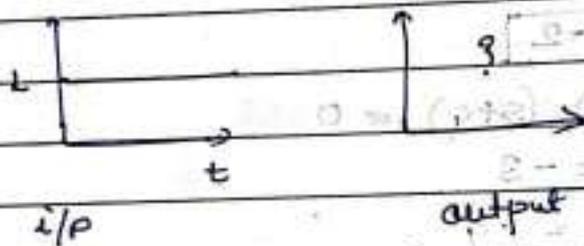
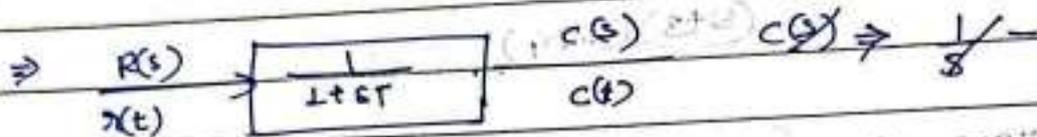
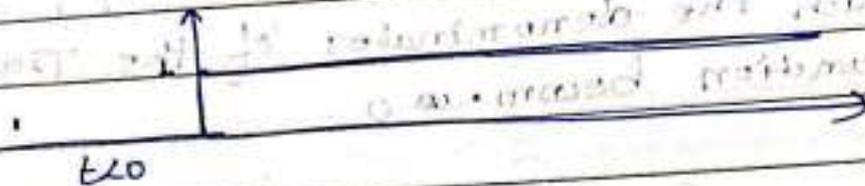
Poles $\rightarrow p_1, p_2, p_3$

Signature..... *[Signature]*

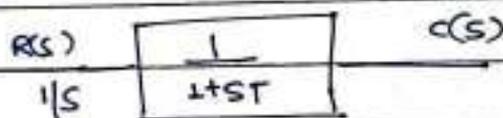
unit step response of the system

$$\Rightarrow u(t) = \begin{cases} 0, & t < 0 \\ 1, & t \geq 0 \end{cases}$$

Example \rightarrow switch operating at time 't'



Laplace transformation



$$\Rightarrow \frac{C(s)}{R(s)} = \frac{1}{s} \cdot \frac{1}{(1+sT)}$$

$$\Rightarrow C(s) = \frac{1}{s} \cdot \frac{1}{(1+sT)}$$

$$= \frac{1}{s} \cdot \frac{(s+T)}{(1+sT)}$$

$$= \frac{1}{s} \cdot \frac{T}{(1+sT)}$$

$$e(s) = \frac{1}{s} - \frac{T}{(1+ST)}$$

$$\Rightarrow u(t) = 1 - T$$

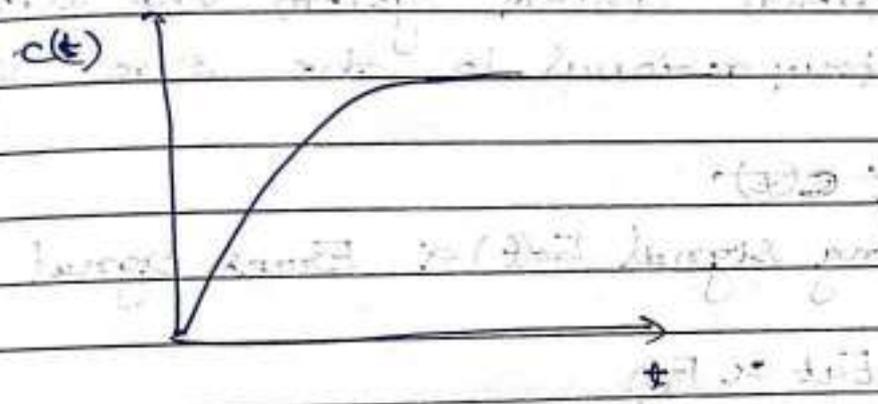
$$e(s) = \frac{1}{s} - \frac{T}{(1+ST)}$$

$$c(s) = \frac{1}{s} - \frac{1}{(s+1/T)}$$

$$= u(t) + -e^{-t/T} \cdot u(t)$$

$$c(t) = [1 - e^{-t/T}] u(t)$$

response of the system



response of first order system

Page No. _____ Date: _____ GENIUS

Basic of Control Action

- 1) Proportional Controller (P)
- 2) Integral controller (I)
- 3) Differential controller (D)
- 4) PID controller.

① Proportional controller



→ In proportional control system the actuating signal is proportional to the error signal.

$$E_a(t) \propto E(t)$$

Actuating signal $E_a(t) \propto$ Error signal $E(t)$

$$E_a(t) \propto E(t)$$

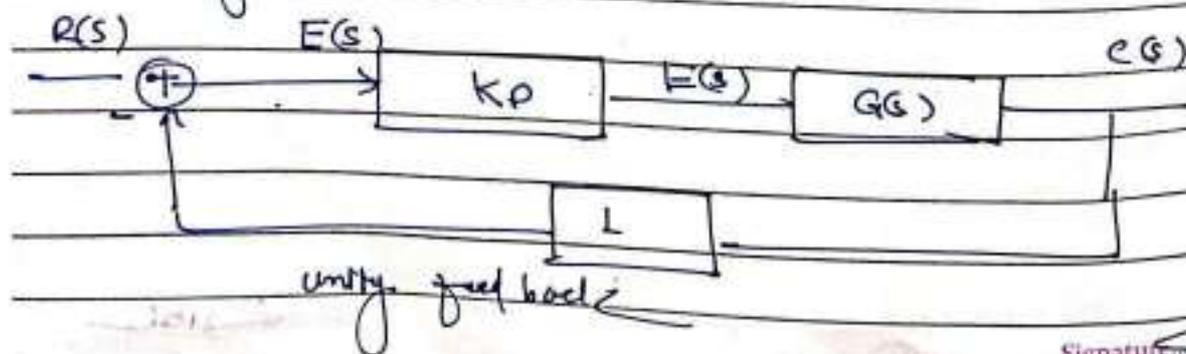
$$E_a(t) = k_p \cdot E(t)$$

k_p = proportional co-efficient →

$$E_a(s) = k_p \cdot E(s)$$

$$\frac{E_a(s)}{E(s)} = k_p \Rightarrow \text{transfer function}$$

Block diagram



Integral controller system.

→ Actuating signal \propto Error signal

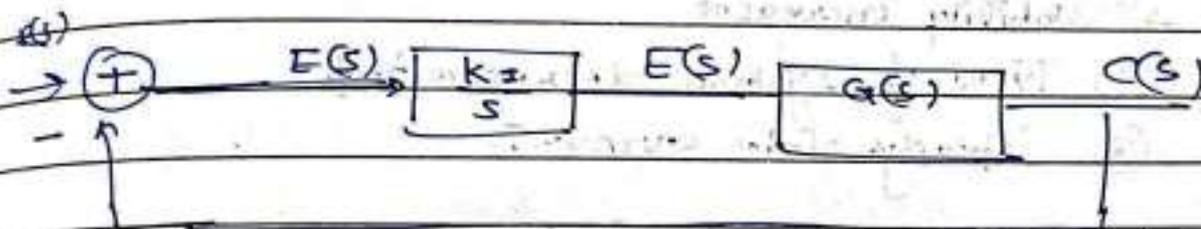
$$e_{act} \propto \int e(t) dt$$

$$e_{act} = k_i \int e(t) dt$$

$$E_a(s) = k_i \cdot \frac{E(s)}{s}$$

Transfer function

$$\frac{E_a(s)}{E(s)} = \frac{k_i}{s}$$



Advantages → types of system increase hence steady state error ↓

Disadvantage → ↓, system stability.

Derivative controller

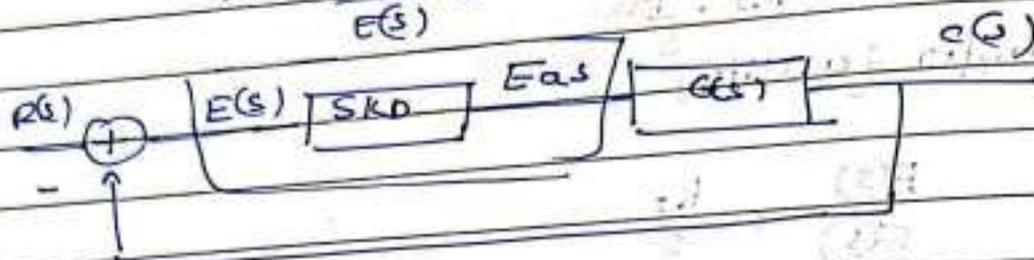
Actuating signal $E_a(t) \propto \frac{d}{dt} E(t)$

$$\Rightarrow C_a(t) \propto \frac{d}{dt} e(t)$$

$$\rightarrow C_a(t) = k_D \cdot \frac{d}{dt} e(t)$$

$$\rightarrow E_a(s) = k_D \cdot s \cdot E(s)$$

$$\Rightarrow \frac{E_a(s)}{E(s)} = s \cdot k_D$$



Advantages \Rightarrow ① Stability increases

② Types of system decrease \downarrow

③ Steady state error \uparrow

P.I.D controller

\Rightarrow In PID controller / control action, the actuating error signal is proportional to the error signal added with the integral of a signal and derivative of a signal

$$e_a(t) \propto e(t) + \int e(t) \cdot dt + \frac{d}{dt} e(t)$$

$$C_a(t) = k_p e(t) + k_I \int e(t) \cdot dt + k_D \frac{d}{dt} e(t)$$

$$E_a(s) = k_p E(s) + k_I \frac{E(s)}{s} + k_D \cdot s \cdot E(s)$$

$$E_a(s) = [k_p + k_I + k_D \cdot s] E(s)$$

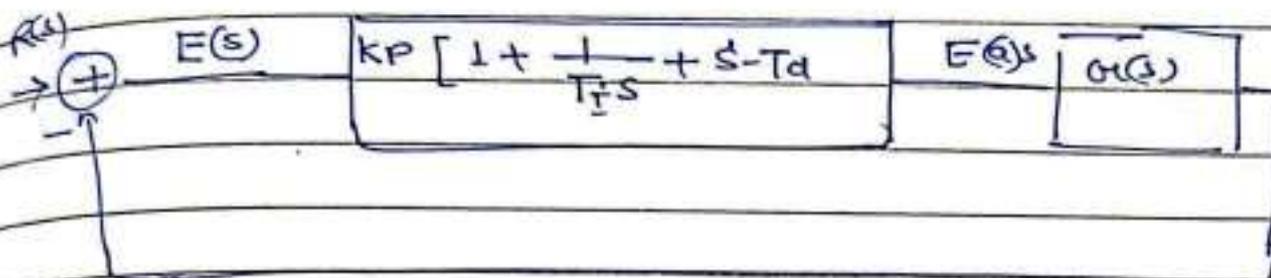
$$E_a(s) = E(s) \cdot k_p \left[1 + \frac{k_I}{s k_p} + \frac{k_D s}{k_p} \right]$$

$$E_d(s) = -E(s)$$

$$\frac{E_d(s)}{E(s)} = \frac{T_I = k_D}{K_I} \quad T_d = \frac{k_d}{k_P}$$

$$E_d(s) = E(s) k_P \left[1 + \frac{1}{T_I s} + s T_d \right]$$

$$\frac{E_d(s)}{E(s)} = k_P \left[1 + \frac{1}{T_I s} + s T_d \right]$$

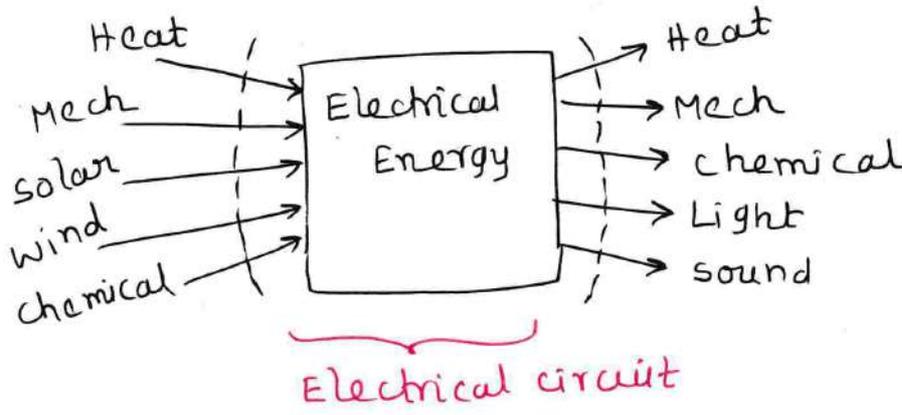
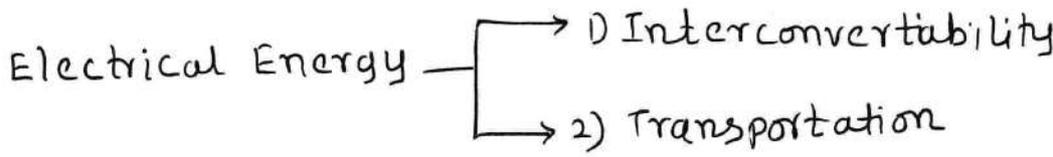


⇒ Stability is controlled

⇒ steady state error reduces ↓

02-10-14

Importance of Electrical energy:

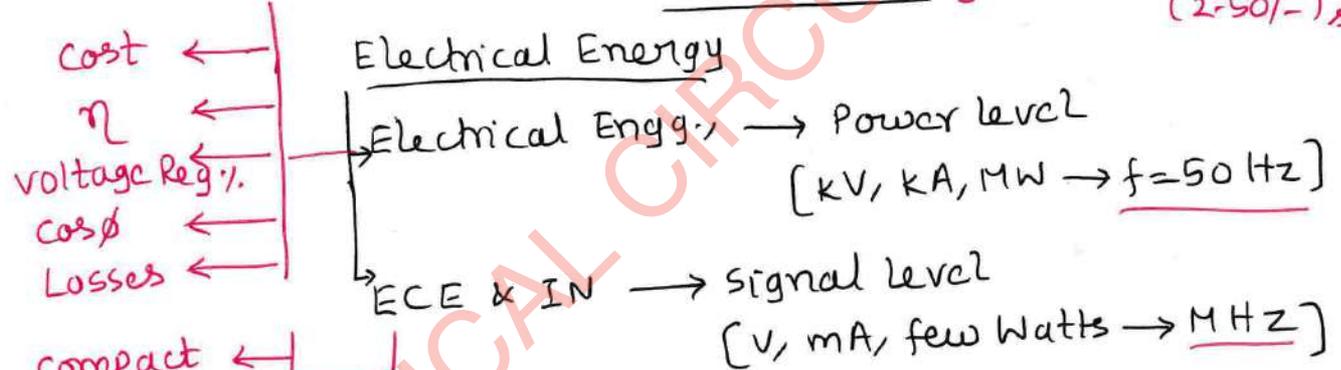


The only energy which we can transport

- in bulk quantities
- Longer distances
- Most economical way

We require medium of transmission
↳ Conductors

1 unit Electrical Energy = 1 kWh
= $1000\text{ W} \times 1\text{ hr}$ } → cheap ⁱⁿ price (2-50/-) say



- Cost ←
- η ←
- voltage Reg. % ←
- $\cos\phi$ ←
- Losses ←

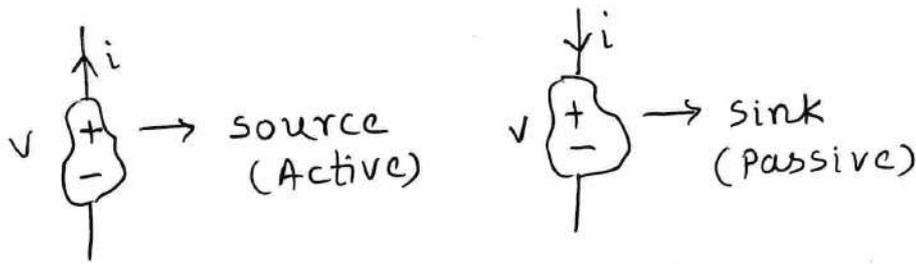
- compact ←
- Automation ←
- Portability ←
- Control ←

Electrical Energy (Problem)

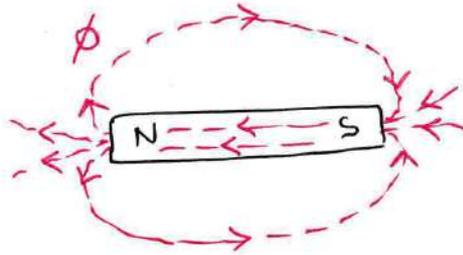
↳ All our 5 senses fail.

- Electrical circuits can be learned using
- 1) Notations → Symbols, laws, formulas etc
 - 2) Maths → Proof

→ Examples → Notations

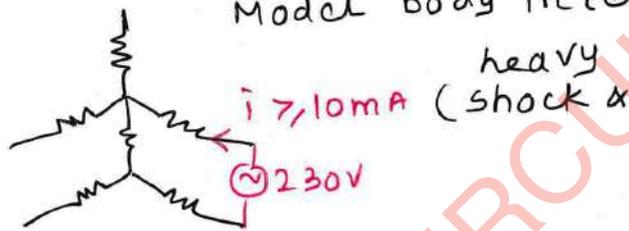


Ex: → Permanent magnet



Ex: $R \rightarrow$ LTI property of matter (Linear Time Invariant)
 $L \rightarrow$ Electro-magnetic property
 $C \rightarrow$ Electro-static property

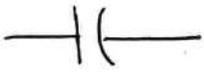
Model body in terms of resistance



→ Body cannot be modelled in terms of inductance
→ Body can be modelled in terms of capacitance
(silk cloth wear has more capacitance than cotton cloth as ϵ of silk $>$ ϵ of cotton)

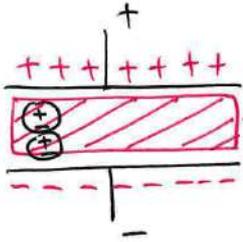
capacitor

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



DC $\rightarrow C \rightarrow 0$

AC \rightarrow 'i' flows (leads 'v' by 90°)

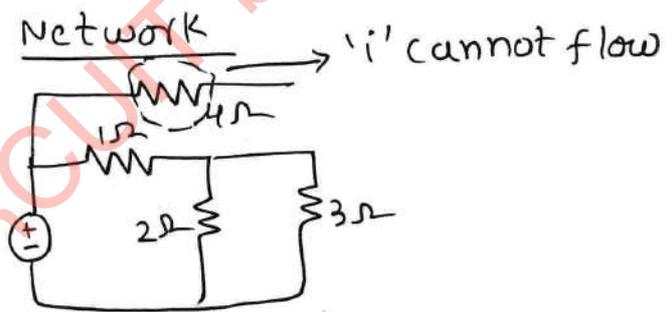
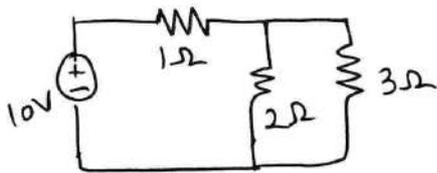


Dielectric (special) \rightarrow Polarization

\rightarrow displacement current (not conventional current)

\rightarrow Engineering is Application of Science

03-10-14 \rightarrow This closed path concept
Circuit \leftarrow



current 'i' is intended to flow through all components.

Practical big systems are always networks.

Circuits are building blocks of networks.

\rightarrow Practical big inter connected systems are always networks, but we do circuit analysis to those parts which are electrically energised.

\rightarrow Circuits are building blocks of networks.

Ex. our power system is a big network where a motor running in it is a circuit.

→ our communication system is a big n/w where a transmitter running in it is a circuit.

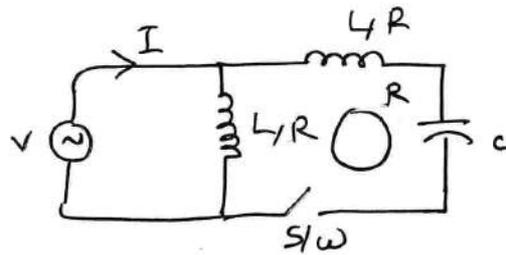
* Network components and elements

→ our practical applications in electrical engineering are components, but when these applications are modelled as a circuit or network, we use fundamental elements such as V, I, R, L, C etc. and perform analysis.

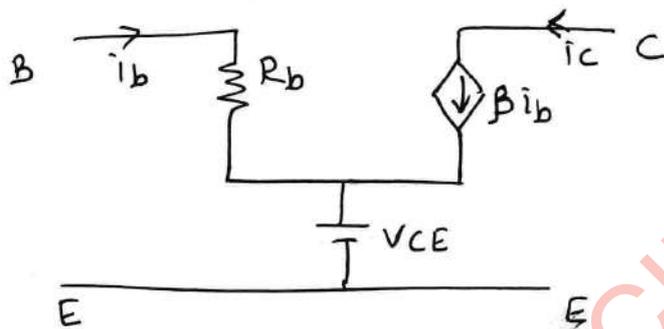
Ex:1 Heater



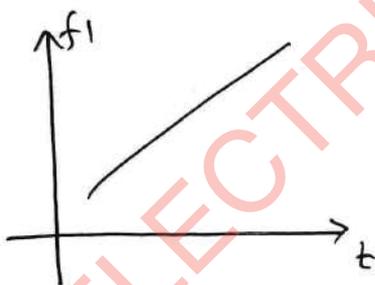
Ex:2 1- ϕ Induction motor (fan)



Ex: BJT

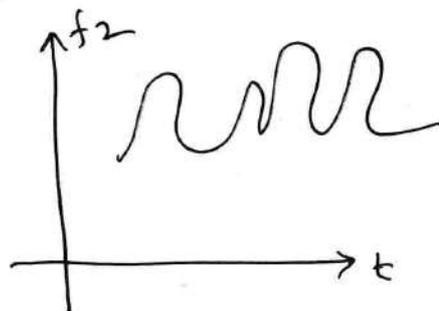


Linear Components / Networks

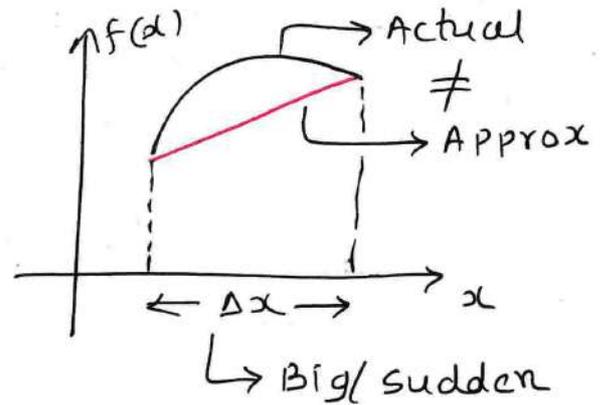
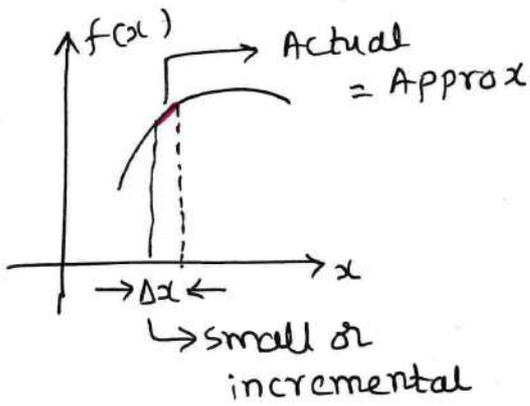


→ can be modeled mathematically

$$\rightarrow y = mx + c$$



→ cannot be modeled mathematically



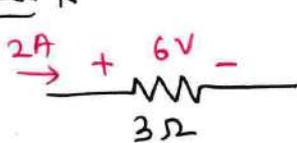
→ Ratings or specifications (within this range they are linear)

→ Most of our practical components and networks are non-linear in nature. But any non-linear system can be linearised for small incremental changes in time. However, the same network for sudden big changes undergoes non linear operation.

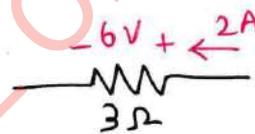
→ In engineering circuit analysis, if any component/network obeys ohm's law, kirchoff's law, superposition principle, homogeneity (proportionality) etc are said to be linear within the specified ratings.

* Bilateral: Property of elements are independent to

Ex: R



$P_{loss} = 12W$



$P_{loss} = 12W$

1) V → Polarity

2) I → direction

* Unilateral: Property depends upon: 1) voltage → Polarity

2) current → Direction

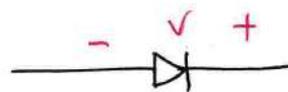
Ex:



→ Forward Biased

→ will conduct

→ $R_{ON} = 0\Omega$

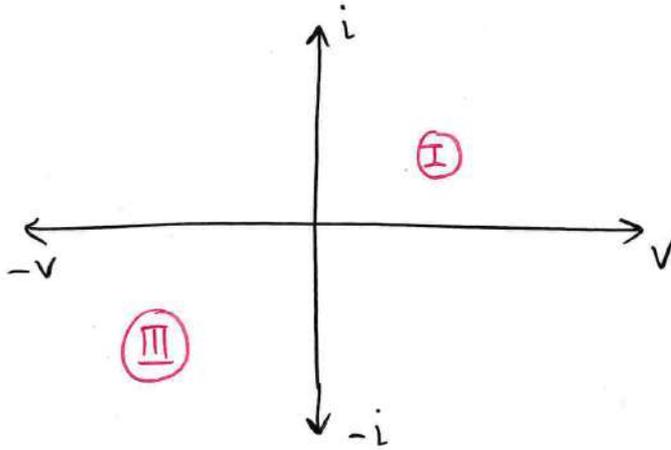


→ will not conduct

→ Reverse Biased

→ $R_{OFF} = \infty\Omega$

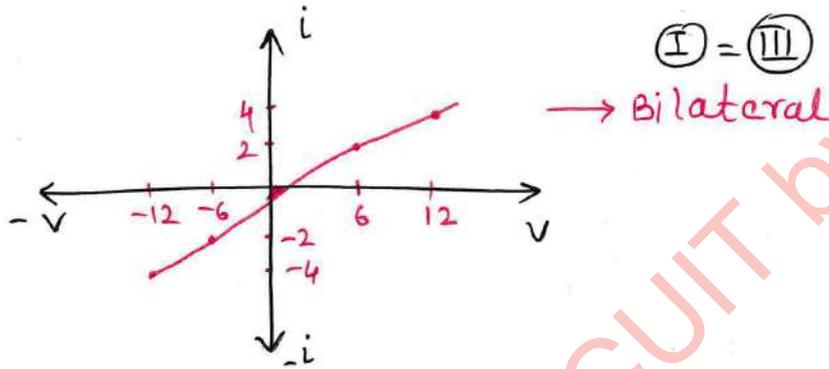
Based on v-i characteristics



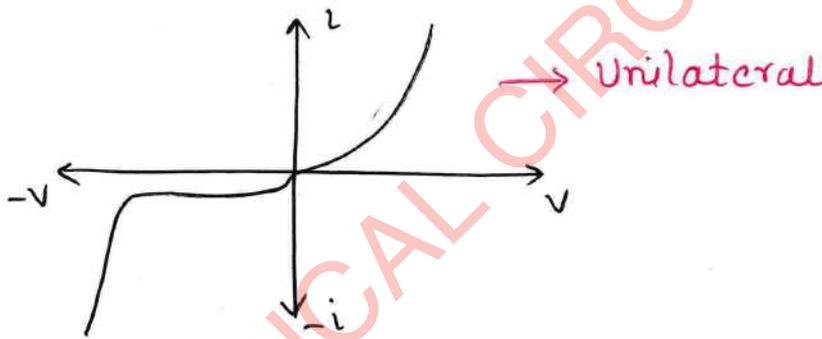
(I) = (III) → symmetrical → Bilateral

(I) ≠ (III) → Asymmetrical → Unilateral

Ex: (R)

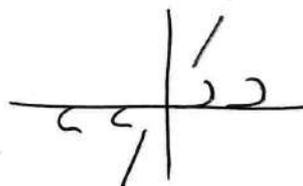


Ex: (D)



Q: SCR → Unilateral

TRIAC → Bilateral



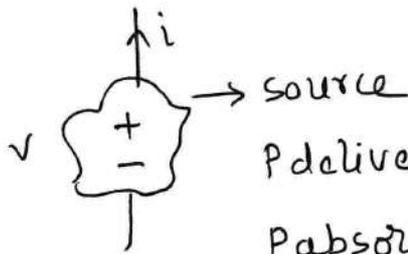
* R, L, C are bilateral

* BJT, SCR, FET, diodes are unilateral

* Active Elements

- Deliver
 - give out
 - Drive
 - Energise
- } Externally with Electrical energy

Ex: Ideal voltage sources, Ideal current sources



$$P_{\text{delivered}} = + \underline{v \cdot i} \text{ Watts}$$

$$P_{\text{absorbed}} = - \underline{v \cdot i} \text{ Watts}$$

* Passive elements

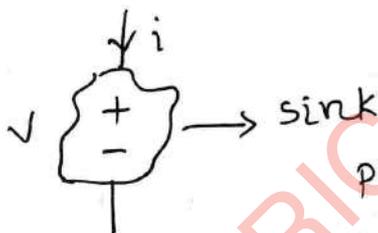
- Absorb
 - Dissipate
 - Waste
 - Convert
 - store
- } E · E ·

Ex: R, L, C

\boxed{R} → dissipates
E · E · → Heat

\boxed{L} → stores
E · E · → Electromagnetic form
(flux)

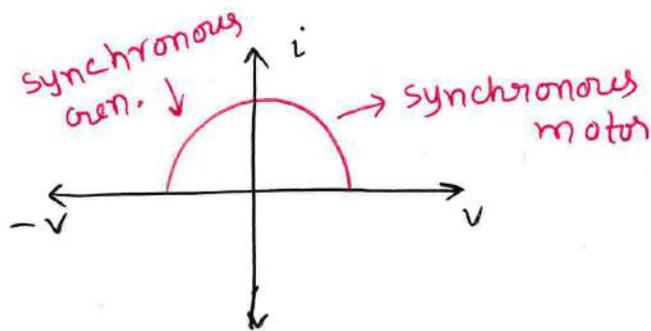
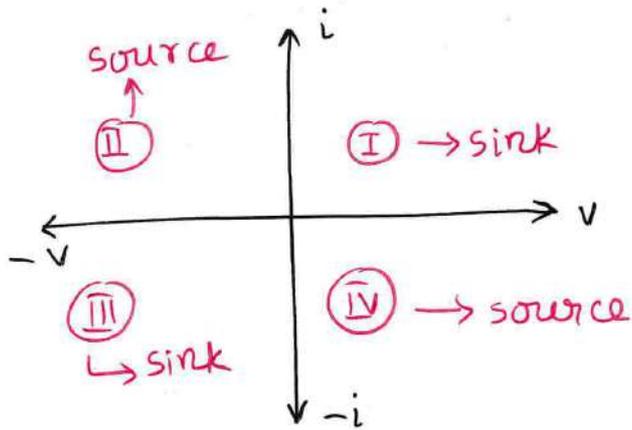
\boxed{C} → stores
E · E · → Electrostatic form (charge)



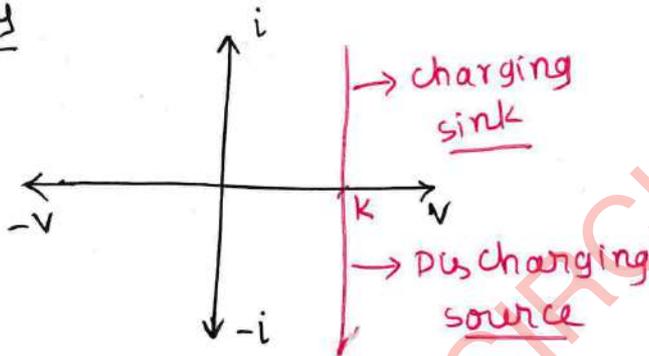
$$P_{\text{absorbed}} = + \underline{v \cdot i} \text{ Watts}$$

$$P_{\text{delivered}} = - \underline{v \cdot i} \text{ Watts}$$

Based on v-i characteristics

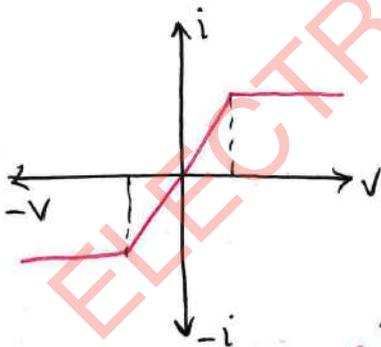


Battery



GATE-07

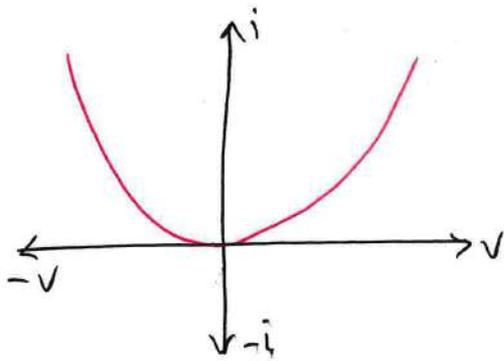
Q: The static v-i characteristics of a particular component are shown below, then the element is



- a) Linear, Active, Bilateral
- b) Linear, Passive, Bilateral
- c) Non-linear, Active, Unilateral
- d) Non-linear, Passive, Bilateral

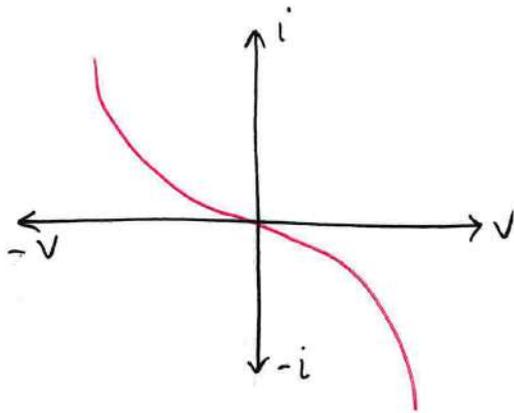
↑ in I & III
Symmetric → Bilateral
I & III → Passive

IES



- Non-linear
- Both passive & Active time
- ↳ Globally active
- Unilateral

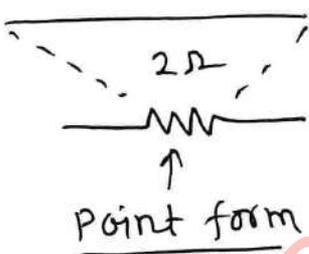
Ex:



- Non Linear
- Active
- Bilateral

- Note: A transistor BJT is globally passive but locally as an amplifier when biased is active.
- Practical inductors/capacitors are globally passive, but locally during transients when they discharge are said to be active.

* Lumped Parameters



Neglect → shape
→ length

- $R \rightarrow \Omega/\text{ph}/\text{km}$
- $L \rightarrow \text{mH}/\text{ph}/\text{km}$
- $C \rightarrow \mu\text{F}/\text{ph}/\text{km}$
- $G \rightarrow \mu\text{S}/\text{ph}/\text{km}$



Ex: PCB components

→ $R_a \rightarrow$ lumped



→ Model of Medium Transmission lines T, π Models

→ Lumped models are: → Simple to represent

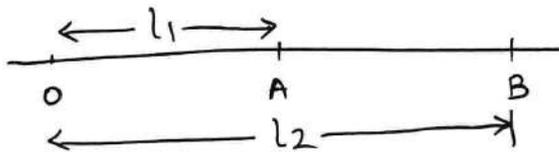
→ Linear Algebraic equations
→ Faster solution
→ Approximate answer

Writing KVL,
KCL possible

Approximate models

* Distributed parameters

→ Actual models/
Absolute models



$$R_{\text{actual}} = \frac{\partial R}{\partial L}$$

Ex: Long transmission lines (rigorous solution)

- Antennas
- EMF concepts
- Wave guides
- Complex to represent
- Differential equations
- Tedious solutions
- very accurate answer

IES
Q: The relations like $v = n\lambda$ holds good for
distributed models only.

* node(n)

→ A node is a part of interconnection (or) junction b/w 2 or more components.

* Branch (b)

→ A branch is an elemental connection b/w 2 nodes.

* Degree of a node (s)

→ The no. of branches incident at any node represents its degree. if

If $\delta = 2 \rightarrow$ simple node (n_s)

$\delta > 2 \rightarrow$ Principle node (n_p)

* For any circuit or network

$$\sum_{i=1}^n \delta_i = 2(b)$$

$n \rightarrow$ no. of nodes

* Mesh (m)

\rightarrow A mesh is a closed path of a circuit or network which should not have further closed paths in it.

* Loop (l)

\rightarrow Loops are all possible closed paths of a circuit/network.

* Note: For any circuit/network $m = b - n + 1$

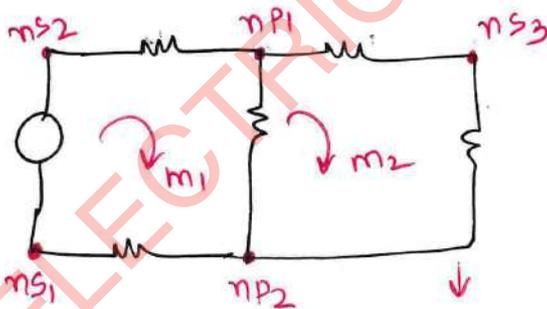
\rightarrow The minimum no. of KVL equations to solve any circuit or network is also equal to m , i.e., $b - n + 1$.

\rightarrow Meshes are specifically called as independent loops.

\rightarrow All meshes are by default loops but all loops are not meshes.

\rightarrow While doing nodal analysis, we may neglect simple nodes but one of the principle node is considered as reference. So, the minimum no. of KCL equations to solve a circuit or network is equal to $n_p - 1$

Ex:



$$\begin{aligned} \sum \delta_i &= 2+2+2+3+3 \\ &= 12 \\ &= 2(6) = 2(b) \end{aligned}$$

Bend
can't
be a node

$$n = 5$$

$$b = 6$$

$$m = 2 = b - n + 1 = 6 - 5 + 1 = 2.$$

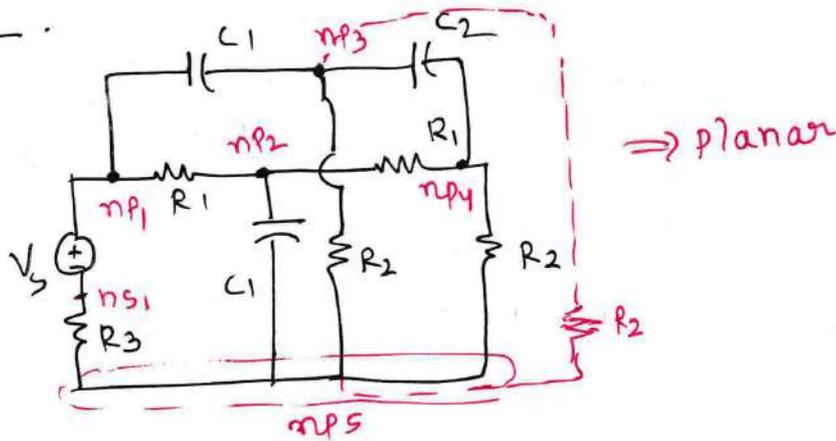
$$l = 2 + 1 = 3.$$

$$\text{KVL} \rightarrow 2$$

$$\text{KCL} \rightarrow 1$$

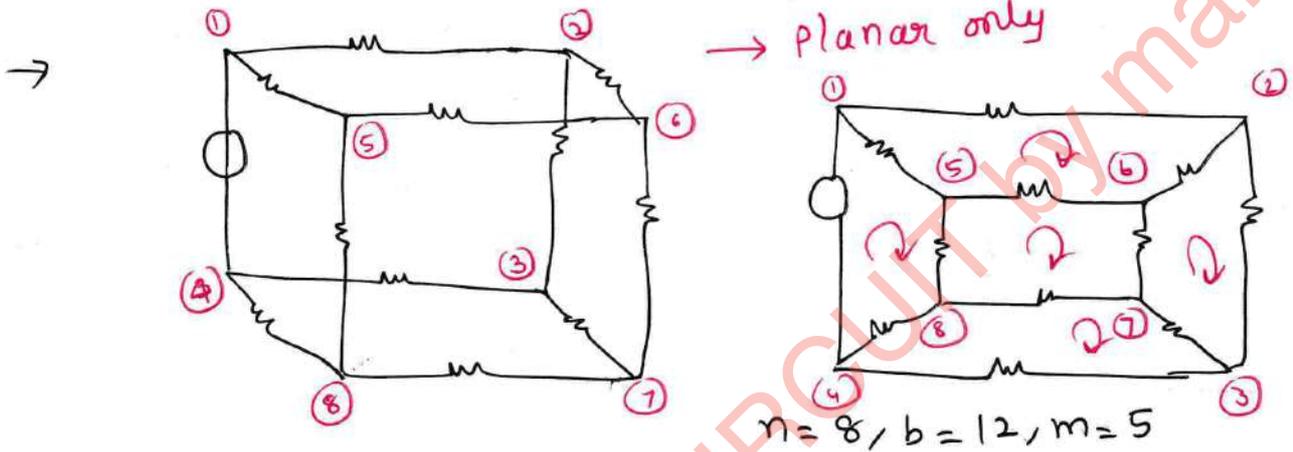
GATE

The min. no of eqns reqd. to solve the circuit below is — .



KVL
 $m = b - n + 1 = 9 - 6 + 1 = 4.$

KCL : $n_p - 1 = 5 - 1 = 4.$



$n = 8, b = 12, m = 5$

→ So, engineering circuit analysis is all about modelling practical networks and systems into simple linear planar lumped bilateral models, and then perform analysis mathematically to determine these performance parameters

IES-13

A network consists of n principle nodes only and b branches. If mesh analysis is simpler than nodal analysis, then n is greater than — .

Mesh < nodal

$b - n + 1 < n - 1$

$b + 2 < 2n$

$\frac{b}{2} + 1 < n$

$n > \frac{b}{2} + 1$

* Ohm's law:

I) LTI Domain

→ Temperature is constant

→ Assume uniform cross sectional area of material

$$\boxed{J = \sigma E} \quad \text{1st form}$$

Electric current density → conductivity → Electric field intensity

II) $\frac{I}{a} = \sigma \frac{V}{L}$

$$V = \left(\frac{L}{\sigma a} \right) I$$

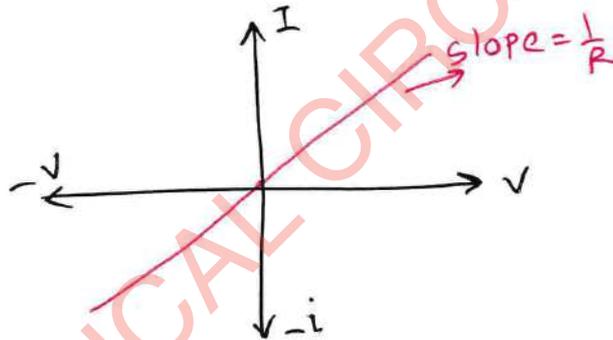
But $\frac{1}{\sigma} = \rho \rightarrow$ resistivity

$$V = \left(\frac{\rho L}{a} \right) I$$

$$\boxed{V = [R] I} \quad \begin{array}{l} \rightarrow \text{2nd form} \\ \text{(circuital form)} \\ \rightarrow \text{Unit: } \Omega \end{array}$$

Graphically

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



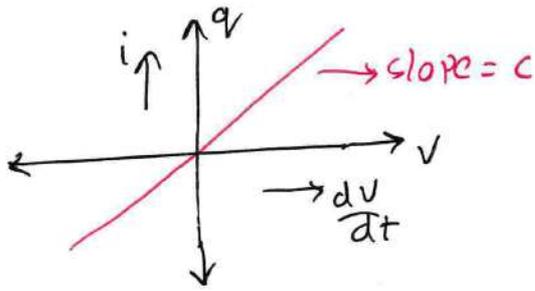
II) Electrostatic Domain

$$\boxed{q = CV} \quad \rightarrow \text{3rd form}$$

$$\frac{dq}{dt} = C \frac{dV}{dt} + V \frac{dC}{dt} \rightarrow 0 \quad (\text{For constant permittivity})$$

$$\boxed{i = C \frac{dV}{dt}} \quad \begin{array}{l} \rightarrow \text{4th form} \\ \text{(circuital domain)} \\ \rightarrow \text{capacitance} \end{array}$$

Graphically



III) Electromagnetic Domain

$\psi = Li$ 5th form

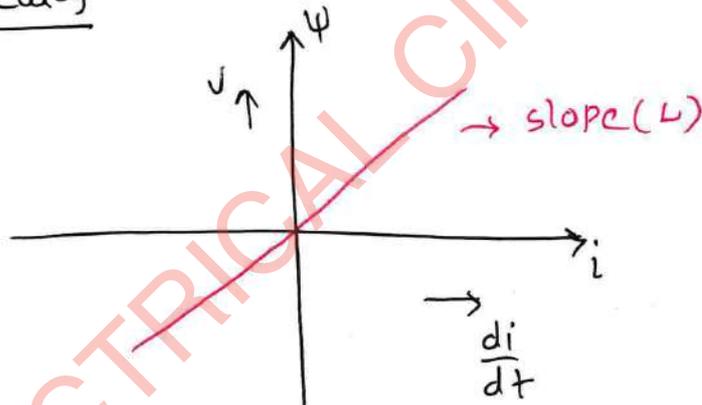
where $\psi = N\phi$
Flux linkages (Wb-T)

$N\phi = Li$

$N \frac{d\phi}{dt} + \phi \frac{dN}{dt} = L \frac{di}{dt} + i \frac{dL}{dt}$ for constant permeability

$v = L \frac{di}{dt}$ 6th form
inductance \rightarrow circuital form

Graphically



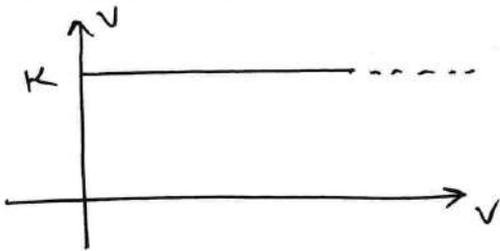
* Properties of DC supply system

- Unipolar
- Unidirectional
- No change in phase/polarity
- Power Frequency

They are used in small independent isolated power supply systems, where EE can be stored in small capacity.

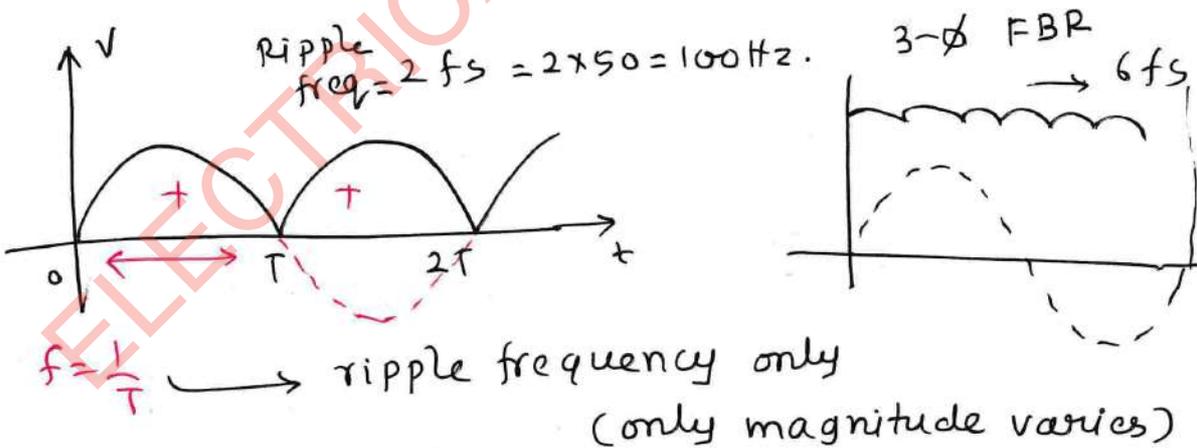
- Automation
- Control
- Precision } → DC motors
- Accuracy } → portable

Ideal DC waveform



Applications:

- M/c Tools
- Automobiles
- Toys, cell phones
- Defence applications.



→ ripple frequency only
(only magnitude varies)

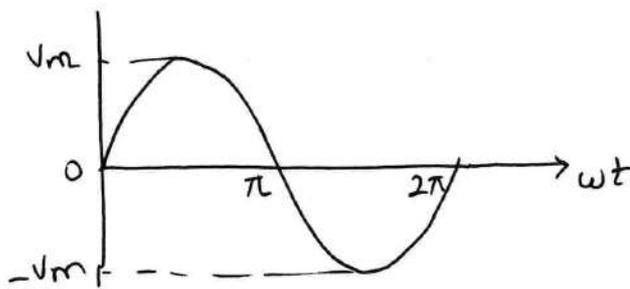
* Properties of AC supply systems

- Bipolar
- Bidirectional
- Definite change in phase/polarity
- Power frequency exist INDIA → 50 Hz
- They are used in large, bulk, continuous power supply systems where E-E cannot be stored
- Robust
- Powerful

Ideal AC waveform

↳ Sinusoid
 ↗ sine
 ↘ cosine

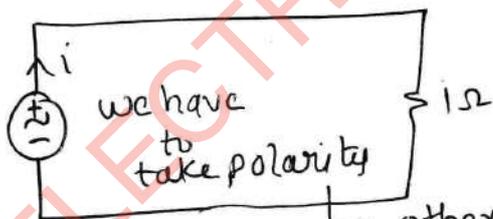
→ $v = V_m \sin \omega t$



→ Applications

Generation
Transmission
Distribution
Utilisation

→ AC
 ↳ 1-ϕ
 ↳ 3-ϕ



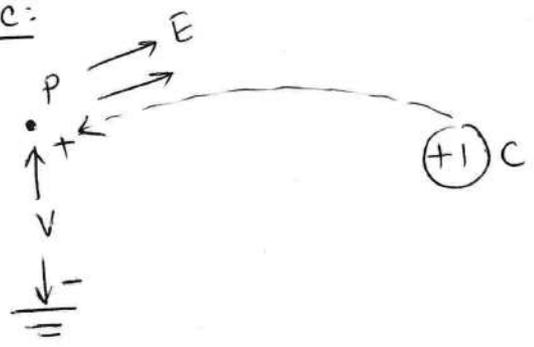
↳ otherwise we can't write KVL etc.

AC - the electrons vibrate in their position

DC - the charges flow. → Used in electrolysis etc where actual charge flows.

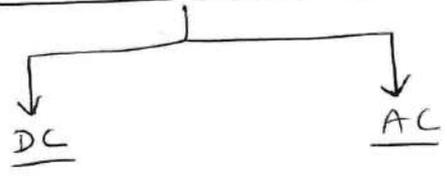
04-10-14

I) voltage:



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

- It is a force (EMF), which can drive charges
- Units: volts (or) $\frac{J}{C}$
- Range : $\mu V, mV, V, KV, MV$
- Symbol: $\mathcal{V}, V, \bar{V}, V(t)$
- Circuit Symbol



* Examples:

- DC → cells, battery, fuel cells, p-v solar panels, Rectified Power sources, DC Generators
- AC → UPS
Inverters
Alternators

ELECTRICAL CIRCUIT by manish sir

II) Current

→ It is the rate of flow of charge

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

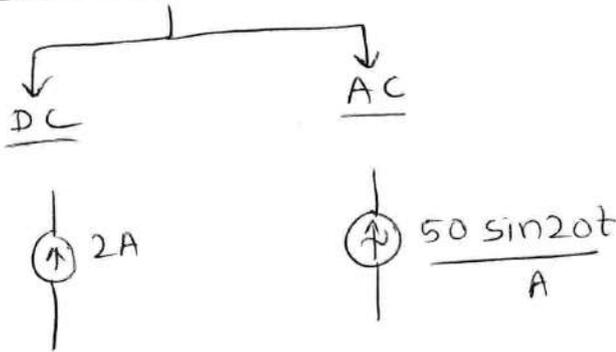
$$I = \frac{\Delta Q}{\Delta t} = \frac{Q}{t}$$

→ Units: Ampere (A) (or) $\frac{C}{sec}$

→ Range: $\mu A, mA, A, KA$

→ Symbol: $i, I, \bar{I}, i(t)$

→ Circuit Symbol



→ Examples

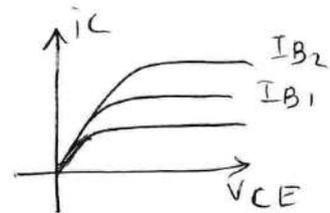
DC → Current mirrors in Analog

→ DC series generators

→ BJT as a dependent current source

AC → A feeder in power system

→ A CSI → constant current density conductor



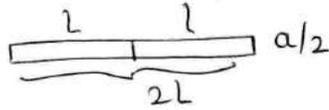
GATE/04

Q: The resistance of a cube shaped material between any of its opposite faces is 2Ω . If this material is stretched in one direction, by applying a linear force to double its original length. Then the resistance b/w the two opposite stretched faces is —.

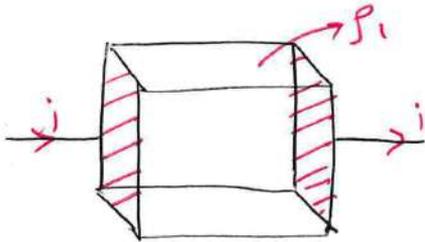
Sol:

$$R = 2\Omega.$$

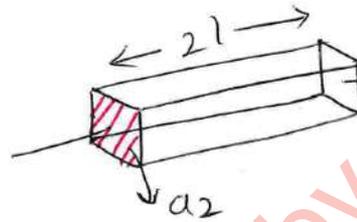
$$\frac{\rho l}{a}$$



$$= \frac{\rho \cdot 2l}{a/2} = \frac{\rho l}{a} \cdot 4 = 2 \cdot 4 = 8\Omega.$$



$$R_1 = 2\Omega = \frac{\rho_1 l_1}{a_1}$$



$$R_2 = \frac{\rho_2 l_2}{a_2} = \frac{\rho_1 (2l_1)}{a_1/2}$$

$$= 4 \left(\frac{\rho_1 l_1}{a_1} \right)$$

$$= 4 \times 2 = 8\Omega.$$

$$V_1 = V_2$$

$$l_1 a_1 = l_2 a_2$$

$$l_1 a_1 = 2l_1 a_2$$

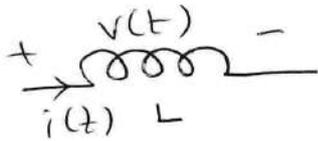
$$a_2 = \frac{a_1}{2}$$

ELECTRICAL CIRCUITS by manish sir

IV Inductance → Electromagnetic property of matter

↳ Inductor is a component to model it

→ classified based on **CORE** material



- iron
- ferrite
- air

Units: Henry (H) or $\frac{V \cdot \text{sec}}{A}$

Range: μH , mH, H

ohm's law

$$v = L \frac{di}{dt} \quad \& \quad i = \frac{1}{L} \int v dt$$

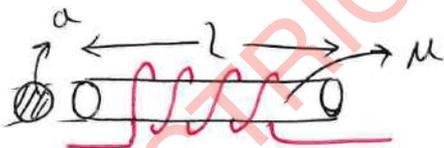
$$i = \frac{1}{L} \int_{-\infty}^t v dt$$

$$= \frac{1}{L} \int_{-\infty}^0 v dt + \frac{1}{L} \int_0^t v dt$$

↳ Initial current

$$i = I(0) + \frac{1}{L} \int_0^t v dt$$

General formula: $L = \frac{\mu N^2 a}{l}$



$\mu = \mu_0 \mu_r$ → permeability of CORE

$$\mu_0 = 4\pi \times 10^{-7} \text{ H/m}$$

$\mu_r = 1$ (air)

$\mu_r > 1000$ (iron)

$N \rightarrow$ No. of turns of coil

$a \rightarrow$ cross sectional area of core (m^2)

$l \rightarrow$ effective length of magnetic flux path (m)

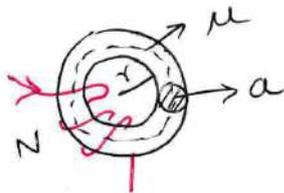
Ex: -choke coils

- Filters

- Transformer, Machine windings

- Transmission lines. mH/ph/km

Ex: TOROID



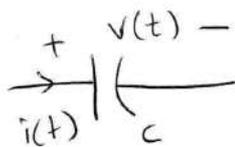
$$l = 2\pi r$$

\hookrightarrow mean circumference (m)

√) Capacitance \rightarrow Electrostatic property of matter

\hookrightarrow "Capacitor" is a component to model it.

\rightarrow classified based on Dielectric material



- Polyester

- electrolytes

- Paper

- ceramics

Units: Farads (or) $\frac{A \cdot \text{sec}}{V}$

Range: PF, nF, μ F, mF

Ohm's law:

$$i = C \frac{dv}{dt} \quad \& \quad v = \frac{1}{C} \int i dt$$

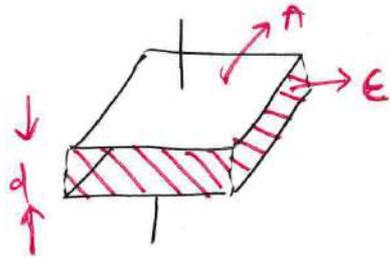
$$v = \frac{1}{C} \int_{-\infty}^t i dt = \frac{1}{C} \int_{-\infty}^0 i dt + \frac{1}{C} \int_0^t i dt$$

initial voltage

$$v = v(0) + \frac{1}{C} \int_0^t i dt$$

→ General formula

$$C = \frac{\epsilon A}{d} \quad F$$



$\epsilon = \epsilon_0 \epsilon_r$ → permittivity of dielectric,

$$\epsilon_0 = 8.85 \times 10^{-12} \text{ F/m}$$

$\epsilon_r = 1$ (air)

$\epsilon_r > 6$ (polyster)

A → common cross-sectional area b/w electrodes (m^2)

d → distance b/w electrodes (m)

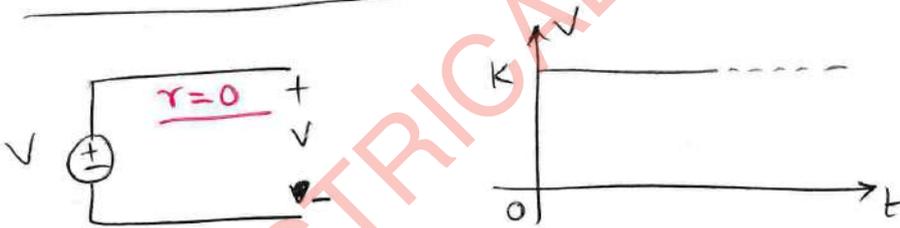
Ex: - Filters

- P.F correction

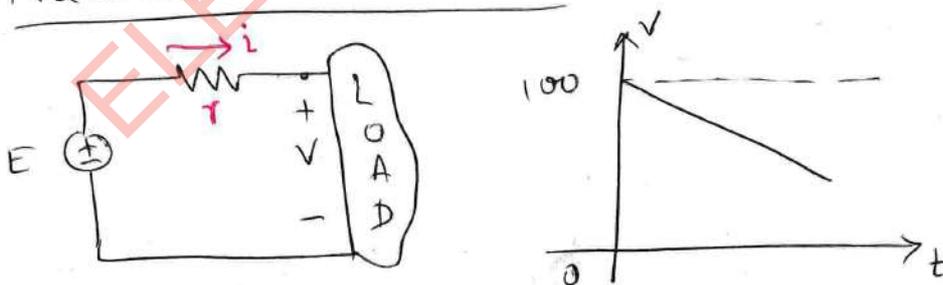
- VAR compensation

- Transmission lines → MF/ph/km

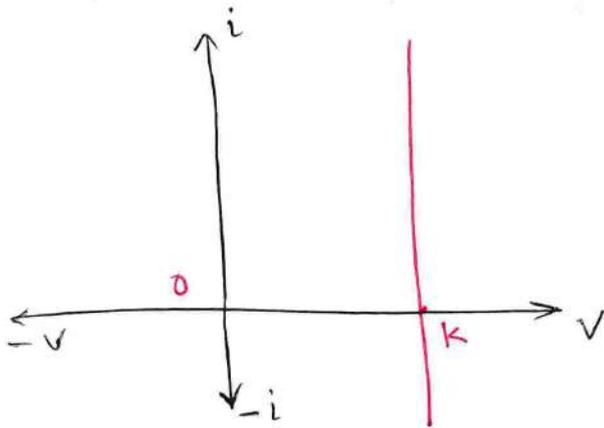
→ Ideal voltage source



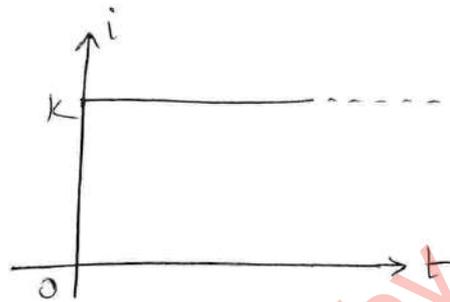
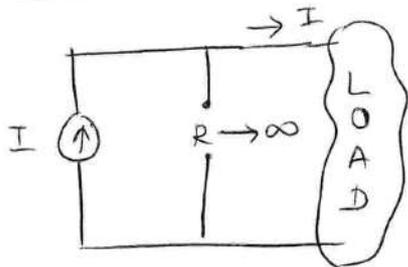
→ Practical voltage source



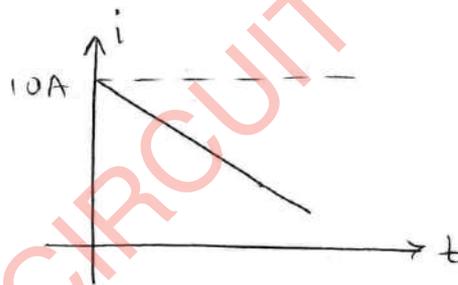
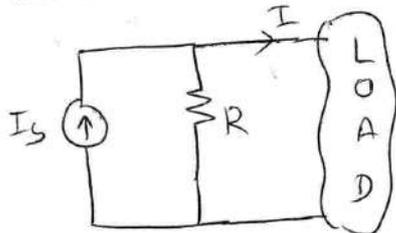
V-i characteristics



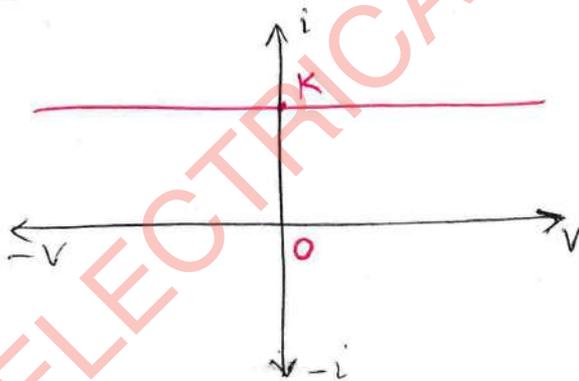
→ Ideal current source



→ Practical



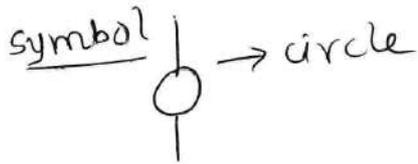
V-i characteristics



* Independent sources

→ If their property is independent to any other parameter within or outside the circuit.

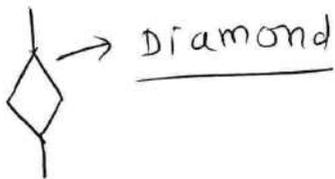
Ex: Ideal sources are independent.



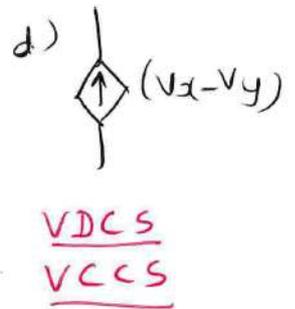
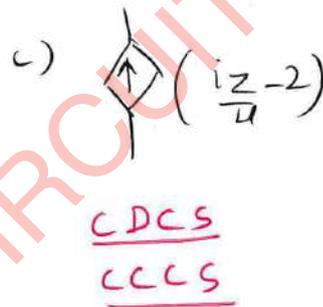
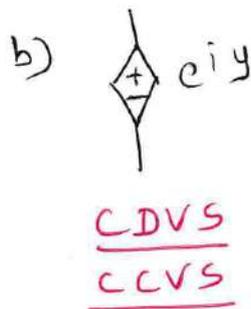
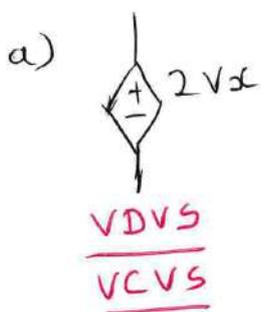
* Dependent sources

→ If their properties depend upon any other parameter within or outside the circuit.

Ex: BJT, solar cells, wind generation.



standard ④ types



Note: Unlike independent sources which can be suppressed in terms of their resistance, but dependent sources cannot be suppressed as they themselves represent complex n/w models in electrical engineering, such as H-parameter equivalent of a BJT, photo transistors, sub-circuit models in P-spice and MATLAB.

Power: It is the rate of change in energy

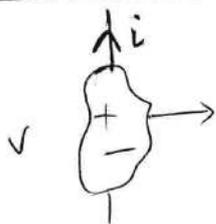
$$P = \frac{dE}{dt} = \frac{dW}{dt}$$

$$P = \frac{W}{t}$$

→ Units: Watts or $\frac{J}{\text{sec}}$

Range: mW, W, kW, MW, GW.

*** 1 hp = 746 W



Active

$$P_{\text{delivered}} = +v \cdot i \text{ W,}$$

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

[R] $P_R = V_R \cdot i_R = i_R^2 \cdot R = \frac{V_R^2}{R} \text{ W,}$

Pure [L] → $P_{\text{avg}} = 0$

We can express (instant) power as

$$P_L = V_L \cdot i_L = L i \frac{di}{dt} \text{ W,}$$

Pure [C] → $P_{\text{avg}} = 0$

We can express (instant)

$$P_C = V_C i_C = C v \frac{dv}{dt} \text{ W} = C v \frac{dv}{dt} \text{ W.}$$

Energy: It is the capacity to do work (electrically)

$$E = \int P dt$$

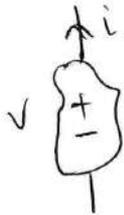
$$E = P \times t$$

→ Units: Joules (or) W-sec

1 unit $E \cdot E = 1 \text{ kWh}$.

**

$$\begin{aligned} 1 \text{ kWh} &= 1000 \text{ W} \times 1 \text{ hr} \\ &= 500 \text{ W} \times 2 \text{ hr} \\ &= 200 \text{ W} \times 5 \text{ hr} \\ &= 2000 \text{ W} \times \frac{1}{2} \text{ hr} \end{aligned}$$



→ Active

$$E_{\text{delivered}} = + \underbrace{v \cdot i}_{\text{sec}} \cdot t \text{ J,}$$

$$1 \text{ kWh} = 36 \times 10^5 \text{ J}$$

$$\begin{aligned} &1000 \text{ W} \times 1 \text{ hr} \\ &1000 \text{ W} \times 60 \times 60 \text{ sec} \\ &36 \times 10^5 \frac{\text{W sec}}{\text{J}} \end{aligned}$$

$$\boxed{R} \quad E_R = \int P_R(t) dt = \int (i(t))^2 R dt \text{ J}$$

But LTI input

$$E_R = V_R \cdot i_R t = i_R^2 \cdot R \cdot t = \frac{V_R^2}{R} \cdot t$$

↳ Heat

$$\boxed{L} \quad E_L = \int P_L dt = \int L i(t) \cdot \frac{di(t)}{dt} \cdot dt \text{ J}$$

If LTI input

$$E_L = \int L i \frac{di}{dt} \cdot dt = \frac{1}{2} L i^2 \text{ J}$$

$$\boxed{\psi = Li}$$

$$E_L = \frac{1}{2} L i^2 = \frac{1}{2} \psi i = \frac{\psi^2}{2L} \text{ J}$$

↳ Electromagnetic form

$$E_c = \int P_c dt = \int C v(t) \cdot \frac{dv(t)}{dt} \cdot dt \quad J$$

If LTI input

$$E_c = \int C v \frac{dv}{dt} \cdot dt = \frac{1}{2} C v^2 \quad J$$

$$q = C v$$

$$E_c = \frac{1}{2} C v^2 = \frac{1}{2} q v = \frac{q^2}{2C} \quad J$$

↳ Electrostatic form.

Kirchoff's law:

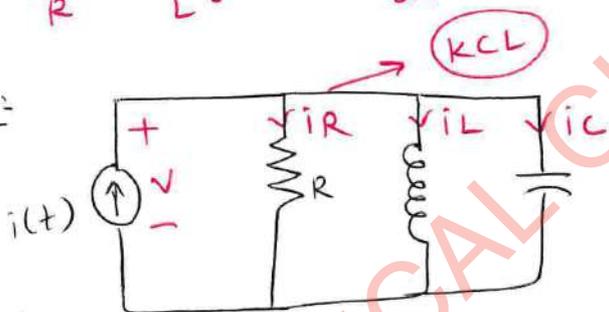
Ist law: KCL only → 'K' 'Node' law

→ Based on law of conservation of charge

$$\sum i_{@node} = 0$$

$$\frac{v}{R} + \frac{1}{L} \int v dt + C \frac{dv}{dt}$$

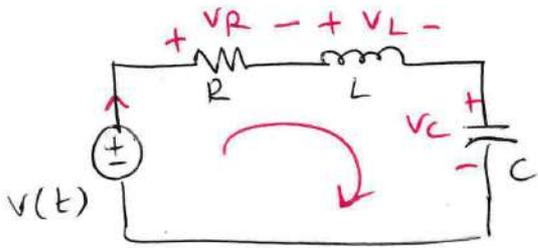
Ex:



$$-i(t) + i_R + i_L + i_C = 0$$

$$\therefore i(t) = \frac{v}{R} + \frac{1}{L} \int v dt + C \frac{dv}{dt}$$

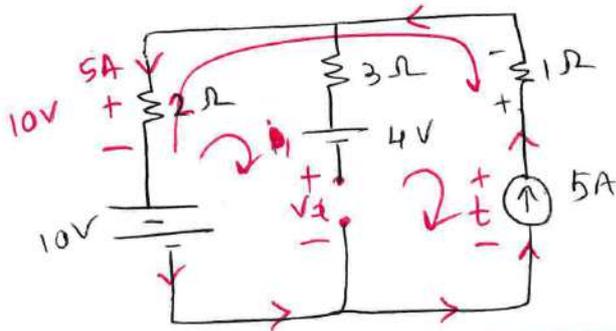
Ex:



$$-v(t) + v_R + v_L + v_C = 0$$

$$v(t) = iR + L \frac{di}{dt} + \frac{1}{C} \int i dt$$

Q:



$$-10 - 10 + 4 + v_x = 0$$

$$v_x = +16V$$

$$(2) -10 - 10 - 5 + t = 0$$

$$t = +25V$$

$$\frac{2.5}{32.5} = \frac{2.5}{32.5}$$

~~$$-10 + 2i + 3(i+5) + 4 + v_x = 0 \Rightarrow 5i + 9 + v_x = 0 \Rightarrow v_x = -5i - 9$$

$$(3) +5 + 3(5+i) + 4 + v_x = 0 \Rightarrow 24 + 3i + v_x = 0 \Rightarrow v_x = -5i - 9$$

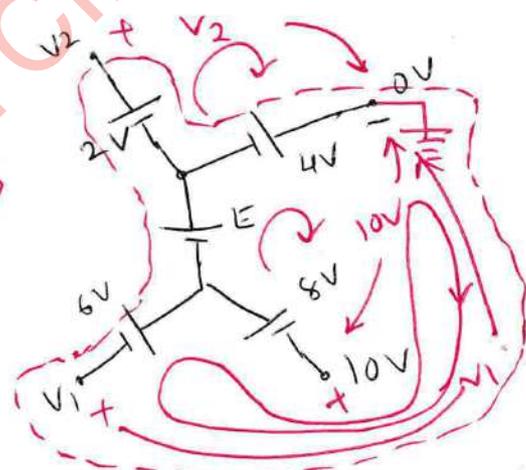
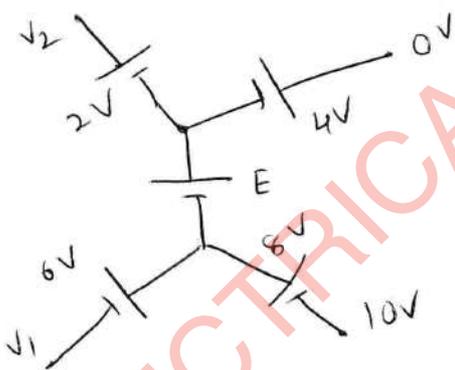
$$\Rightarrow 24 + 3i - 5i - 9 = 0 \Rightarrow 15 = 2i \Rightarrow i = 7.5A$$~~

$$-v_x - 4 - 5 + 25 = 0$$

$$v_x = 16V$$

Q:

$E = \text{---}, V_1 = \text{---}, V_2 = \text{---}$



$$-10 - 8 - E - 4 = 0 \rightarrow E = -22V$$

$$-V_1 - 6 + 8 + 10 = 0 \rightarrow V_1 = +12V$$

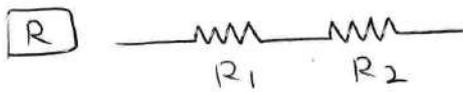
$$+4 - 2 + V_2 = 0 \rightarrow V_2 = -2V$$

$$-V_2 + 2 + E + 6 + V_1$$

$$+2 + 2 - 22 + 6 + 12 = 0 \checkmark$$

* Series Connection of Elements

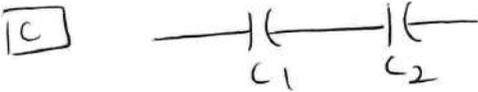
↳ When current through them is "equal"
(in magnitude and direction)



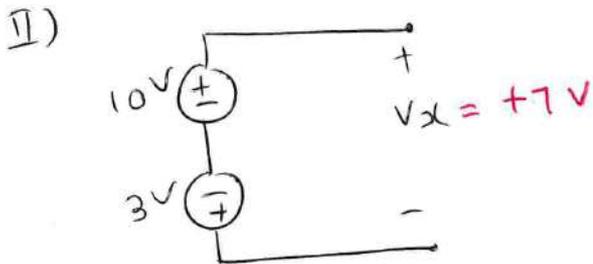
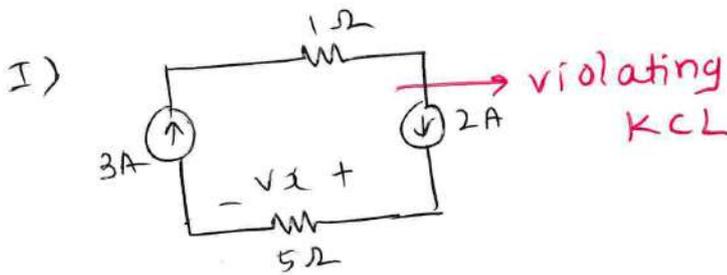
$$R_s = R_1 + R_2$$



$$L_s = L_1 + L_2$$

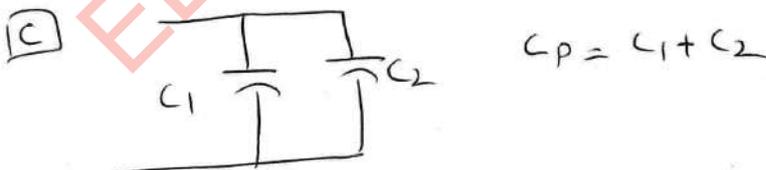


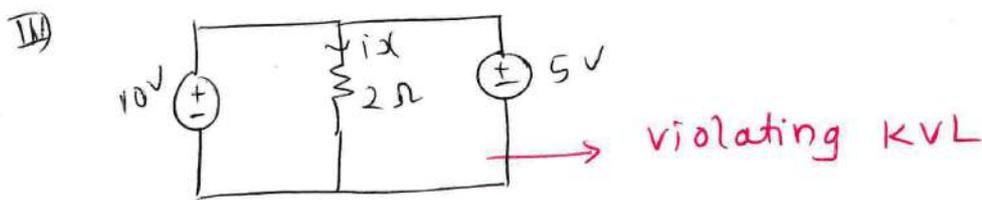
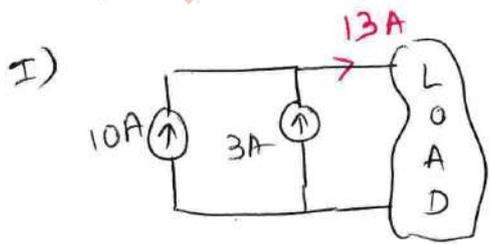
$$\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2}$$



* Parallel connection of elements

↳ When voltages across them is "equal"
(in magnitude and polarity)



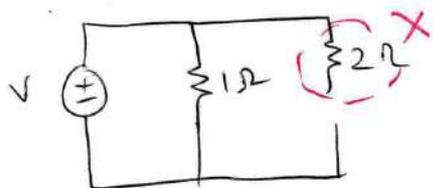


* Open circuit / oc

→ In an oc, $i = 0$ for any 'v'.

$$R_{oc} = \frac{V}{0} = \infty \Omega,$$

→ Any passive element in series to oc can be neglected.

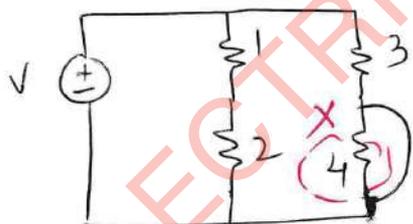


* Short circuit / sc

→ In a sc, $V = 0$, for any 'i'.

$$R_{sc} = \frac{0}{i} = 0 \Omega,$$

→ Any passive element completely in parallel to sc can be neglected.

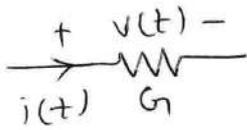


Fuses are there to protect against sc both at LV & HV.

open circuit is more dangerous

→ open circuit live wire faults are more dangerous than short circuits at high voltage engineering level, because of insulation problem. However, sc can be protected both at LV & HV levels by using fuses and CBs.

* Conductance → It is the ability to conduct electrically.
→ It is used to further & classify metals.



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

Units: mho (Ω^{-1})
Siemens (S)

Ohm's law:

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

$$I = VG$$

Basic formula:

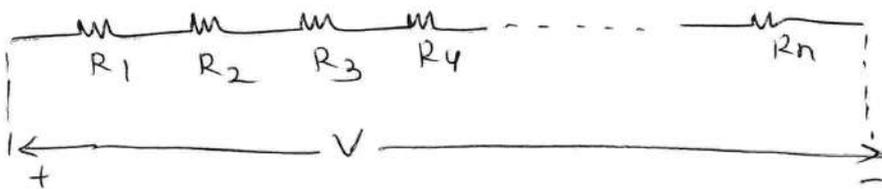
$$G = \frac{a}{\rho l}$$

But $\frac{1}{\rho} = \sigma \rightarrow$ conductivity

$$G = \frac{\sigma a}{l}$$

IESQ:

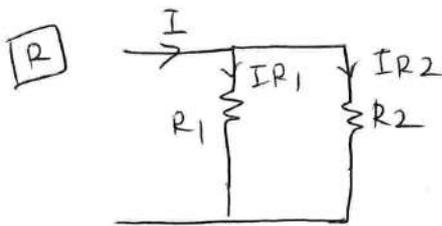
Unit of σ
 $(\Omega \cdot m)^{-1}$
 $= \Omega/m$
 $= S/m.$



$$V_{R3} = V \left(\frac{R_3}{\sum_{i=1}^n R_i} \right)$$

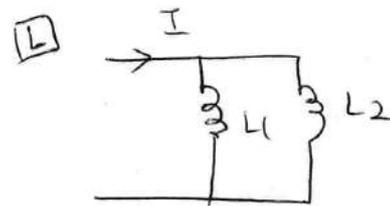
* Current Division Rule

↳ Parallel connected elements only



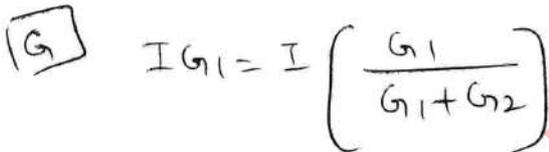
$$I_{R1} = I \left(\frac{R_2}{R_1 + R_2} \right)$$

$$I_{R2} = I \left(\frac{R_1}{R_1 + R_2} \right)$$



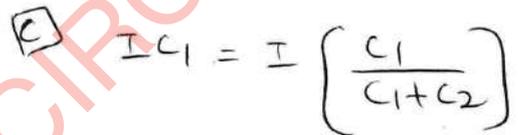
$$I_{L1} = I \left(\frac{L_2}{L_1 + L_2} \right)$$

$$I_{L2} = I \left(\frac{L_1}{L_1 + L_2} \right)$$



$$I_{G1} = I \left(\frac{G_2}{G_1 + G_2} \right)$$

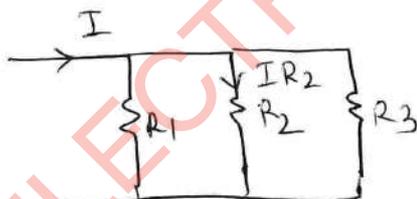
$$I_{G2} = I \left(\frac{G_1}{G_1 + G_2} \right)$$



$$I_{C1} = I \left(\frac{C_2}{C_1 + C_2} \right)$$

$$I_{C2} = I \left(\frac{C_1}{C_1 + C_2} \right)$$

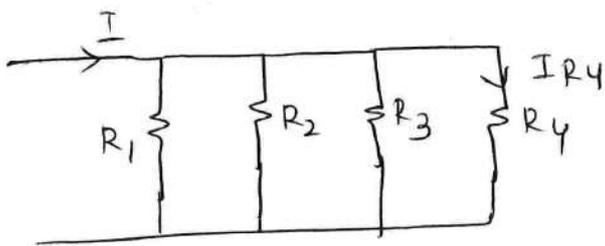
IES: ***



$$I_{R2} = I \left(\frac{R_1 R_3}{R_1 R_2 + R_2 R_3 + R_3 R_1} \right)$$

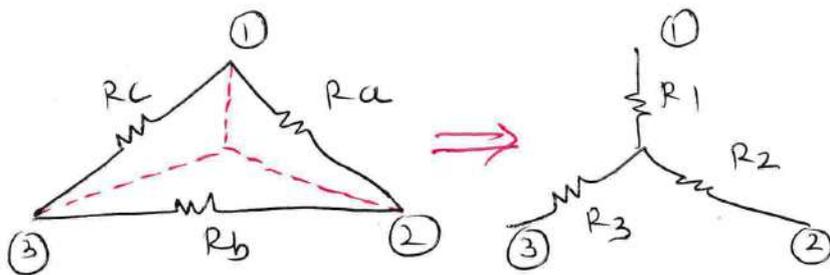
suppose these are capacitors

$$I_{C2} = I \left(\frac{\frac{1}{C_1} \cdot \frac{1}{C_3}}{\frac{1}{C_1} \cdot \frac{1}{C_2} + \frac{1}{C_2} \cdot \frac{1}{C_3} + \frac{1}{C_3} \cdot \frac{1}{C_1}} \right)$$



$$IR_4 = I \left(\frac{R_1 R_2 R_3}{R_1 R_2 R_3 + R_2 R_3 R_4 + R_3 R_4 R_1 + R_4 R_1 R_2} \right)$$

 $\Delta \rightarrow Y$
 [R]



$$R_1 = \frac{R_a R_c}{R_a + R_b + R_c}$$

$$R_2 = \frac{R_b R_a}{R_a + R_b + R_c}$$

$$R_3 = \frac{R_b R_c}{R_a + R_b + R_c}$$

[L]
 \Rightarrow

$$L_1 = \frac{L_a L_c}{L_a + L_b + L_c}$$

$$L_2 = \frac{L_b L_a}{L_a + L_b + L_c}$$

$$L_3 = \frac{L_b L_c}{L_a + L_b + L_c}$$

[C] $\Rightarrow \frac{1}{C_1} = \frac{\frac{1}{C_a} \cdot \frac{1}{C_c}}{\frac{1}{C_a} + \frac{1}{C_b} + \frac{1}{C_c}}$

$$\frac{1}{C_2} = \frac{\frac{1}{C_b} \cdot \frac{1}{C_a}}{\frac{1}{C_a} + \frac{1}{C_b} + \frac{1}{C_c}}$$

$$\frac{1}{C_3} = \frac{\frac{1}{C_b} \cdot \frac{1}{C_c}}{\frac{1}{C_a} + \frac{1}{C_b} + \frac{1}{C_c}}$$

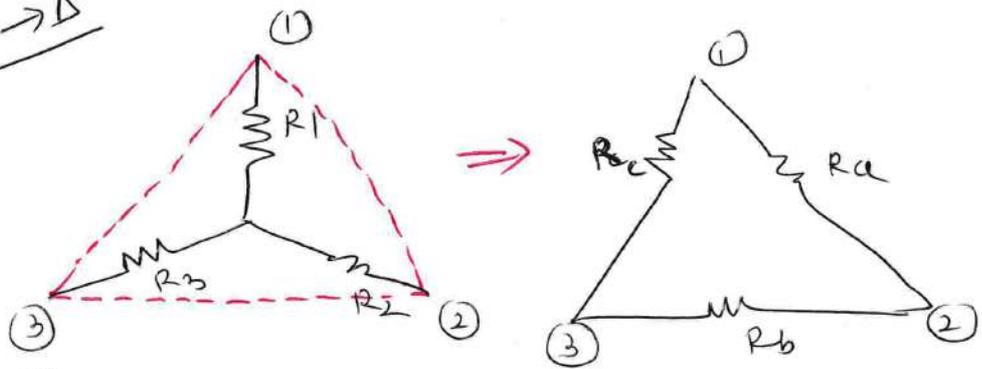
[G] $\Rightarrow \frac{1}{G_1} = \frac{\frac{1}{G_a} \cdot \frac{1}{G_c}}{\frac{1}{G_a} + \frac{1}{G_b} + \frac{1}{G_c}}$

$$\frac{1}{G_2} = \frac{\frac{1}{G_b} \cdot \frac{1}{G_a}}{\frac{1}{G_a} + \frac{1}{G_b} + \frac{1}{G_c}}$$

$$\frac{1}{G_3} = \frac{\frac{1}{G_b} \cdot \frac{1}{G_c}}{\frac{1}{G_a} + \frac{1}{G_b} + \frac{1}{G_c}}$$

ELECTRICALCIRCUITBYmanishSir

Y → Δ



[P]

$$R_a = R_1 + R_2 + \frac{R_1 R_2}{R_3}$$

$$R_b = R_2 + R_3 + \frac{R_2 R_3}{R_1}$$

$$R_c = R_1 + R_3 + \frac{R_1 R_3}{R_2}$$

[L]

$$L_a = L_1 + L_2 + \frac{L_1 L_2}{L_3}$$

$$L_b = L_2 + L_3 + \frac{L_2 L_3}{L_1}$$

$$L_c = L_1 + L_3 + \frac{L_1 L_3}{L_2}$$

[C]

$$\frac{1}{C_a} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{\frac{1}{C_1} \cdot \frac{1}{C_2}}{\frac{1}{C_3}}$$

$$\frac{1}{C_b} = \frac{1}{C_2} + \frac{1}{C_3} + \frac{\frac{1}{C_2} \cdot \frac{1}{C_3}}{\frac{1}{C_1}}$$

$$\frac{1}{C_c} = \frac{1}{C_1} + \frac{1}{C_3} + \frac{\frac{1}{C_1} \cdot \frac{1}{C_3}}{\frac{1}{C_2}}$$

[G]

$$\frac{1}{G_a} = \frac{1}{G_1} + \frac{1}{G_2} + \frac{\frac{1}{G_1} \cdot \frac{1}{G_2}}{\frac{1}{G_3}}$$

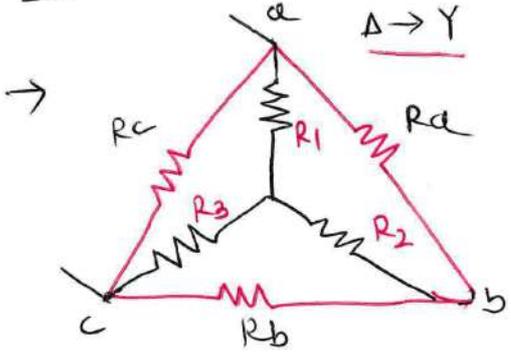
$$\frac{1}{G_b} = \frac{1}{G_2} + \frac{1}{G_3} + \frac{\frac{1}{G_2} \cdot \frac{1}{G_3}}{\frac{1}{G_1}}$$

$$\frac{1}{G_c} = \frac{1}{G_1} + \frac{1}{G_3} + \frac{\frac{1}{G_1} \cdot \frac{1}{G_3}}{\frac{1}{G_2}}$$

ELECTRICAL CIRCUIT by manish sir

H.W.:

- Q: Explain why the stator of our 3- ϕ alternators are Y connected only?
- Q: Why the stator of 3- ϕ induction motors while running is Δ ?
- Q: In reactive power compensation, why our capacitor banks in 3- ϕ are mostly Δ connected?
- Q: Prove the formulas related to Y/ Δ ,



$$R_{ac} = R_1 + R_3$$

$$R_{ac} = R_c \parallel (R_a + R_b) = \frac{R_c \times (R_a + R_b)}{R_a + R_b + R_c} = \frac{R_a R_c + R_b R_c}{R_a + R_b + R_c}$$

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

$$R_{ab} = R_a \parallel (R_b + R_c) = \frac{R_a (R_b + R_c)}{R_a + R_b + R_c} = \frac{R_a R_b + R_a R_c}{R_a + R_b + R_c}$$

$$R_{bc} = R_2 + R_3$$

$$R_{bc} = \frac{R_b (R_c + R_a)}{R_a + R_b + R_c} = \frac{R_b R_c + R_a R_b}{R_a + R_b + R_c}$$

$$R_{ac} + R_{ab} + R_{bc} = \frac{2(R_a R_b + R_b R_c + R_c R_a)}{R_a + R_b + R_c}$$

$$2(R_1 + R_2 + R_3)$$

$$R_1 + R_2 + R_3 = \frac{R_a R_b}{R_a + R_b + R_c} + \frac{R_b R_c}{R_a + R_b + R_c} + \frac{R_c R_a}{R_a + R_b + R_c}$$

$$R_1 + R_2 = \frac{R_a R_b}{R_a + R_b + R_c} + \frac{R_a R_c}{R_a + R_b + R_c}$$

↓

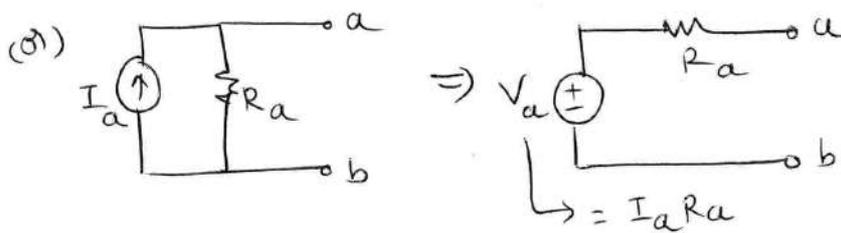
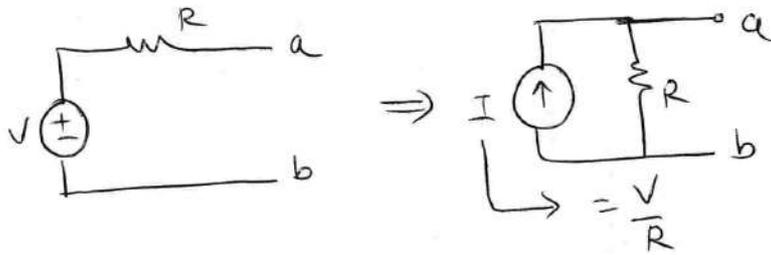
$$\Rightarrow R_3 = \frac{R_b R_c}{R_a + R_b + R_c}$$

1) by $R_2 = (R_1 + R_2 + R_3) - (R_1 + R_3) = \frac{R_a R_b}{R_a + R_b + R_c}$

$$R_3 = (R_1 + R_2 + R_3) - (R_2 + R_3) = \frac{R_a R_c}{R_a + R_b + R_c}$$

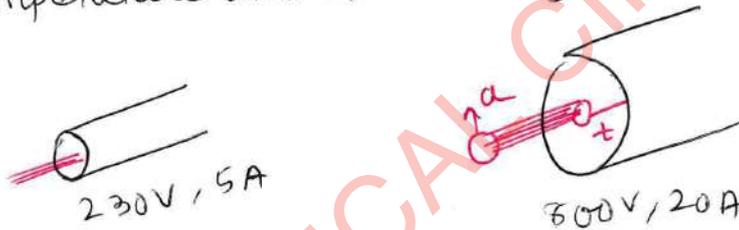
* Source transformation technique:

→ An ideal voltage source in series with resistance can be converted into an ideal current source in parallel with same resistance and vice-versa.



* Ratings or specifications:

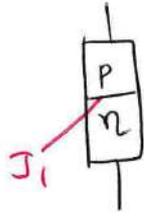
→ They represent maximum permissible safe values for continuous operation of an electrical device/network. In general, for any electrical equipment, we have voltage, current, power, frequency, insulation class ratings with temperature limits, as ratings.



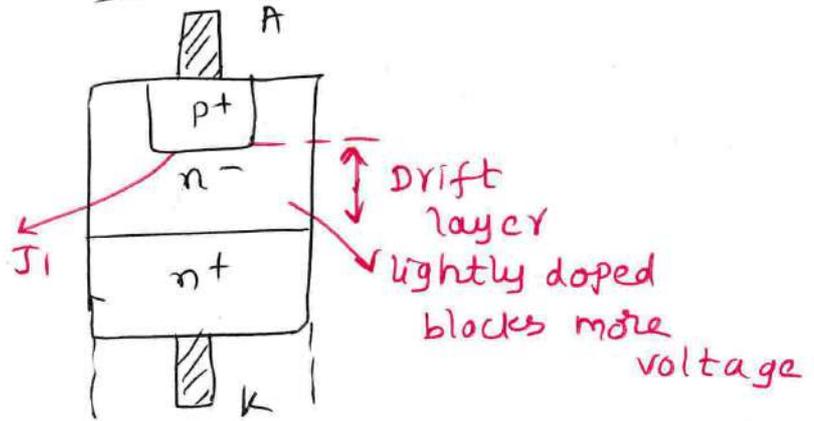
Insulation level → $V \uparrow$

Cross-sectional area → $I \uparrow$

Signal diode



Power Diode



→ Most of our electrical devices are designed for constant **voltage only**.

→ But current through them is decided by **loading level**.

Low Wattage

- V =
- I ↓
- a ↓
- R ↑

High Wattage

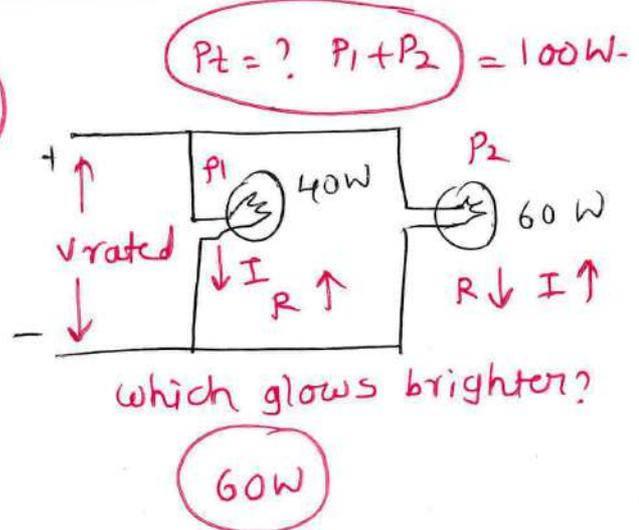
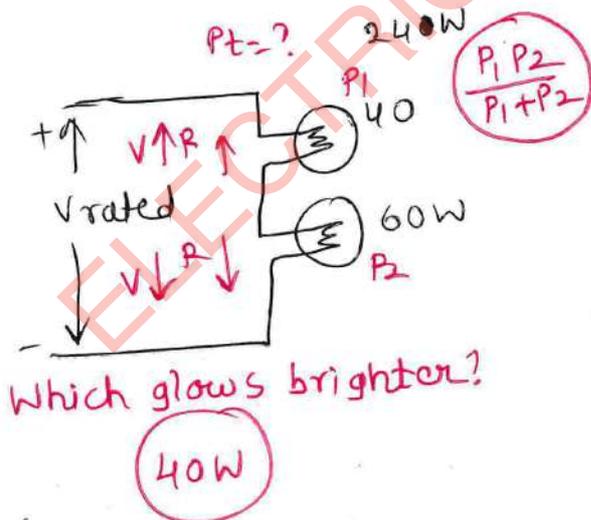
- V =
- I ↑
- a ↑
- R ↓

DC motor

1) 220V, $R_a = 1 \Omega$ → Low Wattage 5 HP (say)

2) 220V, $R_a = 0.2 \Omega$ → High Wattage 50 HP (say)

GATE



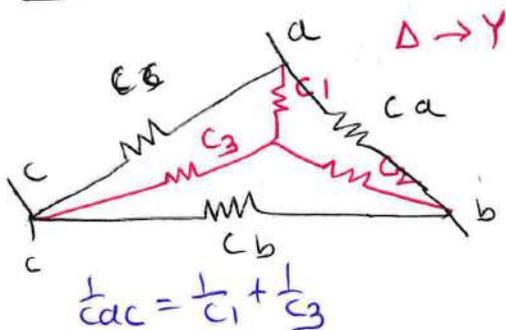
$$P = \frac{V^2}{R}$$

$$R_{\text{actual}} = \frac{(V_{\text{rated}})^2}{P_{\text{rated}}}$$

$$P_T = \frac{(V_{\text{rated}})^2}{R_1 + R_2} = \frac{V_Y^2}{\frac{V_Y^2}{P_1} + \frac{V_Y^2}{P_2}} = \frac{V_Y^2}{V_Y^2 \left(\frac{P_1 + P_2}{P_1 P_2} \right)}$$

$$P_T = \frac{P_1 P_2}{P_1 + P_2} = \frac{60 \times 40}{100} = 24 \text{ W}$$

HW: $\Delta \rightarrow Y$ for capacitor



$$\frac{1}{C_{ac}} = \frac{1}{C_1} + \frac{1}{C_3}$$

$$C_{ba} = \frac{C_1 C_2}{C_1 + C_2}$$

$$\text{or } C_{ab} = \frac{C_b C_c}{C_b + C_c} + C_a$$

$$\therefore \frac{C_{ac} + C_{bc} + C_{ab}}{C_1} = \frac{C_1 C_3 + C_2 C_3 + C_2 C_1}{C_1}$$

$$\frac{1}{C_{ac}} + \frac{1}{C_{bc}} + \frac{1}{C_{ab}} = \frac{C_a + C_b + C_c + C_a + C_c + C_b + C_c}{C_a C_b + C_b C_c + C_a C_c} = \frac{2(C_a + C_b + C_c)}{C_a C_b + C_b C_c + C_a C_c}$$

$$= \frac{1}{C_1} + \frac{1}{C_3} + \frac{1}{C_2} + \frac{1}{C_3} + \frac{1}{C_1} + \frac{1}{C_2}$$

$$\Rightarrow 2 \left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \right) = 2 \left(\frac{C_a + C_b + C_c}{C_a C_b + C_b C_c + C_a C_c} \right)$$

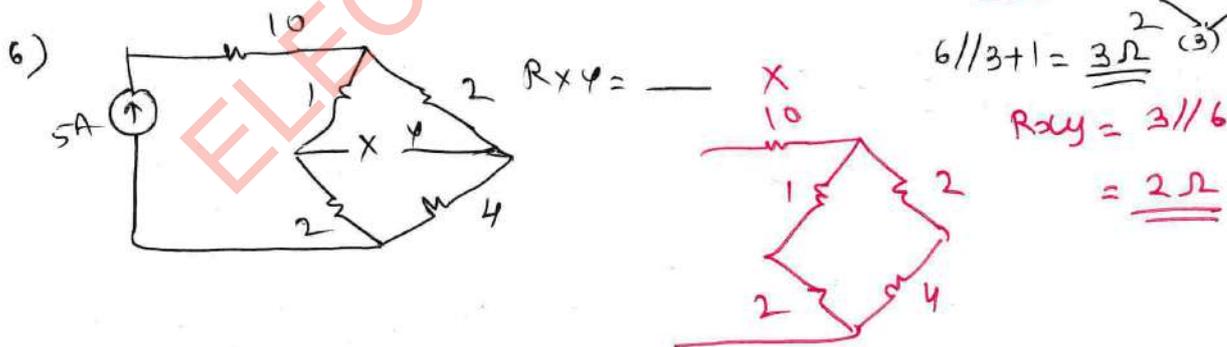
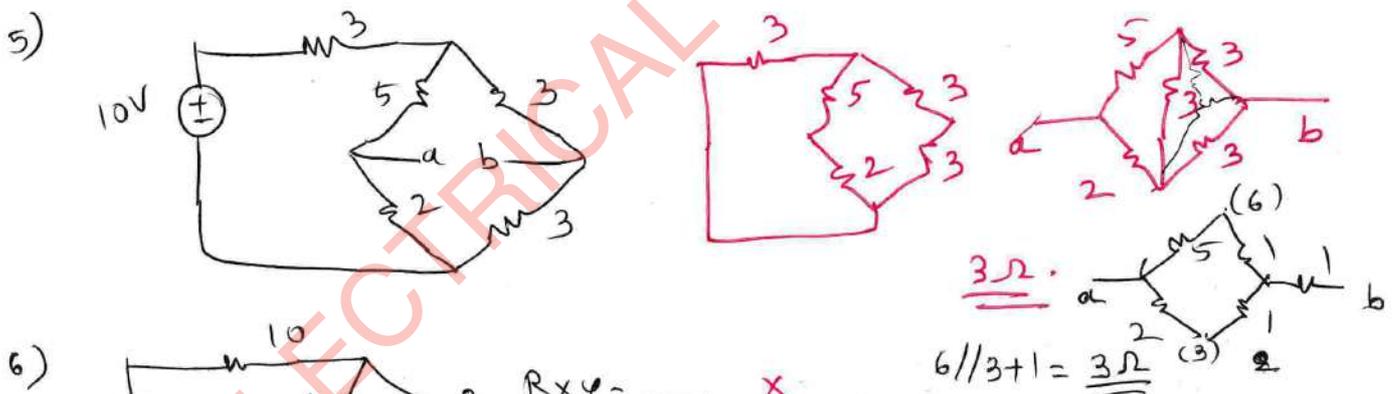
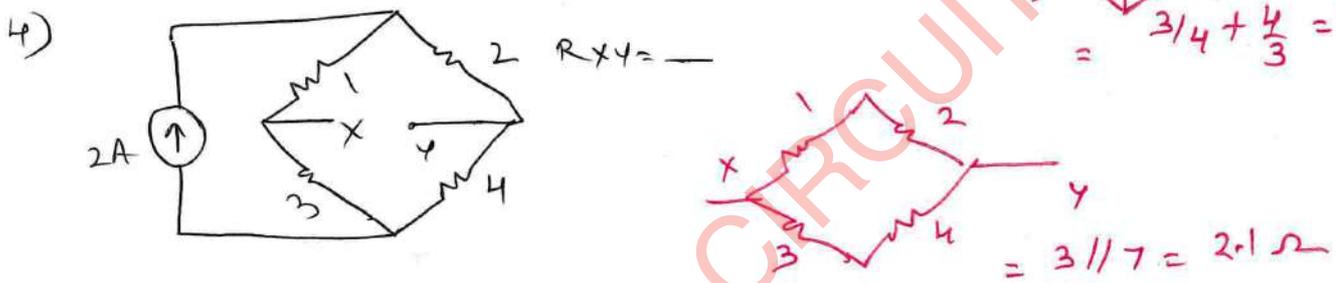
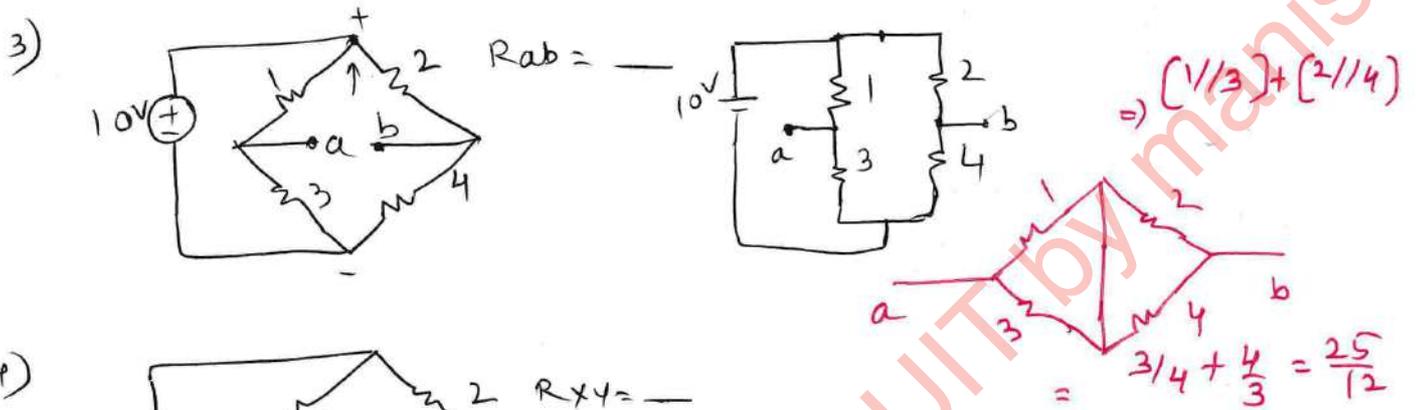
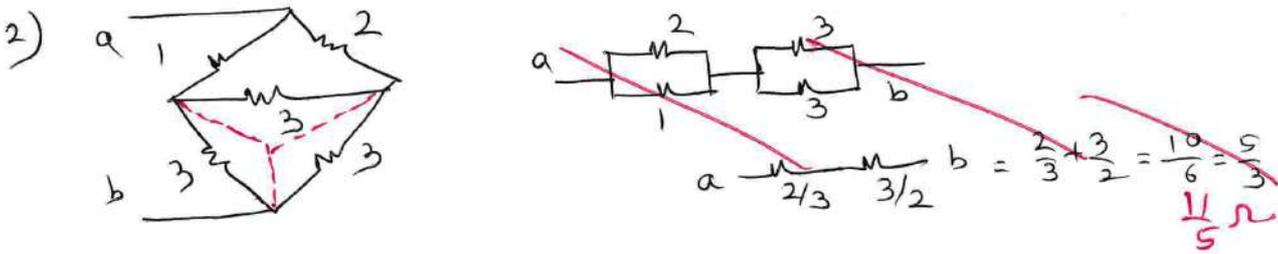
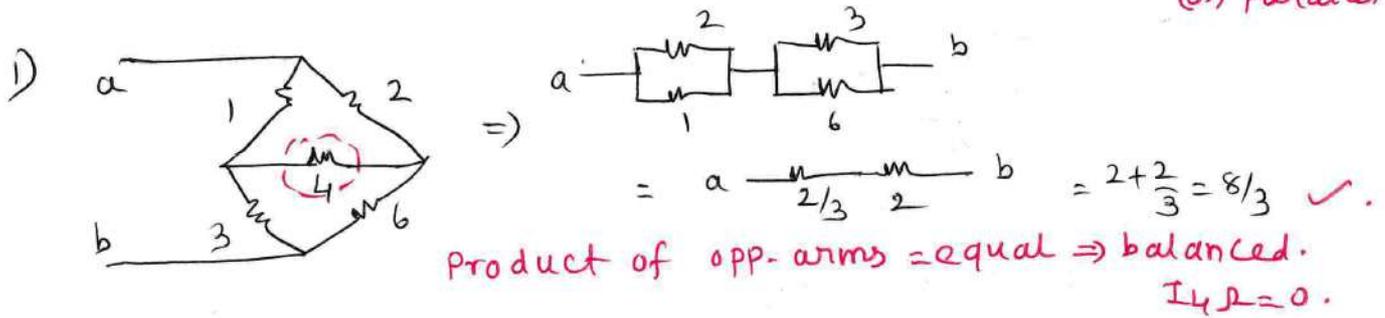
$$\Rightarrow \frac{1}{C_2} = \frac{C_a + C_b + C_c}{C_a C_b + C_b C_c + C_a C_c} \left(\frac{C_a C_b + C_b C_c + C_a C_c}{C_a + C_b + C_c} \right)^{-1} \left(\frac{C_a + C_b}{C_a + C_b + C_c} \right)$$

$$\Rightarrow \frac{1}{C_2} = \frac{\frac{1}{C_a} \cdot \frac{1}{C_b}}{\frac{1}{C_a} + \frac{1}{C_b} + \frac{1}{C_c}} \quad \text{Similarly } \frac{1}{C_1} = \frac{\frac{1}{C_a} \cdot \frac{1}{C_c}}{\frac{1}{C_a} + \frac{1}{C_b} + \frac{1}{C_c}} \quad \frac{1}{C_3} = \frac{\frac{1}{C_b} \cdot \frac{1}{C_c}}{\frac{1}{C_a} + \frac{1}{C_b} + \frac{1}{C_c}}$$

* Resistor Reduction techniques

(Bridge)

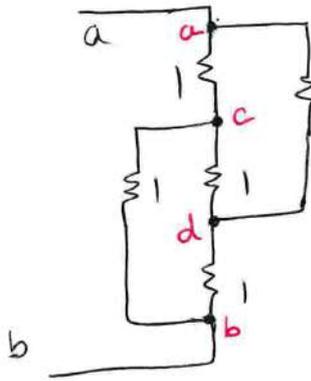
No resistances are series
(a) parallel



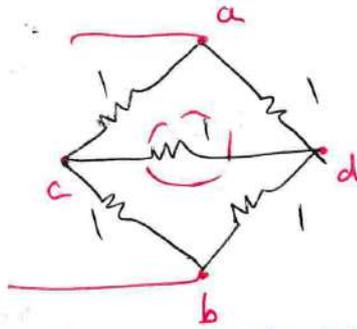
Node shifting technique

IES

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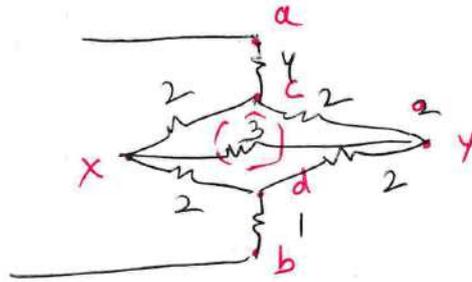
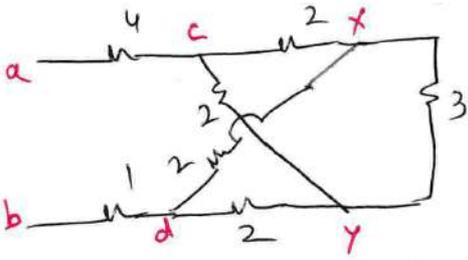
\Rightarrow



$2 \parallel 2 = 1 \Omega$

$R = 1 \Omega$, we get 1Ω only (balanced)

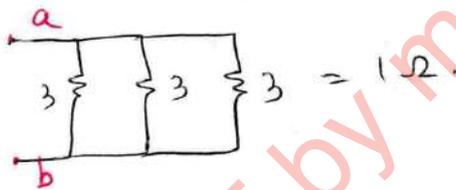
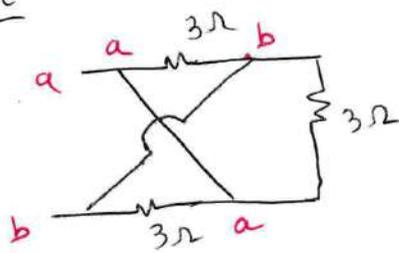
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$4 + 4 \parallel 4 + 1 = 7 \Omega$

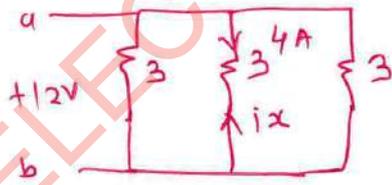
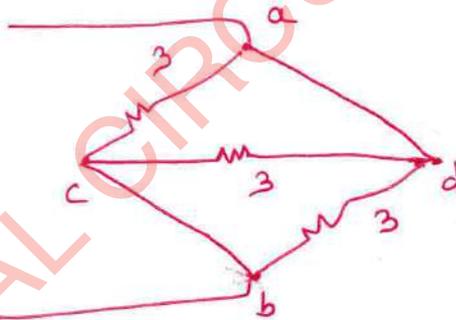
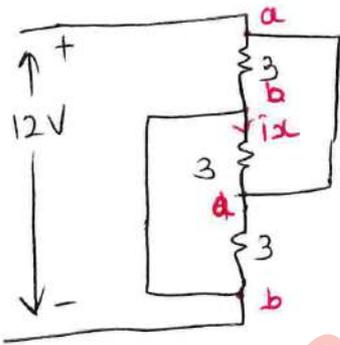
GATE

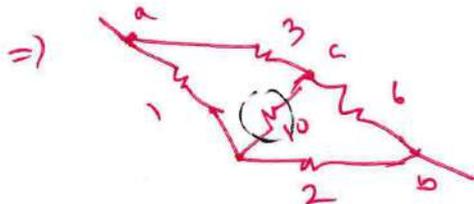
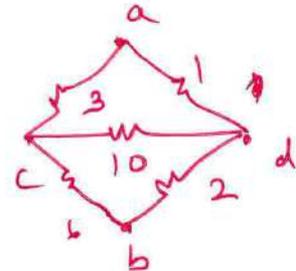
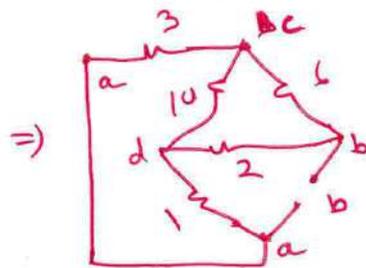
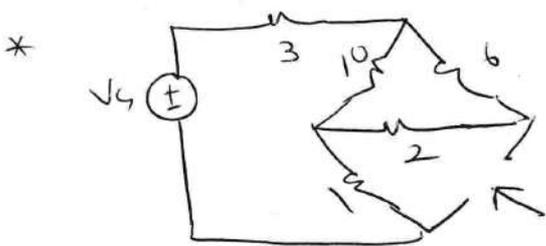
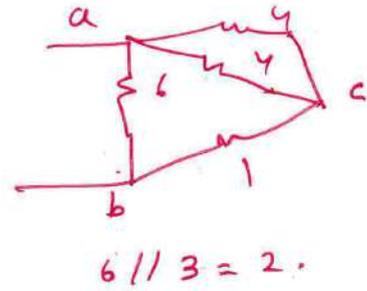
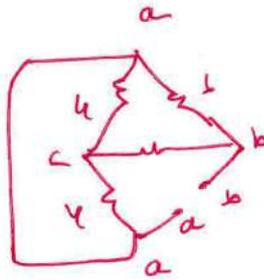
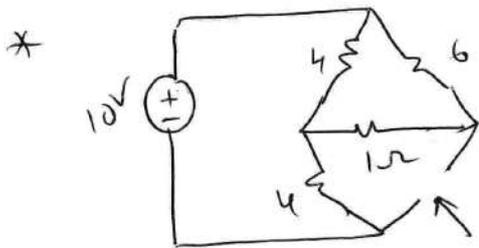
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IES

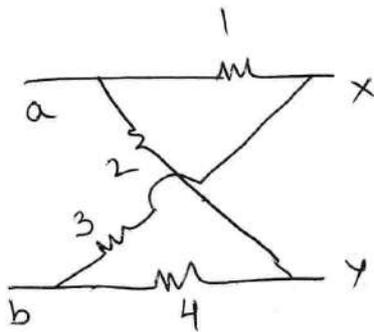
$i_x =$ _____





$\Rightarrow 3 // 9 = \frac{27}{12} = \frac{9}{4} \Omega$

GATE



$R_{ab} = \frac{4 // 6}{1}$

$R_{by} = \frac{4 // 6}{2}$

$R_{xy} = \frac{3 // 7}{1}$

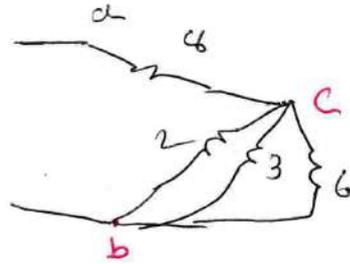
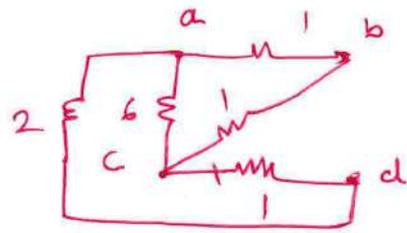
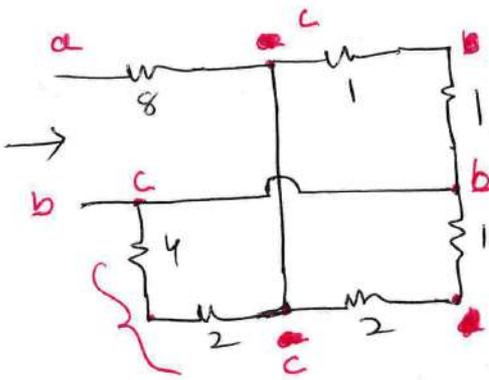
$R_{ay} = \frac{2 // 8}{1}$

$R_{ax} = \frac{1 // 9}{1}$

$R_{bx} = \frac{3 // 7}{1}$

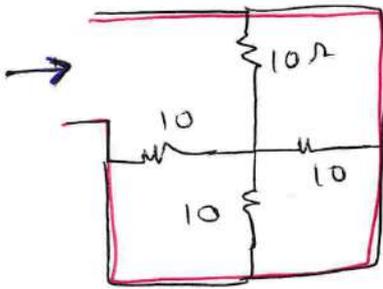
ELECTRICAL CIRCUIT by manish sir

GATE



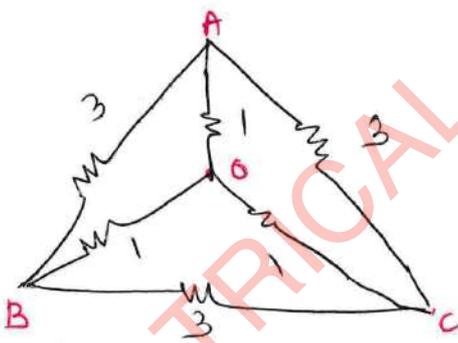
9Ω

IES:

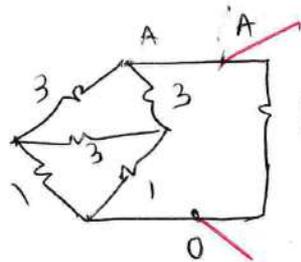
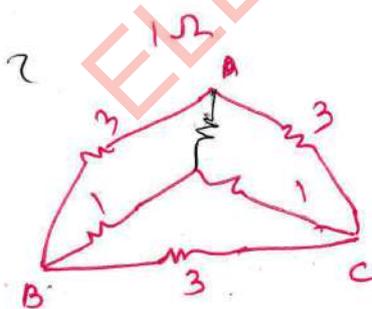


0Ω

→



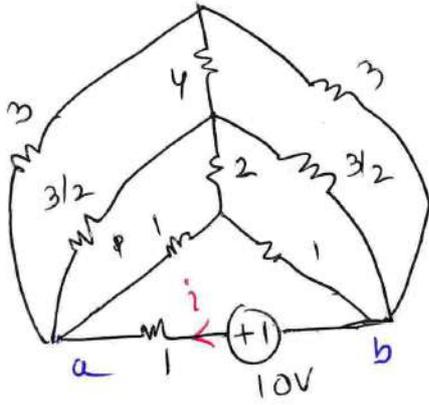
$R_{BC} = \text{---}$ $R_{AO} = \text{---}$



$2/3\Omega$

GATE

$i = 5A$



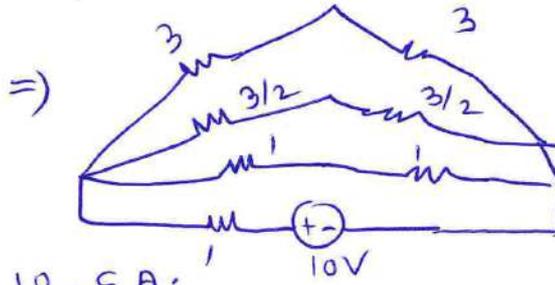
If we see from ab perspective opposite resistances are equal

$(3/2 - 3 = 3/2 - 3)$

$\therefore I_{4\Omega} = 0$

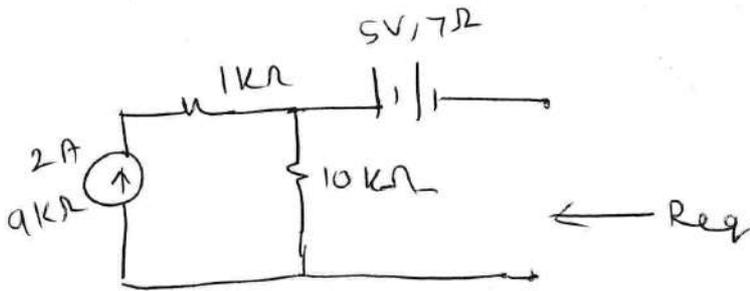
Also $3/2 \cdot 1 = 3/2 \cdot 1$

$\therefore I_{2\Omega} = 0$

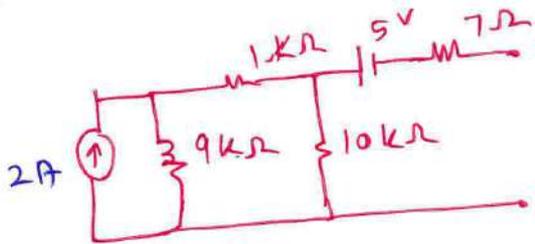


$\Rightarrow (6/3) // 2 + 1$
 $= 2 // 2 + 1 = 2\Omega$

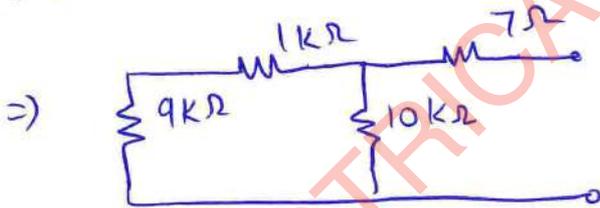
$\frac{10}{2} = 5A$



5007Ω



current of voltage source SC

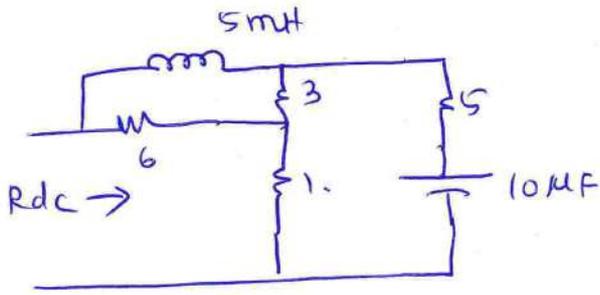


$\Rightarrow 10k\Omega // 10k\Omega + 7\Omega$

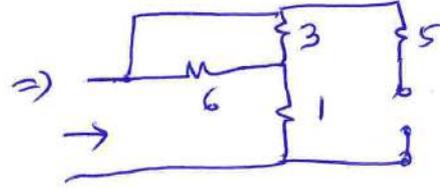
$= 5k\Omega + 7\Omega$

$= 5000 + 7 = \underline{\underline{5007\Omega}}$

→ calculate DC resistance

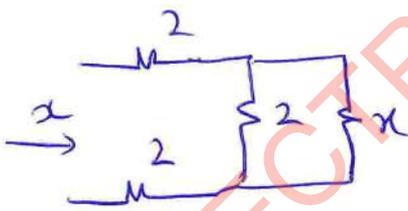
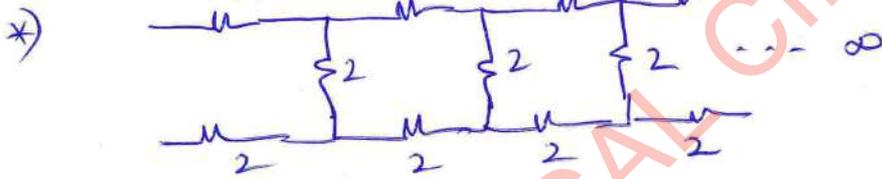
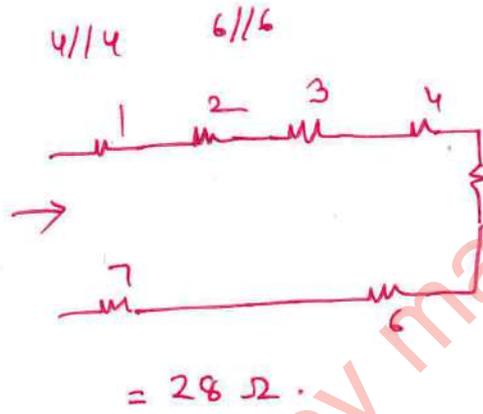
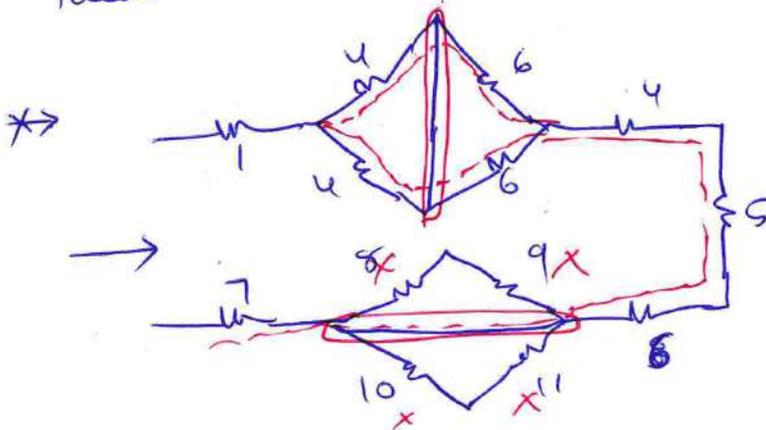


$i = C \frac{dV}{dt} \Rightarrow DC \rightarrow \frac{dV}{dt} = 0$
 $\omega L = 0 \Rightarrow i_c = 0$ (capacitor is o.c.)
 $\omega C = 0 \Rightarrow \frac{1}{\omega C} \rightarrow \infty$ for ideal DC in steady state)



$6 // 3 + 1 = 2 + 1 = \underline{3 \Omega}$

$v = L \frac{di}{dt} \rightarrow DC \rightarrow \frac{di}{dt} = 0 \rightarrow v_L = 0$
 (Inductor is a sc for ideal DC in s.s) steady state



$\Rightarrow x = \frac{2x + 4}{2 + x}$

$\Rightarrow x = \frac{2x + 8 + 4x}{2 + x}$

$\Rightarrow (x + 2) \cdot x = 6x + 8$

$\Rightarrow x^2 + 2x - 6x - 8 = 0$

$\Rightarrow x^2 - 4x - 8 = 0$

$\Rightarrow \cancel{2x - 4x + 4x} \quad x = 5.464 \Omega$

$\frac{4 \pm \sqrt{16 + 32}}{2}$

$\frac{4 \pm \sqrt{48}}{2} = \frac{4 \pm 4\sqrt{3}}{2} = 2 \pm 2\sqrt{3} = 2 + 2\sqrt{3}$ only.

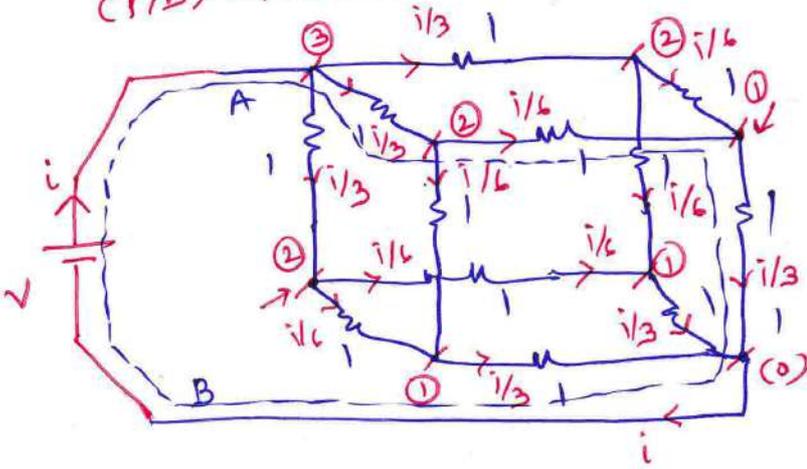
- Linear
- Passive
- Bilateral

R cant be -ve.

* $R_{AB} = \frac{5}{6} \Omega$

(Y/ Δ) \rightarrow Conventional

\rightarrow Symmetrical network



\downarrow (complex n/w)

\downarrow ohm's law apply \downarrow

- 1) All resistors are equal
- 2) Path resistance in every path is same of current

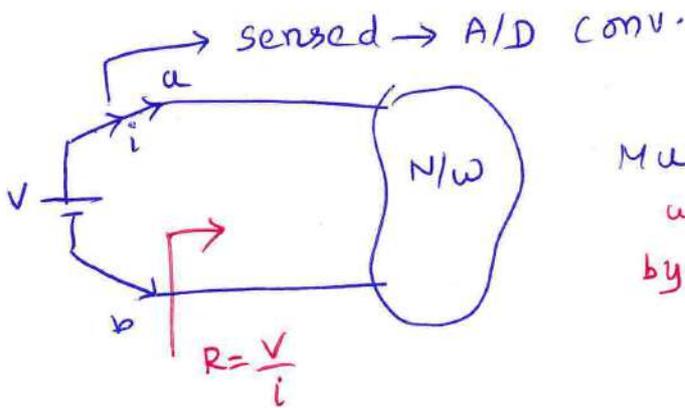
③ \rightarrow High potential

② \rightarrow Next

① \rightarrow Next

⊙ \rightarrow Low pot.

Multimeter will do by $\frac{V}{i}$ method.



$R_{AB} = \frac{V}{i}$

$-V + i/3(1) + i/6(1) + i/3(1) = 0$

$V = i \left[\frac{1}{3} + \frac{1}{6} + \frac{1}{3} \right]$

$V = i \left[\frac{5}{6} \right]$

$R = \frac{V}{i} = \frac{5}{6} \Omega$

* $R \Omega \Rightarrow R_{AB} = \frac{5}{6} R \Omega$

$L H \Rightarrow L_{AB} = \frac{5}{6} L H$

$C F \Rightarrow C_{AB} = \frac{6}{5} C F$

$G S \Rightarrow G_{AB} = \frac{6}{5} G S$

KVL \rightarrow capacitors

$-V + \frac{1}{C} \int \frac{i}{3} dt + \frac{1}{C} \int \frac{i}{6} dt + \frac{1}{C} \int \frac{i}{3} dt = 0$

$\Rightarrow V = \frac{1}{C} \left[\frac{1}{3} + \frac{1}{6} + \frac{1}{3} \right] \int i dt$

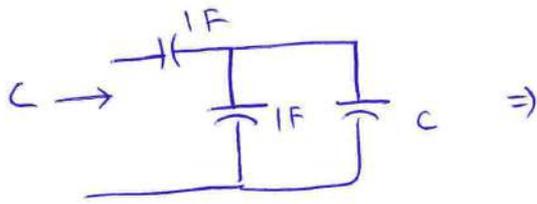
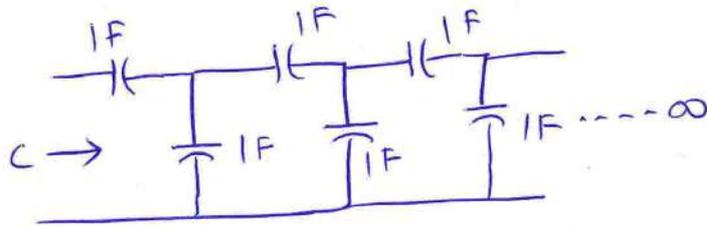
$\Rightarrow V = \frac{1}{C} \left[\frac{5}{6} \right] \int i dt$

$V = \frac{1}{\left(\frac{6C}{5} \right)} \int i dt$

$\rightarrow C_{eq}$

$V = \frac{1}{C} \int i dt$

GATE IM:



$$C = \frac{(C+1) \cdot 1}{C+2}$$

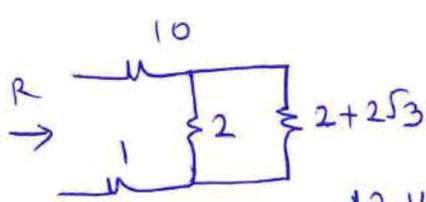
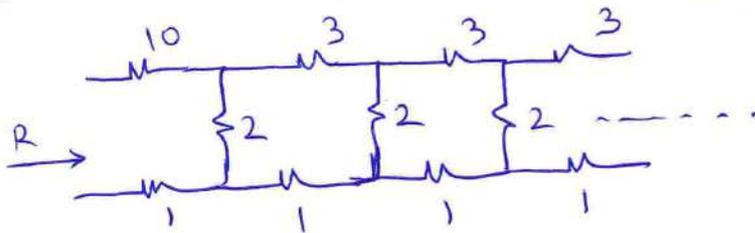
$$\Rightarrow C^2 + 2C = C+1$$

$$\Rightarrow C^2 + C - 1 = 0$$

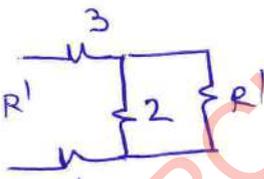
$$C = \frac{-1 \pm \sqrt{1+4}}{2} = \frac{-1 \pm \sqrt{5}}{2} = \frac{-1 + \sqrt{5}}{2}$$

$$C = \frac{\sqrt{5}-1}{2} \text{ F}$$

IES Q: (H.W: write it as conventional ans),



$$= 12.464 \Omega$$



$$R' = \frac{R' \cdot 2}{R'+2} + 3 + 1$$

$$R' = \frac{2R'}{R'+2} + 4$$

$$R' = \frac{2R' + 4R' + 8}{R'+2}$$

$$\Rightarrow (R')^2 + 2R' = 6R' + 8$$

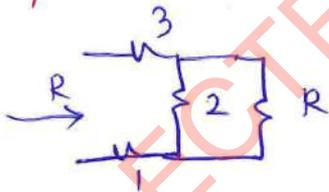
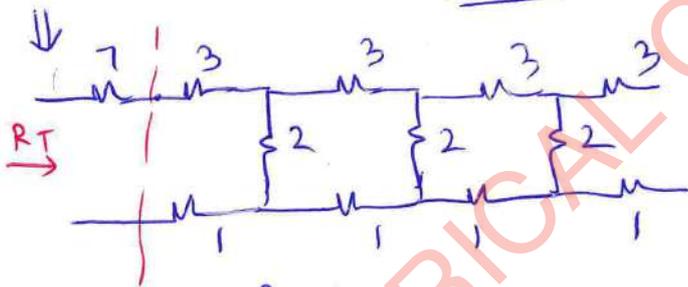
$$\Rightarrow x^2 - 4x - 8 = 0$$

$$x = 2 \pm 2i =$$

$$\frac{4 \pm \sqrt{16 + 4 \times 8}}{2} = \frac{4 \pm 4\sqrt{3}}{2}$$

$$= 2 \pm 2\sqrt{3}$$

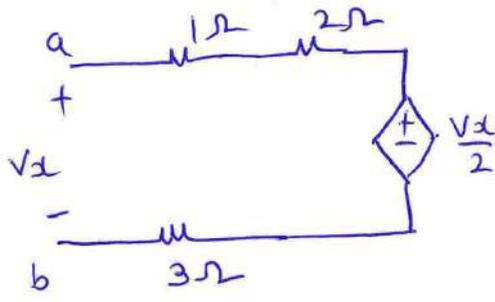
$$= 2 + 2\sqrt{3} \checkmark$$



$$\therefore R_T = 7 + R = 7 + 2 + 2\sqrt{3}$$

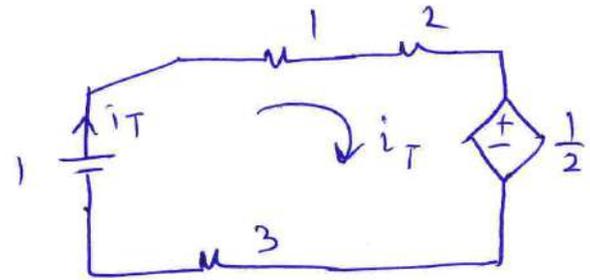
$$= 9 + 2\sqrt{3}$$

*)



Determine $R_{ab} = ?$

Sol:

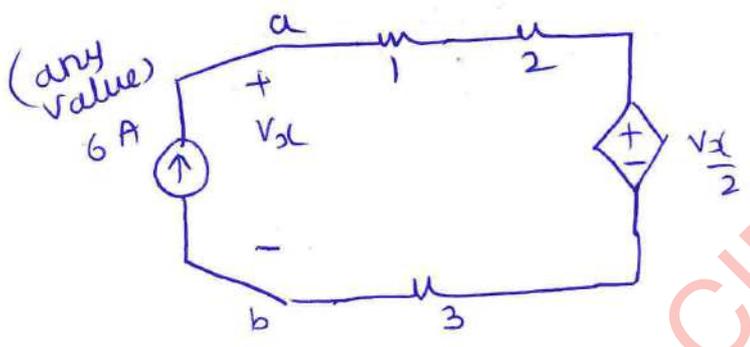


$$R_{ab} = \frac{1}{i_T}$$

$$\therefore -1 + i_T + 2i_T + \frac{1}{2} + 3i_T = 0$$

$$6i_T = \frac{1}{2} \Rightarrow i_T = \frac{1}{12}$$

$$\therefore R_{ab} = \frac{1}{1/12} = 12 \Omega$$



$$R_{ab} = \frac{V_x}{6}$$

KVL $-V_x + 6(1) + 6(2) + \frac{V_x}{2} + 6(3) = 0$

$$6(6) = \frac{V_x}{2}$$

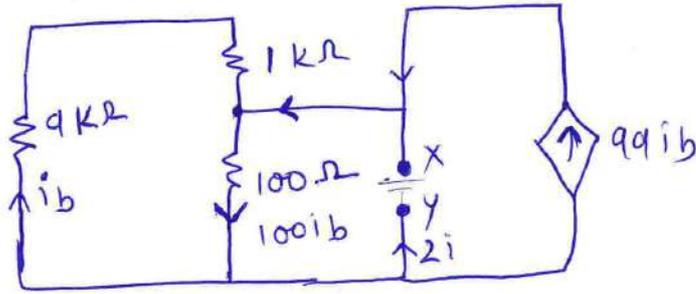
$$\Rightarrow V_x = 72$$

$$R_{ab} = \frac{72}{6} = 12 \Omega$$

ELECTRICAL CIRCUIT by manish sir

GATE/13/2M

Find $R_{xy} =$ _____



Sol:

$$V_{xy} = 100ib(100) + 1k\Omega(99ib) + 9k\Omega(ib)$$

$$= 10,000ib + 1k\Omega(99ib +$$

$$V_{xy} = 1V \text{ (say)}$$

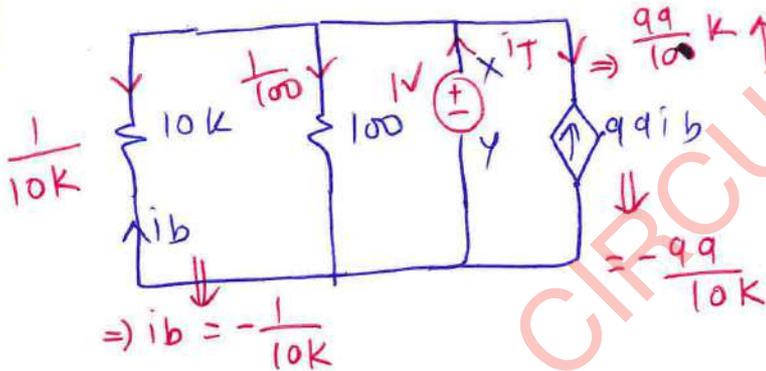
$$-1 + 100ib(100\Omega) = 0$$

$$100 \times 100 ib = 1$$

$$ib = \frac{1}{10,000}$$

$$R_{xy} = \frac{V_{xy}}{i_{xy}}$$

=>



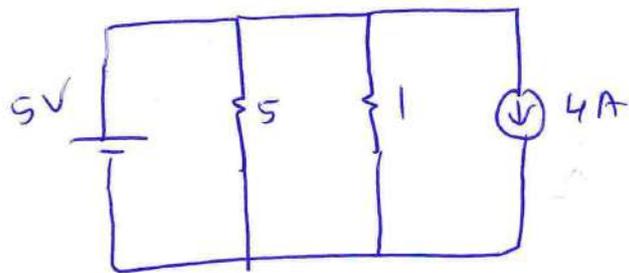
KCL $i_T = \frac{1}{100} + \frac{1}{10k} + \frac{99}{10k}$

$$= \frac{1}{100} + \frac{1}{10k} (1 + 99)$$

$$i_T = \frac{1}{100} + \frac{1}{100} = \frac{2}{100} = \frac{1}{50}$$

$$R_{xy} = \frac{1}{i_T} = \frac{1}{1/50} = \underline{\underline{50\Omega}}$$

IES/12



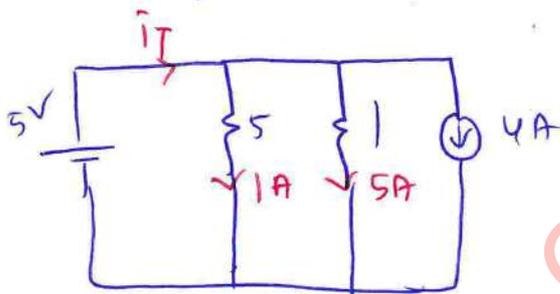
Determine the effective resistance of the network as seen by the voltage source?

Sol: Effective resistance is the resistance offered by the network under working condition, which can be again determined by ohm's law.

Ex: Motor resistance while running
Bulb resistance while glowing

If the circuit is purely passive, then effective resistance is equal to thevenin resistance.

$$R_{\text{eff}} = \frac{5}{i_T}$$



$$i_T = 1 + 5 + 4 = 10 \text{ A}$$

$$\therefore R_{\text{eff}} = \frac{5}{10} = 0.5 \Omega$$

ELECTRICAL CIRCUIT by manish sir

09-12-14

Power Generation

Y. Md. Naveed Attorney.

- 1. Hydel plants
- 2. Thermal plants
- 3. Nuclear plants.

GOI
 NTPC
 NHPC
 NPC



IES → Railway services

Railway stores

4-5 ques

Central Electricity Authority (CEA)

Part-II objective

CPRI

Reference Books:

- 1. Power Generation Utilization and Distribution by C.L. Wadhwa
- 2. Electrical Power by J.B. Gupta.

*** Power Generation - Hydel plants

(Hydro Electric Plant)

- * Dam → only for irrigation ⇒ Hydel Plants
- * If it is also used for power generation, then it is called Hydro Electric Plant. (* Irrigation)
- * In addition to above, if it also provides drinking water then it is called Multi Task (Purpose) plant.

* Power Generation:

→ At any instant of time, the power consumed by the lamp is 40 Watts; the amount of power over a period of time is calculated as energy. (40 Watts, 230V, 1-ϕ, 50Hz)

→ The Potential Energy of the stored water in a reservoir is brought into kinetic energy and the kinetic energy of the flow of water is converted into electrical power.

* 75 kg m/sec. flow of water produces $(735) \frac{W}{mHP}$.
(metric horse power) 1 BHP or HP = 746 Watts (British HP)

1 kg m/sec produces — $\frac{735}{75} \rightarrow mHP = \frac{735}{75}$ Watts

The average power generated by the hydel plant

$$(P) = \frac{735}{75} W \text{ or } h \eta \text{ Watts}$$

$$= \frac{0.735}{75} W \text{ or } h \eta \text{ KW}$$

$$= 9.81 W \text{ or } h \eta \text{ Watts}$$

$$= \frac{9.81 W \text{ or } h \eta \text{ KW}}{1000}$$

W = density of water → 1000 kg/m³

Q = discharge of water → m³/sec

h = head of water → m

η → efficiency of the plant

↓ British unit
cu-sec → cubic feet/sec.

volume of water m^3 Cubic feet.

TMC \rightarrow Thousand million Cu-sec. $\rightarrow 10^9$ cu-sec.

$\eta \rightarrow$ ideal case 100%.

\rightarrow In case of ideal plant, η is taken as 100%.

Q: The hydro electric power station is supplied from a reservoir having a capacity of $3 \times 10^7 m^3$, at a head of 150m. Determine the total energy available in kWh when the η of the plant is 70%.

Sol: $\text{P} = \frac{9.81 W \& H \eta}{1000} \text{ kW} \quad \frac{m^3}{\text{sec}} \times \text{sec}$

Energy generated = $\frac{9.81 \times 1000 \times 3 \times 10^7 \times 150}{1000} \times 0.70$

$= 9.81 \times 3 \times 15 \times 7 \times 10^7 \text{ kW-sec.}$

$= \frac{9.81 \times 3 \times 15 \times 7 \times 10^7}{3600} \text{ kWh.}$

$= 0.858 \times 10^7 \text{ kWh} = 8.58 \times 10^6 \text{ kWh}$

$= 8.58 \text{ MU. (Million units)}$

Q: A hydroelectric station having a catchment area of 120 sq. km. The annual rainfall in the catchment area is 100 cm. The head of water is 250m. The available water for the power generation is only 50%. The η of the plant is 70%. The load factor is 40%. The proposed installed capacity of the hydro electric plant in kW is ?

Sol: $h = 250m \quad \eta = 0.7$

$Q = \text{discharge} = 120 \text{ km}^2 = 120 \times (1000)^2 = 120 \times 10^6 \text{ m}^2$

$= 120 \times 10^6 \times 1 \text{ m}^3 (\because 100 \text{ cm} = 1 \text{ m})$

But only 50% of the water $\Rightarrow 120 \times 10^6 \times \frac{1}{2} \text{ m}^3 = 60 \times 10^6 \text{ m}^3$.

Manish Sahu Sir

$$Q = 60 \times 10^6 \times \cancel{2.77} \text{ m}^3$$

$$Q = \frac{60 \times 10^6}{8760 \times 3600} \text{ m}^3/\text{sec}$$
$$= 1.902 \text{ m}^3/\text{sec}.$$

$$P = \frac{9.81 W Q H \eta}{1000} \text{ kW}$$

$$= \frac{9.81 \times 10 \times 1.902 \times 250 \times 0.70}{1000} \text{ kW}$$

$$= \underline{\underline{3266 \text{ kW}}}$$

$$\text{Load Factor} = \frac{\text{Avg. Load}}{\text{MD}}$$

$$\text{MD} = \frac{\text{Avg. Load}}{0.4} = \underline{\underline{8165 \text{ kW}}}$$

→ Installed capacity of the plant is selected based on the Maximum load on the plant.

Q: A hydroelectric plant is supplied from a catchment area of 150 km^2 with an annual rainfall of 200 cm . The yield factor of the water is 60% . The head of the water is 300 m . The η of the plant is 80% . The avg. power that is generated in MW is —?

Sol: $150 \text{ km}^2 = 150 \times 10^6 \text{ m}^2$.

$$\therefore \text{Volume} = 150 \times 10^6 \times 2 \text{ m}^3 = 300 \times 10^6 \text{ m}^3.$$

$$60\% \text{ of water} \Rightarrow 300 \times 0.6 \times 10^6 \text{ m}^3 = 180 \text{ m}^3 \times 10^6.$$

$$Q = \frac{180 \times 10^6}{8760 \times 3600} \text{ m}^3/\text{sec} = 5.7 \text{ m}^3/\text{sec}.$$

$$\therefore P = \frac{9.81 W Q H \eta}{1000} = \frac{9.81 \times 10 \times 300 \times 5.7 \times 0.80}{1000} \text{ kW}$$

$$= 13420 \text{ kW} = \underline{\underline{13.420 \text{ MW}}}$$

Q: An ideal hydro electric plant has a discharge of $2.5 \text{ m}^3/\text{sec}$, head of water of 60 m . The average power that is generated by the plant in kW is —

Sol:
$$P = \frac{WQH\eta}{1000} \times 9.81 \text{ kW}$$

$$= \frac{9.81 \times 1000 \times 2.5 \times 60 \times 1}{1000} = \underline{\underline{1471.5 \text{ kW}}}$$

$$= \underline{\underline{1.472 \text{ MW}}}$$

Q: A hydroelectric plant is working with a head of 30 m . The catchment area of reservoir is 4×10^4 hectares. The avg. rainfall (annual) is 125 cm . 30% of the water is evaporated into the atmosphere. The efficiency of the plant is 80% . The load factor is 50% . The proposed capacity of the plant in MW is —.

Sol: $h = 30 \text{ m}$. catchment area = 4×10^4 hectares.
 $1 \text{ hectare} = 10^4 \text{ m}^2$. \downarrow
 $(100 \text{ m} \times 100 \text{ m})$ $= 4 \times 10^4 \times 10^4 \text{ m}^2$.
 Rainfall = 1.25 m . \Rightarrow volume = $4 \times 10^8 \times 1.25 \text{ m}^3$.
 70% of water available $\Rightarrow 4 \times 10^8 \times 1.25 \times 0.7 \text{ m}^3$
 $= 3.5 \times 10^8 \text{ m}^3$
 \downarrow
 $\frac{3.5 \times 10^8}{8760 \times 3600} = 11.09 \text{ m}^3/\text{sec}$

$$P = \frac{WQH\eta}{1000} \times 9.81 \text{ kW}$$

$$= \frac{1000 \times 3.5 \times 10^8 \times 30 \times 0.80}{1000 \times 8760 \times 3600} \text{ kW}$$

$$= 2.611 \text{ MW}$$

$\therefore \text{LF} = 0.5$

$\Rightarrow \text{MD} = \frac{\text{Avg. Load}}{0.5} = \frac{2.611 \text{ MW}}{0.5} = \underline{\underline{5.222 \text{ MW}}}$

- The mechanical energy supplied is able to rotate the prime mover so that the rotor of the generator will rotate. The rotational energy of the rotor is able to convert into electrical power by using air gap flux produced by rotor field winding.
- The most commonly used prime mover is the turbine.

Turbines (Classification):

I. Based on the working pressure of the turbine.

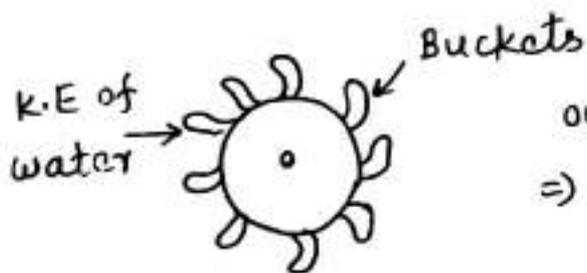
(i) more than atmospheric pressure

Ex: Impulse Turbine (Pelton wheel)

(ii) less than atmospheric pressure

Ex: Reaction Turbine

(Francis, Kaplan and Propeller)



outside the runner → buckets
⇒ More than atmospheric pressure.



inside the runner → blades
(Less than atmospheric pressure)

II. Based on the head of water

(i) 2m - 15m → Propeller (or) Kaplan

(ii) 15m - 70m → Kaplan (or) Francis

(iii) 70m - 500m → Francis (or) Pelton wheel

(iv) > 500m → Pelton wheel

III. Based on the speed of turbine

→ In case of hydro electric plants, the speed of the turbine is measured as specific speed.

→ Specific speed is the speed of the turbine in rpm where the power developed by the turbine is 1 mHP under a head of water of 1m.

$$N_s = \frac{N \sqrt{P}}{h^{5/4}} = \frac{N (P)^{1/2}}{h^{5/4}}$$

N_s → specific speed in rpm.

N → actual speed in rpm.

P → Power developed in mHP

h → head of water in m.

4 rpm - 70 rpm → Pelton Wheel

70 rpm - 420 rpm → Francis

360 rpm - 1100 rpm → Kaplan (or) Propeller.

→ A high head turbine has low speed.

$$N_s = 1.16 \frac{N (P)^{1/2}}{h^{5/4}}$$

only difference is P = Power developed in kW.

* Run away speed:

→ It is the maximum speed of the turbine in rpm that could be withstood by the turbine where the load on the generator is zero and the turbine is supplied with the full capacity of water under the maximum head.

- (i) Low Discharge \rightarrow Pelton wheel
- (ii) Medium Discharge \rightarrow Francis
- (iii) High Discharge \rightarrow Kaplan

$$P = \rho \cdot g \cdot Q \cdot h \cdot \eta$$

$$P \propto Q \cdot h$$

In case of Francis turbine the head of water is medium, discharge of water is assumed to be low that the power generation is high compared to Pelton wheel & Kaplan turbine.

7. Based on the direction of water flow into the turbine

- (i) Tangential flow \rightarrow Pelton wheel
- (ii) Mixed flow \rightarrow Francis ^{Francis} ~~Francis~~ ^{Francis} ~~Francis~~ ^{Francis}
- (iii) Axial flow \rightarrow Kaplan

* Precipitation (P):

It is the amount of water that is available on the earth's surface because of direct rain, or melting of ice after infiltration by the soil.

* Evaporation (E):

The amount of water which gets evaporated into the atmosphere in the form of exaporation due to the heat effect.

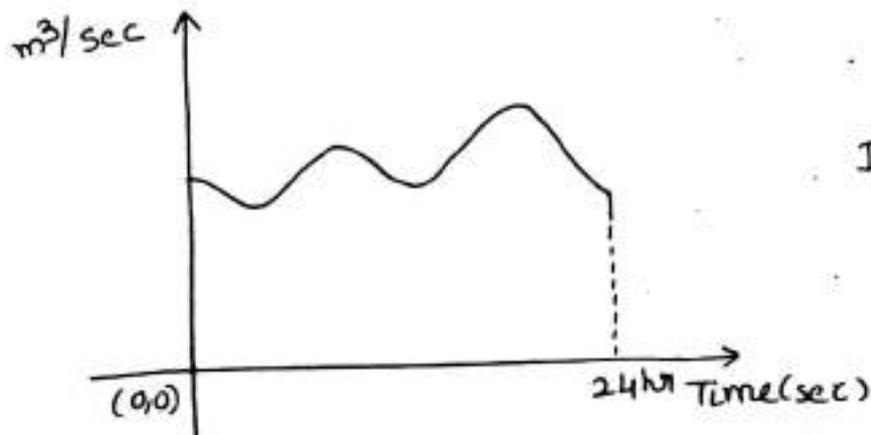
* Run off water: (R)

It is the amount of water that can flow in the river and it can be utilised to generate the power.

$$(R) = (P) - (E)$$

Hydro Graph (or) Flow Graph:

→ It is a graphical representation b/w the discharge of water and the time over a specified period.



Daily Flow graph
(∵ 24 hrs)

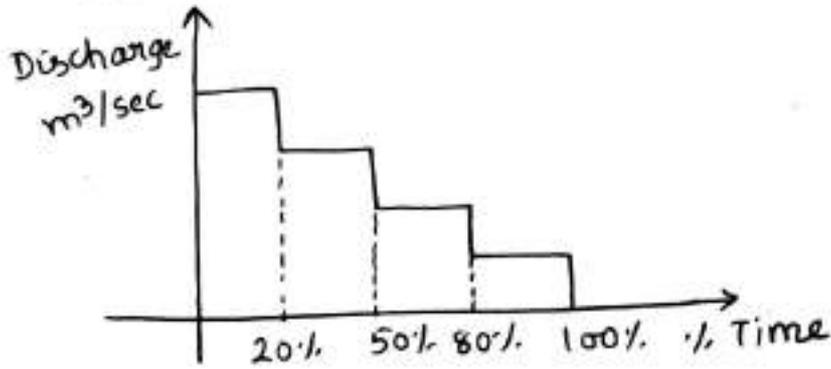
→ It is an electrical equivalent of load curve.

→ The following information can be obtained from the hydrograph.

- 1) It provides the discharge of water at any point of time.
- 2) It provides the minimum discharge and the maximum discharge.
- 3) It can also provide the average discharge.
- 4) The area of the flow graph is useful to generate the ~~power~~ volume of the water which could discharge.
- 5) The flow graph is useful to forecast the amount of power ~~water~~ that is possible to generate so that the installed capacity of the plant is selected.

* Flow Duration Graph:

- The flow graph is made into flow duration graph.
- It gives the discharge of water w.r.to. percentage of time where the discharges are rearranged in descending order.



* Mass Curve

- It will provide cumulative volume of water that can be stored in the reservoir against % of time.

Units: (Day-sec-m)

Q: Day-sec-m is the equivalent of

- a) 8760 m^3
- b) $8760 \text{ m}^3/\text{sec}$
- c) $86,400 \text{ m}^3/\text{sec}$
- d) $86,400 \text{ m}^3$

$$24 \times 60 \times 60 \rightarrow \frac{86,400 \text{ m}^3}{\text{volume of water}}$$

$$\text{(or) Discharge} = \frac{86,400}{24 \times 60 \times 60} \text{ m}^3/\text{sec}$$

$$\text{Same ques} = 1 \text{ m}^3/\text{sec}$$

- a) 8760 m^3
- b) $8760 \text{ m}^3/\text{sec}$
- c) $86,400 \text{ m}^3/\text{sec}$
- d) $1 \text{ m}^3/\text{sec}$

Manish Sanu Sir Power produced by a mass curve (Day-sec-m)

- a) 98.1 kW
- b) 9.81 kW
- c) 0.981 kW
- d) 981 kW

Sol:
$$P = \frac{WQH\eta}{1000} \times 9.81 = \frac{1000 \times 1 \text{ m}^3/\text{sec} \times 1 \times 1 \times 9.81}{1000}$$
$$= \underline{\underline{9.81 \text{ kW}}}$$

* Power produced by a mass curve (10 Day-sec-m)

Sol: Volume = $10 \times 24 \times 60 \times 60 = 8,64,000 \text{ m}^3$.

Discharge $Q = \frac{8,64,000}{10 \times 24 \times 3600} \text{ m}^3/\text{sec} = 1 \text{ m}^3/\text{sec}$.

$\therefore P = \frac{WQH\eta}{1000} \times 9.81 = \frac{1000 \times 1 \times 1 \times 1 \times 9.81}{1000} = 9.81 \text{ kW}$.

* Power produced by 100 Days-sec-m is 9.81 kW.

* Power produced by Day-sec-10m is —.

Volume = $24 \times 60 \times 60 \times 10 = 8,64,000 \text{ m}^3$.

$Q = \frac{8,64,000}{24 \times 60 \times 60} = 10 \text{ m}^3/\text{sec}$.

$\therefore P = \frac{9.81 \times 1000 \times 10 \times 10 \times 1}{1000} = \underline{\underline{981 \text{ kW}}}$ ✓

* Power produced by 10 Day-sec-10m is 981 kW

→ It depends on the head of water but not the no. of days.

Ex: 10 Day-sec-100m \Rightarrow Volume = $\frac{10 \times 24 \times 60 \times 60 \times 100}{10 \times 24 \times 60 \times 60}$

\therefore Power = $\frac{9.81 \times 1000 \times 100 \times 100 \times 1}{1000} = 100 \text{ m}$
 $= 9.81 \times 10^4 \text{ kW}$
 $= 98.1 \text{ MW}$

* selection of site for Hydel plant:

- 1) Availability of ample quantity of water.
- 2) Availability of head of water.
- 3) Facility for storage of water.
- 4) Provision for the construction of Dam.
- 5) It should be accessed by road transportation.

→ Most of the hydel plants are located at hill areas which are remote places. The cost of the transmission network may increase.

* Classification of hydro electric plants:

I. Based on the installed capacity of the plant:

- (i) $\leq 1\text{ MW}$ → Micro Hydel plant
- (ii) $1\text{ MW} - 5\text{ MW}$ → Mini Hydel plant
- (iii) $5\text{ MW} - 100\text{ MW}$ → Medium Capacity
- (iv) $100\text{ MW} - 1000\text{ MW}$ → **High Capacity** → Most of the plants are of high capacity.
- (v) $> 1000\text{ MW}$ → Super capacity

II. Based on the working head of water :

- i) Low head plant → $\leq 70\text{ m}$ (Kaplan)
- ii) Medium head plant → $70\text{ m} - 300\text{ m}$ (Francis)
- iii) High head plant → $> 300\text{ m}$. (Pelton Wheel)

III. Based on the availability of water:

- i) Run off river without pondage → storage
- ii) Run off river with pondage.
- iii) Reservoir type.
- iv) Pumped storage type.

10-12-14

i) Run-off river without Pondage:

ii) Run-off river with Pondage:

iii) Reservoir type:

→ Most of the hydel plants are reservoir type. In the reservoir type, a dam is constructed across the river, to provide the head of water and also to provide the storage facility. During the flood season of the river, the water can be stored in the reservoir and the stored water can be utilised to generate the power. It is useful for a longer period. Hence, it is treated as a base load plant.

iv) Pumped storage plant:

→ It is also similar to that of reservoir type. But the water can be pumped back to the main reservoir and it can be reutilised in order to generate the power to meet the peak load of the system.

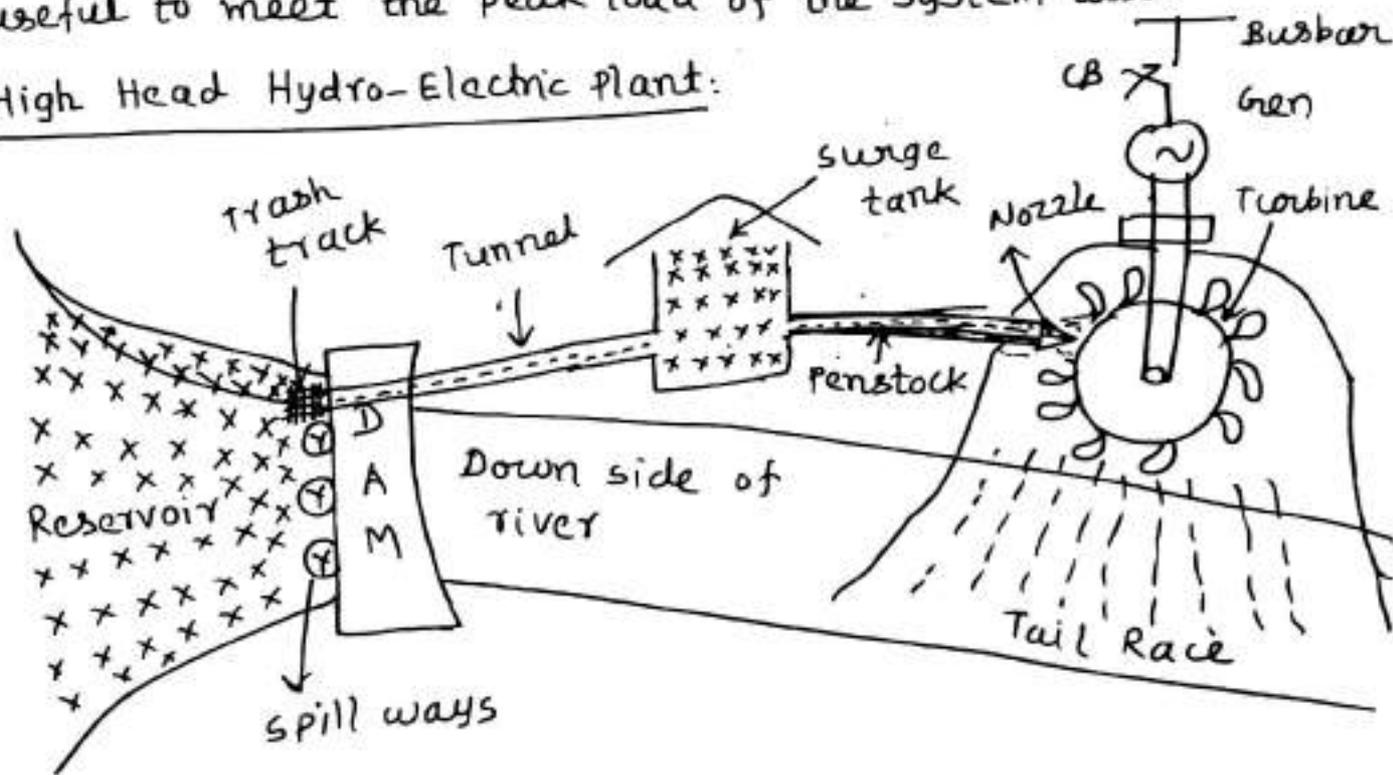
IV. Based on the application of the load

- i) Base load → Run off river without pondage Reservoir type
- ii) Peak load → Run off river with pondage Pumped storage plant

→ The hydel plant can work either as a base load or a peak load plant. one of the advantages of hydel plant, it takes less time to synchronise with the grid.

→ The time taken for synchronisation with the busbar is very less, i.e, around 5-10 minutes so that it is more useful to meet the peak load of the system also.

*** High Head Hydro-Electric plant:



i) Dam

ii) Reservoir

iii) Spill ways

iv) Trash track

v) Tunnel

vi) Surge tank

vii) Pen stock

viii) Nozzle

ix) Turbine

x) Generator

- i) Dam: It is made by RCC (Reinforced Concrete Cement) across the river where there may be a possibility of hills on both sides. The purpose of the dam is to provide the head of water and also to provide the storage facility.
- ii) Reservoir: It is the catchment area of the dam where the water can be stored during the flood season of the river.
- iii) Spillways: The spillways are nothing but the gates of the dam. They are useful to discharge the excess water from the reservoir directly, into the downside of the river so that the damage to the dam can be prevented. They are also treated as safety devices to the dam.
- iv) Trash track: It is an iron mesh, to prevent the entry of debris, into the powerhouse.
- v) Tunnel: In case of a high head plant and also medium head plant, the power house is located away from the dam, in order to reduce the mechanical stresses on the dam. The tunnel is nothing but larger cross-sectional area π made by RCC, to carry the water from the reservoir to the surgetank.
- vi) Surge tank: It will act as temporary regulating reservoir which supplies water to the turbine through penstock.
- vii) Penstock: It is a pipe of smaller cross-sectional area, made by RCC. It will carry the water from the surge tank to the turbine.
- viii) Nozzle: It will act as speed governor to control the mechanical input to the turbine based on the load on the generator so that the turbine rotates at constant speed.

* Water Hammer effect:

→ When the load of the generator is suddenly increased, the amount of water to be admitted to the turbine will increase by opening the nozzle of the penstock which will result in the negative pressure developed in the penstock. When the load on the generator is suddenly reduced, the water supplied to the turbine will be reduced by closing the nozzle of the penstock. It will result in the positive pressure developed in the penstock. The development of a -ve or +ve pressure in the penstock is called as water hammer effect, in the penstock. It can be suppressed by using a surge tank. The surge tank supplies any excess water required by the turbine (or) it can store the water which is rejected by the turbine.

*** The surge tank is preferable to be located near the power house.

ix) Turbine: It acts as a primemover such that it will rotate first by using mechanical energy. It will also rotate the generator so that the rotational energy is converted into electrical power. Based on the head of water, the turbines are selected.

x) Generator: The generators are coupled with the turbines to convert rotational energy into electrical power.

1) Constant speed generator → Synchronous gen.

2) Variable speed generator → Induction gen.

(Wind mill (or) tidal plant)

→ The constant speed generators are coupled with the turbine which are called as synchronous generators.

- 1) Salient pole generator → low speed (4 (or) 6 (or) 8-pole)
- 2) Cylindrical Rotor generator → high speed (2-pole)

→ In case of hydel plant, low speed generators are employed which are salient pole generators.

→ In hydel plant, there is a space constraint so that the generator and the turbine are coupled in a vertical shaft. In a vertical shaft, it is difficult to run the system at higher speeds. Hence, low speed mechanism is employed.

xi) Tail Race: It is the outlet of the turbine where the water from the turbine is discharged into the downside of the river. It is the last point of the hydel plant.

* Overall efficiency (η) = $\eta_t \times \eta_g$.

$$= 0.9 \times 0.95 = 0.855$$
$$= 85\% \rightarrow (0.8 - 0.85)$$

→ Highest efficiency among all the plants → Hydel plant.

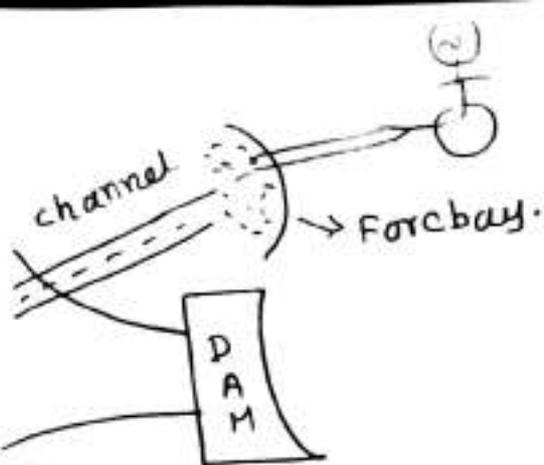
→ Available Generator size → (500 kW - 200 MW)

3.3 kV, 6.6 kV, 11 kV (0.90 - 0.95 lag)

→ In a low head Hydroelectric plant, the power house is located near to the dam. The water is drawn from the reservoir directly by using penstock. The water hammer effect in the penstock is suppressed by the reservoir.

* Forebay:

When the head of water is not created even though the dam is constructed, forebay is created. It will act as temporary regulating reservoir and it can supply the water to the turbine, through penstock. In case of forebay, there is an increase in head of water of the reservoir. In surge tank, there is no change in the head of water.

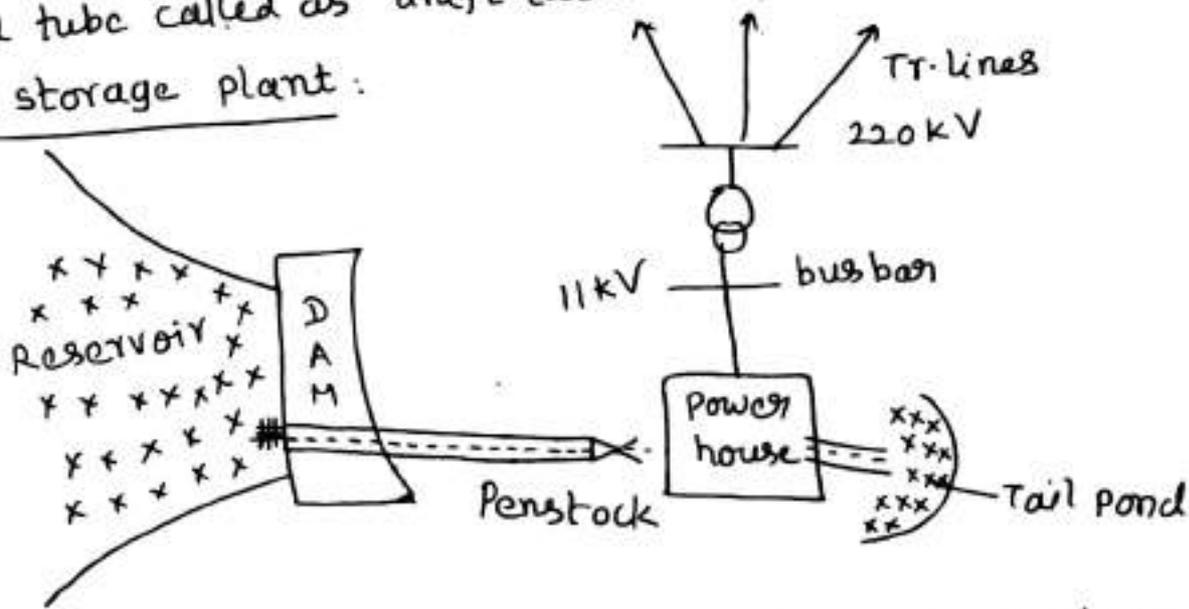


* Cavitation:

→ When the pressure of the water inside the turbine is falls below the atmospheric pressure the water bubbles are developed which is called as cavitation. Due to the Cavitation, the metallic surfaces of turbine get damaged. Hence, the efficiency of the turbine is reduced. The cavitation takes place only in reaction turbines, as they work at a pressure below the atmospheric pressure.

The cavitation in reaction turbine can be prevented by connecting the turbine through the tail race by an external tube called as "draft tube".

* Pumped storage plant:



→ It is a low head hydro electric plant of a reservoir type. During the power generation, water can be drawn from the reservoir. The turbine acts as a prime mover and the synchronous machine acts as a generator. Water that can be discharged will be stored at the tail pond temporarily. During the off peak load condition, the water at the tail

pond can be pumped back to the main reservoir where the synchronous m/c will act as a motor and the turbine will act as centrifugal pump. The pumped water is also reutilised to generate the power in order to meet the peak load of the system. It is only possible provided the turbine is a reaction turbine, because there is a provision of draft tube

Ex: 1 MW Generator action (Srisaïlam Left Bank)

1.5 MW Motor action

52.5 - zero paise

51.5 Rs 1/unit

51.0 Rs 2/unit

50.5 Rs 3/unit

f = 50 Hz

Rs. 4/unit

f = 49.8 Rs 5/unit

f = 49.5 Rs 6/unit

f = 49.0 Rs 8/unit

52 50 paise/unit

off peak load

cost of energy

→ this should be considered not the power more (or) less.

Peak load

** 58 tunnels → Vizag to Araku.

→ In a pumped storage plant, the power is generated during the peak load condition where the cost of energy is high and the pumping is made during the off-peak load condition where the cost of energy is less. Hence, there is an advantage even though 50% extra power is consumed during pumping. It is preferred as peak load plant. As some amount of power is consumed during the pumping operation, the efficiency of the plant is only 60%.

* Advantages of pumped storage plant:

- 1) Due to fast synchronisation, there is greater flexibility in scheduling the power.
- 2) Free from environmental pollution.
- 3) Used as peak load plant (operation.)
- 4) off-peak load period → acts as load on the grid.
Increases the load factor of the plant.

In hydel plant, the load factor is less. Due to pumping action, the average load on the plant increases such that the load factor ↑.

* Thermal plants:

→ High pressure and high temperature steam is used as mechanical energy. It will be converted into electrical power by using prime mover & generator. Steam is produced by heating the water beyond boiling point by using the heat released by the combustion of coal.

Solid fuel:

Coal → Different grades

Peat → Least calorific value.

Lignite

Bituminous

Semi-Bituminous

Anthracite → Highest calorific value.

In power plants, semi bituminous coal is used.

Liquid fuel:

Low grade petroleum products

- For the initial startup of the plant, liquid fuels are used.
- When there is an inferior coal supply, the calorific value of the coal is less. In order to obtain high calorific value (more heat), the liquid fuels are mixed with the solid fuels.

11-12-14

* Selection of Site for Thermal Plant:

1. 1 MW → (10-15) tonnes of coal/day

The amount of coal requirement is high. In order to reduce the cost of coal transportation, it is preferable to be located near the coal field, i.e., pit head plant

2. 1 MW → (3-4) acres of land.

The land requirement is high. The availability of land at less cost. (For steam production and also

3. Available of ample quantity of water ← condenser)

4. It should be accessed by rail and road transportation

→ Most of the thermal plants are located near the coal mines, which are far away from the populated areas, hence the cost of the transmission network increases.

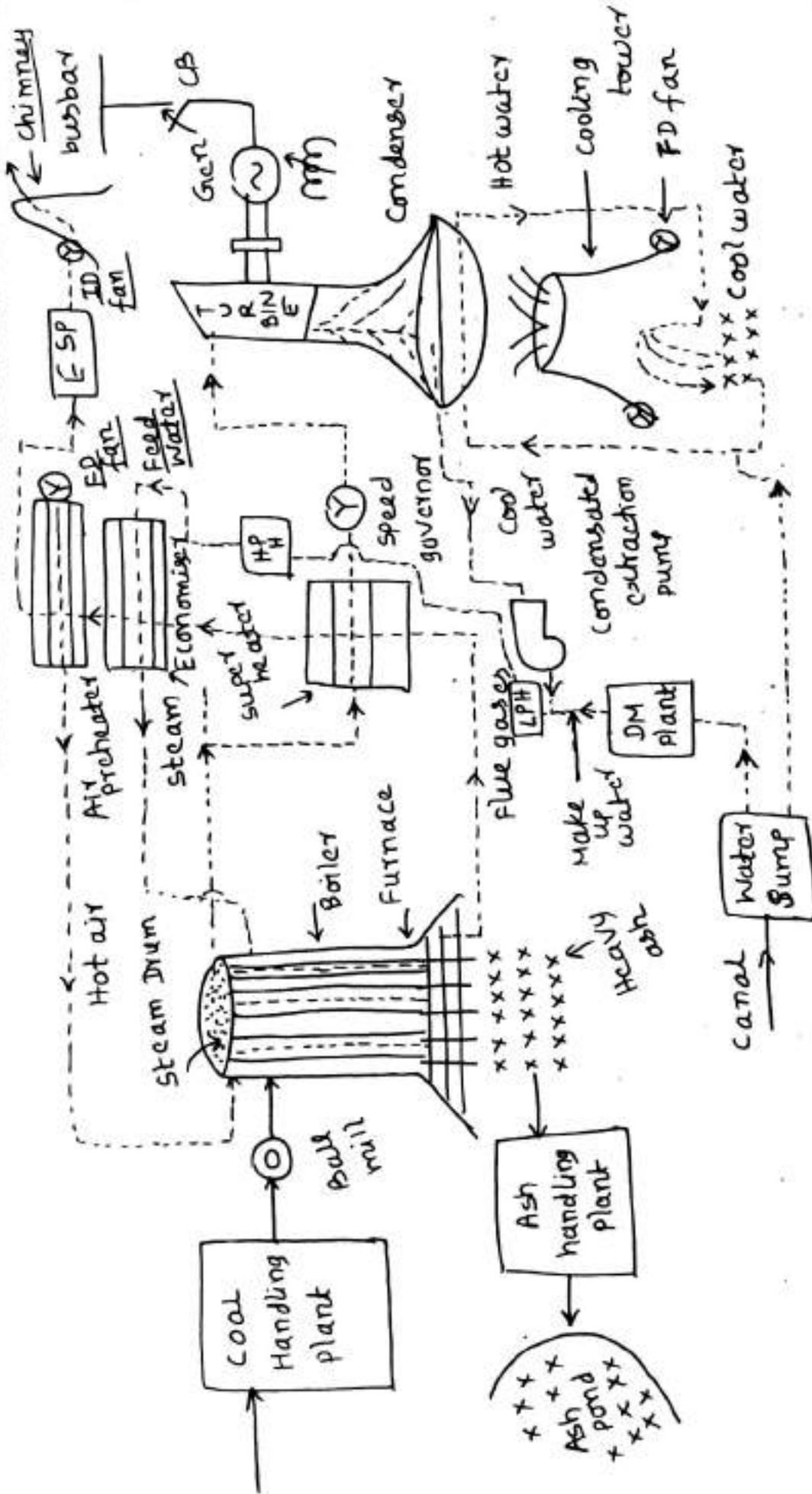
* Classification of Thermal Plants based on Installed Capacity

- 1) Industrial plants: The power generated by the industrial plants are utilised for the industrial purpose. (≤ 10 MW)

- 2) Commercial plants (or) Central plants: In commercial plants, the bulk amount of power produced is supplied to various consumers on cost basis.

→ Most of the thermal plants are of commercial type.

Working diagram of Thermal plant



LPH → Low Pressure Heater
 DM → De Mineralised

1) Coal Handling Plant:

The coal from the coal mines is transported by rail to the coal handling plant. The following steps are involved at the coal handling point.

i) Unloading: Wagon Tripler

ii) Coal Preparation:

a) Separator: → Remove debris

b) Crusher: To crush coal into small pieces.

c) Dryers: To remove moisture.

The unloading of coal and preparation is made at the coal yard.

iii) Coal transportation: The prepared coal at the coal yard is transported to the boiler by using belt conveyor.

iv) Coal storage: The transported coal is stored in coal bunkers by using bull-dozers.

2) Ball Mill:

The purpose of the ball mill is to prepare pulverized coal, i.e., ~~powdered~~ powdered coal to the boiler furnace, to increase burning and heating properties of coal so that the wastage of coal can be reduced.

3) Boiler:

It consists of many tubes made of cast iron. It is classified as i) Water tube boiler: In case of water tube boiler, the tubes are filled with water and on the surface of the tubes, heat is surrounded.

ii) Fire tube boiler: The heat is inside the tube and on the surface of the tube, the water surrounds it.

In thermal plants, water tube boilers are preferred for the effective collection of steam.

→ The boiler tubes are filled with demineralized water. The water in the water tubes is slowly heated up by using the heat released by combustion of coal. When the water is heated up beyond the boiling point, it converts into steam slowly. The steam is collected at the steam drum. The purpose of DM (De Mineralized) water is to prevent the scaling on the surface of the tubes. The pH value of DM water is slightly greater than 7. pH of drinking water → 7.
(Percentage Hydrogen ion concentration in water).

→ The pressure and temperature of the steam collected at steam drum → 110-160 kg/cm² and 300°C.

→ The combustion of coal at the boiler may result in releasing waste material which is called as ash. Indian coal has 20-40% ash. The disposal of ash is one of the major problems in thermal plants.

* Ash:

- i) Bottom Ash (or) Heavy Ash
- ii) Fly Ash (less)

The ash which is collected at the boiler furnace is called heavy ash and ash mixed with the flue gases is treated as fly ash.

The best way to dispose ash is hydraulic system. In hydraulic system, ash is mixed with water and it can be pumped to the ash pond.

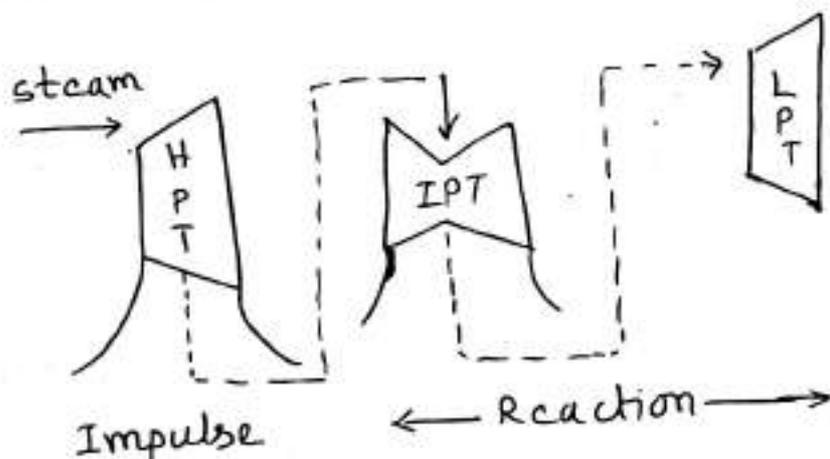
* Super heater

→ The purpose of super heater is to increase the temperature of steam without change in pressure. It consists of tubes in which steam is flows inside the tubes and on the surface of the tubes, the flue gases flow. The temperature of flue gases is absorbed by the steam so that temp ↑ to 540°C without change in pressure.

* Turbine:

It acts as a prime mover to the generator so that the mechanical energy of the turbine is converted into electrical power.

In thermal plants, & nuclear plants, a combinational turbine (impulse + reaction) is used.



In order to get good mechanical output from steam, the steam is allowed to expand at 3 different stages instead of only one stage.

* Generator: Synchronous generators are used.

Cylindrical rotor (or) turbo alternators
2-pole, 3000 rpm and 50 Hz.

- Turbo Generator - upto 500 MW. (6.6 KV (or) 11 KV (or) 13.2 KV)
- Modern Turbo Generator - (500 MW - 1000 MW)
(22 KV - 30 KV)

→ The heat generated should be dissipated using a cooling system. Normally air cooling is employed. For the generators having 100MW capacity, Hydrogen gas cooling is also employed in addition to air cooling. Pressure of $H_2 \rightarrow 0.0354 \text{ kg/cm}^2$ used for cooling.

→ H_2 molecular weight is less. Hence it is used. (\because Less weight on rotor)

* Overall efficiency (η_0) = $\eta_b \times \eta_t \times \eta_e$

η_b = boiler efficiency = 90%

η_t = turbine efficiency = 32%

η_e = electrical efficiency = 95%

$\therefore \eta_0 = 0.90 \times 0.32 \times 0.95 = 27.36\%$

$\eta_0 = \frac{\text{Heat Equivalent of electrical energy in kWh}}{\text{Heat of combustion of coal in KCal}}$

1 kWh = 860 KCal
 1 kWh = $36 \times 10^5 \text{ J}$
 = 3600 KJ.

1 KCal = 4200 J.
 1 KCal = 4.2 KJ

** $\eta_0 = (25-30\%)$

$\eta_T = \eta_b \times \eta_t$

Thermal efficiency $\eta_T = \eta_b \times \eta_t$

$\therefore \eta_0 = \eta_T \times \eta_e$

$\eta_T = \frac{\text{Heat equivalent of mechanical energy in KJ}}{\text{Heat of combustion of coal in KCal}}$

$\eta_0 = \frac{\text{Heat equivalent of mechanical energy} \times \text{Heat equivalent of elec energy}}{\text{Heat of combustion of coal}}$

Heat equivalent of mech. energy

→ In case of a thermal plant, the steam is expanded with the help of a condenser so that the pressure of the steam is very low in order to collect the water from the steam, so that it could be used as feed water to the boiler. The turbine efficiency will be less so that the overall efficiency of the thermal plant is reduced.

Q: A thermal plant has an overall efficiency of 20%. 0.75 kg of coal is burnt to produce 1 unit of electrical energy. The calorific value of the coal in kcal/kg is —.

Sol:
$$0.20 = \frac{\text{Heat equivalent of electrical energy in kWh}}{\text{Heat of combustion of coal in kcal}}$$

$$0.20 = \frac{1 \times 860}{\text{Heat (Amount of coal in kg) } \times \text{Calorific value of coal in kcal/kg}}$$

$$0.75 \text{ kg} \times \text{calorific value in kcal/kg} = \frac{860}{0.20}$$

$$\Rightarrow = \underline{\underline{5,733 \text{ kcal/kg}}}$$

Q: overall η of the thermal plant is 20%. The generated is rated as 100 MW. The average load on the gen is 80 MW. with an operating time of 10 hr. The calorific value of the coal is 4500 kcal/kg. The amount of coal reqd. in tonnes?

Sol:
$$0.20 = \frac{80 \text{ MW} \times 10 \text{ hr}}{(\text{Amount of coal in kg}) \times \text{Cal in kcal/kg}}$$

$$0.20 = \frac{80 \times 10 \times 10^3 \times 860}{\text{amount} \times 4500}$$

$$\Rightarrow \text{Amount in kg} = 764.444 \times 10^3 \text{ kg}$$

$$\therefore \text{Amount in tonnes} = \frac{\text{Amount}}{1000} = \underline{\underline{764.44 \text{ tonnes}}}$$

Q: A 75 MW thermal plant has thermal efficiency 30%. the electrical efficiency 80%. The calorific value of the coal is 6400 kcal/kg. The coal is transported by a rail. Each wagon will carry 5 tonnes of coal. The no. of wagon required to transport the coal for 1 day, when the generating is delivering Full load.

Sol: $0.80 \times 0.30 = \frac{75 \text{ MW} \times 24 \text{ hours}}{\text{Amount} \times 6400 \text{ kcal/kg}}$

$$0.24 = \frac{75 \times 24 \times 10^3 \times 860}{\text{Amount} \times 6400}$$

Amount (in kg) = $1007.812 \times 10^3 \text{ kg}$.

∴ Amount (in tonnes) = 1007.812.

∴ No. of wagons = $\frac{1007.812}{5} = 201.56$.

≈ 202 wagons

Q: A 65 MW thermal plant uses a coal of 15,000 kcal/kg calorific value. 0.5 kg of coal is burnt to produce 1 unit of electrical energy. The LF is 40%. $\eta_0 = ?$

Sol: $\eta_0 = \frac{1 \times 860}{0.5 \times 15,000} = \underline{\underline{11.46\%}}$

Consider 1 hour

LF = 40% = 0.40 = $\frac{\text{Avg. load}}{\text{Max. Load}}$

Avg Load = $0.40 \times 65 \text{ MW} = 26 \text{ MW}$.

$$\eta_0 = \frac{26 \times 10^3 \times 1 \times 860}{0.5 \times 26 \times 10^3 \times 15,000} = \underline{\underline{11.46\%}}$$

Efficiency can be taken as daily or monthly or annual as numerator and denominator has hours and will be cancelled.

* Condenser:

- The purpose of the condenser is to reduce the pressure and temperature of the steam as water can be collected from the steam and it can be used as feed water to the boiler.
- In thermal plants, surface type of condensers are used.
- By increasing the cross sectional area of the condenser, the pressure of the steam is reduced. The temperature of the steam is reduced by using cool water in the condenser and it becomes hot water. The pressure and temperature of the steam at the condenser is brought down to 0.4 kg/cm^2 and 40°C .

* Condensated extraction pump:

- It is used to collect the water from condensated steam. During the expansion of the steam at the turbine, there is loss of steam. The water which is collected at the condenser is not sufficient as feed water to the boiler. Make up water is added from the DM plant to compensate the loss of steam. The combination of makeup water and the condensated extraction water is treated as feed water to the boiler.

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* Low Pressure and High Pressure Heaters:

- The purpose of the low pressure heater and also high pressure heater is to raise the temperature of the feed water.
- The feed water will be heated up with the help of the steam which is tapped from the high pressure turbine and also low pressure turbine.

* Economiser:

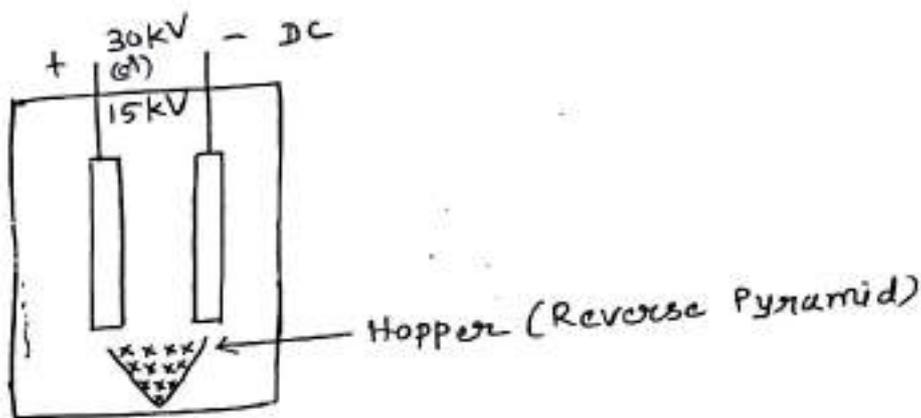
- It acts as one of the accessories to the boiler so that its efficiency (boiler η) increases.
- The feed water passes through the tubes of economiser and on the surface of the tubes, the flue gases flow. The temperature of the flue gases is extracted by the feed water so that the temperature of the feed water increases. Economizers are normally installed in a thermal plant where the pressure of the steam required is 70 kg/cm^2 & above.

* Air pre-heater:

- For the effective combustion of coal at the boiler furnace, sufficient air is required.
- Hot air is more useful when compared to atmospheric air. Air preheater will supply hot air to the boiler furnace. The forced draught fan will supply air to the air preheater which gets heated up with the help of temperature of the flue gases. It will act as another accessory to the boiler so that the efficiency of the boiler increases.

* Electrostatic Precipitator (ESP):

→ In the flue gases, there are flyash particles and also the gases like CO_2 , CO , SO_2 . CO and SO_2 have poisonous nature. Electrostatic precipitator is used to collect the flyash particles and also the poisonous gases. It consists of two plates supplied by 30 kV (or) 15 kV DC. Electrostatic field intensity is developed b/w the two plates. The opposite charged particles are collected on the plates. The brushing is made on the plates to clean them regularly. The flyash is collected in a storage device called "hopper".



→ The ash collected at the hopper is utilised for the manufacturing of the bricks or during the processing of cement. When there is no such utilisation, it is mixed with the bottom ash and then disposed at the ash pond.

→ The efficiency of the electrostatic precipitator should be high (99.5-99.8%)

* Draught:

→ Draught is nothing but creation of pressure difference b/w the two points, for the exhaust of flue gases or vapour particles into the atmosphere. The chimney or cooling tower are the examples for the draught. The draught developed by chimney or cooling tower may not be sufficient.

→ It is supported by artificial draught.

→ Artificial draught can be produced by a fan.

(i) Forced draught fan → +ve pressure (Ex: Ceiling fan)

(ii) Induced draught fan → -ve pressure (Ex: Exhaust fan)

→ The induced draught fan is employed at the bottom of the chimney such that it will collect the flue gases from the boiler furnace and sends into the atmosphere through chimney.

→ The forced draught fan is used at the air preheater to supply the natural air from the atmosphere to the air preheater.

→ When the FD fan is employed, it is to be located at the boiler furnace. The pressure at the boiler furnace is high, the flue gases can be swept away from the boiler furnace. However, the air preheater may not supply air to the boiler furnace. Hence ID fan is preferable.

* Cooling tower:

→ When fresh water is available throughout the year from a reservoir, there is no need of a cooling tower. When the water is not available, it can be reutilised, the cooling towers are employed. The purpose of the

cooling tower is to remove vapour particles from the hot water of condenser so that the cool water is available and it can be reutilised. The cooling tower is supported by FD fan, which is located at the bottom of the tower which can maintain a pressure more than atmospheric pressure.

→ When ID fan is used, it is located at the top of the cooling tower, inside.

* Nuclear Plants:

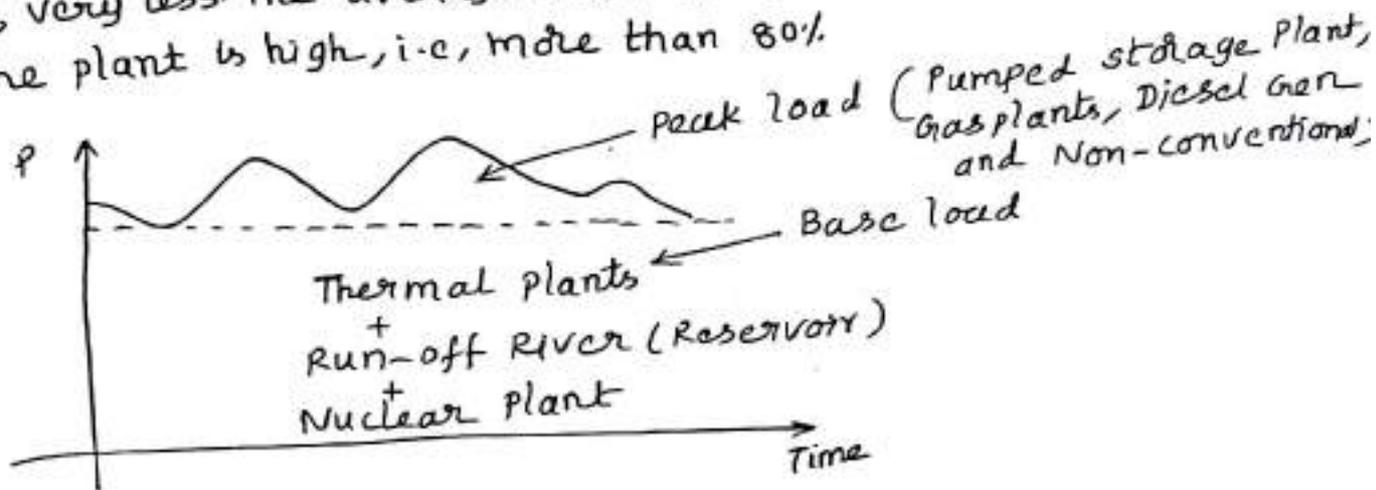
- The power generation in a nuclear plant is similar to that of thermal plant, i.e., the mechanical energy (steam) is converted into electrical power. The heat released by radio active material at the nuclear reactor is utilised to produce the steam from the water.
- Fuel: Radio active materials
- The weight of the radio active materials are measured in AMU. (Atomic Mass Unit)
 $1 \text{ AMU} = 1.67 \times 10^{-27} \text{ kg}$
- The heat released by radio active materials is measured in eV (or) MeV.
 $1 \text{ a mu} = 931 \text{ MeV.}$
- 1 kg of radio active material = 2500 tonnes of coal
 1.2 kg of radio active material ^{produces} = 1 MW for 365 days.

* Selection of location of Nuclear Plant:

- 1) The amount of fuel requirement is very less, so that the cost of fuel transportation is less. Hence it is preferable to be located near load centres. When the plant is near to the load centres, the cost of transmission n/w reduces.
- 2) Availability of ample quantity of water for the condenser and also steam.
- 3) It should be accessible to rail and road transportation.
 ↓
 (For transport of reactor)
- 4) The provision for disposal of waste material, i.e., the waste is buried in the ground (or) dumped into the sea.

* Advantages of Nuclear plant:

- 1) The amount of fuel requirement is less so that the fuel cost of the plant is less.
- 2) The power generation in nuclear plant has a critical operation so that the variation of the load on the plant is very less. The average load is high. The load factor of the plant is high, i.e., more than 80%.



- 3) It is located at the load centre. Cost of transmission n/w is reduced.
- 4) Land requirement is less.

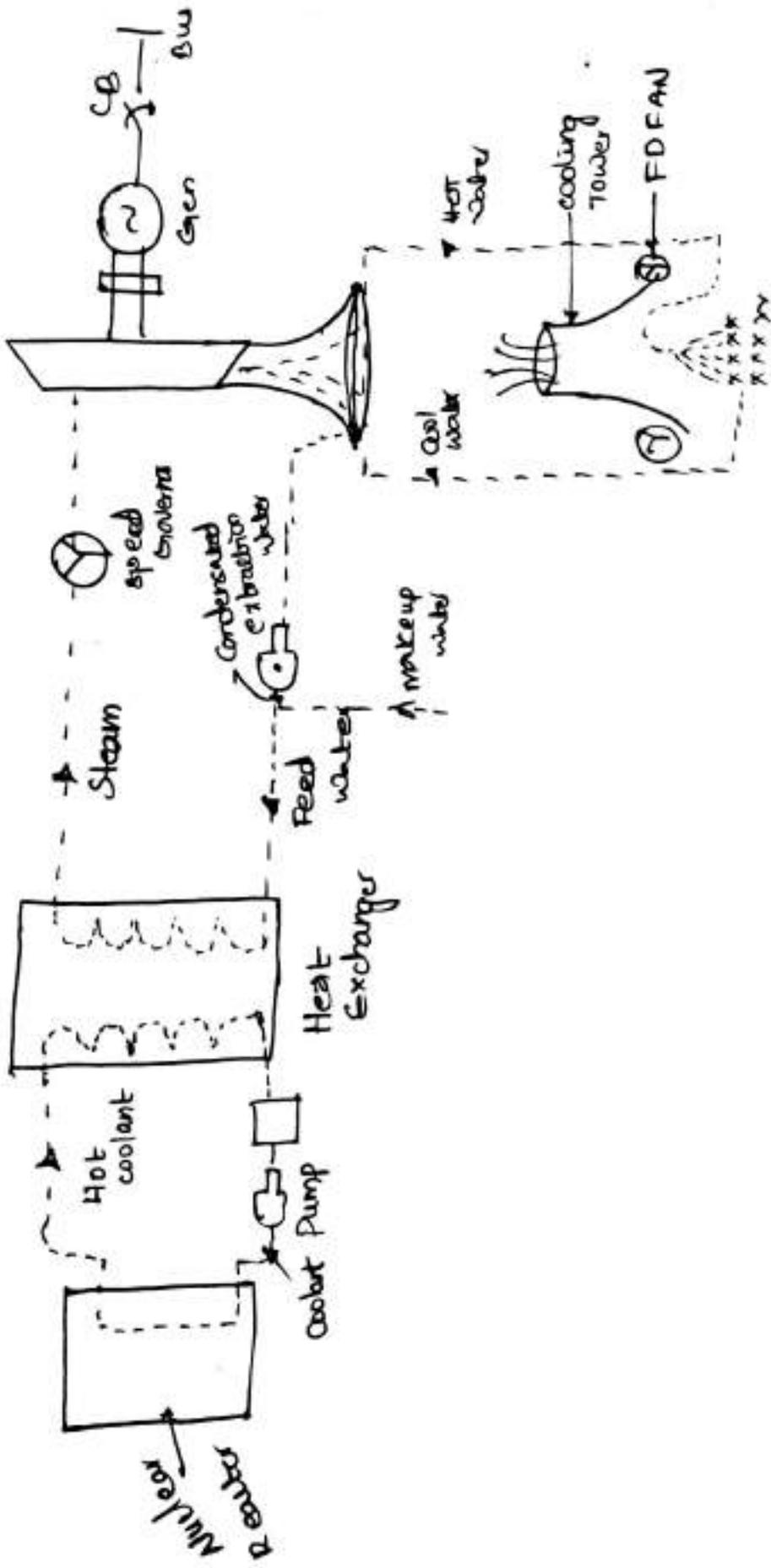
* Disadvantages:

- 1) Fixed cost is high.
- 2) Power generation is critical, skilled employees are required. The cost of the employees is high.
- 3) Due to the radioactive material, atmospheric pollution is high. In order to reduce the atmospheric pollution, maintenance cost is increased.

$$\rightarrow \text{Cost/unit} = \frac{\text{Fixed cost} + \text{Running cost}}{\text{No. of units}}$$

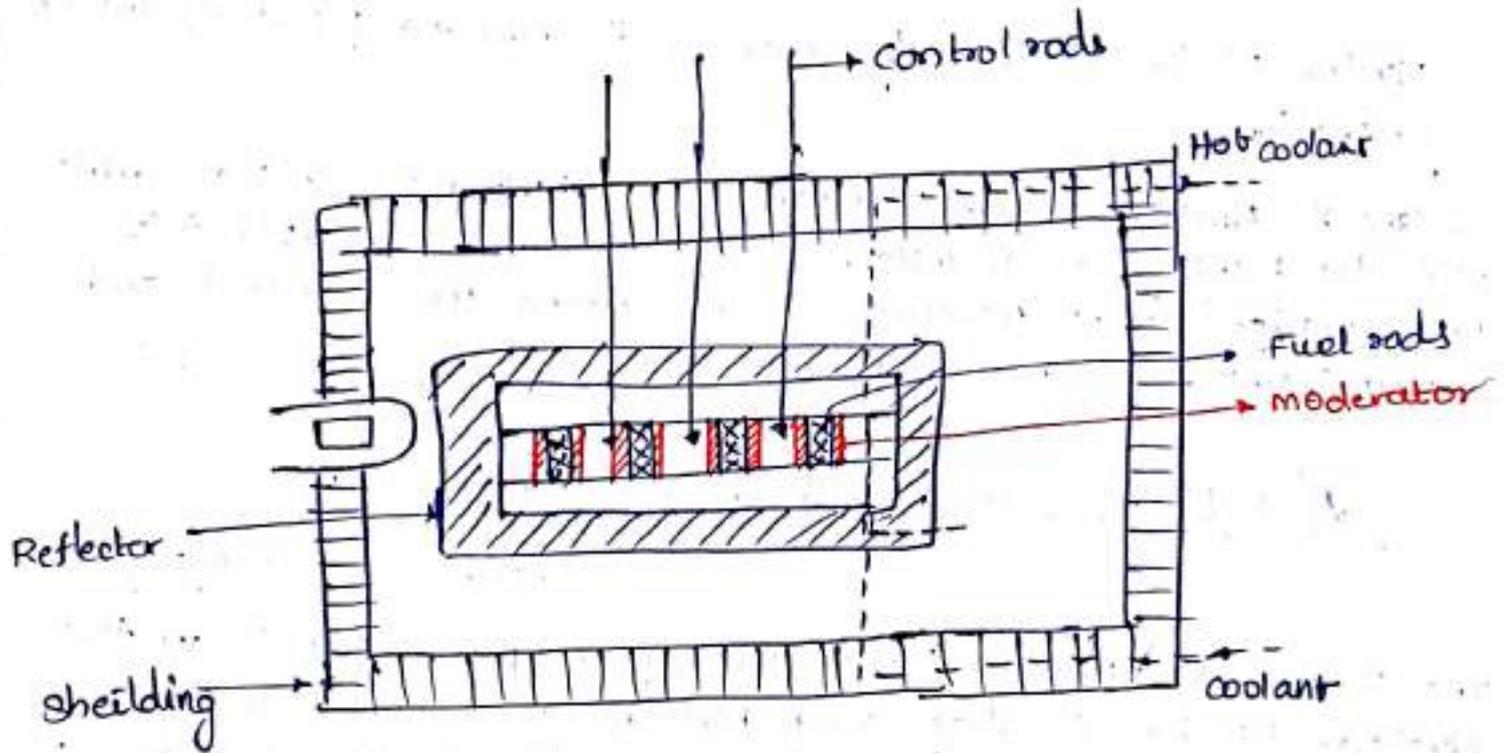
(Salaries + fuel cost + maintenance)

Nuclear plant:



Manish Sahasr and the generator in nuclear plant are similar to that of thermal plant. The boiler is replaced with nuclear reactor along with the heat exchanger

Details of Nuclear Reactor



Fuel rods

The uranium isotopes are normally used as fuel rods in nuclear plant

U^{235}_{92} → Natural Uranium 0:7% of Uranium

U^{238}_{92} → enriched Uranium 99.3%

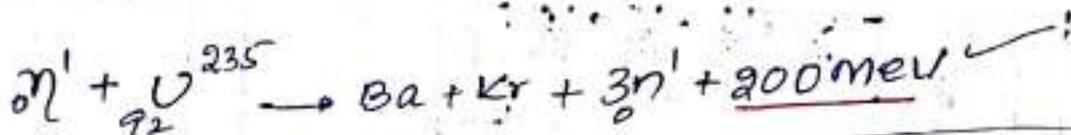
Most of the Nuclear Reactor in India is using Natural Uranium as the fuel.

Different ways to start Nuclear Reaction

- (i) Elastic Nuclear Reaction
- (ii) Inelastic Nuclear Reaction
- (iii) Neutron capture
- (iv) Nuclear Fission ✓

Nuclear Fission is normally used in the Nuclear plants for the power generation.

In case of Nuclear Fission, the high speed neutron is able to collide with the larger atomic molecule so that it is converted into two smaller atomic molecules, Few neutrons are released and certain amount of heat also released.



$1 \text{ a.m.u} = 930 \text{ meV}$

The Released neutrons are once again participated in the Nuclear Fission so that each neutron will release 3 more neutrons and it will be continue till the radioactive material exhausted after half life period. it is also called as chain Reaction.

If uranium U^{238} is used as a fuel, it is first converted into plutonium 239 (Pu^{239}), subsequently it will be converted into two smaller molecules.

In some countries thorium (Th) is also used as a fuel thorium is treated as enriched material. The thorium is converted into U^{239} , U^{233} is converted into fissile material.

Fissile material \rightarrow ${}_{92}^{235}\text{U}$

Enriched material \rightarrow ${}_{92}^{238}\text{U}$, ${}_{90}^{232}\text{Th}$ (Not Fissile)

Rare material \rightarrow ${}_{92}^{233}\text{U}$, ${}_{94}^{239}\text{Pu}$ (Fissile)

The enriched materials are converted into rare materials. The rare materials are the materials which are not available on the Earth surface directly.

The power generation in a Nuclear plant can be analysed in terms of the multiplication factor (or) Reproduction Factor (K).

Multiplication Factor (or) Reproduction Factor (K)

$$K = \frac{\text{No. of Neutrons in a cycle}^{\text{Release}}}{\text{No. of Neutrons lost in the same cycle}}$$

$K = 1.0$ Critical condition.

$K > 1.0$ Nuclear Reaction was Build up

$K < 1.0$ Nuclear Reaction is slow down

In a practical case the value of K is slightly maintained as > 1

Critical Mass :

During the Nuclear Fission, there may be some loss of Neutrons. The amount of material which is participated in the Nuclear Fission. In order to maintain the value of $K = 1$, to compensate the loss of Neutrons is called as critical mass. In the Nuclear plant.

Moderator:

The purpose moderator is to reduce the speed of the Neutron which will collide with Fuel rod.

Liquids: H_2O — water [Fuel: ${}_{92}^{238}U$]
 D_2O — Heavy water [Fuel: ${}_{92}^{235}U$]

Reflector:

During the Nuclear Fission, the Neutrons are Released, the Released Neutrons may try to escape from the Nuclear Reactor. It is necessary to prevent the escaping of the Neutrons, for which the reflector are employed.

Solids

Graphite (or) Beryllium.
 ↓
 less cost

Shielding:

During the Nuclear Fission, β , γ particles are Released in addition to Neutrons, the velocity of these particles are very high. When compared to neutron, the Reflector cannot prevent them. When these particles are enter in to the atmosphere there is a radio active pollution. The shielding is employed in order to prevent the β & γ particles to enter in to the atmosphere. The shielding is employed by reinforce concrete Cement in the form of wall. When the β & γ particles are collide with the concrete wall, they lose the energy and become dead.

In order to slow down the Nuclear Reaction, the control rods are used, when the no. of Neutrons loss can be more than the no. of Neutrons Released, the Nuclear Reaction can be slow down. The materials which are used for the control rods should be capable of absorbing the Neutrons. In order to slow down the Nuclear Reaction.

Boron (or) Cadmium used as control rods.

Coolant:

During the Nuclear Fission certain amount of heat is released the Released heat is to be collected in order to produce the steam from the feed water, the coolant is used. The purpose of the coolant is to collect the heat released in the Nuclear Reactor and give exchange with the Feed water at the heat exchanging chamber. So that the feed water is converted into steam and it can be supplied to the turbine.

Liquids → H_2O & D_2O

gases → H_2 (or) Helium. (Normally we use Low Molecular weight because high speed)

To prevent fire extinguish we go for Helium.

Liquid metal: Na (or) K → (cost is more)

${}_{92}^{238}U$ → H_2O (moderator and coolant)

${}_{92}^{235}U$ → D_2O (moderator and coolant)

} to reduce cost

Reactors based on speed of Neutrons.

- I. Thermal Reactors - $\leq 2000 \text{ m/sec}$ (India)
- II. Fast Breeder Reactors - $> 2000 \text{ m/sec}$

The Reactors in India to generate the power are thermal Reactors (low speed)

Thermal Reactors classified as

(a) Pressurized Water Reactor (PWR) :-

Fuel: ${}_{92}^{238}\text{U}$

H₂O: Moderator & coolant

Graphite: Reflector

Boron (or) Cadmium: control rods.

→ pressure & Temperature of the steam 140 kg/cm² & 274°C

The pressure & Temperature of the steam in a Nuclear plant are less than the pres & temp of steam in thermal plant [∴ 160 kg/cm²]

Drawbacks.

The overall efficiency of PWR is around 30% only.

The efficiency can be increased to 30% by using boiling water reactor

(b) Boiling Water Reactor (BWR) :- → (First Reactor in India Maharashtra, Tarapur)

Fuel: ${}_{92}^{238}\text{U}$

H₂O: Moderator & coolant

Graphite: Reflector

Boron & Cadmium: control rods.

∴ efficiency ↑ to 30%.

① CANDU → Canadian Deuterium & Uranium Reactor :
 (Heavy Water Reactors (HWR))

Fuel : ${}_{92}^{235}\text{U}$

D₂O : Moderator & coolant

Reflector : Graphite

Control rods : Not required*

In order to slow down the Nuclear Reaction, more volume of Heavy water can be allowed in to the Nuclear Reactor so that the velocity of the Neutron can be made as zero. When the velocity is zero, there is no further Nuclear Fission.

Most of the Reactors in India are these type.

② Fast Breeder Reactor :

Fuel : ${}_{92}^{238}\text{U}$ (enriched material)

Moderator : Not employed*

Coolant : Gas* (Helium)

Reflector : Graphite

Control rods : Boron (or) cadmium.

Nuclear plants in India :-

- | | | | |
|----------------------|---------------|------------------------------|---------------------------|
| 1. Tarapur | → Maharashtra | (BWR) | } ${}_{92}^{238}\text{U}$ |
| 2. Rana Pratap Sagar | → Rajasthan | (CANDU) | |
| 3. Kalpakkam | → Tamilnadu | (CANDU) | |
| 4. Narora | → UP | (CANDU) | |
| 5. Kakrapar | → Gujarat | (CANDU) | |
| 6. Kaiga | → Karnataka | (CANDU) | |
| 7. Kudankulam | → TN | (Water cooled Water Reactor) | |
- (1000 MW) at 24.5 KV
 modern Reaction turbine.

* The power generation in nuclear plant is difficult to control so that the avg load on the plant is high hence it is used as Base Load plant:

Power Generation : in Gas plants :

The power generation in the Gas plants is having two cycles

1 cycle :

The compressed air is mixed with the gas (CH_4) along with proper ignition to make the combustion of the gas the energy released by the combustion of the gas is able to rotate the turbine, which in turn rotate the generator to convert the rotation energy into electrical power

2nd cycle :

During the combustion of the gas, the flue gases are released which are having certain temperature the flue gases are send in to the boiler in order to heat the water in the tubes so that the steam can be produced, which will rotate the turbine, so that the rotation energy is converted into electrical power by using a generator.

The combustion of the gas is at a faster rate when compared to the combustion of the coal hence it is used for Peak Load applications because it is first Synchronising unit. The cost of the fuel is high so that it cannot be recommended as a Base Load.

Installed Capacity In India

70,000 MW as on 31-03-2014. closing of Financial year

- 58% Thermal plants
- 22% Hydel plants
- 07% Gas plants
- 03% Nuclear

→ Remaining Non conventional
[Solar, wind & Biomass]

Hydel plant	Thermal plant	Nuclear plant	Gas plant
High	LOW	Highest	Lowest
Lowest	High	LOW	Highest
Lowest	High	Highest	LOW
80-85%	25-30	30-35%	35-40%
50 years	20 years	20 years	15 years
Base (or) Peak 5-10 min	Base 2 hours	Base 2 hrs	Peak 10-15 min

The diesel Generator can be used as stand by supply i.e. Back up it may also recommended during the Peak load.

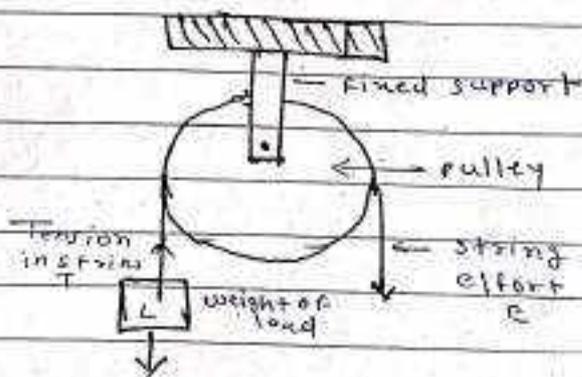


⊕ Equipment used for Loading and unloading of Heavy electrical machine.

- Heavy equipment should not be handled by workers because it can lead to accident and it will take time to handle it.
- equipments like pulley, hand hoists, material handling.
- overhead jip cranes, monorails with trolley hoists, titt take block, road transport, automobile tractor & railway cranes, electric hoists, jacks, compound block etc can also be used for handling, loading & unloading of electrical machines.

⊕ pulley

पुली एक सामान्य lifting machine होता है जिसका उपयोग प्रायः घरो में या बास पास किया जाता है।



इसमें एक fixed controller बस होता है। जिसके धारों पर रॉन्डो बने होते हैं जिस पर इसी लपेटा जाता है यह एक fixed point (केन्द्र) में लटका रहता है तथा इस fixed point के दोनों तरफ freely चलने की सक्षमता है।

→ यह मुख्यतः धातु से बना रहता है, कभी कभी लकड़ी का प्रयोग भी पर किया जाता है।

→ इसका प्रयोग प्रायः workshops तथा factories में heavy loads को उठाने में किया जाता है।

→ इसका प्रयोग भारी engines को भी chain की सहायता से lift करने के लिए।

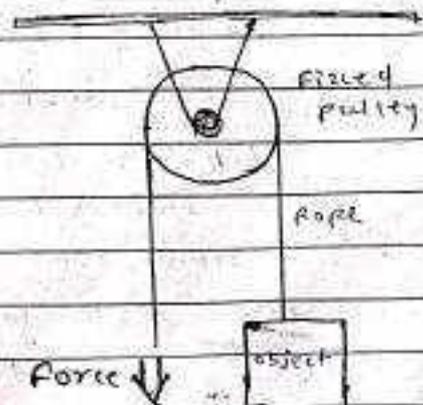
⑦ Types of pulley -

1) single fixed pulley :-

यह pulley का simplest form होता है इसमें इसका rotation axis fixed होता है।

अतः इसे fixed pulley कहते हैं।

चित्र में single fixed pulley दिखाया गया है जिसमें pulley के रॉन्डो से एक string गुजरता हुआ दिखा दे रहा है।

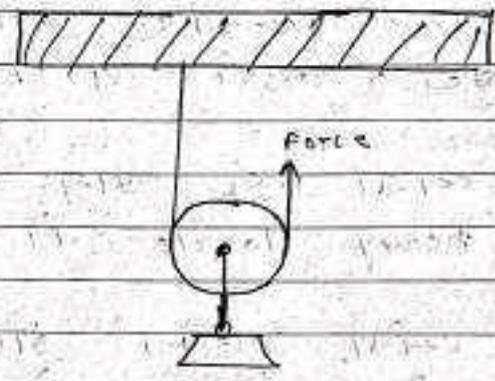




इस प्रकार के pulley का use small load जैसे कुर्छे से पानी वाली या bucket में पानी रखने के लिए किया जाता है।

(2) single movable pulley

इस प्रकार के pulley में rotation के बिना अपने स्थान पर fixed नहीं होता अतः इसे single movable pulley कहा जाता है।



चित्र में load से जुड़ा हुआ single movable pulley दिखाया गया है। इसमें pulley के दोनों सिरे पर तनाव बढ़ता है। इसके मुक्त सिरे पर (free ends) पर लगने वाला effort (बल) इसके तनाव को बराबर करना है।

II Cranes :-

Cranes एवं hoists machine होता है जिसे बड़ी सहायता से भारी machines को lifting तथा displaced किया जाता है। आजकल प्रायः प्रत्येक workshop तथा plants में cranes का use किया जाता है, material handling के लिए भी cranes एवं महत्वपूर्ण भूमिका निभाता है।

Cranes are machine in which hoists, wire ropes or chains and use heavy machines to lift heavy loads from one place to another place or to lift and move heavy loads.

Types of cranes-

- 1) Overhead cranes
- 2) Mobile cranes
- 3) Truck mounted cranes
- 4) Side lift crane
- 5) Crawler crane.

① Overhead cranes.

- 1) crane span structure: composed of main beam, end beam & platform
- 2) crane travelling mechanism
- 3) Trolley
- 4) Lifting mechanism
- 5) control cabin.
- 6) pendant track
- 7) end trucks bumper
- 8) Bridge roller wheel
- 9) Trolley conductor track.

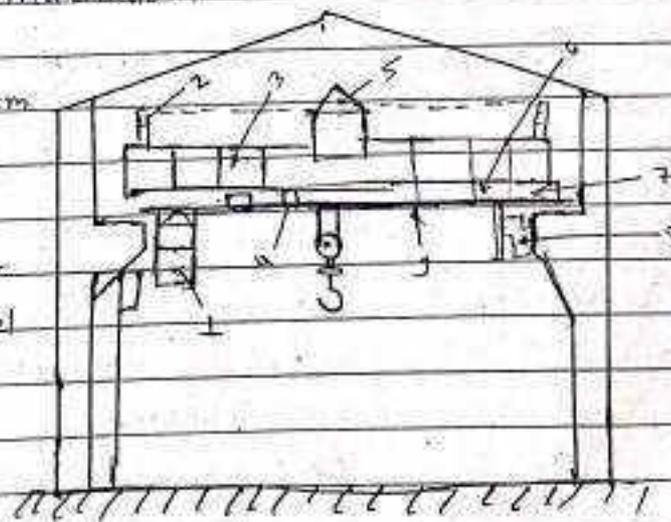


Fig - Schematic diagram of travelling overhead cranes.



→ overhead crane को bridge crane भी कहते हैं। इस प्रकार के cranes में एक hook तथा एक line mechanism और horizontal beam में गति करता है तथा स्वयं में इसके परितः लगे हुए Railing में भी गति करता है।

इस प्रकार पर्याप्त स्पेस वरदान होने के कारण इसके floor obstructions (जमीनी बाधा) या कन्डाक्ट नहीं होती अतः इसमें 3-way motion होता है। इसके लिए special motor का प्रयोग किया जाता है।

Application - Precision work, steel plants, power plants, तथा बड़े machine दुकानों में किया जाता है।

→ इसके मुख्य दो भाग होते हैं:

1) Bridge.

2) Trolley.

Bridge में दो girders होते हैं जो tram wheels से connect रहता है जो बि रेल में गति करने के लिए चलती होती है। (एक electric motor shaft की जुड़ाव है)

- parts -
- 1) crane span
 - 2) crane travelling mechanism
 - 3) Trolley
 - 4) lifting mechanism
 - 5) control cabin

The crab consists of a hoisting gear mounted on a frame. यह फ्रेम एक इगरे चक्के के ऊपर mount है तथा मॉबिल हाइड्रोल के ऊपर गति करता है इस प्रकार लीन तंत्र से गति प्रदान करता है।

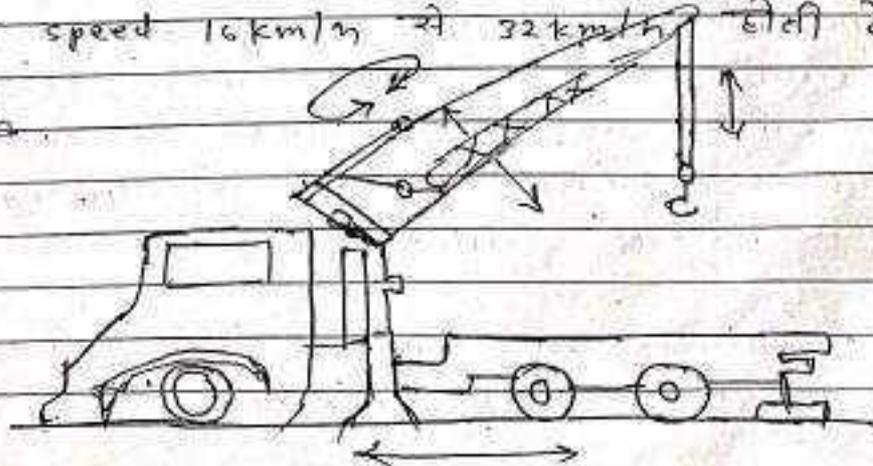
(2) mobile crane - यह सबसे basic type of crane है इसमें truss होता है जो mobile platform के ऊपर स्थापित होता है यह शॉट शॉट रॉल के ऊपर स्थापित होता है।

(3) Truck Mounted Crane - यह crane truck के ऊपर mounted होता है तथा इस प्रकार के crane में mobility या गतिशीलता होती है इसके मुख्यतः दो भाग होते हैं -

(i) carrier, (ii) lifting component

यह दोनों भाग आपस में जुड़े होते हैं तथा truck (सुभालदार) होता है इस प्रकार के crane का प्रयोग शीघ्रता वाले कार्यों में तथा construction, hard तथा श्रवण, सोल गुरुत्व में भी किया जा सकता है। इस प्रकार का crane diesel engine से चलता है एवं इसकी speed 16 km/h से 32 km/h होती है।

Diagram





(4) Jib crane self supported on wall mounted:

इस प्रकार के क्रेन का पदर 5 टन तक के वजन उठाने के लिए बिया जाता है (10m radius तक) तथा भारी machines को उठाने के लिए इसका प्रयोग बिया जाता है।

(II) Hand Hoists इसका प्रयोग medium weight वाले machine के repair के लिए किया जाता है। यह manually क्रेन में horizontally तथा vertically गति करता है।

(III) Electric Hoists इसका प्रयोग medium handlings में करते हैं। यह electricity से operate होता है।

(*) PRECAUTION TO BE TAKEN DURING LOADING AND UNLOADING OF HEAVY ELECTRIC MACHINE

भारी machines को loading unloading करते समय निम्न सावधानियाँ रखनी चाहिए -

(1) machines को hoist - lifting machine, pulley, cables इत्यादि के द्वारा उठाया जाना चाहिए तथा उन machines को समय-समय पर repair करना चाहिए। हमेशा machine में lifting hook को पकड़ करना चाहिए।

(2) machines या motion को नियंत्रित स्थानों से ही उठाना चाहिए।



(iii) उठाने वाले machine अधिकतम तथा न्यूनतम भार उस machine पर लिखा होना चाहिए।

(iv) machine को जमीन पर ग्राउन्डिंग तथा दृश्य नहीं करना चाहिए।

(v) machine को उठाने के लिए इकीलरक workers का प्रयोग करना चाहिए।

(vi) machine को उठाने समय उससे नीचे कोई व्यक्ति या जीवित वस्तु नहीं होनी चाहिए।

(vii) lifting machine का weight उठाए जाने वाले machine से अधिक होनी चाहिए।

(viii) लीटे वाले हिस्से को जंग से बचना चाहिए।

(ix) machine का निर्धारित समय में repair & maintenance होना चाहिए।

(*) Testing & commissioning of different type of Electrical machine.

⇒ Installation: - इसमें कार्य स्वस्थ पर assembly on foundation of site होता है।

electrical मचिन circuit तथा उपकरणों का electrical circuit बनाया जाता है।



equipment बनाये जाते हैं, तथा सभी equipment testing और commissioning के लिए ready रहते हैं।

Testing:- testing से अभिप्राय विभिन्न operations, mechanical, electrical तथा machines में perform test से है।

commissioning:- equipment test होने के बाद commissioning test तथा performance test किया जाता है। इसके लिए training manufacturer को चुना जाता है।

machine के commissioning के पश्चात उसका trial period होता है। trial period के success होने के पश्चात इस machine को नियमित कार्य के लिए फीड दिया जाता है।

Routine activity:-

preventive maintenance. -

यह एक regular periodic planned होता है जिसमें breakdown का outages की संभावना कम होती है।

Breakdown maintenance - जब कोई system में equipment breakdown ही जाता है तो breakdown maintenance किया जाता है।

Emergency Maintenance -

⊕ Various type of test perform on the electrical machine or equipment -

① Mechanical test before commissioning -

- (a) Name plate data should be checked.
- (b) check presence of complete part of machine
- (c) check brush holder & brushes.
- (d) Nut bolts used for fixing machine tightness
- (e) Alignment of shaft coupling.
- (f) check gearing & oiling.
- (g) Bearing noise check.
- (h) check tightness of terminal connection.
- (i) check clearance between stator & rotor.

② Electrical test before commissioning -

- ① check winding resistance with supplier value.
- ② insulation resistance testing (wdg to wdg etc)
- ③ High voltage test
- ④ No-load testing with rated voltage & frequency
- ⑤ load-testing & records verified with data
- ⑥ cooling (temperature) system checking
- ⑦ Earth resistance test
- ⑧ protective device (C.B, fuse, MCB, relay etc)
- ⑨ Fault test

③ Electrical commissioning test :-

यह एक comprehensive test होता है जिसमें equipment test, subsystem test तथा plant तथा सामानों को शामिल होता है।

- यह test installed equipment में किया जाता है।
- इस test से यह पता चलता है कि equipments में कोई effect नहीं तथा यह सही तरीके से स्थापित है इस test के पर्याप्त equipments को supply दिया जाता है या रखता है या machine को supply दिया जा सकता है या machine को operation department को दिया जा सकता है।

④ Electrical preventive maintenance test -

जिसी भी electrical equipment के एक बिना power सिस्टम से connect होता है तथा इसका इसका सिरा load से जुटा होता है abnormal operating condition, short circuit voltage surges etc. temperature cycle, vibration के लिए electrical preventive maintenance किया जाता है।

(5) Factory test - यह test factory के अंदर machine के proper working या operation की check करने के लिये किया जाता है। यह दो प्रकार के होता है -

(i) Factory type test - इस test में नये machine या equipment के लम्बा या आबतन करने के तथा यह check करने के बिना यह निर्धारित working के योग्य है या नहीं। (इस test में machine के design तथा working का परीक्षण होता है)

(ii) Factory Routine test - यह test machine या equipment के वॉल्यूम पर नियमित उचालने को check करने के लिए किया जाता है। यह test एक specified standard के आधार पर किया जाता है। यह test पहले equipment के लिए किया जाता है।

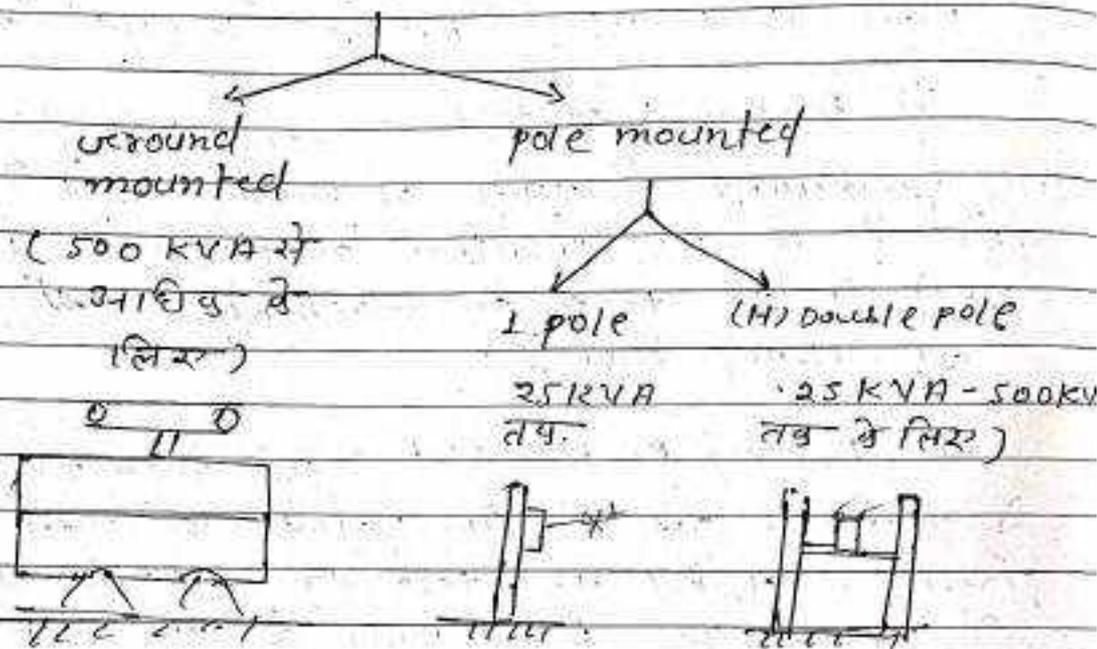
(6) commissioning test - यह test machine के installation के पश्चात् कार्य स्थल पर किया जाता है। इस test में machine के proper operation तथा foundation की check किया जाता है।

(7) Energizing test - इस test में machine को plant के साथ synchronize किया जाता है तथा plant को शुरुआत से synchronize करते हैं। या electricity supply किया जाता है। इस test में voltage, frequency phase sequence, polarity etc को verify किया जाता है। इसमें circuit breaker को on तथा off किया जाता है।

Date: _____
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①
Imp

Transformation
Transformer installation



installation करने के लिए steps

① Inspection of arrival of site

- (a) proper availability of space.
- (b) packing should be checked properly. if any damage or loss of equipment, than intimated to manufacture
- (c) check oil leakage.
- (d) flooring should be moisture free, dust free, big grass free.
- (e) provide lugs & sockets for lifting the transformer.
at the time of lifting proper balancing should be checked.



② Foundation -

- (a) It should be strong bear the load of transformer without any vibrations
- (b) base should be horizontal.

③ H pole structure or 1 pole / plinth pole structure
are -

(depend upon size, weight & rating)

- (a) upto 500 KVA → pole mounted (3-φ)
- (b) upto 2.5 KVA → 1-pole mounted (1-φ)
- (c) 2.5 to 500 KVA → H pole mounted (3/1 φ)
- (d) more than 500 KVA → plinth type or multiple pole mounted (3-φ)

④ ground clearance →

ground clearance is 3x2m
→ लंबाई (नीचे की दूरी) 3m / चौड़ाई 2m.

in this space is distribution should be provided on the pole.

⑤ doors (locking)

असुर

इसबाधित चीजों से बचाने के लिए D B को
locked करना चाहिए।



- (7) Anticlamping device should be provided on the structure. (pole structure)
- (8) Bushing, lightning Arrester, Insulator of all three phases should be tightened & cable conductor shank be properly connected & tightened
- (9) cross arm or angle iron should be properly connected & tight
- (10) conductor should be ACSR.
- (11) properly clearance arc distance should be provided near to road & populated area.
- (12) Transformer rating should be selected according to the load and the site.
of Area.

IMP

Installation of Induction motor and other Rotating Electrical machine at commissioning.

① Acceptance and storage: and storage at site.

(a) proper availability of space.

(b) packing should be checked properly. if any damage or loss of equipment, then intimated to manufacture.

(c) flooring should be moisture free, dust free, big grass free.

(d) motor को लान की सहायता inclined जेन पर की सहायता से नीचे उतारा जाता है कई स्थानों पर rope (रस्सी) तथा wedges की सहायता से machines को सुरक्षित तरीके से unload किया जाता है।

(e) कुछ warning instruction जैसे "no smoking", "handle with care", & do not turn over यदि वो उल्टा से पालन होना चाहिए

(f) motor से floor में किसी प्रकार का vibrations नहीं होना चाहिए vibrations से बचाने के लिए rubber blocks provide किया जाता है

(2) Shape & size of foundation

(v) foundation machine के weight को सह वरने से सक्षम होना चाहिए।

(b) यह machine के alignments को maintain करने योग्य होना चाहिए।

(c) यह vibrations तथा unbalance forces को सहन (बहन) करने योग्य होना चाहिए।

(3) Typing of supply is controllable

(a) motor के manufacturer या कंपनी को motor के साथ हरावा Terminal diagram तथा इसके स्थापना के बारे में connection diagram, भेजना चाहिए।

(b) भेजे गये दिक्कतों के अनुसार machines के cable का connections करना चाहिए।

(c) machines properly earth होना चाहिए।

(d) cable का साइज इस प्रकार होना चाहिए जिससे वह motor के हवा load व्यवस्था flow करने में सक्षम हो।

(e) cable को प्रायः जमीन के अंदर trench की सहायता से 25 cm चौड़ा तथा 20 मीटर की गहराई में स्थापित करते हैं, trench के नीचे 15cm कम चौड़ाई का dry रेंट की परत बिछाते हैं।

(4) checking air gap between stator & rotor

(A) Stator तथा rotor के बीच का गैप मशीन के आधार पर निर्धारित करता है।
 dc motor की अपेक्षा ac motor में यह गैप कम होता है।
 air gap की मापन करते हैं।
 लंबे steel के feeler का उपयोग करते हैं। इसे मशीन के चारों ओर Top, bottom, front, back पर मापन करते हैं।

(5) coupling

motor को rod की सहायता से generator या prime mover से couple करते हैं।

coupling can be provided by pulleys running over the belt (not except for d.c series motor)

$$\text{Load speed} = \frac{\text{motor speed} \times \text{diameter of rotor pulley}}{\text{diameter of load pulley}}$$

(6) Trail Run, No load Run

motor की manufacturer से name plate के अनुसार सुमात्र देना जाता है। check किया जाता है। यह trail Run 2-3 second के लिए होता है। इसमें motor की rotation starting current, function of contactor, circuit breaker, relay, इत्यादि की जांच की जाती है।
 Temp, smock, smell तथा अन्य conditions को check किया जाता है।

⑦ installation of cooling system for large machine

for medium & large rotating machine
Hydrogen gas used in cooling system

इसके लिए machine के चारों ओर cooling ducts provide किये जाते हैं।

जो machine के radiators के पारस पान का use करते हैं।

Step ⑧ Procedure for Dismantling of a large rotating machine dispatched in fully assembled condition.

⇒ For large rotating motor को dismantling करने के लिए निम्न लिखित steps manufactures के द्वारा बताये जाते हैं -

- (a) check all the parts & assemblies for identification marking
- (b) disconnect all oil pipes at the bearing & joints
- (c) sleep rings को अलग करना तथा brush holder को remove करना
- (d) remove the side cover plate at the end and the lifting bolts.



- (e) separate the stator head plate
- (f) remove the bearing of caps
- (g) cool the rotor out of the stator
- (h) shift the stator by means of suitable arrangement
- (i) check the insulation resistance of winding & insulating parts of the brush gear etc.
- (j) check the condition of commutator bars and commutator bars

UNIT - 2

commissioning of Electrical equipment and machine.

Testing of transformer (static equipment)

IS 2026/1962 के अनुसार Transformer विद्ये जाने विभिन्न test निम्न - लिखित है -

(i) Routine test :-

Routine test वह Test है जिसे उद्योग (industries) के सभी transformers में किया जाता है। ये test नि. लि. है -

- (a) measurement of winding resistance.
- (b) measurement of impedance, short circuit impedance & copper loss.
- (c) measurement insulation Resistance (IR test)
- (d) ~~se~~ - polarity test
- (e) phasing out test
- (f) Magnetising current and core loss.
- (g) HV test
- (h) load losses
- (i) No load loss and no load current.
- (j) Dielectric strength of transformer oil
- (k)

(ii) Type test

Type test वह Test है जो कुछ उपकरणों पर किया जाता निम्न निर्माण नईत माता में है -

example -

यदि manufacture के द्वारा 100 transformer जो same dimension तथा same इन्वोल्यू का भेजा जाता है तब इनमें से एक

या की Transformer लेखर निम्न Test किया जाता है

- (a) Temperature Rise test
- (b) impulse test
- (c) Noise level test

③ Supplementary test

यह Test है जिसे Transformer के बारे में अतिरिक्त जानकारी के लिए किया जाता है

- (a) Efficiency test
- (b) back to back test

④ Commissioning test :-

यह Test Transformer की supply देने के पूर्व किया जाता है यह Test Transformer के kVA rating, voltage rating तथा site पर उपलब्ध सुविधाओं के आधार पर किया जाता है।

ISS 1886-1967 के अनुसार, निम्न लिखित Test किये जाते हैं-

- (a) General observations
- (b) Secondary injection test
- (c) primary injection test
- (d) A overall inspection of the control and relay panels, cable junction boxes is carried out and observed if

any connection is left open.

(e) Tests on relay such as over current, earth fault, reverse power etc. is carried out for their operation.

(f) voltage ratio with equal tappings on all phases, can be checked.

(g) Measurement of earth resistance and necessary steps for bringing it within suitable value.

(h) Tests carried out on buchholz-relay for its correct operation.

(i) Test can be carried out, on cooling fans, cooling water pumps, about their direction of rotation, speed and troubles in starting etc.

(j) If no loading tap changing arrangement is there its operation can be checked with the indication of tap number on panel and buzzer etc. at the time of change.

(k) If required phasing out is carried out.



✓ 1000

Commissioning of power Transformer

⊕ Preparation prior to Commissioning.

- (i) Fitting of accessories.
- (ii) Filling of oil
- (iii) Drying out
- (iv) charging of breather with fresh silica-gel
- (v) clearing of porcelain of bushing with dry chloroethylene and then by dry cloth.
- (vi) conductors and/or cables
- (vii) Earthing of tank and cover.
- (viii) Neutral earthing as per schematic diagram
- (ix) connection of protection circuits and alarm circuit with current transformer.
- (x) setting of relays.

After the above preparations, the commissioning tests are carried out.

pre-commissioning checks on →

- (i) Transformer
- (ii) Tap changer bushings
- (iii) protection system
- (iv) control system
- (v) marshalling kiosks
- (vi) main connections
- (vii) control connections.
- (viii) cooling system.

precautions to be taken while commissioning
Transformer are -

All the basic safety rules should be followed.

- ① To check the permanently installed transformer tank ground.

★ LEMP

Test ON Three-phase Induction motor:

उत्तम induction motor में निम्न टेस्ट किये जाते हैं-

- (i) Type test - यदि किसी industry या factory से 100 (सैकड़ों) induction motor का उत्पादन (manufacturing) करता है तो उसमें से randomly किसी एक या दो induction motor पर ही यह type test किया जाता है और इसी दो test से बाकि की भी performance decide कर ली जाती है।
- (ii) Routine test - इस standard के अनुसार routine test industry में manufactured होने वाले प्रत्येक motor में होता है। जब industry में motors निर्मित होता है तो उसके प्रत्येक motor को इस test से गुजारा जाता है।
- (iii) special test - यह test motor के किसी

विशेष स्तरों को जानने के लिए किया जाता है। जैसे noise level, induced voltage में harmonics की उपस्थिति, zero phase sequence के impedance आदि को determine करने के लिए यह test किया जाता है।

(iv) pre-start test - induction motor को start करने से पूर्व निम्न test किये जाते हैं -

- (i) Measurement of resistance of winding.
- (ii) High voltage test.
- (iii) Trial start test.
- (iv) No load test.
- (v) Load test.
- (vi) test on cooling system.
- (vii) test on lubricating system.

(v) performance test - (i) no load test, (ii) Full load test, (iii) speed control test, (iv) speed-torque test, (v) speed stopping/reversing/braking test.

IMP

Installation and commissioning of induction motors and other electrical ^{rotating} Machine.

① Acceptance and storage at site. निर्माता से machine sample करने के बाद इसे स्थायी तथा अस्थायी रूप से store करने से पहले machine का निरीक्षण किया जाना चाहिए। कि machine specification में है और हमारी requirement के अनुसार ही।

(ii) shape & size of foundation: यह मागी जाती है कि machine के आधार रखा जाता है तथा इसे support प्रदान करता है यह एक भाग foundation सुझाता है। यह foundation machine के weight को सहाय करेगी और होना चाहिए तथा vibration free होना चाहिए।

(iii) Laying of supply and control cables

(iv) Making the motor/machine ready for installation
(एल साइड, Nut bolt बदले, rotor shaft को सुगाव देकर) insulation resistance measure करें यह सब packings की installation के पहले करना चाहिए।

(v) Installation of the motor on foundation and alignment of

(vi) checking of air gap between stator & Rotor.

(vii) coupling.

(viii) Trall run. No load run under close supervision.

(ix) Installation of cooling system for large machines

(x) Installation of fitting other parts Accessories, piping.

(xi) Installation of motor with gear drive

(xii) Drying-out the wet parts.

(xiii) setting / adjusting of protection relay.

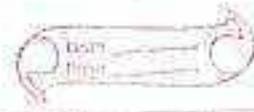
(xiv) setting / adjusting of protection relay.

(xv) Tests on motor starter and associated equipments

(xvi) Final commissioning and handing over to customer's operating staff.

UNIT-3

Earthing System



Earthing

earthing का अर्थ होता है connecting earth terminals to earth terminal electrode installed solidly in the mass of earth.

electrical connections to the general mass of earth, whose dimensions are very large, is as comparison to the electrical system being considered.

④ Need of earthing

the earthing की आवश्यकता निम्न कारणों से होता है -

- ① human life तथा properties को electric shock तथा electric fire से बचाने के लिए इसका प्रयोग किया जाता है।
- ② fault condition में सुरक्षित line के voltage maintain करने के लिए ताकि insulation Breakdown न हो।
- ③ fault condition में earthing के द्वारा protective devices को low impedance पार्थ provide करता है।
- ④ arcing burn को reduce करता है।



⑤ induced current के लिए पाथ provide कराता है।

Purpose of earthing -

⑥ to maintain the line voltage constant

⑦ एग स्टैल earthing system वह है जो किसी ele. machine या equipment के heavy current (in fault condition) को low resistance पाथ provide कराये।

Factor

⑧ earth resistance को affect करने वाले कारक -

① earth condition of soil

② temperature of the soil.

③ quantity of moisture in the soil.

④ shape & size of earth electrode.

⑤ different types of material use to make earth electrode.

⑥ depth to which electrode is embedded (जहाँ electrode को बिजली रास्ता में लगाया गया है।)

⑦ quantity of charcoal and salt powder in the earth electrode path (गुत्ता)

⑧ quality of the earth conduction



10/10

Earthing system

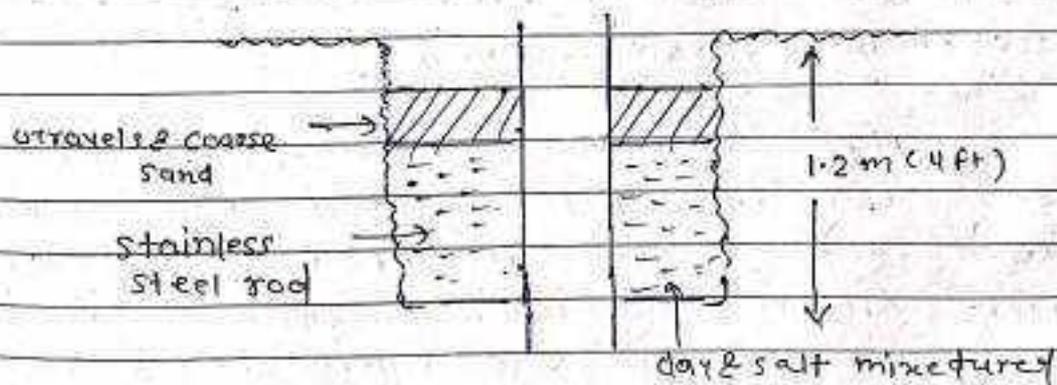
Earthing system को निम्न भागी में विभाजित किया जा सकता है -

- ① pipe earthing.
- ② plate earthing.
- ③ strip earthing.
- ④ Rod earthing.

pipe earthing -

- ① galvanized pipe earthing 38 mm in diameter & 2 meter long is driven in to the ground.

his used has the earth electrode, ~~high resistance~~



- ② its resistance must be cap bellow specified limit, percentage salt & powder coke are charcoal, to a depth of 70 cm all around the pipe in low resistance.



③ Keeping the the earth moist by pouring water in the pipe in this way low resistance is maintaince in earthing

④ indian electricity rule के अनुसार सभी प्रकार के motor, transformer इत्यादि उपकरणों के frame को लकड़ा metal part को को separate connections के द्वारा earth किया जाता है।

⑤ machine के foundation bolt का प्रयोग प्रायः earthing से connect करने के लिए किया जाता है।

② plate earthing.

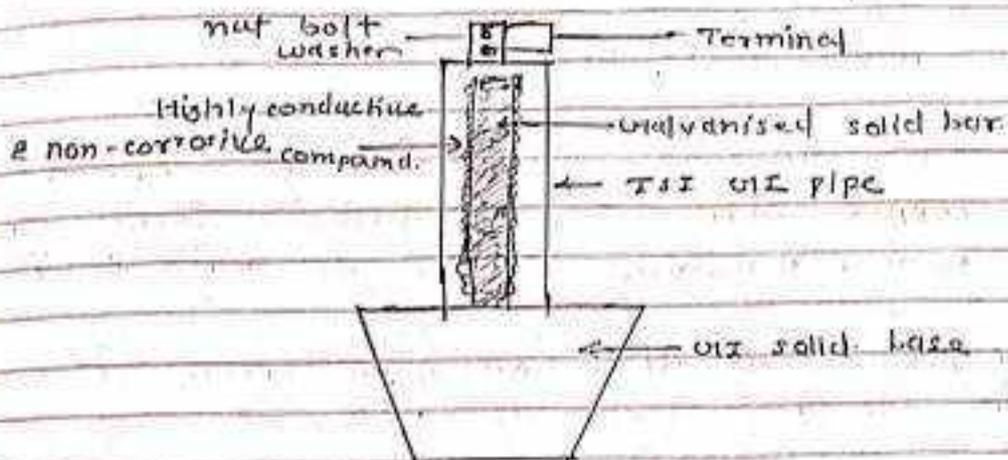
① Plate earthing can be provided with help of copper or plate.

② when or plate is used it should not less then $60 \times 60 \times 6.35 \text{ mm}$
cm cm

③ plate को vertically (सतहसे) उभारनी गहराई पर इस प्रकार स्थापित किया जाता है जिससे इसमें coke तथा कमच का alternate layer जिसकी minimum thickness 15cm होना है, इस ब्लैक के चारों तरफ भेगाया जाता है।

④ earth wire को अलग से एक plate से bolt के द्वारा जोड़ा जाता है इसके साथ तथा

वायर का की प्रयोग किया जाता है।



5) earth wire should be made of same material as that of earth electrode

6) the minimum section area electrode not be less than 0.02 square inch & not be more than 0.15 square inch

7) earth conductor का size live conductor के size से छोटी से कम नहीं होना चाहिए।



(3) Strip earthing (1) इस प्रकार के earthing का use rocky soil में नहीं किया जाता है। इस earthing का use करते हैं।

(2) इस प्रकार के earthing में 5 sq. cm के copper wire का use करते हैं जिसका आकार 25mm x 1.6mm से कम का उपयोग करते हैं।

(3) copper strip को horizontal trench की सहायता से स्थापित किया जाता है।

(4) Rod earthing

(1) इस प्रकार के earthing का उपयोग रेतीली स्थानों पर किया जाता है।

(2) इस प्रकार के earthing में copper rod को hammer की सहायता से सीधे ही अर्थ (ground) में स्थापित कर लिया जाता है।

(3) यह सबसे सस्ती विधि होती है तथा strip earthing की तरह इसके में low resistance का मान होता है।
(532)

1 mark

Methods of reducing earth resistance.

① By using of Number of earth electrode in connect parallel - parallel में एक से अधिक earth electrode connect करे से resultant resistance का मान कम हो जाता है।



② by increasing depth of pit (गहरा) एप the earthing - गहरे की गहराई एक करे पर earthing resistance का मान कम हो जाता क्योंकि अधिक गहराई पर अपेक्षा-कृत अधिक धातु उपलब्ध होती है।

③ by using large size of earth electrode -

$R \propto \frac{1}{A}$
 $R \propto \frac{1}{AT}$

एक बड़ा earthing electrode के क्षेत्रफल का मान अधिक होने पर resistance का मान कम होता है।

④ earthing wire को चारों छे वल्लव को बड़ा कर इसमें तमब वषा चादकील के layer को निखाकर earthing resistance का मान कम किया जाता है। in dry place

5) गमी के दिनों में सहस्रकोय layer के ऊपर जमठ पाली वा बोल पाइय के द्वारा न- गला जाता है जिससे earth resistance का मान कम हो जाता है।

37/11/24
3

Measurement of earth resistance with help of earth tester

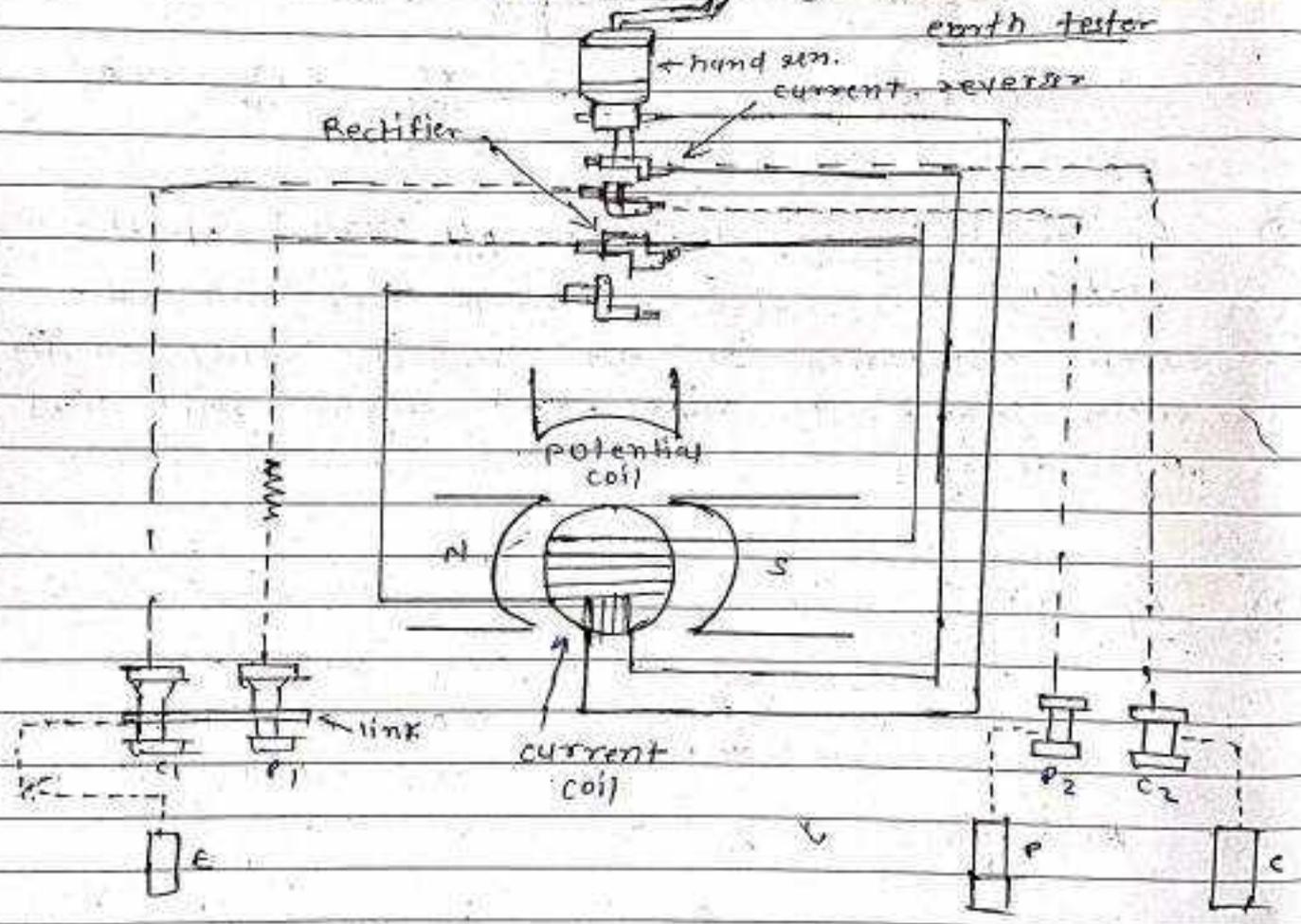


Diagram 3

एक earth resistance measurement के लिए earth tester को स्थिति में दिखाया गया है।

यह एक special type measure megger होता है जिसमें megger के प्रतिरक्त को special part होते हैं -

- (1) rotating current reverser
- (2) rectifier

ये दोनो additional equipment commutators की तरह होते हैं तथा 'D' shape segments से बने होते हैं। इसे hand driven generator से शाफ्ट में स्थापित किया जाता है।

प्रत्येक commutator में चार divided segments होते हैं। प्रत्येक bus या एव जोड़ा (रक्त) उस प्रकार स्थापित होता है जिससे वह commutator के किसी एक segment से connect होता है। Bus या इसका रक्त commutator में उस प्रकार स्थापित किया जाता है जिससे वह commutator segment से continuously connect रहता है।

एक earth resistor में चार terminal P₁, P₂, C₁, C₂ होते हैं। दो terminal P₁ तथा C₁ को जोड़कर common point होता है जिसे अन्य दो terminal P₂, C₂ को earth auxiliary electrode P & C से connect किया जाता है।



Earth tester में pointer वा deflection earth resistance के मान को दर्शाता है।

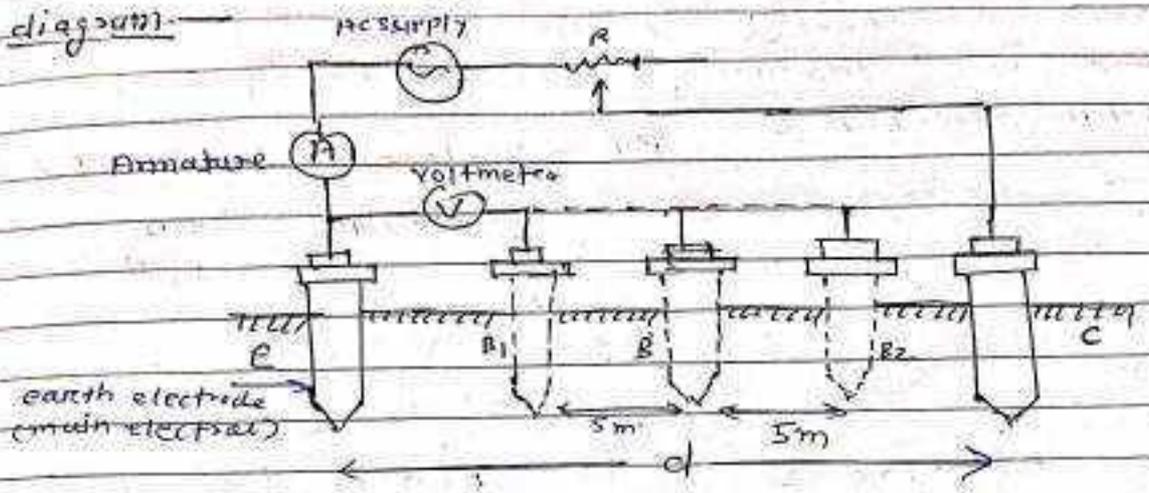
Earth tester एक permanent magnet moving coil instrument होता है तथा यह केवल dc supply में operate होता है बिना current reverser तथा rectify device वा प्रयोग करके इसे AC से supply किया जा सकता है।

AC supply का use करने से मीटर में back emf के कारण induce होने वाले अनवांछित effects eliminate (निःशुद्ध) हो जाता है।
अन्यथा मीटर में electrostatic action वा प्रभाव नहीं बन ही जाता है।



④ Measurement of earth resistance using "fall of potential method"

diagram



चित्र में Fall of potential method का circuit diagram दिखाया गया है इस विधि में तीन electrode का use होता है जिसमें से दो auxiliary electrode तथा एक main electrode होता है

चित्र में E = earth electrode
C & B = auxiliary electrode

electrode C की electrode E से इस प्रकार दूरी नापा जाता है जिससे two resistance area do not overlap (area overlap नहीं होता) तथा electrode B की भी E और C के बीच में रखते हैं

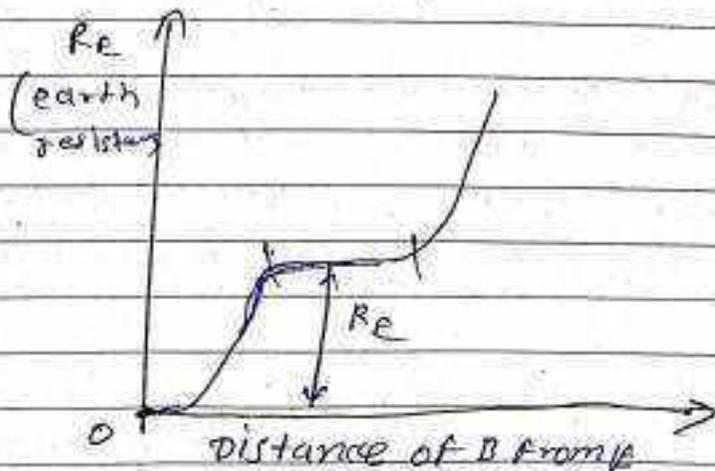
earth electrode E का auxiliary
 electrode C से बीच supply दिया जाता है।
 तब electrode E और B के बीच voltage
 drop को measure किया जाता है। इस पर
 earth resistance

$$R_E = \frac{\text{Voltage drop between E \& B}}{\text{Current through earth path}}$$

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

electrode B की बिना B₂ पर से
 स्थान पर ले जाने पर electrode E का C
 के बीच का resistance area. overlap नहीं
 होना चाहिए।

इस स्थिति में resistance का माप
 measure किया जाता है (From B₁, B & B₂)
 तथा इसका Average लिया जाता है जो कि
 earth resistance electrode (main electrode)
 के resistance के बराबर होता है।



→ electrode distance table.

Depth of earth electrode	Minimum distance between the earth electrode & electrode C (m)	Distance between the earth electrode & electrode B (m)
1	30	15
2	40	20
5	60	30
10	85	43
20	120	60

UNIT-4Maintenance

Definition - Maintenance is the process for maintain an equipment or machinery in a proper and efficient condition for getting satisfactory and trouble free service.

Types of Maintenance -

Maintenance can be classified into following types

- ① Breakdown maintenance
- ② scheduled maintenance
- ③ preventive maintenance

① Breakdown maintenance:-

Breakdown maintenance तब किया जाता है जब कोई equipment या machine normal या सामान्य रूप से कार्य नहीं करता या कार्य करने में असमर्थ होता है

for example → ① electric motor का start न होना
 ② बेल्ट का टूटना इत्यादि
 ③ winding का जलना
 ④ sparking होना

इस condition में Breakdown maintenance किया जाता है)

इस अवस्था में Production department maintenance department को लिख अनुरोध करता है।

Maintenance department इस अनुसंधान के आधार पर इस equipment की Test करता उसमें Fault होता है तथा उसके लिए आवश्यक maintenance provide करता है।

निम्न कारणों से equipment breakdown से सदा है -

- ① incorrect installation
- ② faulty design construction
- ③ lack of lubrication. (जो वही)
- ④ failure of cooling system.
- ⑤ by avoiding miners faults.
- ⑥ external factors - over voltage, over current ect.
- ⑦ by avoiding the ^{abnormal} sound ^{summed} rotating parts.

Disadvantages - the breakdown maintenance

- ① इससे machine या equipment की efficiency reduce हो जाता है।
- ② Break down maintenance की quality पहले की अपेक्षा पहले से कम हो जाती है।
- ③ Break down होने से accident की संभावना बढ़ जाती है सुरक्षा मानक कम हो जाते हैं।
- ④ यह breakdown का समय, स्थान तथा मात्र अनिश्चित होता है जब इससे machine या equipment की खराब होने की संभावना अत्यधिक होता है।

② Scheduled Maintenance

Break down से वो minimise करने के लिए
Scheduled Maintenance दिया जाता है।

⇒ इस प्रकार के maintenance में एक निश्चित
समय अथवा अवाची में उस machine या
equipment inspection, lubrication तथा servicing
दिया जाता है।

⇒ किसी machine या equipment की उच्च
शक्ति के लिए एक निश्चित अथवा
बार-बार Scheduled maintenance करना पड़ेगा।

इस प्रकार के maintenance से machine
में major mesor. Fault नहीं आते जिससे
किसी प्रकार की खराब तथा time की बचत
होती है।

⇒ किसी machine के Scheduled maintenance के
लिए उसके सभी प्लान व आवश्यक सामग्री उपलब्ध
होना चाहिए।

Advantage -

- ① it is reduced the major fault
- ② Breakdown minimise & machine operate
high efficiency.
- ③ इस प्रकार Maintenance से machine
की नियमित रखरखाव तथा निरीक्षण होता है।

③ Preventive maintenance.

preventive maintenance
 work con में एक निश्चित समय अवधि में एक निश्चित तरीके से (Plan + Manpower) से maintenance किया जाता है तथा इससे आर्थिक रूप से machine की कार्य क्षमता बढ़ती है।

इस maintenance का मुख्य उद्देश्य Breakdown से बचना होता है तथा सुरक्षा और कार्य क्षमता सम्बन्धी इसका मुख्य उद्देश्य है।

Types of preventive maintenance -

- ① Routine Maintenance
- ② periodic Maintenance
- ③ over hauling.

(1) Routine Maintenance - यह maintenance संभव होने पर daily किया जाता है।

इस प्रकार के maintenance में visual inspection, minor repair जैसे छोटे parts को replace करना शामिल है।

Routine Maintenance में cleaning work जैसे dust को हटाना cleaning of fitting इत्यादि किया जाता है।

Routine maintenance में machine या equipment को बिना उभारे बिना supply को off करने के पर्याप्त किया जाता है।

(ii) periodic Maintenance - यह maintenance weekly, Monthly, half yearly, yearly किया जाता है इस maintenance समय का निर्धारण machine के condition के आधार पर किया जाता है।

इसके अन्तर्गत loose connection का निर्धारण Ventilation system, Replacement of damaged part, change of oil checking of insulation (Megger) etc.

(iii) Over hauling

इस प्रकार का maintenance half yearly या yearly किया जाता है इसके अन्तर्गत मुख्य मुख्य उपकरणों का Replacement किया जाता है यह Half yearly maintenance होता है।

इसके अन्तर्गत Rewinding of motor stator & rotor, Replacement of brush circuit breaker इत्यादि कार्य किया जाता है।

Advantage -

- ① Breakdown maintenance की आवश्यकता नहीं पड़ती
- ② Measure Fault की कम करता है।
- ③ stand by machine की आवश्यकता कम पड़ता है
- ④ Employ के लिए अनिश्चित सुरक्षा प्राप्त होता है
- ⑤ low repair & maintenance cost.



- Ⓒ machine की life बढ़ जाती है।
- Ⓓ it improve machine working condition.
- Ⓔ कम लागत और समय पर machine का maintenance

* Objective (उद्देश्य) =>

- (i) मेक्सिमम fault को कम करने में सहायक है।
- (ii) plant equipment या machine को निरंतर तैयार रखना।
- (iii) धर्मचारी की सुरक्षा व्यवस्था सुनिश्चित करना।
- (iv) maintenance खर्च को अल्पतम तथा कम करना।
- (v) machine की उपयोगिता को लंबे समय तक बढ़ाना।

IMP

preventive maintenance of electric motor.

जब motor breakdown होता है तब motor में losses, damage इत्यादि समस्या होती है इससे अनावश्यक समय जैसे खर्च होते हैं इससे बचने के लिए preventive maintenance आवश्यक होता है।

→ Preventive maintenance costly thing आवश्यक होता है preventive maintenance के लिए निम्न आवश्यकताएँ होती हैं-

- (i) proper Recorders,
- (ii) skilled labour staff.
- (iii) facility of repair & testing
- (iv) storage of spare-parts.

on



प्रश्न
✓*

Preventive maintenance of 3- ϕ induction motor.

① According to IS 2 300-155C for induction motor is follows maintenance.

(1) Daily Maintenance.

- (a) visually inspection of earth connection of motor leads.
- (b) checks motor winding for over heating the permitted maximum temperature.
- (c) determine the voice of induction motor.
- (d) control equipments वा निरीक्षण
- (e) Temperature and bearing को नीचे रखना।
- (f) oil को देखना चाहिए और
- (g) checks coupling connection.

(2) Weekly Maintenance.

- (i) checks belt tension.
- (ii) check air gap between rotor and stator.
- (iii) धूल वाले स्थानों पर रहने हुए motor के winding को साफ़ करने हैं।
- (iv) starting equipment के connection को चेक कर देना
- (v) स्नेहक oil को चेक करना चाहिए इसमें बहुत ध्यान देना है। स्नेहक के रंग (भावता) को देखकर उसके quality वा ध्यान करना।

(3) Monthly Maintenance

- ① oil circuit breaker को ध्यान करना तथा साफ़ करने।

- (d) control equipment का जांच करना तथा सफाई करना।
- (e) Bearing की change करना यदि आवश्यक होती।
- (f) oil level की देख कर oiling करनी होती वांग गले।
- (g) check Bearing houses of slip ring motors.

④ Half yearly Maintenance

- (a) motor के parts में जर्म जर्म इत corrosion (जंग) को remove करना
- (b) सबसे बड़े slip ring motor में आवश्यक रूप से चुस गया है
- (c) ball bearing में greasing करना ठंडाई ठंडाई ^{बाहर निकालना} _{महाकासे।}
- (d) सभी वांग को निचालकर पेट्रोल से साफ करना तथा इसमें clean oil डालना।

⑤ Yearly Maintenance

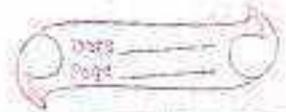
- (a) Alignment shut box properly check.
- (b) switch & fuse connected if damage, check air gap
- (c) check resistance on earth connection
- (d) cleaning करना & सफाई करना।
- (e) Blow out all motor winding with clean dry air, but pressure of lower is not so high otherwise it damage the insulation.

⑥ External Maintenance.

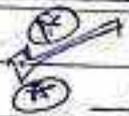
- (a) check Name plate data.
- (b) check the machine missing parts.
- (c) check the surface of commutator.
- (d) check the earthing of the body.
- (e) check the winding & —

⑦ Expression Mechanical parts.

- (a) check the shaft layout
- (b) check the foundation level
- (c) check the bearing.



- (iv) check Tightness of terminal connection
- (v) check the tightness of belt & machine body & foundation.



preventive maintenance of dc machine/motor.

DC machine के लिए निम्न preventive maintenance दिया जाता है -

(i) Daily Maintenance

- (a) check the earth wire & other wire motor
- (b) check the motor winding are overheating
- (c) check the bearing that oil rings or working.
- (d) check the length of the brushes
- (e) check the dc motor starter of the motor (point)

(ii) Weekly Maintenance

- (a) check the belt tension
- (b) check the air gap between Armature & field winding.
- (c) check the terminal connection of machine

(iii) Monthly Maintenance

- (a) check the surface of the brushes are commutator
- (b) Replace the noise bearing
- (c) check the grease & oil.

- (d) test of all control equipment.
- (e) check proper lubrication in bearing.

(IV) Half yearly Maintenance

- (a) check all motor electrical connection
- (b) check grease oil in ball bearing and rotor bearing
- (c) सभी bearings को सही ढंग से सही proper lubrication करें।
- (d) parts में लगे दूध जंजीर (corrosion) हिलने को remove करें सही ढंग से।
- (e) यदि आवश्यक हो तो replace the brushes & commutator.

(V) Yearly Maintenance

- (a) check all high speed bearing.
- (b) check resistance of eurt connection
- (c) check the insulation resistance to earth between motor winding
- (d) check all the connection & tight the all electrical connection.
- (e) brush & commutator को सही ढंग से replace करें।

① Preventive Maintenance of transformer

For long trouble free service transformer should be given attention regularly. The maintenance of depend on the size of transformer, operating condition & its location.

In proper maintenance या poor maintenance के कारण transformer में नि. नि. fault हो सकते हैं -

- (i) core bolts तथा clamp ढीला होने से - (loose connection) से vibration तथा noise उत्पन्न होता है।
- (ii) winding के loose connection होने से external short circuit fault हो सकते हैं।
- (iii) joints में proper soldering नहीं होने से अत्यधिक heating तथा oil leakage हो जाता है।
- (iv) oil leakage होने से transformer tank over heat होता है जो कि winding को गर्म करता है।
- (v) transformer के Bushings में dust जमने से leakage current flow हो सकता है जिससे flash over होता तथा insulator खराब हो सकता है।
- (vi) यदि transfor oil में sludge या निर्माण होता है तो यह oil के flow (प्रवाह) को block कर सकता है।

जिससे transformer over heat होता है।

Maintenance - ISS 1880-1969 के अनुसार transformer में निम्न प्रकार के maintenance कार्य किया जाता है।

⊕ transformer में कोई भी maintenance करने से पूर्व उसके सभी supply - (main supply), control supply, circuit breaker आदि) को पहले disconnect किया जाता है। तथा उसके पश्चात् proper earthing करने के बाद ही maintenance का कार्य किया जाता है।

Ⓐ Hourly maintenance (Routine maintenance)

- (i) checks winding temperature.
- (ii) check oil temperature.
- (iii) checks load, adjust load with to keep the temperature safe limit.
- (iv) check voltage.

(b) daily maintenance -

- (i) checks oil level and at the oil if oil level is low then the oil oil
- (ii) check oil main tank & radiators for noise.



- (iii) check oil level in bushings
- (iv) check cooling fans, oil circulation pump
- (v) check that passages are clean
- (vi) check the colour silica gel in breather. colour should be blue. If colour of the silica gel is pink then replace them
- (vii) check Relay panel temperature
- (viii) check position of tap changer
- (ix) check all control, power supply circuit, switches are good & fuses are circuit well placed.

(c) Monthly maintenance -

- (i) feel the transformer ^{dry} oil
- (ii) cleaning the bushing surface from dust & oil etc
- (iii) transformer से आवा-परा बड़े पीसे की सफाई।
- (iv) check terminal connection & earthing connection & tighten them

(d) quarterly Maintenance

- (i) Bushing में cracks को check करा जाय crack होने पर Bushing को replace करा।
- (ii) cooling fans तथा circulating पंप की maintenance

(e) half yearly maintenance

- (i) check dielectric strength of the oil

- (ii) change the insulator & bushings if damage
- (iii) check cable boxes, pitter
- (iv) replace oil
- (v) check for moisture in transformer tank.

(f) Yearly Maintenance

- (i) check foundation for cracking & settling
- (ii) radiators की सफाई - radiator pipes, plugs, tube सफाई की सफाई।
- (iii) safety danger boxes की properly locked करना
- (iv) Relay & circuit breaker maintenance.
- (v) check lightning arrester & isolators for proper operation.
- (vi) check the insulating resistance between each winding & winding to ground.

(g) Five yearly Maintenance

- (i) clean the transformer by drying the transformer oil
- (ii) open transformer tank, conservator tank, busholts relay ect. for cleaning & Assembling

(H) Undeduced Maintenance

- (i) जब त्रुटि की maintenance transformer में अचानक होने वाले fault के कारण करना पड़ता है। ये fault external व internal दोनों प्रकार के होते हैं। external fault में प्राकृतिक कारणों जैसे अत्यधिक बारिश, तूफान आदि के कारण ^{out} transformer से बिजली-रफ्ट्स

ये विभिन्न प्रकारों में fault-

* External faults ये अंतर्गत internal short
circuit fault over loading इत्यादि कारणों
से होता है।

उपरोक्त fault होने पर main supply
दाया सही supply गंद बरये वर्जेंट condition
में unscheduled maintenance दिया जाता है।

⊕ Preventive Maintenance of circuit Breaker

circuit breaker का maintenance उत्तम गहलरणी है कपोडि यह इस्से electrical equipment को abnormal protect करे के लिए उपयोग होता है।

Electrical transmission तथा distribution system में circuit breaker के दिव से operate करती हैमे से major equipment जैसे transformer इत्यादि से supply breakup आ disturbance हो सकता है। लंबे समय तक open call dosing होने से कुछ समय पश्चात circuit breaker के contact surface में lubrication की आवश्यकता होती है। अतः इसका समय पर preventive maintenance आवश्यक होता है।

सभी प्रकार के circuit breaker के लिए सामान्यतः निम्न लिखित maintenance कार्य किये जाते हैं -

(1) period of inspection under normal condition

(a) once in 6 month or 12 month for circuit-breaker operating frequently

(b) once in 1 month or 3 month for circuit-breaker operating repeatedly, or according to manufacturers.

(c) on clearing a fault: ~~जब~~ circuit breaker में fault clear हो पर

(d) over head:- once in 3 years
maintenance



(e) Replacement - when life of circuit breaker expires

(2) During periodic checkup

- (a) check the oil level and condition
- (b) check the insulators fabric clock etc.
- (c) carbon deposits तथा गिरे हुए oil को साफ करने के लिए trichloroethylene chemical का प्रयोग किया जाता है।
- (d) check contacts (moving & fix contact)
- (e) check indicating devices
- (f) check overlayer switches
- (g) tight nuts, bolts etc
- (h) test insulation resistance by using high voltage (1000V DC) megger in case of high voltage circuit & by 5 volt megger in case of (220V DC) circuit.

(3) when the breaker operate on fault the internal & external exp inspection should be carried out -

- (a) oil का निरीक्षण
- (b) check arking contacts
- (c) check the insulation
- (d) check the tripping circuit.

(4) Relay Maintenance - Relay के फाल्ट होने के कारण Relay के contact की जांच तथा ठीकी गई पदार्थ के जलने की निवारण का जांच तथा इसे साफ करने के लिए glass paper का पद लिया जाता है। इसमें Relay के windings को भी maintenance दिया जाता है।

(5) check contact pressure -

(a) Medium voltage circuit breaker -

contact pressure लगभग जांच होना चाहिए contact pressure check करने के लिए 0.002 inch gauge (0.002 inch) को contact के नीचे डाला जाता है तथा इसे spring की सहायता से खिंचा जाता है। तथा spring balance के pressure को note लिया जाता है।
generally contact resistance का मान 20 micro Ω for 1200 Ampere current rating. यदि contact जल जाता है तो इसे replace किया जाता है।



* Preventive maintenance of transmission & distribution line

(*) Over head transmission वॉट distribution line of periodic inspection आवश्यक होता है। inspection of frequency geographical condition वॉट line of सुयोग्यता पर निर्भर करता है।

Over head transmission वॉट distribution line के सुयोग्यता निम्न maint steps में maintenance की है।

- ① Routine patrolling & inspection
- ② cleaning insulator periodically
- ③ Tightening of clamps
- ④ Replacement of broken insulators
- ⑤ clearing of trees bushes (सुयोग्यता) etc.
- ⑥ inspection of earthing.
- ⑦ check tower for corrosion & take remedial action
- ⑧ check continuously of all phases
- ⑨ conductor high voltage test with increased voltage
- ⑩ check the condition of terminal box for any cracks etc.
- ⑪ Measure insulation resistance by megger between phases & the earth.

④ Hot line / live line maintenance.

- इस प्रकार के maintenance में live line (या जिसके supply धारा प्रवाहित हो रही हो) बिना supply को रोके maintenance दिया जाता है।
- line conductor, line insulators, pole structure, इत्यादि का maintenance कार्य दिया जाता है।
- इस प्रकार का maintenance वही पर आवश्यक होता है जहाँ पर substation में बिना बिल्ट आर्किंग की बंद किये बिना maintenance कार्य करना होता है।
- यह high voltage पर तथा DC line, low DC इत्यादि में दिया जाता है।
- इसके लिए special tools तथा trained staff तथा special work permit की आवश्यकता होती है। यह maintenance पर्याप्त सुरक्षा उपकरणों के साथ ही दिया जा सकता है।
- live line maintenance में कार्य करने वाले व्यक्ति high electric field strength के उभाव में रहता है जब वह live line पर कार्य करता है तथा वह उसका शरीर alternating electric field के संपर्क में रहता है उससे change होता है यह field person की वे ground से स्थिति पर निर्भर करता है। यदि person के body का कोई भी part ground से touch होता या किसी conducting part से ground से connect होता है तो उसके शरीर



से व्यवस्था में उच्च पर्याप्त flow हो सकती है
 अतः इसे रोबने के पर्याप्त सुरक्षा उपकरण मानकर
 है। अतः live line में कार्य करने वाले व्यक्ति
 को इन्वोल्व या grounded part से insulated
 होना आवश्यक है इसके लिए special tools
 जैसे (1) hand jackets, (2) shoes,

(3) Hot stick, (4) या इत्यादि का

प्रयोग किया जाता है।

इसी-इसी तरह "Faraday cage" (sliding
 metallic cage) का प्रयोग किया जाता है ताकि
 live line में कार्य करने वाले person सुरक्षित रहे

⇒ steps or Activities (Procedures) for live line
 Maintenance -

(1) live circuit में over head line, conductor,
 Bus bar, insulator, इत्यादि का repair
 करना

(2) circuit के live condition में conductor के
 बीच के distance की जांच करना।

(3) insulators की मरदर्द करना तथा इसे इरे इरे
 insulator की replace करना

(4) pole structure की जांच करना तथा
 loose connection, (contact) की tight करना।

live line maintenance में use होने वाले उपकरण -

① Insulating ladder

Insulating ladder wood या fiber glass region का बना होना चाहिए।

② Insulating tongs

③ clips on instruments

④ Earthing rod

⑤ Insulating gloves

⑥ Insulating shoes

⑦ Faraday cage

⑧ Hot stick

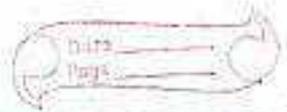
⑨ insulating support

⑩ special insulating cloths

HOT STICK

HOT STICK method for maintenance of transmission line.

⇒ electric energy distribution में Hot stick एक insulated pole होता है आमतौर पर fiber glass से बना होता है इसका उपयोग electric से कार्य करने वाले कुराल में कामियों द्वारा किया जाता है जब वे high voltage live line पर कार्य करते हैं। Hot sticks

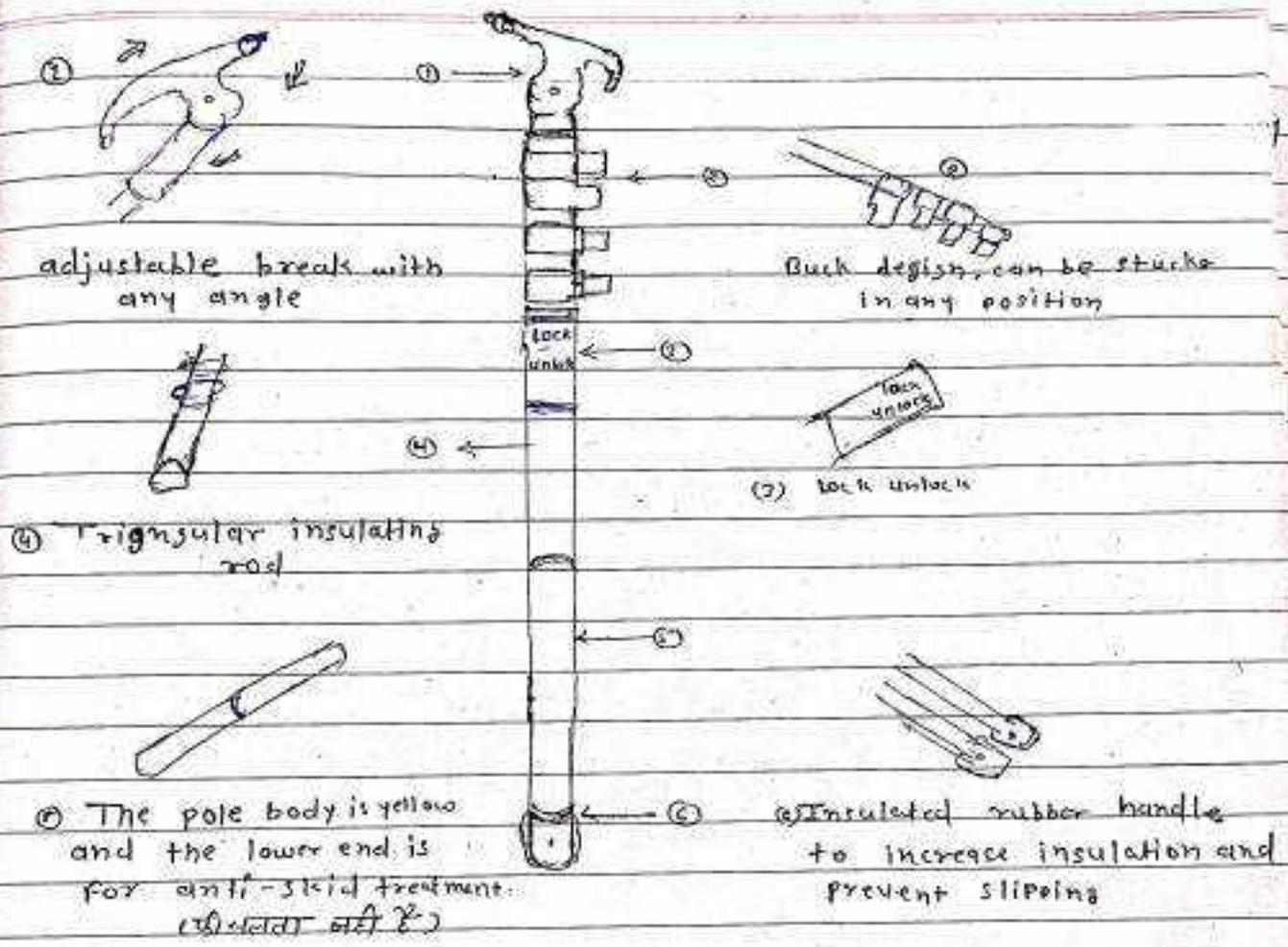


⇒ Hot stick का प्रयोग करी से कार्य करने वाले व्यक्ति का शरीर conductor से properly insulated होता है जिससे उसे electric shock नहीं लगता।

⇒ Hot stick की सहायता से voltage का परिवर्तन करना, Nut bolt को tight करना, insulator की बांधने वाले wire को लगाना, switch खोलना और बंद करना इत्यादि कार्य किये जाते हैं। इसके उपरी आधार

⇒ इसके ऊपरी आधार पर अन्य उपकरणों की जोड़कर अन्य कार्य जैसे -
(1) Fuse बदलना
(2) तारों पर insulator पर clips लगाना इत्यादि कार्य किये जाते हैं।

⇒ Hot stick अलग-अलग लंबाई में बर्तित जाती है (3 फीट) 3m से लेकर (30 फीट) 9 meter लगभग तक उपलब्ध होता है।



(1) adjustable break with any angle

इसे किसी भी कोण पर घुमाया जा सकता है तथा इस को ब्रेक दिया जा सकता है यह स्टिक का सबसे ऊपरी भाग है। on

(2) Buck design can be stuck in any position

④ Preventive maintenance of Underground cable

underground cables में निम्न maintenance कार्य किये जाते हैं -

① terminal Boxes का inspection -

terminal box में नमी किसी प्रकार का भी leakage हुआ हो तो इसकी सफाई की जाती है।

② cable की Temperature की जांच :-

③ insulation resistance test -

insulation का resistance testing किया जाता है इसके लिए Megger या insulation meter का use किया जाता है। Fall potential method के द्वारा भी insulation resistance की जांच किया जाता है।

④ cable duct में पानी की जमाव की जांच करना तथा इसकी सफाई करना।

⑤ insulation resistance test formula

overall insulation resistance of cable

= $\frac{\text{Insulation resistance}}{\text{length}}$

length of cable in meter

- (6) cable के चारों तरफों का water तथा किसी अन्य liquid गी जांच करना तथा इसकी उपस्थिति पाई जाने पर cable की proper insulation provide करना।
- (7) cable के lead sheath में corrosion (जंग) की जांच करना तथा इसके दूरे पर उसे replace करना।
- (8) cable के ऊपर बाहरी wall में mechanical stress की जांच करना। विशेषकर heavy traffic वाले स्थानों पर जहाँ underground cable पर बाह्य mechanical pressure पड़ता है ऐसे स्थानों पर cable के ऊपर safety duct provide करना।

④ Qualities of insulating material used in machine

- ① इसमें machine parts तथा component को electrically ~~space~~ ~~support~~ करने की क्षमता होनी चाहिए। ② यह high temperature एवं ~~वृद्ध~~ ~~वृद्ध~~ ~~वृद्ध~~ में भी अभिरक्षित नहीं होनी चाहिए।
- ③ यह dust तथा corrosion, chemical fumes इत्यादि से अभिरक्षित होना चाहिए।
- ④ यह ~~आहसी~~ ~~mechanical~~ ~~friction~~ से ~~वामवश~~ नहीं होना चाहिए।
- ⑤ insulation को ~~दाग~~ ~~धरा~~ ~~गया~~ ~~स्थान~~ कम से कम होना चाहिए ताकि machine में ~~corrosion~~ ~~वृद्ध~~ ~~वृद्ध~~ ~~वृद्ध~~ के लिए भी पर्याप्त स्थान मिल सके। अतः insulation पतला होना चाहिए।
- ⑥ इसमें ~~आहसी~~ ~~वातावरण~~ से ~~मोडिफाई~~ ~~absorb~~ न कर पाने की योग्यता होनी चाहिए।
- ⑦ यह उच्च ~~वामवश~~ के ~~वामवश~~ में ~~वामवश~~ या ~~punch~~ नहीं होना चाहिए।

S.No.	class	Insulating material	Use	Maximum operating temp.
01	Y/O	cotton, silk, paper, press board, wood, PVC, VTR etc.	Rarely used without impregnation	90°C
02	A	cotton, silk, paper, press board, vulcanized fiber, wood etc.	Leathered paper as slot insulation, cotton covered wire impregnated in shellac, varnish, spot wages etc.	105°C
03	E	leatherised paper, polyvinylacetal (PVA), enamel for super enamelled conductors, epoxy resins, cotton fabrics and paper laminates.	slot insulation, winding wires, insulation, insulating mouldings with epoxy resin in case of chokes CT etc.	120°C
04	B	Glass fibers, asbestos mica, built up mica, laminations etc. with bonding substance like epoxy and silicon alkyl resins	slot liners, phase separators etc. Insulating tape, binding cord etc. polyester enamel conductor.	130°C
05	F	glass fiber, asbestos, mica, varnished glass fiber textile, built up mica, etc. with bonding substance like epoxy and silicon alkyl resins.	slot liners, spacers, taps, polyester mica enamel or fiber glass braided and varnished with poly urethane wires for coils	155°C

B	H	Same materials as for class with suitable binding materials i.e. silicon based glass fabric, flexible mica with suitable resins or polymers films glass fabric	slat liners, insulation tappers, separators, conductors, insulation sleeves etc.	180°C
B7	C	mica, porcelain, ceramics glass, quartz, asbestos, treated glass fiber or treated asbestos with inorganic binders such as glass or cement and silicon resins, slate, marble	same as class H, also insulating material is given etc.	above 180°C

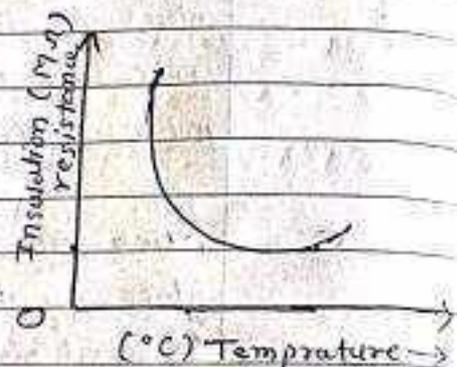
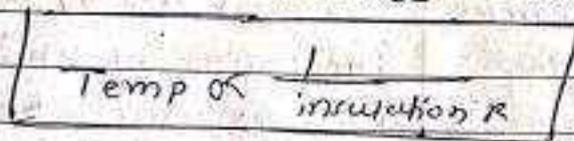
② Effect of temperature & moisture on insulation resistance

① जब किसी insulating material के temperature में वृद्धि की जाती है तो उसके insulation resistance का मान कम हो जाता है अर्थात् material की insulation power कम हो जाता है।

② जब insulating material नमी के प्रभाव में आता है तो इसका insulation कम हो जाती है अर्थात् इसका insulation resistance decrease हो जाता है।

① insulation Resistance के बढ़ने के कारण / deterioration
insulation Resistance के निम्न कम होने के निम्न
कारण होते हैं -

① Temperature: - insulation material
की temperature बढ़ने पर
insulation Resistance घटता है



② Atmosphere:

moisture तथा आर्द्रता के प्रभाव से
भी insulation resistance का मान घटता है
क्योंकि इससे insulation material की गुणवत्ता
क्षय होती है। example - overhead line
तथा outdoor sustation में प्रयोग होने वाले
insulator atmosphere से ज्यादा प्रभावित होता है।

③ Applied voltage:

Applied Voltage का मान
अधिक होने पर मान जब insulating material
के लम्बा से अधिक हो जाता है तो insulating
material की insulation Resistance घटता है।

④ dielectric strength:

किसी insulating material में अधिक voltage
में जब उसके diameter की विभाजित दिया

जाता है तो इसे Voltage gradient माना जाता है इसका unit kV/mm होता है। इस Break down strength को dielectric strength कहा जाता है। अर्थात् वह न्यूनतम voltage जिससे insulation Resistance खराब हो जाता है उसे Break-down voltage कहा जाता है। इस प्रकार Break down voltage का मान अधिक होने पर dielectric strength घट जाता है।

⑤ Tracking — जब insulating material में burning तथा melting होता है तब इसे arcing (अनियमित) holes बनते हैं, जिससे कम voltage पर भी लगभग पाप insulating (अनियमित) हो जाती है जिससे insulation strength घटता है। इस घटना को tracking कहते हैं।

⑥ Oxidation — insulation material की oxidation बढ़ने से insulation Resistance का मान कम हो जाती है। ताप बढ़ने पर material शीघ्रता से oxidized होता है जो resistivity को reduce करता है।

⑦ Light :- light की intensity अधिक होने पर insulating material की resistivity घटती है।

⑧ Ageing:— insulators के आयु में ^(अधिक) वृद्धि होने पर भी insulation Resistance में समय के साथ कम गीर (घटने) जाता है। कुछ insulating materials जैसे porcelain, mica इत्यादि का insulation Resistance लंबे समय तक बना रहता है जबकि paper, Cellulose इत्यादि जल्दी खराब होते हैं।

⑨ Methods of cleaning Insulation :

① Removed of loose dust:-

machine के winding surface, Ventilating duct इत्यादि में loose dust का जमाव होता है जिसे vacuum cleaner की सहायता से हटाया जा सकता है। साथ ही 2.8 kg/cm² तक compress करके साफ किया जाता है। साथ ही loose dust को हटाया जाता है। साथ ही समय व्यतीत की safety goggles तथा safety mask का प्रयोग करना चाहिए।

② Encrusted dust:- (जमा हुआ धूल)

सामान्यतः Ventilating duct में machine corners में Encrusted तथा sticky dust का जमाव होता है जिसे hand wood या fiber scraper की सहायता से हटाया जाता है। धातु scrapers का प्रयोग नहीं किया जाता क्योंकि इससे insulation क्षतिग्रस्त होता है।

cleaning of

③ Oily Viscous Film :-

Cheese cloth and lintlers
 रबड़ की सहायता से oily viscous film को
 हटाया जाता है इसमें petrolium solvent का
 भी प्रयोग किया जाता है किन्तु इसका अल्पधिव
 प्रयोग वर्जित है क्योंकि इससे insulating
 प्रवण्यता कमजोर हो जाता है। CCl₄ उर्ध्व
 रेखा क्लोराइड को excellent cleaning solvent
 होता है किन्तु जहरीला होने के कारण इसे
 avoid किया जाता है।

④ cleaning with water :-

सामान्यतः class II
 insulation को पानी तथा detergent की सहायता
 से repair shop में clean किया जाता है।
 cleaning का काम तेज गति से rapidly
 किया जाता है तथा machine की सजि
 (एन), fresh water से साफ़ किया जाता है तथा
 तथा अतिरिक्त नमी को सुरवे बुपडे से साफ़
 करके machine को ज्वॉन प्राधिव सुरवाने
 के लिए oven का प्रयोग किया जाता है।

⑤ Drying of Electrical insulation :-

Electrical insulation की
 सुरवणे की सबसे प्रचलित विधि external heat
 method है इसमें machine को ख नियत ताप
 पर रखा जाता है तथा इसके तापमान को
 thermostat से control करते हैं। छोटे

machines को सामान्यतः Boiler के ऊपर में रख कर सुखाया जाता है इस विधि में यह ध्यान रखा जाता है कि winding temperature 90°C से अधिक न पहुँचे। बाहरी ताप के लिए electric heater, heat lamp स्थापित वा उपयोग insulation की heat करने के लिए किया जाता है।

(6) Revarnishing Insulation Revarnish के लिए निम्न माथोद वा प्रयोग किया जाता है।

- (a) By Brush using air drying varnish
- (b) By spraying method.
- (c) Hot-dip method using baking varnish
- (d) Vacuum impregnation using baking varnish

(a) By Brush using air drying varnish -

इस मथोद में Brush द्वारा Revarnish किया जाता है।

(b) By spraying method:-

इस मथोद में spray करके Revarnish किया जाता है।

* (c) Hot dip method using baking varnish -

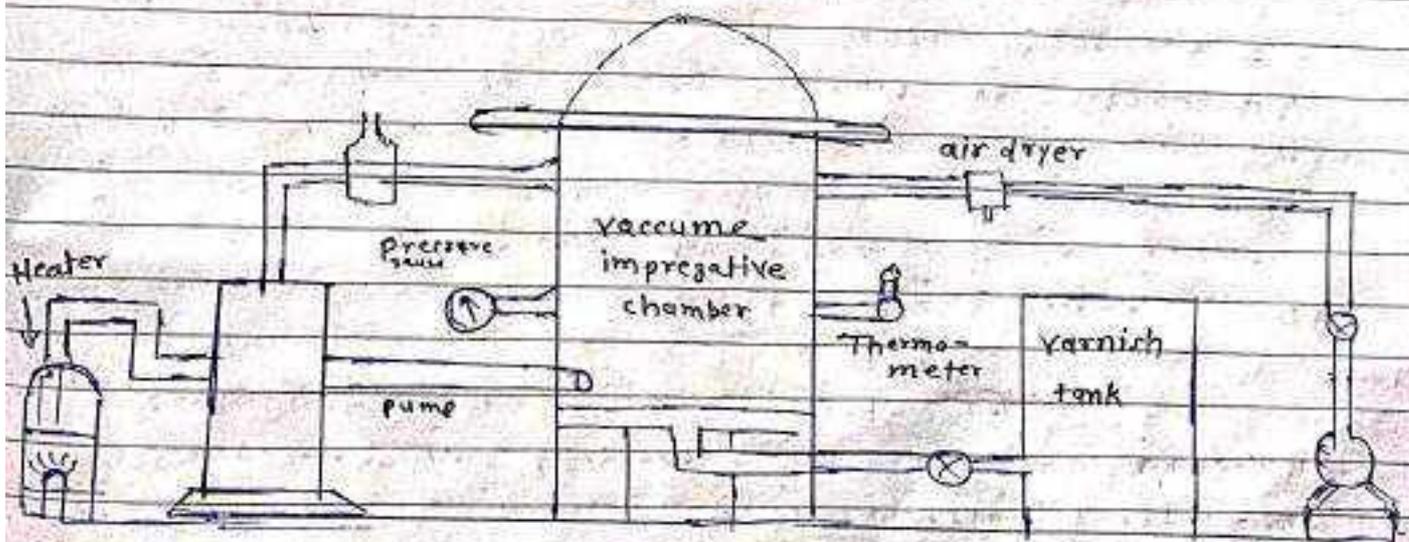
इस विधि में woundl armature, stator वा rotor स्थापित की पहले baking oven में 200°C तापमान तक गर्म किया जाता है। यह प्रक्रिया 1 घण्टे तक की जाती है।

जिससे उसमें उपस्थित moisture वाष्पित हो जाता है।

इसके पश्चात् इसे varnish tank में डुबाया जाता है तथा धीरे धीरे तब उसे इसके अंदर रखा जाता है। इससे सभी जंगली तथा insulator में सभी स्थानों पर varnish भरने से मिले जाये।

इसके पश्चात् इसे बाहर निकालकर कुछ समय के लिए iron tank में रखा जाता है जिससे excess varnish बाहर निकल जाता है। इसके पश्चात् अंत में इसे backing-oven में 100°C - 110°C ताप पर प-ठ धरे तब रखा जाता है जिससे varnish पूरी तरह से सुख कर machine की सहाय पर स्थापित हो जाता है।

44* Vacuum impregnation using backing varnish





चित्र में vacuum impregnation plant दिखाया गया है। इसमें एक double jacket, vacuum impregnation chamber होता है। जिसके ऊपर में removable cover लगा होता है।

इस chamber को jacket की सहायता से circulating steam या hot oil से गर्म किया जाता है।

इसमें backing varnish के लिए अलग से chamber होता है। इसमें compress vacuum exhaustor की सहायता से chamber में valve की सहायता से vacuum pressure maintain किया जाता है।

इसमें pressure measurement के लिए pressure gauge तथा temperature के लिए thermometer लगा होता है।

कार्य विधि :-

इस विधि में wound armature stator या rotor को vacuum chamber में top cover को open कर डाला जाता है। इसके पश्चात cover को tight किया जाता है तथा chamber को circulating steam या hot oil की सहायता से पहले तब तक तप पर गर्म किया जाता है।

इस अवस्था में vacuum chamber में vacuum exhaustor की सहायता से vacuum को maintain किया जाता है जो winding में



उपस्थित नमी को remove करता है।

खरगोश tank में उपस्थित insulating varnish को तब तब भरा जाता है जब तब की इस chamber में winding पूरी तरह से दूरे न जाये। इसके बाद खरगोश पत्रों को बंद कर दिया जाता है तथा इसके अंदर 1.5 से 2.5 kg/cm² तक pressure maintain किया जाता है जिससे मशीन के सभी भागों में 0.1 खरगोश अच्छी तरह से लग जाती है जाये। यह pressure हब या आधे घंटे तक रखा जाता है।

इसके पश्चात् खरगोश tank को रोल कर machine की access खरगोश को वॉर प्रेसचर की सहायता से हटाया जाता है तथा machine को chamber में डालते तब 100°C से 110°C में गर्म किया जाता है जिससे खरगोश पूरी तरह से machine में स्थापित हो जाता है।

इसके पश्चात् वॉर प्रेसचर, insulating 0.1 आदि को बंद कर दिया जाता है तथा machine parts की top cover निकाल कर अलग कर लिया जाता है।

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Measuring system

मापन वह प्रक्रिया है जिसमें एक राशि के परिमाण को दूसरी स्वरूप राशि की तुलना में ज्ञात करते हैं। Electrical विद्युत Engineering में हम समान्यतः Current, Voltage, Power, Energy, Flux आदि अदृश्य राशियों की अध्ययन करते हैं।

Classification of measuring Instrument :-

1. प्राथमिक (Primary / Absolute Instrument)

2. Secondary Instrument

(i) Primary Instrument - प्राथमिक Instrument में मापा जाने वाली राशि के instrument के स्वरूप तथा उसके विक्षेप (Deflection) के रूप में सूचित किया जाता है। इन instrument को किसी अन्य उपकरण से Calibration करते हैं। इस प्रकार के यंत्रों का उपयोग केवल (Standardization) के लिए किया जाता है।

Exp - गैल्वेनोमीटर

(ii) Secondary Instrument - इसेक द्वारा मापी जाने वाली राशि के परिमाण को Deflection द्वारा सीधा मापा जाता है। इन instrument value का उपयोग करने से पहले इसे absolute instrument के द्वारा Pre calibrate होना आवश्यक है।

Exp. - Galvanometer, Energy meter etc.

Types of secondary Instrument

- i) Indicating Instrument - इनके सीधे मूल मिला है जैसे - Galvanometer, Voltmeter
- ii) Recording Instrument - इन instrument में Value record किया जाता है जैसे ECG, Anemometer
- iii) Integrating Instrument - इनमें शुरू से आखरी तक का total value लिखा है। जैसे Energy meter, Bike का distance meter

ERROR

Errors are TWO Types

- i) Static Errors
- ii) Dynamic Errors
- iii) Static Errors - Errors depends does not on time
- iv) Dynamic Errors - Errors depends on time

$$Error = A_m - A_n$$

Accuracy - एक माप मान (true value) के निकट पहुंचने की माप (measure) है accuracy के उपयुक्त की पूर्ण स्केल के प्रतिशत में व्यक्त करते हैं Accuracy सभी मान के रूप में व्यक्त होता पूर्ण मापन परिमाण से सम्बंधित है। उपयुक्त की accuracy के प्रतिशत के रूप में प्रदर्शित किया जाता है।

$$Accuracy = \frac{V_m - V_t}{V_t} \times 100$$

V_m = सही माप मान
 V_t = वास्तविक माप

Guaranteed Accuracy Error - यह तुरंत Manufacturers द्वारा निर्धारित किया जाता है।

Precision (परिच्छेदता) - यह स्थिर माप या repeatability का माप है अर्थात् माप के समुदाय (Group of measurement) में समानता कि उपयुक्त की माप परिच्छेदता कहलाती है।

Accuracy उपयुक्त परिच्छेदता से अधिक हो सकता है परंतु परिच्छेदता उपयुक्त accuracy नहीं हो सकता।

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Absolute Error - इसमें मापन अधिकतम त्रुटि से हो और यह किसी राशि के मापे गए मान और सत्य मान के अंतर के बराबर होता है।

$$\text{Absolute Error} = \text{Measured value} - \text{True value}$$

Relative Error (सापेक्ष त्रुटि) - त्रुटि के Absolute Error उपरान्त की शक्यता की सीमा निर्धारित नहीं होती जब तक की उसका तुलनात्मक मान सत्य मान से अधिकतम त्रुटि की सापेक्षता राशि के शक्य मान से तुलना करके त्रुटि के मान का अनुमान लगाया जाता है कि वह त्रुटि स्वीकार्य प्रतिशत त्रुटि से कम है या अधिक।

$$\text{Relative Error} = \frac{A_t - A_m}{A_t} \times 100$$

$$A_t = \text{True value}$$

$$A_m = \text{Measured value}$$

इस Error द्वारा किसी यंत्र की quality का निर्धारण किया जाता है यदि किसी Instrument की relative error कम है तो इस Instrument की quality उत्तम ही मानी जाती है।

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Limiting Error (सीमा त्रुटि) - किसी विद्यमान राशि के Nominal value से विचलनों (deviation) को Manufacturer द्वारा बताना करना पड़ता है। निर्दिष्ट किया हुआ मान से विचलनों की सीमा को सीमा त्रुटि या **Guaranteed Error** कहते हैं।

Sensitivity :- यह मीटर का वह गुण होता है जिसमें बहुत छोटी सी धारा भी स्या बहुत deflection प्रदान करता है। शीघ्र एवं शक्यता मटरसा करने की क्षमता को **Sensitivity** कहते हैं।

$$\text{Sensitivity} = \frac{\text{Change in Input}}{\text{Change in output}}$$

किसी भी यंत्र की sensitivity हमेशा अधिक होनी चाहिए। इसके लिए मापन में प्रयोग किये जाने वाले Instrument की range मापी जाने वाली मान से अधिक होना चाहिए।

Resolution (विभेदन) - Instrument के किसी input signal में होने वाले कम से कम परिवर्तन का पता करना Resolution कहलाता है।

या Instrument के input signal में कम से कम होने वाले परिवर्तन resolution कहलाता है किसी भी यंत्र का resolution हमेशा अधिक होना चाहिए।

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Resolution को full scale मान के प्रतिशत में व्यक्त करते हैं।

$$\text{Resolution (R)} = \frac{\text{full scale value}}{\text{Total no. of division}}$$

tolerance (सहनशीलता) - किसी मापन में basic माप के ऊपर की गई अधिकतम limit और न्यूनतम limit के अंतर को tolerance कहते हैं।

Different types of torque measuring instrument working of measuring instrument

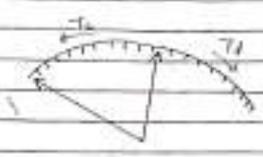
- (i) Deflecting torque (T_d) $T_d \rightarrow$ Electro magnetic torque
- (ii) Controlling torque (T_c) $T_c \rightarrow$ Physical arrangement
- (iii) Damping torque (T_{da})

Depend on \rightarrow Torque \propto Current - DC
 \rightarrow Torque \propto (current)² - AC

Controlling torque \rightarrow Gravity control, spring control

Damping torque \rightarrow Eddy current Damping
 Air friction, fluid friction

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(i) Deflecting torque - Instrument का वह भाग जो नियुक्त पारा या कोरेज को यांत्रिक बल में परिवर्तित करता है Deflecting system कहलाता है।

इस बल को Deflecting force या Deflecting torque कहते हैं। किसी भी Instrument का moving system इसी torque पर निर्भर करता है।

Deflecting torque instrument के अंदर Deflection प्रणाली में गति उत्पन्न करता है रज संकेतक, पारा नोलेन आदि को स्थिति करता है। इस प्रकार से deflecting system संकेतक का रजक पुनर्घूर्णन प्रसिक कारण संकेतक में Deflection आता है।

(ii) Controlling system / Controlling torque -

Controlling torque : Deflecting torque को नियंत्रित करता है और उसे स्थिर करता है कि प्रवाहित पारा के मात्रा के लिए संकेतक को Deflection समान हो Controlling system में Deflection torque उत्पन्न होता है। इस Deflection torque के ना होने पर Deflecting

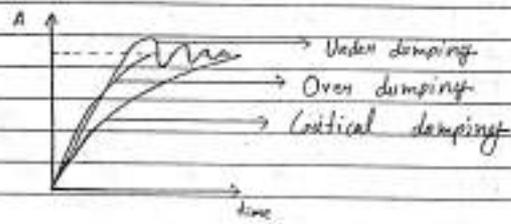
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system में संकेतक किसी भी मात्र की चारा एवं होलता से Deflection की अधिकतम सीमा तक Deflect हो जायेगा एवं यह प्रणाली संकेतक को जबरन शून्य अवस्था में लाने का कार्य करता है। अर्थात् Controlling शून्य Deflective torque न होने की स्थिति में संकेतक को वापस शून्य में लाता है।

(iii) Damping torque - Damping system में Instrument का एक तीसरा आवश्यक भाग है इन प्रणाली में उचित Damping torque या torque का कार्य समय बल अवस्था अर्थात् संकेतक में Deflection position में उसे ठहरा स्थिर अवस्था में लाया जाता है।

Deflection system के ना होने पर अंतिम सूचक के दोनो ओर oscillate करता है जिससे reading लेने में समय बर्बाद हो जाता है।

Deflecting system दोलन पर brake का प्रयोग कारण दोलन बिना देरी फिर सीधे में स्थिर हो जाता है।



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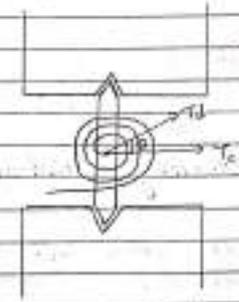
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Method of producing Deflecting torque -

- (i) Electro Magnetic Effect - यह नोन्-पीर, सीरर आदि में प्रयोग किया जाता है।
- (ii) Electrodynamic Effect
- (iii) Thermal Effect
- (iv) Electrostatic Effect

Method of controlling Torque

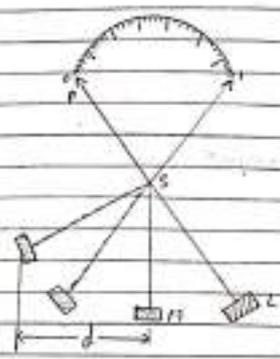
(i) Spring Control



$T_c \propto \theta$, $T_c = k\theta$

Advantage - Controlling torque & deflecting angle के समानुपाती होता है और इस कारण पैमाने में full range संकलमान होगा है।

Disadvantage - Spring में बहुत ताममान की वजह से मुठे अलग होला है।



- P = Pointer
- S = Spindle
- L = Balance weight
- M = Control weight
- θ = Angle of deflection

Advantage of Gravity Control -

1. Spring control की तुलना में यह तकनीक सरली होती है।
2. यह ताममान द्वारा निष्प्रभावित रहती है।
3. इसे अधिक समय तक लगातार प्रयोग में लाया जा सकता है।

4. Control weight लीवर को change करके controlling torque को change किया जा सकता है।

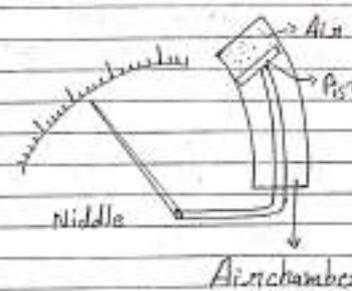
Disadvantage -

1. इसका पैमाना प्रारंभ में सिकुड़ा तथा बाद में फैला हुआ होता है जिसके कारण reading लेना कठिन होता है।
2. Gravity control instrument का उपयोग सिर्फ vertical position में किया जा सकता है।
3. Control weight moving system के रेट को बढ़ा देने से अतः मीटर में torque to weight ratio कम हो जाता है।

Method of Damping Torque

(i) Air friction damping -

यह शून्यप्रियम का बना हुआ पिरन सिलिंडर arrangement होता है जिसका एक छिरा बंद होता है एवं इसके अंदर पिरन गति करता है।



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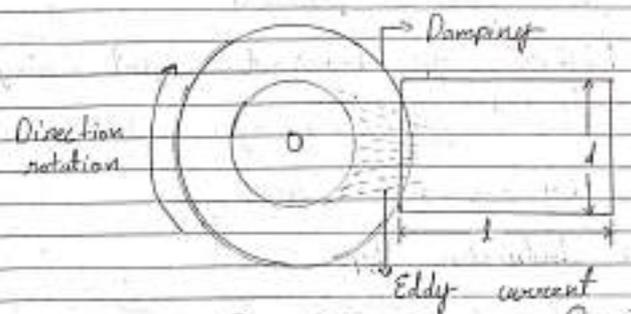
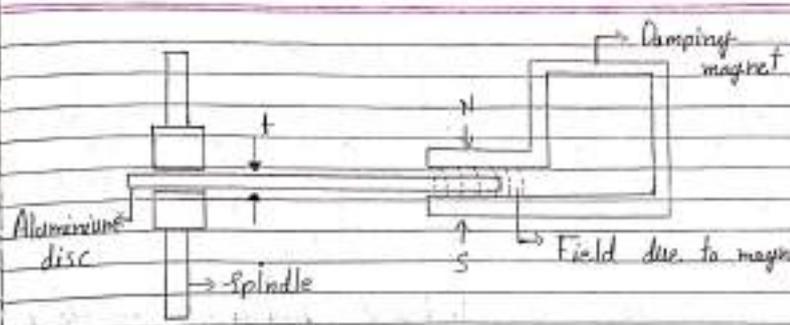
Air chamber की construction को बदलकर या आयताकार हो सकती है जब प्रणाली में उतार-चढ़ाव होने वाले दोलनों का अवमंदन विस्तार की वायुमंडल में वायु पर compression तथा suction किया से होता है

(ii) Fluid friction damping

प्रथम विधि में एक गोल चकती जो कि स्वतंत्र spindle से जुड़ी होती है को एक कर्न में जिसमें तेल या कोई अन्य तरल भरा हो डुबा दिया जाता है। जब mechanical displacement घूमती है तब चकती में fluid में घुमती है जिससे की चकती पर friction drag उत्पन्न होता है।

दूसरी विधि में vertical fan को तेल से भरे पात्र में डुबा दिया जाता है। तेल के में पंखों के घुमने से damping force उत्पन्न होता है यह तकनीक बड़ा प्रयोग किया जाता है। बड़ा बंदल को damping force की आवश्यकता होती है।

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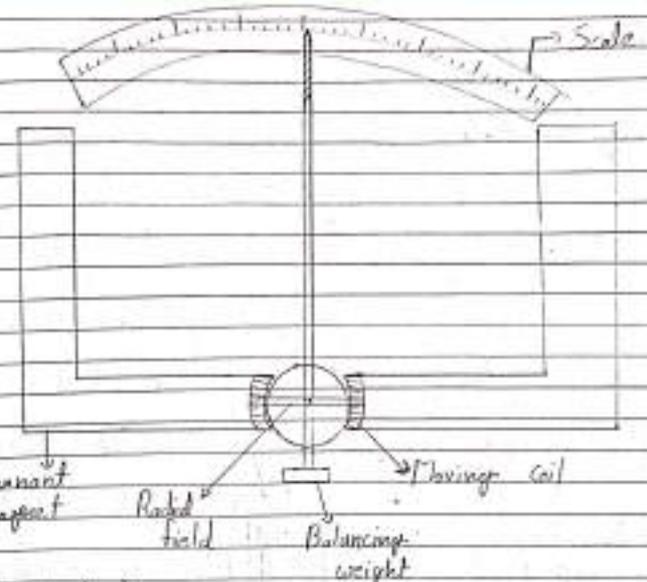
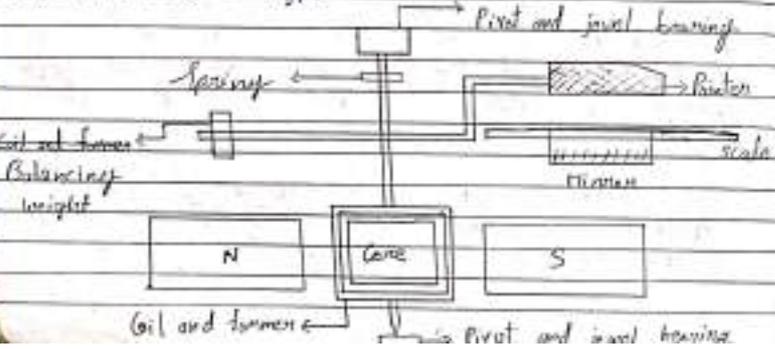
इस तकनीक में spindle चकती से जुड़ा रहता है चकती को रेखी स्थिति में रखा जाता है कि उसका कोर एक स्थायी चुम्बक N तथा S ध्रुवों के बीच रखता जाए से घुम सके।

चूंकि तब चकती घुमती है तब वह चुम्बकीय क्षेत्र का काटती है जिससे उसमें संतर धाराएं उत्पन्न होती हैं।

हैं। के नियमानुसार संवर्धक
 का विरोध करती है। फलस्वरूप चुकती को
 गति संपूर्ण, moving system सहित : मय
 हो जाती है। इसे "not zero" instrument
 में damping के लिए द्रव्य तकनीक का
 इस्तेमाल किया जाता है।

Classification of Electrical Instrument according to working principal

- (i) PMMC Type (Permanent magnet moving coil)
- (ii) MI Type (Moving coil)
- (iii) Dynamometer Type
- (iv) Induction Type
- (v) PMMC Type



(Construction) Parts of PMMC Instrument

- (i) Magnet system - Horse shoe pole type magnet (U-shape)
- (ii) Moving coil (core) - Aluminium former (frame) on coil attach with jewel bearing line
- (iii) Control torque - Spring Control
- (iv) Damping torque - Aluminium former

10. Pointer & scale - Uniform scale & mirror arrangement

Working Principle - Work of a DC Motor

B = Magnetic field

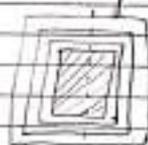
I = Current, circuit current

L = Length of conductor

Force = BIL newton

Torque = Deflecting torque $T_d = NBILd$

Co - Dimensional constant



$T_d = NBILd \times I$

$T_d = GI$

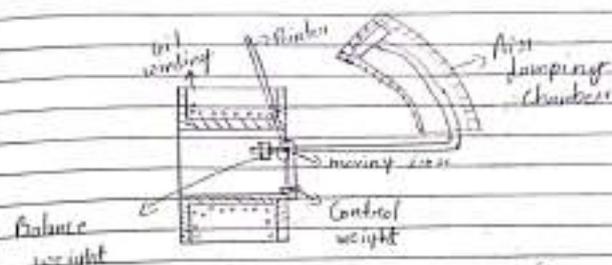
$T_d \propto I^2$

* Controlling torque $T_c = k\theta$

for a final value $T_d = T_c$

$kI = k\theta$

$\frac{GI}{k} = \theta$



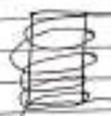
Moving Iron (coil fixed)

Works on A.C./D.C

(i) Attraction Type

(ii) Repulsion Type

Electromagnetic Induction



$T_d = \frac{1}{2} I^2 \frac{dL}{d\theta}$

$T_c = k\theta$

$T_d = T_c$

$\frac{1}{2} I^2 \frac{dL}{d\theta} = k\theta$

$\frac{1}{2} I^2 \frac{dL}{d\theta} = k\theta$

$\frac{dL}{d\theta} = \frac{2k\theta}{I^2}$

$\frac{1}{\theta} = \frac{d}{dL} (2I^2 k\theta)$

$\theta = \frac{dL}{d} \frac{1}{(2I^2 k)}$

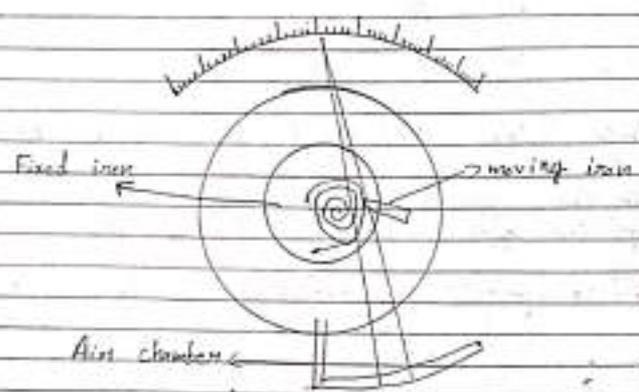
(ii) Scale - Non uniform

(i) Control weight = Gravity

$\theta \propto T^2$

PMMC की reading ज़्यादा accurate होती है। PMMC Instr.

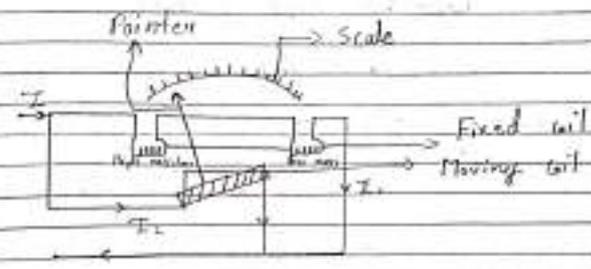
Repulsion Type



Construction :-

- (i) Fixed iron - main supply (V) Pointer & scale - Non Uniform
- (ii) Moving Iron - DC coil winding
- (iii) Controlling force - Spring control
- (iv) Damping system - Air friction damping

Dynamometer Instrument



MI (A) (V) ⇒ AC/DC

MC (A) (V) ⇒ DC

Dynamometer (A) (V) (W) ⇒ AC/DC

Construction -

- (i) Fixed coil
- (ii) Moving coil
- (iii) Controlling system (Spring control)
- (iv) Damping system (Air friction damping)
- (v) Pointer & Scale - Non-Uniform

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Working - Deflecting Torque = $i \cdot i$

$$T_d = k i^2$$

$$T_d = k i^2$$

$$T_c = k' \theta \quad T_c = \text{controlling torque}$$

$$T_d = T_c$$

$$k i^2 = k' \theta$$

$$\theta = \left(\frac{k}{k'} \right) i^2$$

जब fixed coil के दो धारों में से एक धारा प्रवाहित हो जाती है तो उस धारा के कारण magnetic field उत्पन्न होता है जो कि I_1 धारा के कारण उत्पन्न होता है।
 जब I_2 धारा moving coil में प्रवाहित होती है तो उस धारा के कारण magnetic field उत्पन्न होता है जिसके कारण दो धारों के बीच Deflection torque उत्पन्न होता है।

इस प्रकार यह एक dynamo की एक विशेषता है।
 Instrument एक dynamometer है।

The total energy stored in the magnetic field of the fixed coil

$$E = \frac{1}{2} L_1 i^2 + \frac{1}{2} L_2 i^2 + M i^2$$

L_1 = Inductance of fixed coil (Self Inductance)

L_2 = Self Inductance of moving coil

M = Mutual Inductance between moving & fixed coil

The introduction of this current give rise to deflecting torque (T_d)

$$T_d = \frac{dE}{d\theta} = \frac{1}{2} i^2 \frac{dL_1}{d\theta} + \frac{1}{2} i^2 \frac{dL_2}{d\theta} + i \frac{dM}{d\theta}$$

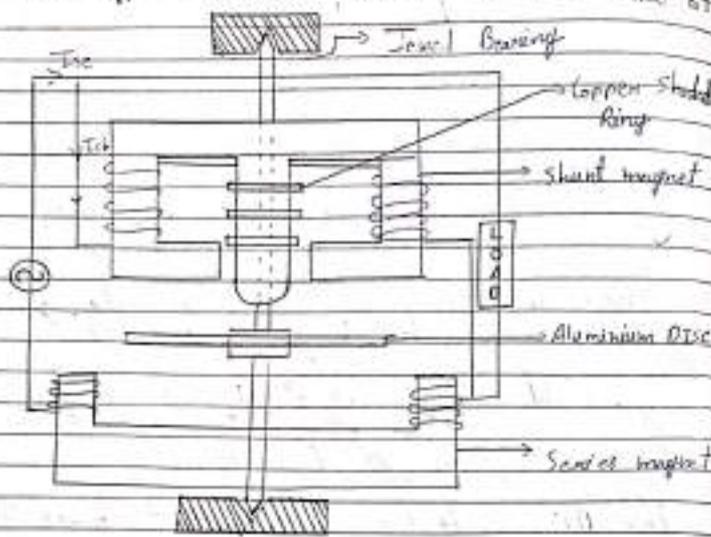
this is for AC:

For DC L_1 & L_2 are constant hence $\frac{dL_1}{d\theta} = \frac{dL_2}{d\theta} = 0$
 for AC $\frac{dL_1}{d\theta}$ is constant = $\frac{dL_1}{d\theta} = 0$

$$\text{And } T_d = i_1 i_2 \frac{dM}{d\theta}$$

Induction Type (A) (V) (W) (E) \rightarrow AC/DC

Induction Type Instrument (AC) \rightarrow (A) (V) (W) (E)



Scale = Uniform

Parts of the induction type instrument -

- (i) Shunt magnet = LOAD के साथ Parallel में connect होता है। इसमें no. of turns छोटी है।
- (ii) Series magnet = यह LOAD के साथ series में connect होता है। इसमें no. of turns बड़ा होता है।

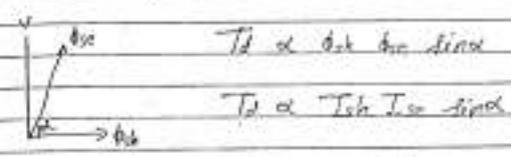
(iii) Aluminium DISC - यह Non-magnetic conductor होता है जो AC wave करता है।

(iv) Copper shaded Ring - यह flux angle को 90° पर Adjust करना होता है।

(v) Scale = Uniform होता है।

Working principal - Electromagnetic Induction

Theory - जब परिपथ में AC को मिला जाता है तो शunt magnet में धारा I_{sh} व series magnet में धारा I_{se} प्रवाहित होने लगती है इससे magnetic flux $I_{sh} \rightarrow \phi_{sh}$, $I_{se} \rightarrow \phi_{se}$ प्राप्त होता है और इन दोनों के interaction के कारण एक deflection torque T_d होता है जो -



$T_d \propto \phi_{sh} \phi_{se} \sin \alpha$
 $T_d \propto I_{sh} I_{se} \sin \alpha$
 I_{sh} का मान कम और I_{se} का मान बड़ा इसलिए होता है क्योंकि I_{sh} में अल्पतम धारा का मान जारा होता है।

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Controlling Torque Type 2 -

- (i) Gravity Control
- (ii) Spring Control

Controlling Torque - Spring Control

Damping Torque - Eddy current

UNIT - 03

Measurements using Bridges / Meters

Date			
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- (i) Measurement of Resistance
- (ii) Measurement of Inductance
- (iii) Measurement of capacitance

Classification / Types of resistance

- (i) Low Resistance ($< 1 \Omega$)
- (ii) Medium Resistance ($1 \Omega - 0.1 M \Omega$)
- (iii) High Resistance (Insulation Resistance) ($> 0.1 M \Omega$)

(i) Low Resistance find out points -

- (i) VA Method
- (ii) Potentiometer method
- (iii) Kelvin double bridge

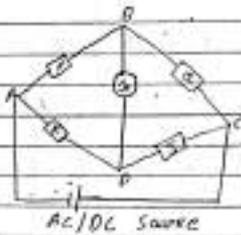
(ii) Medium Resistance find out points -

- (i) Voltampere method
- (ii) Wheat stone method Bridge
- (iii) Ohm method-meter

(iii) High resistance finding points -

- (i) Megger
- (ii) Megohm meter
- (iii) Loss of charge method

Bridges



When AC use it called AC Bridge

When DC used it called DC Bridge

Null deflection का मतलब है जब $Sx = a$ मीटर

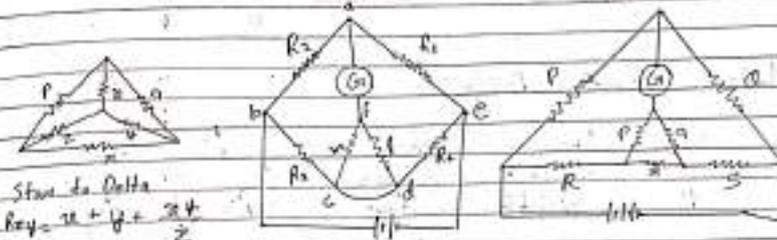
$$V_a = V_b \Rightarrow PS = QR$$

Bridge Balance है या नहीं यह पता लगाने के लिए जिस लचीले स्ट्रिंग्स का उपयोग किया जाये है -

- (i) Vibration galvanometer (5-200 Hz)
- (ii) Headphone (200-400 Hz)
- (iii) Loud amplifier (> 5 kHz)

Measurement of low resistance

(i) Kelvin Double Bridge



Star to Delta

$$R_{xy} = x + y + \frac{xy}{z}$$

$$R_{yz} = y + z + \frac{yz}{x}$$

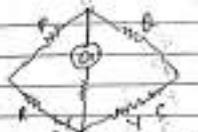
$$R_{zx} = z + x + \frac{zx}{y}$$

Delta to star

$$R_x = \frac{P \cdot Q}{P + Q + R}$$

$$R_y = \frac{P \cdot R}{P + Q + R}$$

$$R_z = \frac{Q \cdot R}{P + Q + R}$$



इसका उपयोग low resistance को measure करने के लिए किया जाता है।

At balance condition -

$$P(Q+S) = Q(R+Z)$$

$$PS + PQ = QR + QZ$$

$$QR - PS = PQ - QZ$$

$$QR - PS = \frac{PQ \cdot R}{P+Q+R} = \frac{Q \cdot P \cdot R}{P+Q+R}$$

$$QR - PS = \frac{R}{P+Q+R} [PQ - QR]$$

$$QR - PS + \frac{R}{P+Q+R} (PQ - QR)$$

$$R = \frac{PS}{Q} + \frac{R}{P+Q+R} (PQ - QR)$$

$$R = \frac{PS}{Q} + \frac{R \cdot Q}{Q(P+Q+R)} \left[\frac{P \cdot Q}{Q} - \frac{P \cdot R}{Q} \right]$$

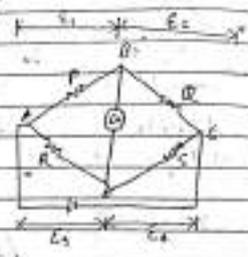
To eliminate contact resistance two additional known resistances are added in the circuit

To eliminate contact resistance $\frac{P}{a} = \frac{P}{a}$

Wheat Stone Bridge

- R, Q = Known resistance
- S = unknown resistance
- P = variable resistance

संज्ञित प्रतिरोध मापन (ACRM) प्रतिरोध का मापन करने के लिए



$G_0 = \text{Deflection Zero}$
 $V_0 = V_0$
 $E = E_1 + E_2 = E_3 + E_4$
 $I = I_1 + I_2$
 $E_1 = E_3$ & $E_2 = E_4$



$$I_1 = \frac{I(R+S)}{P+Q+R+S}$$

$$I_2 = \frac{I(P+Q)}{P+Q+R+S}$$

$$\frac{I(R+S)}{P+Q+R+S} \times P = \frac{I(P+Q)}{P+Q+R+S} \times R$$

$$(R+S)P = (P+Q)R$$

$$\frac{R+S}{R} = \frac{P+Q}{P}$$

$$\frac{R}{R} + \frac{S}{R} = \frac{P}{P} + \frac{Q}{P}$$

$$1 + \frac{S}{R} = 1 + \frac{Q}{P}$$

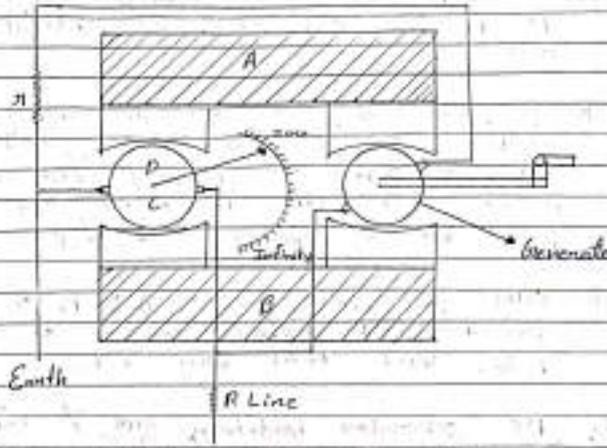
$$\frac{S}{R} = \frac{Q}{P}$$

$$\frac{P}{Q} = \frac{R}{S}$$

Current distribution in parallel path

Current find = $\frac{\text{total incoming current} \times \text{opposite resistance}}{\text{total resistance}}$

Megger



- (i) Megger एक हार्डवेयर DC जनरेटर से बनाया जाता है। जिसका उपयोग High resistance (insulation resistance), Earth resistance का मापन करने के लिए किया जाता है।
- (ii) यह एक पोर्टेबल मशीन है जो मापन के लिए direct scale पर Pointer की मदद से इंगित करता है।

(iii) चूंकि insulation resistance का मान $10^9 \Omega$ (Megohm) में होता है। इस कारण इसे मापने के लिये

Construction -

(i) इसमें P और C में moving coil होते हैं जिसमें P, Pressure coil एवं C को current coil कहा जाता है।

(ii) ये दोनों coil एक दूसरे के साथ 90° पर मजबूती से जुड़े होते हैं एवं दोनों coil एक साथ एक pivot पर pivoted होते हैं ताकि bar जे एक साथ घूम सके जिसमें एक pointer fixed coil से connect रहता है।

(iii) इसमें दो fixed magnet A & B के द्वारा generator तथा moving system को magnetic field प्रदान किया जाता है।

(iv) DC generator hand-driven होता है एवं moving के गैर gear होता है जिससे generator के armature के speed को control किया जाता है।

(v) Current coil, C का एक धीरा generator के negative brush से connect रहता है और यह coil resistance R के द्वारा line सिरे से series में adjust रहता है।

(vi) Pressure coil, P एक दूसरे resistance जे द्वारा armature brush से series में जुड़ा रहता है।

Note

- इसका scale infinite to zero होता है।

Workings -

(i) Megger का उपयोग निम्न कार्य में किया जाता है लेकिन इसका ज्यादातर इस्तेमाल Very high resistance (insulation resistance) को measure करने के लिये किया जाता है।

(ii) किसी भी अज्ञात resistance को very high resistance के measurement के लिये अज्ञात resistance को megger के line terminal से तथा दूसरे टर्मिनल को earth terminal से connect किया जाता है।

(iii) यदि resistance किसी वजह से open हो जाता है तो pointer infinite value indicate करता है।

(iv) यदि resistance किसी वजह से short हो जाता है तब यह zero show करता है।

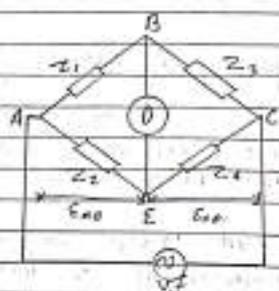
Application -

(i) इसका उपयोग insulation resistance के measurement के लिये किया जाता है।

(ii) Line to Earth fault के testing में किया जाता है।

- (iii) Line to Line full π testing में किया जाता है।
- (iv) Continuity की testing में किया जाता है।

AC Bridge



$R_1 + jX_1 = Z_1 =$ Impedance of branch AB
 $R_2 + jX_2 = Z_2 =$ Impedance of branch BC
 $R_3 + jX_3 = Z_3 =$ Impedance of branch CE
 $R_4 + jX_4 = Z_4 =$ Impedance of branch EA

At null deflection in detector D then

$$V_A = V_C$$

$$E_{DB} = E_{EA}$$

$$I_1 Z_1 = I_2 Z_2$$

$$I_1 = \frac{V}{Z_1 + Z_3} \quad \text{Voltage / Impedance}$$

$$I_2 = \frac{V}{Z_2 + Z_4}$$

$$\left(\frac{V}{Z_1 + Z_3}\right) Z_1 = \left(\frac{V}{Z_2 + Z_4}\right) Z_2$$

$$\frac{Z_1}{Z_1 + Z_3} = \frac{Z_2}{Z_2 + Z_4}$$

$$\frac{Z_1}{Z_1} + \frac{Z_1}{Z_3} = \frac{Z_2}{Z_2} + \frac{Z_2}{Z_4}$$

$$1 + \frac{Z_1}{Z_3} = 1 + \frac{Z_2}{Z_4}$$

$$\boxed{Z_1 Z_4 = Z_2 Z_3}$$

$$|Z_1| \angle \theta_1 \times |Z_4| \angle \theta_4 = |Z_2| \angle \theta_2 \times |Z_3| \angle \theta_3$$

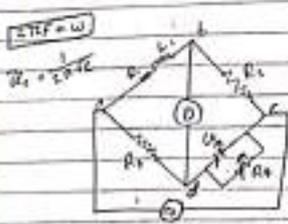
$$|Z_1| |Z_4| \angle \theta_1 + \theta_4 = |Z_2| |Z_3| \angle \theta_2 + \theta_3$$

$$|Z_1| |Z_4| = |Z_2| |Z_3|$$

$$\angle (\theta_1 + \theta_4) = \angle (\theta_2 + \theta_3)$$

Advantage of Maxwell bridge

Maxwell Inductance capacitance Bridge



C_2, R_2 = Variable resistors
 R_1, L_1 = Unknown resistance and inductance
 R_3, R_4 = Standard resistances
 Capacitor is ∞ (-) negative value \neq

$Z_1 = R_1 + j\omega L_1$

$Z_2 = \frac{1}{\frac{1}{R_2} + (-j\omega C_2)}$

$Z_3 = R_3$

$Z_4 = \frac{1}{\frac{1}{R_4} - j\omega C_4}$

$Z_5 = R_5$

$Z_6 = \frac{-j\omega R_6 C_6}{R_6 - j\omega C_6}$

at Balance condition

$Z_1 = \frac{R_1}{1 + j(2\omega)R_2 C_2}$

$V_a = V_d$
 Hence $I_1 Z_1 = I_3 Z_3$

$I_1 Z_1 = I_3 Z_3$

Inductance - 20% error
 $\frac{1-10}{10}$ के बीच किया जाता है।

$Z_1 \left(\frac{V}{Z_1 + Z_2} \right) = Z_3 \left(\frac{V}{Z_3 + Z_4} \right)$

Capacitance - 20% error
 0. factor > 10 में किया जाता है।

$\frac{(R_1 + j\omega L_1) R_4}{(1 + j\omega R_2 C_2)} = R_3 R_5$

$(R_1 + j\omega L_1) R_4 = R_3 R_5 (1 + j\omega R_2 C_2)$
 $R_1 R_4 + j\omega L_1 R_4 = R_3 R_5 + j\omega R_2 C_2 R_3 R_5$

Separate real and imaginary parts

$R_1 R_4 = R_3 R_5$
 $R_1 = \frac{R_3 R_5}{R_4}$

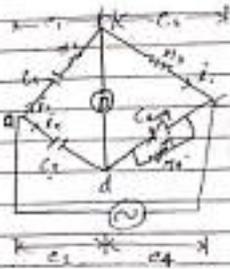
$j\omega L_1 R_4 = j\omega R_2 C_2 R_3 R_5$

$L_1 = \frac{j\omega R_2 C_2 R_3 R_5}{j\omega R_4} = L_2 C_2 R_3 R_5$

Q-factor value = $\frac{\omega L_1}{R_1} = \omega C_2 R_5$

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Measurement of Capacitance



- R_1 = Variable resistance
- C_1 = Unknown capacitance
- R_2 = Standard resistance
- C_2 = Standard capacitance
- R_3 = Standard resistance
- C_4 = Variable capacitance

Schering Bridge

For Balance Condition

$V_a = V_d$
 $C_1 = C_2$

$I_1 Z_1 = I_2 Z_2$

$Z_1 \left(\frac{V}{Z_1 + Z_2} \right) = Z_2 \left(\frac{V}{Z_3 + Z_4} \right)$

$\frac{1}{j\omega C_1} \left(-11 - \frac{1}{j\omega C_2} \right) =$

Impedance of Branch

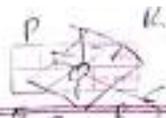
- $ab = Z_1$
- $ad = Z_2$
- $bc = Z_3$
- $cd = Z_4$

$Z_1 = \left(R_1 + \frac{1}{j\omega C_1} \right)$

$Z_2 = \frac{1}{j\omega C_2}$

$Z_3 = R_3$

$Z_4 = \frac{R_4}{1 + j\omega C_4 R_4}$



$\frac{V}{\omega} = \frac{R}{S}$
 $P.S = R \omega$

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$\frac{V}{j\omega C_1} \left(\frac{1}{R_1 + \frac{1}{j\omega C_1} + \frac{1}{j\omega C_2}} \right) = \frac{V}{R_2} \left(\frac{1}{R_2 + \frac{1}{j\omega C_4 + R_4}} \right)$

$\frac{R_1(j\omega C_1) + 1}{j\omega C_1} \left(\frac{V}{R_1(j\omega C_1)(j\omega C_2) + j\omega C_2 + j\omega C_1} \right) = -11$

$\frac{R_1(j\omega C_1) + 1}{j\omega C_1} \left(\frac{V(j\omega C_1)(j\omega C_2)}{R_1(j\omega C_1)(j\omega C_2) + j\omega C_2 + j\omega C_1} \right) = -11$

$\frac{(R_1 j\omega C_1 + 1)(j\omega C_1)(j\omega C_2) + V(j\omega C_1)(j\omega C_2)}{R_1(j\omega C_1)^2(j\omega C_2) + j\omega C_2 + (j\omega C_1)^2} = -11$

$\frac{V/j\omega C_1 + V}{j\omega C_1 + 1 + j\omega C_1} = \frac{R_3 + j\omega C_4 R_3 R_4 + R_4}{R_2 + j\omega C_4 R_4}$

$\frac{V(1 + j\omega C_4 R_4)}{R_2 + j\omega C_4 R_3 R_4 + R_4}$

$\frac{(V + V j\omega C_4 R_4)}{R_2 + j\omega C_4 R_3 R_4 + R_4}$

$= \frac{2V}{R_2 + R_4}$

$\frac{R_1 + 1}{j\omega C_1} = R_3$

$\frac{R_1 j\omega C_1 + 1}{j\omega C_1} = R_3$

$R_1 = \frac{R_3(j\omega C_1)}{j\omega C_1} = R_3$

$$Z_1 Z_2 = Z_3 Z_3$$

$$\frac{R_1 + j\omega L_1}{j\omega C_1} = \frac{R_2 + j\omega L_2}{j\omega C_2}$$

$$(R_1 + j\omega L_1 + 1) R_2 = j\omega L_2$$

$$j\omega C_1 (R_1 + j\omega L_1 + 1) = j\omega C_2$$

$$\frac{R_2 + j\omega L_2 + 1}{j\omega C_1 + j\omega C_1 j\omega L_2 + 1} = \frac{R_3}{j\omega C_2}$$

$$(R_2 + j\omega L_2 + 1) j\omega C_2 = R_3 (j\omega C_1 + j\omega C_1 j\omega L_2 + 1)$$

$$j\omega C_2 R_2 + j\omega C_2 j\omega L_2 + j\omega C_2 = R_3 j\omega C_1 + R_3 j\omega C_1 j\omega L_2 + R_3$$

$$\frac{R_2 + j\omega L_2 + 1}{j\omega C_1 + j\omega C_1 j\omega L_2 + 1} = \frac{R_3}{j\omega C_2}$$

$$j\omega C_2 R_2 + j\omega C_2 j\omega L_2 + j\omega C_2 = R_3 j\omega C_1 + R_3 j\omega C_1 j\omega L_2 + R_3$$

Comparing real terms

$$C_2 R_2 = R_3$$

$$R_2 = \frac{R_3}{C_2}$$

Comparing imag terms

$$j\omega C_2 j\omega L_2 + j\omega C_2 = R_3 j\omega C_1 + R_3 j\omega C_1 j\omega L_2 + R_3$$

$$C_2 L_2 = C_1 R_3$$

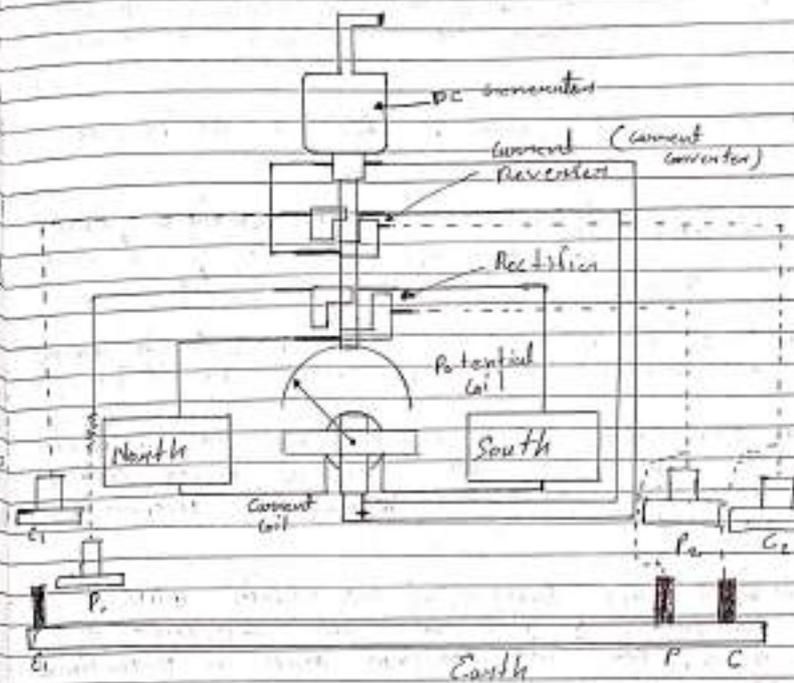
$$L_2 = \frac{C_1 R_3}{C_2}$$

Capacitors \Rightarrow Comparing imaginary terms

$$j\omega C_2 R_2 = R_3 j\omega C_1$$

$$C_2 = \frac{C_1 R_3}{R_2}$$

Earth Tester - Earth resistance measurement



(i) Earth tester एक गुणक या मल्टीप्लायर है जो कि Earth resistance measurement के काम आता है। Earth tester के द्वारा 0-50 Ω, 150 Ω या 300 Ω तक उच्च व Angles में resistance को measure किया जाता है।

(ii) Earth tester Potential drop के सिद्धांत पर काम करता है।

Construction - (i) इसके अंदर एक डायलमीटर होता है जो standing वोल्टेज है उसमें एक Hard driven construction होता है।

(ii) लोग फलन में दो Gal होते हैं जो परस्पर एक निश्चित angle पर लगे होते हैं।

(iii) इसमें एक Gal Current coil होता है जिसमें से flow होने वाले Current tested contact में flow होने वाले Current के Directional होता है।

(iv) दूसरा Gal Because Gal होता है इसमें प्रवाहित Current test किने जाने वाले resistance के across होने वाले voltage drop के proportional होता है।

(v) Ohm's meter में होने वाला deflection उन्ही Current के अनुपात पर निर्भर करता है।

(vi) Instrument में एक variable current converter (multiplication) current converter

और एक D.C. measurement होता है।

(iii) Variable Current Converter का उपयोग D.C. को AC में Convert करने के लिए किया जाता है।

(iv) Terminal C_1, C_2 के across AC वोल्टेज उठाता होता है। एवं Terminal P_1, P_2 के across AC वोल्टेज, D.C. वोल्टेज में Convert का जाता है।

Working principle - (i) इस Instrument के Electrode को Earth में समाया जाता है और galvanometer को हाथ से चलाया जाता है जो galvanometer से D.C. Current, Ohm meter की Current coil में होती हुई Current reverse में जाती है।

(ii) फिर Current, galvanometer से Earth में electrode E और C के बीच जाती है।

(iii) Electrode E और P के बीच होने वाले AC वोल्टेज drop है यह वोल्टेज drop Ohm meter के Pressure coil में किना जाता है।

(iv) Ohm meter की Indication इसके Resistance coil के across वोल्टेज drop तथा Current coil में flow होने वाले Current के

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अनुपात पर निर्भर करता है इसीलिए सरलीकरण
ohm meter का Indication direct scale
resistance के समानुपाती होता है।

UNIT - 02

Electromechanical measuring Instruments

Principle of current and voltage measurement -

Current के measurement के लिए प्रायः ammeter का उपयोग किया जाता है। अधिक मात्रा की धारा को मापने के लिए ampere meter के साथ shunt का उपयोग किया जाता है।

कम मात्रा की धारा को high accuracy से मापने के लिए - मीटर्स द्वारा का एक Standard resistance में प्रवाहित किया जाता है।

Standard resistance में जो Voltage drop होता है उसे वोल्टमीटर से मापा जाता है। इस Voltmeter के readings को Standard resistance में प्रवाहित कर measured current का मान परिचित किया जाता है।

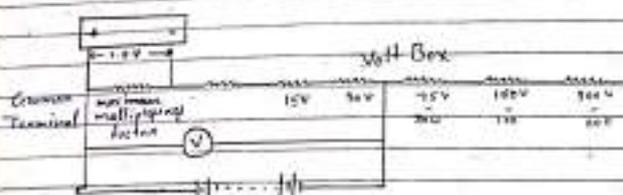


Unknown Current -

$$I = \frac{V_s}{R_s}$$

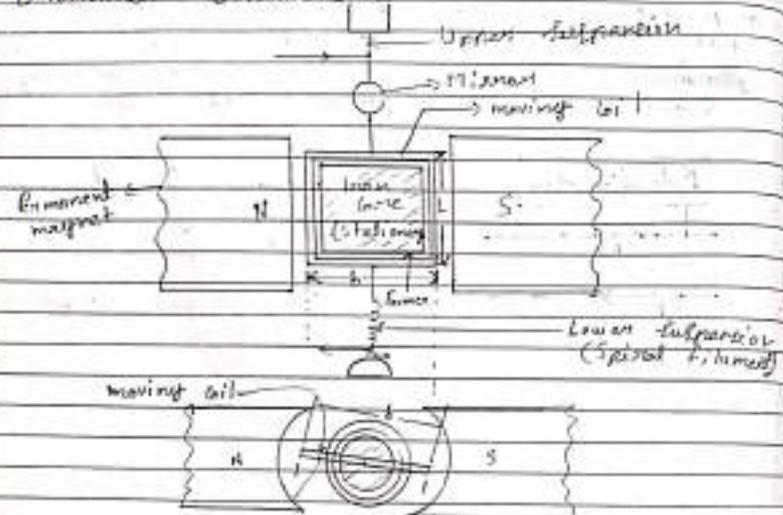
$V_s =$ Voltmeter reading

Principle of voltage measurement



Voltage to be Measured

D'Arsonval Galvanometer



D'Arsonval galvanometer

इस galvanometer को AC Bridge में 50 Hz से कम आवृत्ति वाले Bridge में use किया जाता है।

और DC Bridge में wheatstone, Kelvin, Potentiometer में use किया जाता है।

Torque Equation -

$$T_d = NBILb$$

$$T_c = k\theta$$

N - No. of turns

B - m.F. wb/m²

I - Current

L - length of moving coil

b - width of moving coil

θ - Angle of deflection

k - Spring constant

$$T_d = T_c$$

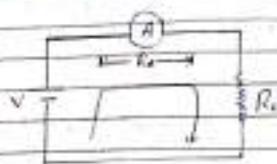
$$NBILb = k\theta$$

$$\theta = \frac{NBILb}{k}$$

$$\theta = \left(\frac{NBILb}{k} \right) I$$

$$\theta = GI$$

Ammeter -



Ammeter को circuit में series में जोड़ा जाता है और इसका internal resistance कम होना है और Ideal condition में R_s का मान शून्य हो जाता है।

$$I = \frac{V}{R_s + R_i}$$

जब अमीटर का resistance बढ़ेगा तब current का मान कम होगा।

$$R_s \uparrow \rightarrow I \downarrow$$

और जब अमीटर का resistance कम होगा तब current का मान बढ़ जायेगा।

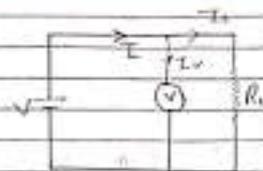
$$R_s \downarrow \rightarrow I \uparrow$$

$$T_d = NBI\ell b$$

$$T_d \propto I$$

∴ वकी सब constant है।

Voltmeter -



Voltmeter को circuit के साथ parallel में जोड़ा जाता है इसका Volt resistance High होना है और Ideal condition में R_s का value ∞ (Infinite) होना है।

$$V = I_v \cdot R_s$$

जब I_v (volt current) का मान बढ़ेगा तब I_v व V का मान कम हो जायेगा।

$$I_v \uparrow \rightarrow I_s \downarrow \rightarrow V \downarrow$$

और I_v का मान कम होगा तब I_v व V का मान बढ़ेगा।

$$I_v \downarrow \rightarrow I_s \uparrow \rightarrow V \uparrow$$

$$I_s R_s = I_v R_v$$

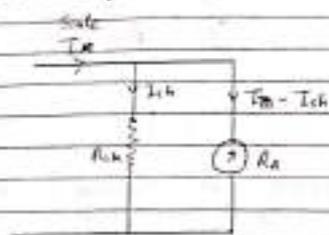
$N = \text{Height}$
 $l = \text{width}$
 $d = \text{depth}$

$$T_d = NBI\ell b$$

$$R_v = \frac{I_s R_s}{I_v}$$

$$T_d \propto I$$

Extension of Range for Ammeter



$$I_m R_h = (I_m - I_h) R_a$$

$$R_h = \left(\frac{I_m - I_h}{I_h} \right) R_a$$

$$= \left(\frac{I_m}{I_h} - 1 \right) R_a$$

$$R_h = (m - 1) R_a$$

m = multiplication factor

Q. A millimeter of 2.5Ω resistance read up to 100 milliamperes calculate the resist. which is necessary to enable it to be used as -

1. An ammeter reading up to 10A
2. A voltmeter reading up to 10V

$$V = I \cdot R$$

$$1. \quad V = 2.5 \times 100$$

$$V = 250 \text{ mV}$$

$$2. \quad V = I \cdot 2.5$$

$$\frac{10}{2.5} = I$$

$$I = 4$$

$$2. \quad V = I \cdot R$$

$$= 0.1 \times 2.5$$

$$= 0.25$$

$$V_m = 10 \text{ V}$$

$$R_{sh} = \frac{10}{0.1} - 2.5$$

$$= 100 - 2.5$$

$$= 97.5 \Omega$$

$$1. \quad R_{sh} = \left(\frac{I_m}{I_h} - 1 \right) R_a$$

$$= \left(\frac{10}{0.1} - 1 \right) 2.5$$

$$R_{sh} = 97.5 \Omega$$

$$R_a = 2.5 \Omega$$

full scale reading (I_m) = 100mA

I_h = reading

$$I_h = I_m - I_a$$

$$= 10 - 0.1$$

$$I_h = 9.9$$

$$V = I \cdot R_v = I \cdot R_{sh}$$

$$R_{sh} = \frac{V - I \cdot R_v}{I}$$

$$R_{sh} = \frac{V}{I} - R_v$$

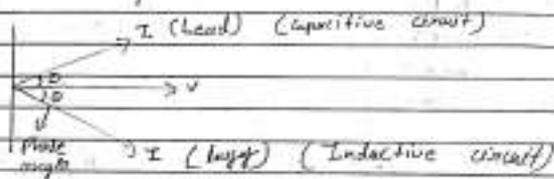
Power - शर्ज करने की दर को शक्ति कहते हैं।
इसे P से प्रदर्शित करते हैं।
एकता मापक वाट होता है। $P = \frac{E}{t}$

Energy - शर्ज करने की क्षमता को ऊर्जा कहते हैं।
इसे E से प्रदर्शित करते हैं।
It is the storing or dispatching
generating capacity of electrical power.

Electrical Power (AC)

3 phase Electrical power 2 phase Electrical power

P
 $\phi \rightarrow 120^\circ$
 $\phi \rightarrow 120^\circ$



Power Factor (P.F.) = $\cos \phi$

A value of angle between voltage and current in a load or electrical circuit is called Power factor.

Wattless power (Pure Inductive load)

$\phi = 90^\circ$
 $\cos 90^\circ = 0$
 $P = V I \cos 90^\circ$
 $P = 0$

Wattmeter - Power को मापने के लिए
इसका उपयोग किया जाता है।



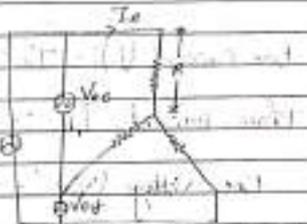
3 Phase -

Phase voltage V_e, V_f, V_o

Line current = I_e, I_f, I_o

Phase current = I_e, I_f, I_o

Line voltage (Phase to phase voltage)
 $= \sqrt{3} V_e, \sqrt{3} V_f, \sqrt{3} V_o$



Star connection

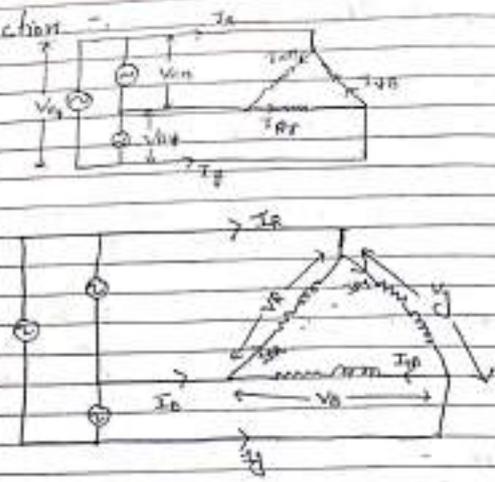
Line current = Phase current

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

Line vol = line $\sqrt{3}$ phase

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

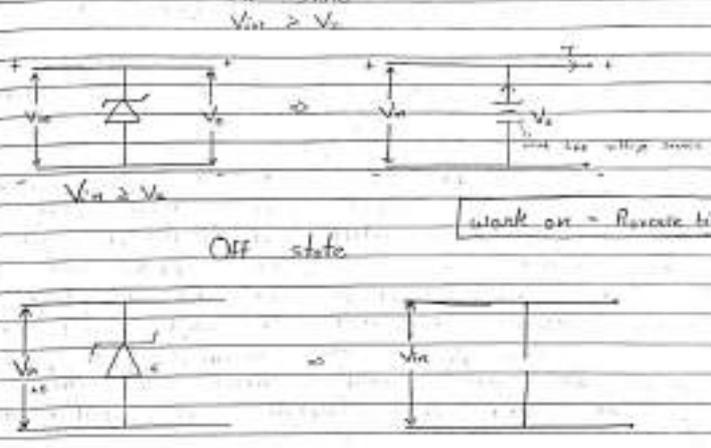
Delta Connection



Line Current (IL) :- I_L, I_L, I_L
 Phase Current (IP) :- I_{L1}, I_{L2}, I_{L3}
 Line Voltage (VL) - V_L, V_L, V_L
 Phase Voltage - V_L, V_L, V_L
 Line Voltage = Phase Voltage
 $V_L = V_{ph}$
 Line Current = $\sqrt{3}$ Phase Current
 $I_L = \sqrt{3} I_{ph}$

Basic Electronics

Working of Zener Diode



$V_{in} < V_Z$ Zener diode works as a normal PN Junction diode
 On state - जब on state में Zener diode के input voltage दिया जाता है तो वोल्टेज Zener diode में गजर जाता है और एक निश्चित वोल्टेज Zener diode से आगे flow करता है जोकि Zener diode reverse bias mode में कार्य करता है इसलिए अधिक voltage से पहले पर भी वह एक निश्चित वोल्टेज ही प्रदान करता है और निश्चित वोल्टेज को

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flow को बढ़ा कर का oppose कर देता है। इसमें input voltage बढ़ और बढ़ता है। Zener voltage से।

मतः इस कारण Zener voltage को नियंत्रित करने का तरीका कार्य करने लगता है। और current flow करता है।

OFF state - जब off state में Zener diode को input voltage दिया जाता है तब एक निश्चित सीमा में वोल्टेज का flow करता है और का oppose कर देता है। इस input voltage का नाम का मान जब Zener voltage से कम हो जाता है। तब Zener diode एक normal PN Junction diode की तरह कार्य करता है और की जो वही मोल्ता को प्रभावित करता है।

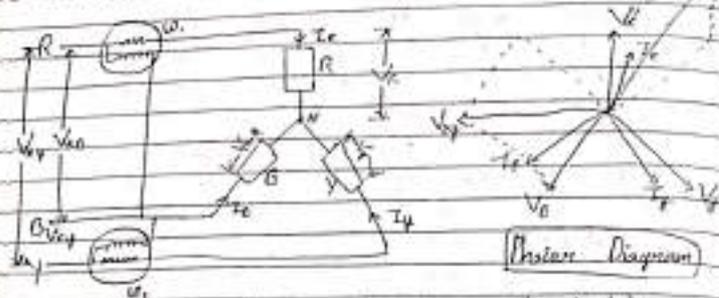
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Zener diode works as a voltage stabilizer (regulator)

Zener diode का उपयोग voltage regulator के काम में constant voltage को प्राप्त करने के लिए एक जो न-लिना जाता है। जो source voltage एक निश्चित सीमा में रहता है। Zener diode को load के साथ parallel में, reverse में जोड़ा जाता है जो VO-LOAD के across constant voltage प्रदान करता है। इसमें एक series resistance R, source के साथ series में जोड़ा जाता है जो output में Voltage fluctuation को stabilize करने का कार्य करवा करता है।

Zener diode तब तक कार्य करता है जब तक input voltage का मान Zener voltage से कम नहीं हो जाता।

3 ϕ Power Measurement using 2 wattmeter Method



$$V_{ab} = V_b - V_a \Rightarrow V_b + (-V_a)$$

$$V_{cb} = V_b - V_c$$

$$V_{cb} = V_c - V_b$$

Let the load is balanced for 3 phase four wire system then $I_a + I_b + I_c = 0$ and $W_1 + W_2 = P_{total}$ (Subscript).

$$V_a = V_b = V_c = V_{ph} \quad (\text{ph} = \text{phase})$$

$$V_{ab} = V_{bc} = V_{ca} = V_L$$

$$I_a = I_b = I_c$$

for star connection
Phase current = line current
 $I_{ph} = I_L$
 $I_a = I_b = I_c = I_L$

Angle between V_{ab} and I_a is $30 - \phi$

Reading of wattmeter $W_1 =$

$$P_1 = V_{ab} \cdot I_a \cos(30 - \phi)$$

$$P_1 = V_L \cdot I_L \cos(30 - \phi)$$

$$P_1 = \sqrt{3} V_{ph} I_{ph} \cos(30 - \phi)$$

$$V_{ab} \& I_{ph} \Rightarrow 30 - \phi$$

$$V_{cb} \& I_{ph} \Rightarrow 30 + \phi$$

Reading of wattmeter $W_2 =$

$$P_2 = V_{cb} \cdot I_c \cos(30 + \phi)$$

$$P_2 = V_L \cdot I_L \cos(30 + \phi)$$

$$P_2 = \sqrt{3} V_{ph} I_{ph} \cos(30 + \phi)$$

Total power = $P_1 + P_2 = \sqrt{3} V_{ph} I_{ph} \cos \phi$

$$P = \sqrt{3} V_{ph} I_{ph} \cos(30 - \phi) + \sqrt{3} V_{ph} I_{ph} \cos(30 + \phi)$$

$$P = \sqrt{3} V_{ph} I_{ph} [\cos(30 - \phi) + \cos(30 + \phi)]$$

$$P = \sqrt{3} V_{ph} I_{ph} [\cos 30 \cos \phi + \sin 30 \sin \phi + \cos 30 \cos \phi - \sin 30 \sin \phi]$$

$$P = \sqrt{3} V_{ph} I_{ph} [\cos 30 \cos \phi + \sin 30 \sin \phi + \cos 30 \cos \phi - \sin 30 \sin \phi]$$

$$P = \sqrt{3} V_{ph} I_{ph} [\sqrt{3} \cos \phi]$$

$$P = 3 V_{ph} I_{ph} \cos \phi$$

$$\frac{\sqrt{3}}{1} \cos \phi + \frac{1}{2} \sin \phi + \frac{\sqrt{3}}{2} \cos \phi - \frac{1}{2} \sin \phi$$

$$= \sqrt{3} \cos \phi + \frac{1}{2} \sin \phi + \frac{\sqrt{3}}{2} \cos \phi - \frac{1}{2} \sin \phi$$

$$= 2 \sqrt{3} \cos \phi$$

$$P_1 - P_2 = \sqrt{3} V_{ph} I_{ph} \sin \phi \quad \dots (ii)$$

$$P = \sqrt{3} V_{ph} I_{ph} [\cos(30 - \phi) - \cos(30 + \phi)]$$

$$P = \sqrt{3} V_{ph} I_{ph} [\cos 30 \cos \phi + \sin 30 \sin \phi - (\cos 30 \cos \phi - \sin 30 \sin \phi)]$$

$$P = \sqrt{3} V_{ph} I_{ph} [\cos 30 \cos \phi + \sin 30 \sin \phi - \cos 30 \cos \phi + \sin 30 \sin \phi]$$

$$P = \sqrt{3} V_{ph} I_{ph} \left[\frac{\sqrt{3}}{2} \cos \phi + \frac{1}{2} \sin \phi - \frac{\sqrt{3}}{2} \cos \phi + \frac{1}{2} \sin \phi \right]$$

$$= \frac{\sqrt{3} \sin \phi + \sin \phi}{2}$$

$$= \frac{2 \sin \phi}{2}$$

$$P = \sqrt{3} V_{ph} I_{ph} \sin \phi$$

Equation (ii) \div (i)

$$\frac{P_1 - P_2}{P_1 + P_2} = \frac{\sqrt{3} V_{ph} I_{ph} \sin \phi}{3 V_{ph} I_{ph} \cos \phi}$$

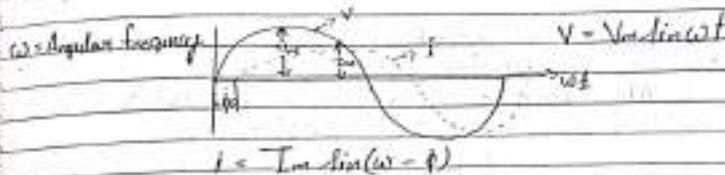
$$\frac{P_1 - P_2}{P_1 + P_2} = \frac{1}{\sqrt{3}} \tan \phi$$

$$\tan \phi = \sqrt{3} \frac{P_1 - P_2}{P_1 + P_2}$$

$$\phi = \tan^{-1} \left[\frac{\sqrt{3} (P_1 - P_2)}{P_1 + P_2} \right]$$

Measurement of power in $\pm \phi$ phase in A.C.

$P = VI$, $P =$ Instantaneous value of power
 $V =$ Instantaneous value of voltage
 $i =$ Instantaneous value of current



Then Instantaneous Power

$$P = Vi = V_m \sin \omega t \times I_m \sin(\omega t - \phi)$$

$$P = V_m I_m \sin \omega t \cdot \sin(\omega t - \phi)$$

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

$$P = \frac{V_m I_m \cos \phi}{2}$$

$$P = \frac{V_m}{\sqrt{2}} \times \frac{I_m}{\sqrt{2}} \cos \phi$$

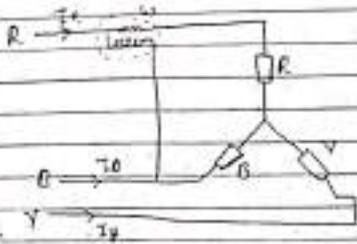
$$P = V_{rms} I_{rms} \cos \phi$$

3 Phase Power measurement

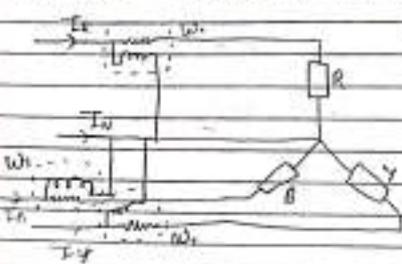
- (i) One wattmeter method
- (ii) Two wattmeter method
- (iii) Three wattmeter method

(i) One wattmeter method

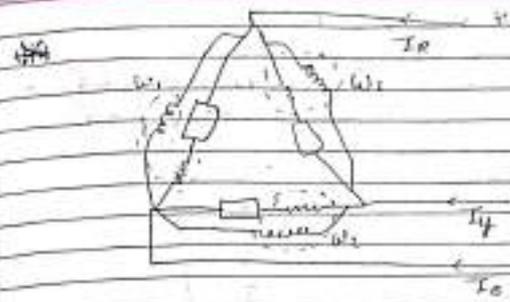
1. No. of wattmeter = 1
2. LOAD Balanced, 3. Power factor calculation not possible



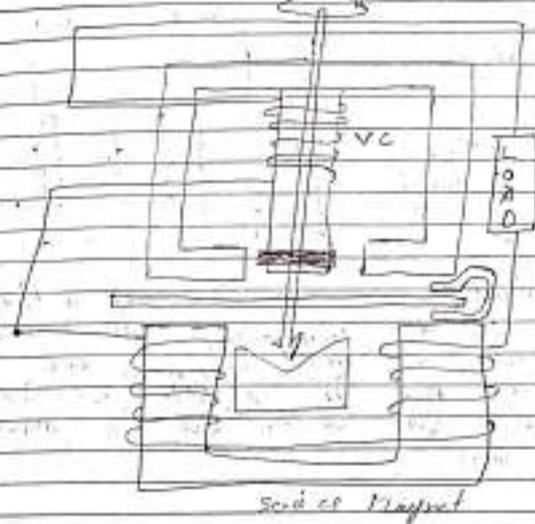
(ii) Three wattmeter method



1. Unbalanced LOAD
2. P.F. Calculation not possible



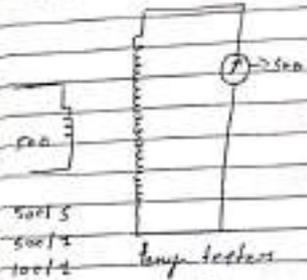
Single phase Energy meter



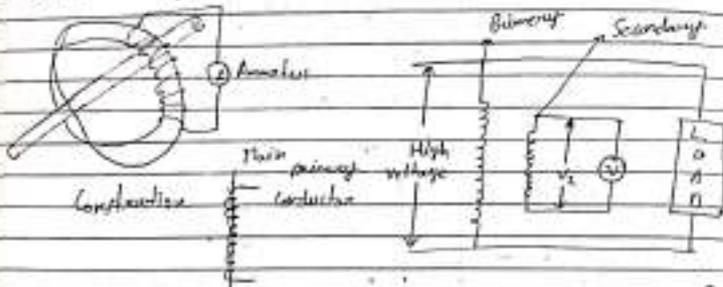
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also used for protection

CT
Current transformer



PT
Potential transformer
Voltage transformer



CT का उपयोग: उच्च धारा के मापन के लिए किया जाता है। यह transformer धारा के मान को, उच्च धारा के मान में step down करके निम्न धारा के मान में परिवर्तित कर देता है। इसके साथ इसे समान्य रेंज के मापन यंत्र द्वारा मापा जाता है।

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Current transformer को उच्च मान के धारा के मापन के लिए प्रयोग में लाया जाता है। Current transformer के Primary में केवल 1 Conductor, तथा Secondary में बहुत सारे Turns होते हैं।

इसका उपयोग उच्च मान के Voltage के मापन के लिए किया जाता है। यह transformer उच्च मान के Voltage को step down करके निम्न मान के Voltage में परिवर्तित कर देता है। Potential transformer को

Digital Energy meter - Energy meter एक आवश्यक Instrument है जिसका इस्तेमाल electrical energy के खपत के मापन के लिए किया जाता है। यह व्यक्तिगत उपभोक्ता द्वारा खपत की मात्रा में परिवर्तित करने के कार्य आता है। इसका उपयोग residential, Commercial, Industrial, Agriculture etc. द्वारा निम्न खपत की गई विद्युत ऊर्जा के मापन में इस्तेमाल किया जाता है। इसमें electrical energy का खपत kWh (यूनिट) के रूप में प्रदर्शित होता है।

Working of Digital energy meter -

Digital Energy meter current & voltage को लगातार मापकर और Instant electrical power देने के लिए उपयोग किया जाता है।

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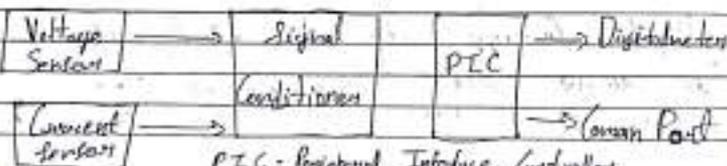
जिसे पश्चात उपयोग की गई ऊर्जा को सामान्य के अनुसार सक्रिय किया जाता है।

Types of Electronic meters अत्यधिक Integrated Components या अन्य Indicated Element का उपयोग करके ऊर्जा को मापते हैं। ये उपकरण, इन Resolution Signer, delta, EDC (Analog to Digital Converter)

के माध्यम से analog से Digital में परिवर्तित किया जाता है। इस के पश्चात Common rail voltage में Digital value को Multiply करके Power या Instant Power को मापा जाता है। जिसे नॉड में एकीकरण से उपयोग की गई ऊर्जा मिलती है जिसे RWH में मापा जाता है।

Advantages -

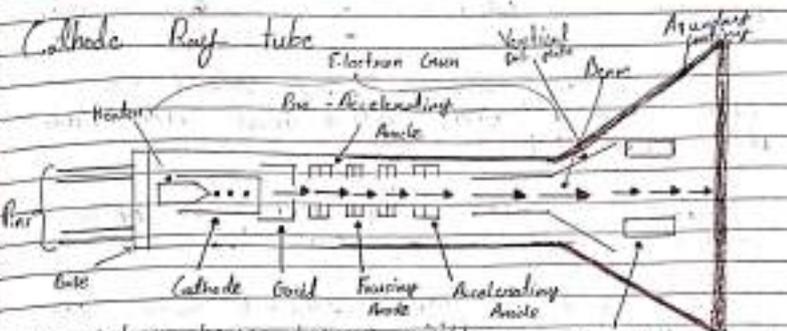
- (i) Digital electro meter, electro mechanic meter की तुलना में याता Efficient, Compact size, userfriendly होता है।
- (ii) Digital energy meter में Copying loss नहीं होता।



PIC - based Interfacing Controller

UNIT - 05

Cathode Ray Oscilloscope & Digital Storage Oscilloscope



The electron beam becomes visible. Horizontal Deflection Yoke, Vertical Def. Plate, Anode, Focusing Anode, Accelerating Anode, Cathode Grid, Focusing Anode, Accelerating Anode, Horizontal phosphor screen.

CRT-Elect generate an electron beam, accelerate the beam to a High velocity, deflect the beam to create the image & enhance a phosphor screen screen.

Main part of CRT - (i) Electron Gun Assembly - इससे electron beam को निकालते (flow) होते हैं।

(ii) Vertical & Horizontal Def. plate - Vertical plate left & right move करता है जबकि Horizontal plate up & down move करता है।

(iii) Electron Gun Assembly - Elect^{ve} electron beam को उत्पन्न करता है, इसके एक Control Grid जो कि Cathod को घेरा हुआ होता है, Focusing Anode A₁ एवं Accelerating Anode A₂ होते हैं Cathode एक Nickel cylinder coated with Oxide coating of Barium or Strontium को मिलता है। Cathod को Anoding - surface कहा जाता है।

Electron gun assembly
 cathode beam - control gun, grid, pre-accel. anode

Electron का emission Cathode Current पर नियंत्रित करता है जिसे Control Grid द्वारा नियंत्रित किया जाता है।

Cathode में प्रवाहित होने वाली धारा Approx 60mA at -6.3V. (AC or DC) होता है।

Control Grid एक Metal Cylindrical Grid होता है जिसमें Low Permeability Steel का इस्तेमाल होता है जिसका आकार diameter 15mm. एवं Length 15mm. होता है।

Control Grid assembly cathode की तुलना में Negative Potential होता है।

जब electron beam Control Grid से बाहर आता है तब वह पहले Pre-accelerating Anode जो कि Halo Cylinder के आकार का होता है एवं इसमें Potential up to few 100 Volts (Positive with respect to cathode) होता है।

जब electron beam screen पर focus होता है तब यहां दो और Cylindrical Anode, Focusing Anode A₁ एवं Accelerating anode A₂ से मिलता है एवं दोनों Anode का काम beam को Focus करना एवं beam को गति प्रदान करना होता है।

Deflecting plate assembly

Electron beam, electron gun से निकलने के बाद two pairs of deflecting plates में से गुजरता है जिसमें एक pair horizontally mounted होता है एवं Vertical Plate में electric field produce करता है। यह pair Vertical Deflection plate और Y-plates कहलाते हैं।

Deflecting plate की दूसरा pair vertically mounted होता है एवं Horizontal direction में electric field produce करता है यह pair horizontal plate और X-plate कहलाते हैं।

जब Y-plate में AC voltage apply किया जाता है तब beam ऊपर-नीचे Plate के Potential के अनुसार move करता है एवं जब X-plate में AC voltage apply किया जाता है तब beam right-to-left direction में move करता है।

variable quality.

(iii) Comparisons of phase & frequency.

(iv) Measurement of capacitance & Inductance. used in television & radar systems.

(v) Finding B-H curve for hysteresis loop

(vi) For engine pressure analysis.

(vii) For studying the Heart-beat, Nerv system.

Components of block diagram of an oscilloscope

Vertical amplifier - It amplifies the signal wave form to be viewed

Horizontal amplifier - It is fed with a short burst voltage which is then applied to horizontal deflection plate

Swip base generator - It produce short burst voltage wave form used for horizontal deflection of the electron beam.

Trigger circuit - It produces trigger pulse to start horizontal swip

High & Low voltage supply - The power supply block provides the voltage required by CRT to generate the beam it is generate & accelerate the beam.

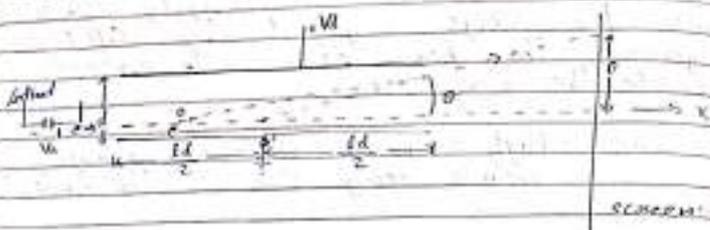
Delay Line - High frequency oscilloscope always include delay line in the vertical amplifier.

Working of CRO

(i) When the signal is to be displayed and viewed on the screen, it is amplified

Some copy of CRT

Electrostatic Deflection =



When electron beam passes between vertical (Y-plate) of a CRT then it deflects in the upward direction because of Y-plate is positive with respect to lower Y-plate & it the electron change the path from horizontal path to upward vertical parabolic path.

Let - m mass of electron v_0

v_0 = velocity of electron from electron gun

V_d = Deflecting voltage

e = Charge of electron

electron's energy

$$eV_0 = \frac{1}{2} m(v_0)^2$$

$$\frac{2eV_0}{m} = V_0$$

Electrostatic Deflection due to Y-plate

Let - d = distance between Y-plate

L = Length of Y-plate

L = Distance from O' to screen

V_d = Deflecting voltage (Potential difference between Y-plate)

D = Deflection to screen

$$V_d = \frac{eV_d}{md} \cdot \frac{Ld}{V_0}$$

After leaving the Y-plate electron moves in straight line because it is field free region. During the motion between the deflecting plates a uniform acceleration is acting on the electron & hence force its path is parabolic.

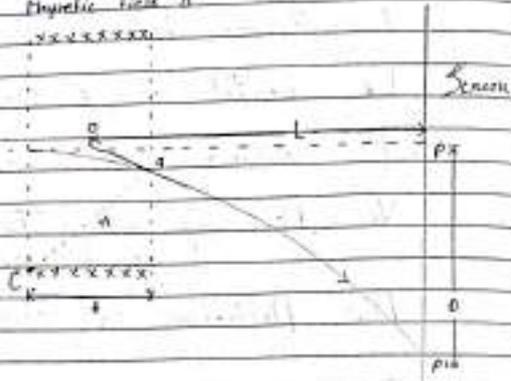
The Deflection D of the electron when it leave the field is

$$D = \frac{L V e B}{2 d \sqrt{2eV}}$$

Magnetic Deflection

Magnetic field B
 $\times \times \times \times \times \times \times \times$

Electron beam
 \rightarrow



When a charge particle (electron) enters into the magnetic field then it is affected by Lorentz force & moves into circular direction.

$$\text{then } F_c = BeV$$

F_c = Lorentz force, B = Magnetic field
 F_c = Centrifugal force, v = Velocity of electron
 e = Charge of electron

$$F_c = \frac{mv^2}{r}$$

$$\frac{mv^2}{r} = BeV$$

$$\frac{mv^2}{BeV} = r$$

$$r = \frac{mV}{Be}$$

From the above figure the radius of the circular path is r & the center is at point c .

The angle of deflection θ is very small then

$$\theta \approx \frac{D}{L}$$

Let - D = deflection on screen
 L = Distance between P & O
 l = length of applied magnetic field

Since distance L is very large as compare to l therefore

The deflection $D = L \tan \theta$
 when θ is very small then $\tan \theta \approx \theta$

$$D = L \theta$$

$$D = \frac{L l B e}{mV}$$

$$D = \frac{L B \theta}{m V_d}$$

$$D = \frac{L B \theta}{m \sqrt{\frac{2 e V_d}{m}}}$$

$$D = \frac{L B \theta}{m \frac{\sqrt{2 e V_d}}{m}}$$

$$D = \frac{L B \theta \sqrt{m}}{m \sqrt{2 e V_d}}$$

$$D = \frac{L B \theta}{\sqrt{m} \sqrt{2 e V_d}}$$

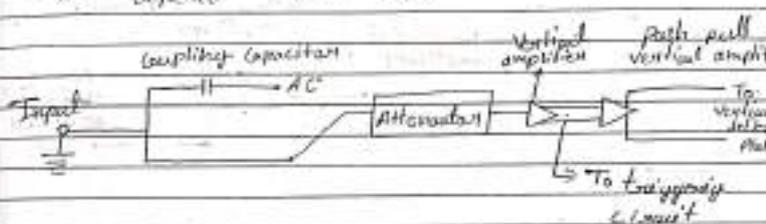
Vertical Amplifier -

(i) Vertical Amplifier का main purpose input signal को amplify करना होता है।

(ii) Vertical amplifier में Input signal को deflecting plate के across apply किया जाता है।

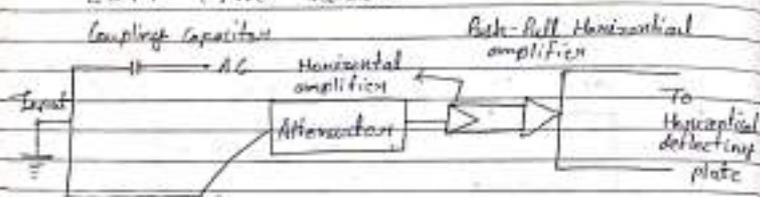
(iii) Vertical amplifier में input signal को fixed gain के अनुसार बढ़ाया जाता है जिसका output stage एक push-pull amplifier होता है। Amplification करते समय इस नोटा का ध्यान रखा जाता है कि signal को display screen से जाया नहीं होना चाहिए। इसके लिए हमें attenuator का इस्तेमाल किया जाता है।

(iv) Oscilloscope की sensitivity and bandwidth पर depend होती है। मुख्य vertical amplifier



Horizontal Amplifier -

- (i) Horizontal amplifier of main purpose input signal is amplified across the plate.
- (ii) Horizontal amplifier is input signal 'X' deflecting plate is across apply from other plate.
- (iii) Vertical amplifier is input signal is across fixed grid is across other plate.
- (iv) Voltage in current measurement is done horizontal amplifier is sawtooth wave form apply this and frequency 30 Hz (Phase measurement is done external signal send from other).
- (v) Horizontal amplifier is input impedance approx (1 mega ohm) shunted by capacitance 20 PF (Pico farad) and coupling capacitor.



ii) Vertical deflection system (Y-Deflection sys.)

इसका प्रयोग signal को Vertically प्रदर्शित करने के लिए किया जाता है। जब signal Vertical deflection plate में acceleration में convert होता है। जो कि CRT screen में display होता है। जो कि signal की तीव्रता कम होता है। जब Vertical amplifier के द्वारा इसे तब मात्रा में बढ़ा कर मापा जाता है।

Amplifier से निकलने वाला Amplified signal (High Voltage) Synchronisation selecton के द्वारा Horizontal sweep के साथ signal में Horizontal sweep के साथ trigger होने सम्भव किया जाता है।

iii) X-Deflection system (Horizontal def. sys.)

जब sweep voltage X-deflection plate में apply होता है तब signal को time base बनता है। जो कि signal amplification में time विभिन्न प्रमाण में horizontal deflection plate में insert an apply होता है। तब

जब sweep generator या किसी बाहरी signal से receive होता है। यह receiving signal horizontal plate में apply होता है तब horizontal amplification के द्वारा इसे receive कर इसके दुबला होने पर इसे amplification कर चढ़ाये जाता है।

जब signal द्वारा signal के frequency को निर्माण करता है।

iv) Synchronization (सम्य-साध)

Sweep generator या बाहरी external signal के द्वारा हम signal तब सकृति को screen में synchronise कर सकते हैं। इसके लिए sweep selecton switch को बाहर या बाहर स्थित कर सकते हैं।

(iv) Sweep generator

यह horizontal deflection plate में apply होने वाला strength waveform को उत्पन्न करता है। यह timebase generator कहलाता है।

(v) Power supply

CRO में कई प्रकार के power supply की आवश्यकता होती है।

1. विभिन्न प्रकार के फिलामेन्ट tube को चलाने के लिए low voltage supply की आवश्यकता होती है।

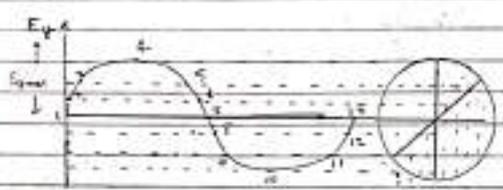
2. Value एवं CRT की गेट को चलाने के लिए high voltage supply की आवश्यकता होती है। (control section).

Lissajous Pattern

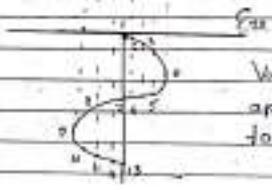
जब deflection plate के दोनों परस्पर पर
 Alternating voltage लगाए किया जाता है तब
 एक जो स्क्रॉल सीटी रेखा और एक जो स्क्रॉल
 के साथ loop के रूप में मिलित सक्रियता
 समय पर प्राप्त होती है। ये सक्रियता
 Lissajous Pattern कहलाती है।

(i) Lissajous Pattern का इस्तेमाल विभिन्न signals
 के RMS phase angle, frequency, amplitude of
 voltage, current, power को मापने के लिए किया
 जाता है।

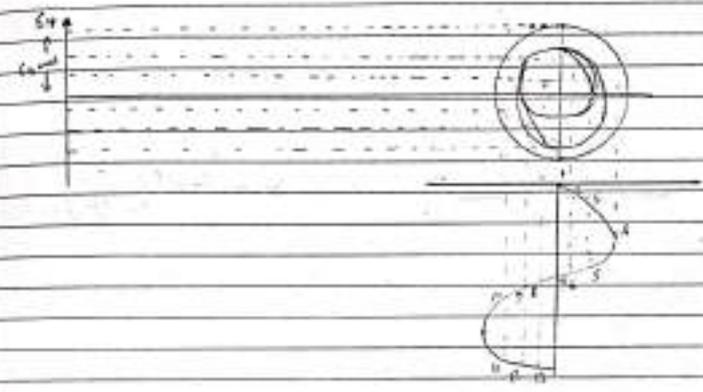
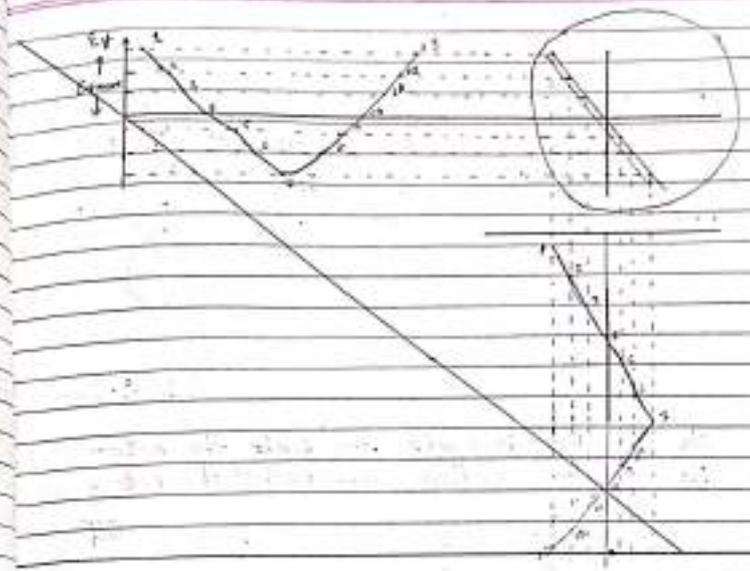
(ii) Lissajous Pattern का आकार दोनों signal के बीच
 Phase angle पर निर्भर करता है।

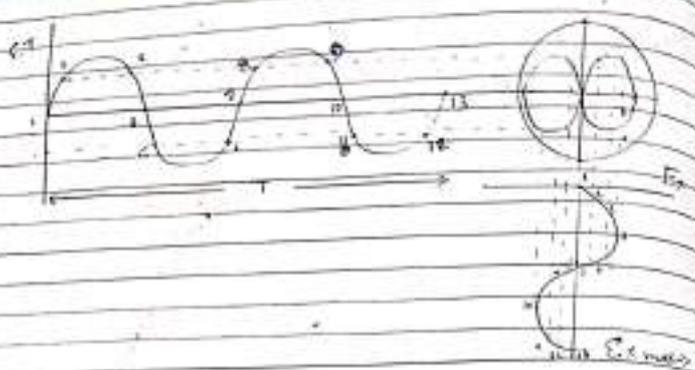


Voltage applied
 to Y plate



Voltage
 applied
 to X plate

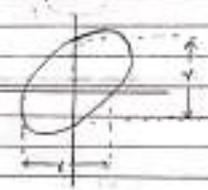




f_x = No. of times Horizontal line touches the pattern
 f_y = No. of times Vertical line touches the pattern

$$\frac{f_x}{f_y} = \frac{2}{1}$$

$$\therefore f_x = 180$$



$$\theta = \cos^{-1} \left(\frac{x}{y} \right)$$

Common Collector Configuration (C.C.)

Common Collector Configuration (C.C.)

Characteristics of C.C. Configuration

- Input Impedance is high
- Output Impedance is low
- Voltage Gain is less than 1
- Current Gain is high
- Phase Shift is 0°

Advantages of C.C. Configuration

- It has high input impedance
- It has low output impedance
- It has a voltage gain less than 1
- It has a current gain greater than 1
- It has a phase shift of 0°

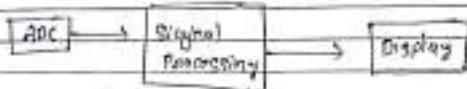
Disadvantages of C.C. Configuration

- It has a voltage gain less than 1
- It has a current gain less than 1
- It has a phase shift of 0°

Mesurement
UNIT - 04

Digital instrument :- एक ऐसा device है जो किसी input के output Voltage को digital number में measure कर measurement Voltage को digital number में convert करे।
यह किसी input के output Voltage को digital number में measure कर measurement Voltage को digital number में convert करे।
यह किसी input के output Voltage को digital number में measure कर measurement Voltage को digital number में convert करे।

Block diagram of digital instrument

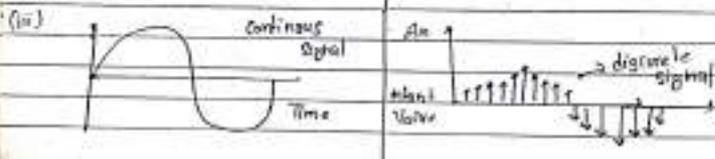


Difference between Analog or digital instrument

Analog

Digital

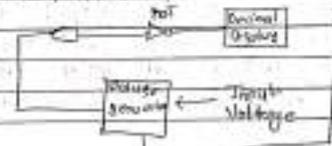
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|---|---|
| (i) यह Analog signal को माप करता है। | (i) यह Digital signal को माप करता है। |
| (ii) Analog signal का output continuous signal होता है। | (ii) Digital signal का discrete signal होता है। |



- | | |
|--|--|
| (i) Analog signal Sinusoidal form में प्रदर्शित होता है। | Digital signal pulse के रूप में प्रदर्शित होता है। |
| (ii) Analog signal waves के रूप में measure किया जाता है। | Digital instrument signal को binary form में measure करता है। |
| (iii) Analog signal के recording के लिए कोई Input device या device को ताले किता जाता है। | Digital instrument में digital signal को store करने के लिए memory की आवश्यकता होती है। |
| (iv) Ex - Analog Voltmeter, Ammeter, energy meter, Analog wattmeter | Ex - Digital Voltmeter, Digital Ammeter, Digital energy meter, Digital Wattmeter |

- Advantages of Digital Instrument** :-
- (i) यह Input को जितने numeric Voltage में Display करता है तितने इसे पहले के प्रदर्शित होता है।
 - (ii) इसकी accuracy जाड़ा होती है।
 - (iii) Digital instrument में data store करने की जरूरत नहीं है।
 - (iv) Digital instrument में Power consumption analog से कम होता है।
 - (v) Digital instrument का आकार छोटा होता है।

Digital Voltmeter (DVM)



एक एक digital Voltmeter में AC व DC दोनों Voltage को measure कर सकता है। यह measuring Voltage के digit के form में Display करता है। इसके accurate एवं result - error free है।

जोकि इसे parallel circuit की आवश्यकता नहीं है इससे size analog voltmeter से कम होता है। इसमें power consume कम है। इसमें कोई सर्किट ब्रेकर, counter, principle की वजह से Voltage को कम प्रभाव दिया जाता है।

Construction / Working

- (i) Input signal - यह conversion करने के लिए input voltage को
- (ii) Pulse generator - यह input signal को rectangular signal के form में convert करता है। यह Digital/Analog या दोनो का use करके rectangular pulse में convert करता है। इसके अलावा a rectangular pulse को digital circuit के लिए output दिया जाता है तथा amplitude, rising तथा falling time को analog circuit के द्वारा detect किया जाता है।
- (iii) Andgate - जब rectangular pulse और square pulse High होगे तो के Andgate में High output मिलेगा है।
- (iv) NOTgate - यह Andgate के output, train pulse को उल्टा कर देता है। यह output को उल्टा करके उसके अवधि में प्रभाव करता है तथा उसके value को calibrate करने के लिए LED।

LED display में प्रदर्शित करता है।

Types of DVM

- (i) Ramp type DVM
- (ii) Integrating type DVM
- (iii) Potentiometric type DVM
- (iv) Continuous balance type DVM
- (v) Successive approximation type DVM

Advantages of DVM

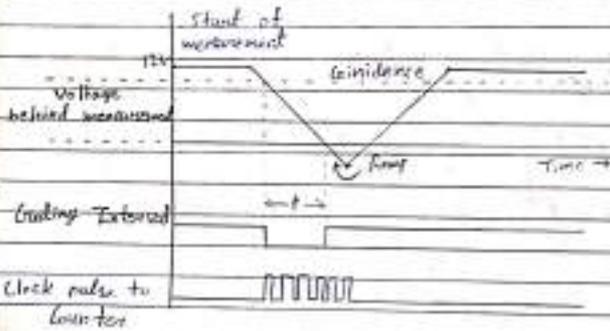
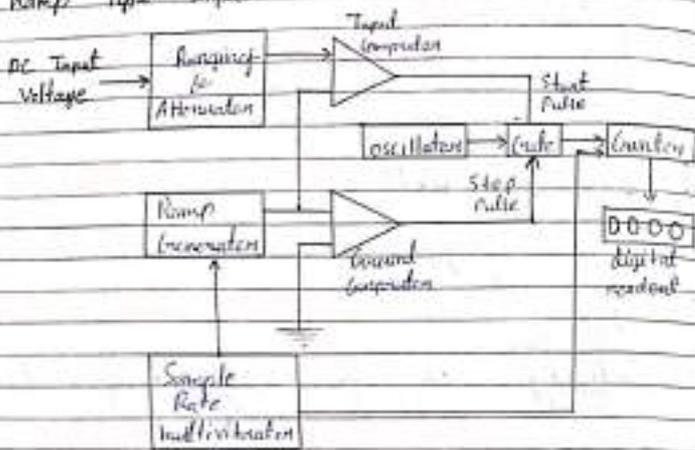
- (i) Higher accuracy & resolution
- (ii) Greater speed
- (iii) No parallax error
- (iv) Reduced human error
- (v) Compatibility with other digital equipment for further process & recording

Application

- (i) DVM are used in data processing unit & data logging system.
- (ii) The digital value is then transmitted to a printer along with the information about the input line from which the signal has been derived.

(ii) The large number of input signal can be automatically stored or process & their value either printed or logged.

Ramp type Input -



(i) Ramp type के digital voltmeter का संशोधन बहुत ही सरल है जो एक निश्चित समय voltage को input voltage के level से 0 voltage में खाने में जाता है।

(ii) इस समय भारत को electronic यंत्रों भारत (counter) से प्राप्त होता है। यह किसी के voltmeter के output readout के electronic गैजेट लंबे पर जोड़ने की रचना के रूप में मिलाया जाता है।

Working principle of Ramp type DVM

(i) Measurement की शुरुआत में एक ramp voltage शुरू किया जाता है।

(ii) Ramp voltage माप की शुरुआत लगातार माप जो से anone voltage से की जाती है।

(iii) Instant Ramp voltage की Max anone voltage के बराबर हो जाता है।

(iv) Ramp voltage तब तब घटता है जब तक यह zero voltage पर पहुंच नहीं जाती।

(v) इस क्षण में एक समय Comparing supply प्रदान होता है जो ground comparison करता है जब stop pulse produce होता है। इस पूरे समय के संतराल एक clock pulse generation (oscillator) से pulse

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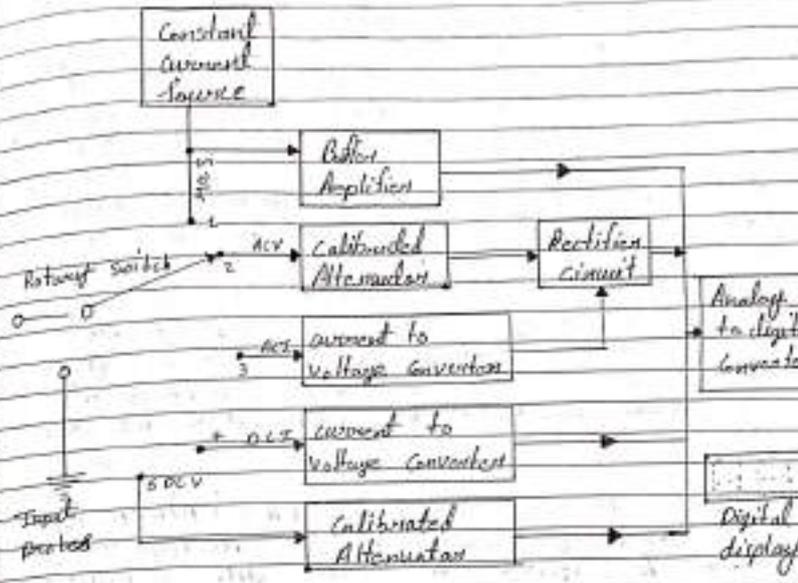
घटे से तेज़ गति से 1 से 1000 तक का रेंज में बदलाने के लिए 10:1 का रेटिंग का उपयोग करना है।

(vi) Sample and hold multimeter, ramp voltage generator को मिला कर multimeter, Ramp voltage देना करना है और इसका Start pulse जनरेशन करना है साथ ही जो क्विज़िंग pulse भी जनरेशन करता है जो इन सभी को Zero पर set करता है।

Digital Multimeter - इसमें AC & DC दोनों supply को मापा जा सकता है। Multimeter एक ऐसा device है जो दो या दो से अधिक electrical quantity को मापने (measure) करने के लिए उपयोग किया जाता है। जैसे Voltage, current, resistance etc. digital multimeter में DC या AC एक ही current को मापा जा सकता है।

1. जब voltage, frequency, resistance को मापने में जाता है तो probes में connect किया जाता है।
2. जब current या common (ground) को parallel में connect किया जाता है।

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Working

1. Input terminal को, rotary switch से connect किया जाता है। इससे input terminal को negative व Ground से जोड़ा जाता है। rotary switch में तीन positions होती हैं और प्रत्येक position पर अभी कार्य किया जाता है।

2. Multimeter में button amplification लगा होता है जो प्राप्त input AC या DC Current, Voltage को संबंधित जोड़ rotatory switch से जोड़ दिया जाता है एक constant current source को जो input terminal से जोड़ दिया जाता है।

3. पहली Position पर resistance मापने को संकेत मिलता है। rotatory switch को इस switch पर ले जाते unknown resistance को मापा जाता है। button amplification unknown resistance को current apply voltage को amplify करेता है और constant current source से प्राप्त current को unknown resistance में flow करके resistance की value मिल कर लेता है।

4. दूसरी Position पर voltage (A.C.) और होता है rotatory switch को इस position पर ले जाते A.C. voltage को मापा जाता है। तीसरी position पर AC current मिलता है। चौथी position पर DC current marked होता है rotatory switch को इस पर ले जाते DC current मापा जाता है। पांचवी position में D.C. voltage marked होता है इसमें DC voltage को मापा जाता है।

5. Rectifier circuit digital multimeter में जो electronic circuit तथा elements को DC Power

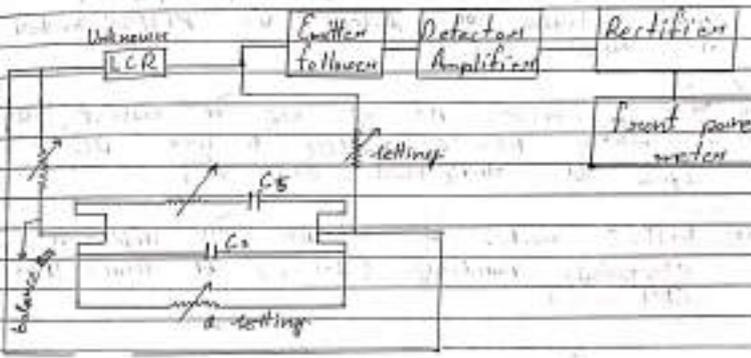
प्रदान करता है।

6. Digital multimeter द्वारा मापे गये विभिन्न राशियों के मान को LCD या LED screen पर प्रदर्शित किया जाता है।

* LCR meter

यह एक प्रकार का multimeter है जिसका उपयोग inductance, capacitance और resistance को मापने के लिए किया जाता है इस प्रकार इसे LCR कहा जाता है जो L - inductance, C - Capacitance, R - Resistance को दर्शाता है। LCR को मूलभूत AC Component Wheatstone bridge और $\frac{R}{\omega L}$ ratio arm से

यह null indication के principle पर कार्य करता है।



Working

- (i) Bridge के balance condition में समायोजित किया जाता है तथा meter के sensitivity को भी adjust किया जाता है।
- (ii) इसमें मुख्य रूप से emitter, follower, detector, amplification, rectification तथा beam Panel meter लगता होता है।
- (iii) जिस electrical quantity (R-L-C) को measure करना है उसे bridge में रखा जाता है।
- (iv) Bridge में emitter follower को input प्राप्त होता है अर्थात् bridge का output मिलता है।
- (v) Emitter follower का output detector amplification में input होता है जो detector amplification input signal को detect कर PMMC meter में जाता है।
- (vi) यहाँ rectification AC को DC में convert करती है क्योंकि PMMC meter के लिए DC signal की आवश्यकता होती है।
- (vii) PMMC meter की सहायता से unknown electrical quantity (R-L-C) का value प्राप्त होता है।

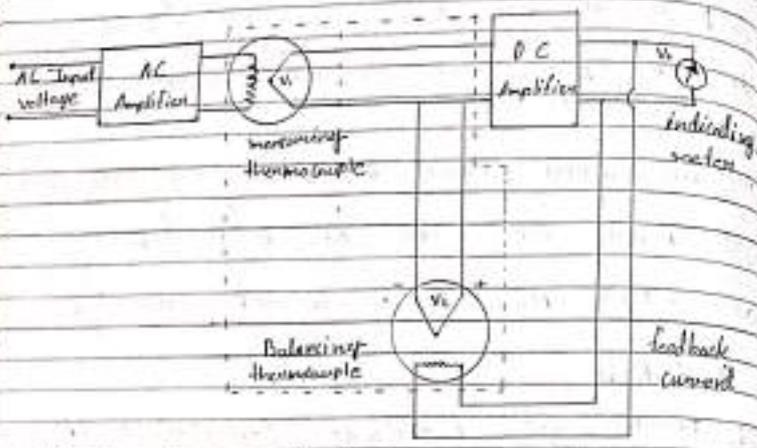
Advantage

- (i) LCR का accuracy 0.1% होता है।
- (ii) इसके battery को 24 घंटे इस्तेमाल किया जा सकता है।
- (iii) Electricity (Power) consumption कम होता है।
- (iv) Power स्तर बंद हो जाती है।
- (v) इसमें Parallel connection नहीं होता है।

Application

- (i) इसका use Inductance, Capacitance व resistance को measure में किया जाता है।

True RMS reading voltmeter



Block diagram of true RMS reading voltmeter

True rms reading voltmeter

True rms reading voltmeter एक ऐसा electronic device है जो किसी input voltage wave form के heating power को sense/detect करके किसी indicating meter (PMMC) में measure करके value को indicate / Calibrate करता है जो Input voltage के rms value को दर्शाता है। (Operational)

Working of true rms voltmeter

- (i) True rms reading voltmeter को, block diagram में दिखाया गया है।
- (ii) इसमें एक block AC amplifier measuring & balancing thermocouple & DC amplifier का PMMC meter भी है।
- (iii) जिस AC input voltage को measure करना होता है, उसे AC amplifier में भेजा जाता है जहाँ wave signal को strong signal में convert करती है।
- (iv) AC amplifier का output measuring thermocouple के heating elements में जाता है।
- (v) एक thermocouple पर heating wave / Volt generate की input voltage sine के square के बराबर होता है।
- (vi) इसमें दो thermocouple हैं। measuring thermocouple और balancing thermocouple और ये दोनों DC amplifier input का बिस्म होता है।
- (vii) एक जो non linear में दोनो amplifier होते हैं इसलिए यह प्रभाव को रोकता है।

(viii) Measurement thermocouple voltage को generate करता है जो heating wave के समानुपाती होता है।

(ix) Measurement thermocouple के द्वारा generate voltage bridge को unbalance करेता है।

(x) अब unbalance voltage DC amplifiers द्वारा amplified करके लिया जाता है और balance thermocouple के heating element को दिया जाता है जो voltage generate करता है।

(xi) जो वोल्टेज thermocouple की output करके आता है तो bridge balance हो जाता है।

(xii) जो DC amplifiers की output current हमारे value के input voltage से directly proportional होता है।

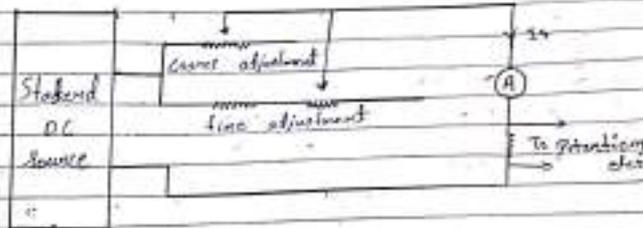
(xiii) अब DC voltage indicating meter में जाता है जो उस value को indicate करता है। इसी महीने हम input volt की same value प्राप्त होता है।

$$\text{Current } I_s = \frac{V_o}{S}$$

उपरोक्त formula से मापता से ammeter को calibrated किया जाता है।

5. यदि ammeter में error है तो उसे zero point की सहायता से adjust किया जाता है।

Calibration of Ammeter -

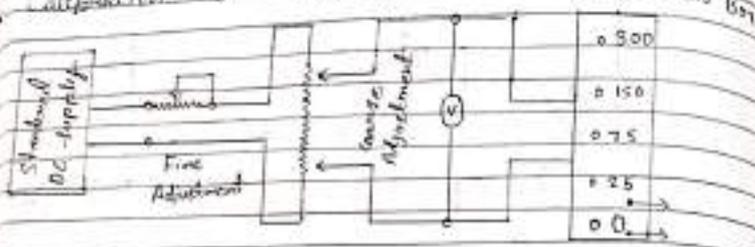


Ammeter की Calibration DC Potentiometer से करके किया जाता है जिसकी विधि निम्नानुसार है -

1. पहले Standard DC supply दिया जाता है तथा 2 resistance (unknown) लगा होता है जो कि zero (zero adjustment high value के लिए, zero adjustment low value के लिए) रहे किया जाता है।
2. Ammeter के series में Standard resistance लगा होता है जो Potentiometer से जुड़ा होता है।
3. जो Stabilized DC supply (constant) दिया जाता है current जो ammeter में होत है उस circuit में flow होता है जो ammeter में measure कर लेता है।
4. जो Current I_s Standard resistance से गुजरता है तो Standard resistance (R) में जो V के voltage drop होता है जिसे Potentiometer की सहायता से माप लिया जाता है।



Calibration of voltmeter



Voltmeter का calibration DC Potentiometer का use करके किया जाता है इसमें निम्नकी विधि निर्माता द्वारा दी जाती है-

- इसमें दो rheostat लगे होते हैं-
 - coarse adjustment
 - fine adjustment

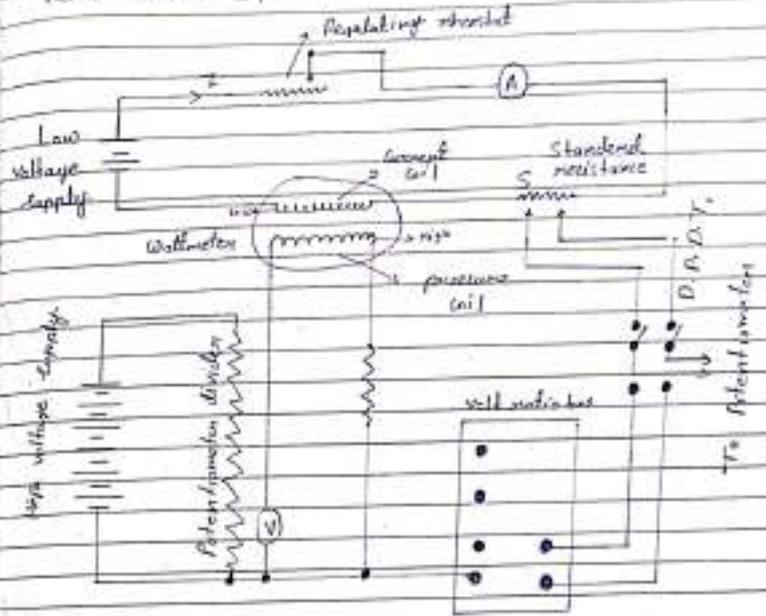
Coarse adjustment को इस्तेमाल high value रेंज में fine adjustment को इस्तेमाल low value को calibrate करने के लिए किया जाता है।

2. Stabilized DC supply के साथ fine adjustment तथा DC supply के parallel में coarse adjustment, voltmeter, voltage ratio box के दो terminal में Potentiometer को connect किया जाता है।

Voltmeter

3. Voltage ratio box के across voltage को step down कराते हैं ताकि Potentiometer Voltage को accurate measure कर सकें।

4. Supply देने के बाद voltmeter की connection Potentiometer के across voltage में ही connection करके, rheostat की सहायता से adjust किया जाता है ताकि voltmeter की reading सही कर उस प्रकार से voltmeter का calibration किया जाता है।



Calibration of wattmeter with a DC Potentiometer

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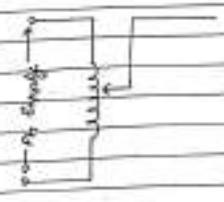
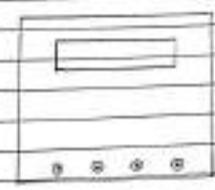
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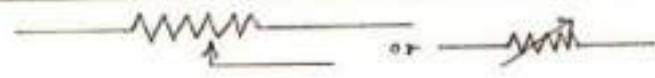
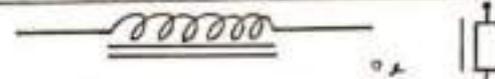
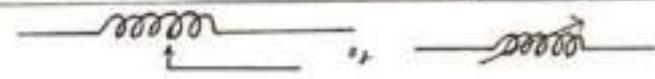
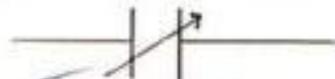
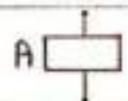
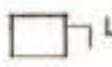
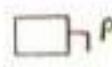
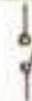
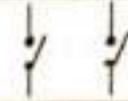
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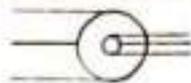
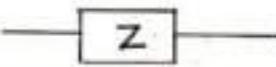
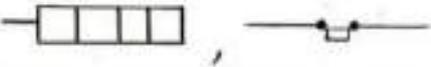
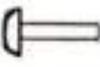
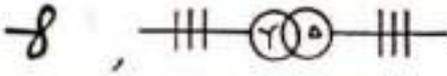
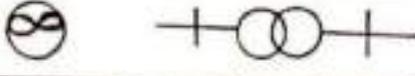
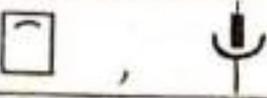
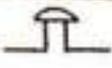
Single Phase energy meter

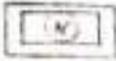
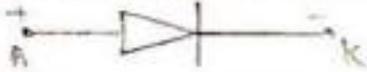
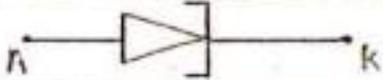
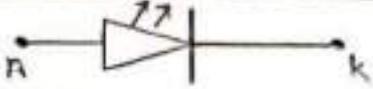
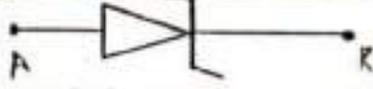
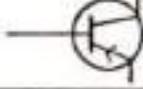
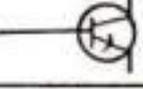
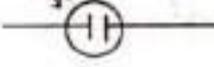
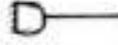


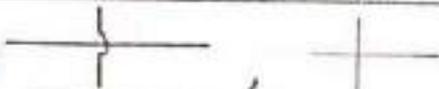
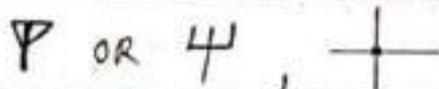
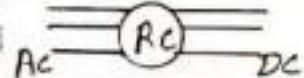
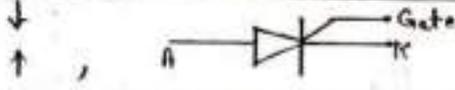
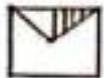
SYMBOLS (SIGNS)

SNO	Descriptions	Symbols
1	Resistor (Fixed)	
2	Resistor (Variable)	
3	Resistor (Tapped)	
4	choke coil	
5	choke coil (Variable)	
6	Capacitor (Fixed)	
7	Capacitor (Variable)	
8	Electromagnetic Relay or (contactor)	
9	Thermal Over load Relay	
10	Relay (Normally Open) NO	
11	Relay (NC- Normally closed)	
12	Single way Switch	
13	Two way switch	
14	Main switch (light)	
15	Main switch (Power)	
16	Single way switch single Pole	
17	Double Pole switch linked (single Throw)	

18	Tripple Pole Switch Linked (Single Throw)	
19	Change Over Switch	
20	Bell push	
21	Isolator	
22	Selectoer Switch	
23	Three Phase Transformer	
24	Power Factor meters (w)	
25	Frequency (Hz)	
26	Galvanometer	
27	Synchroscope	
28	Single Phase Energy meter	
29	Auto Transformer	
30	Potential Transformer (PT)	
31	Current Transformer (CT)	
32	Generator	
33	Motor	
34	MG Set	
35	DC Generator	
36	DC Motor	

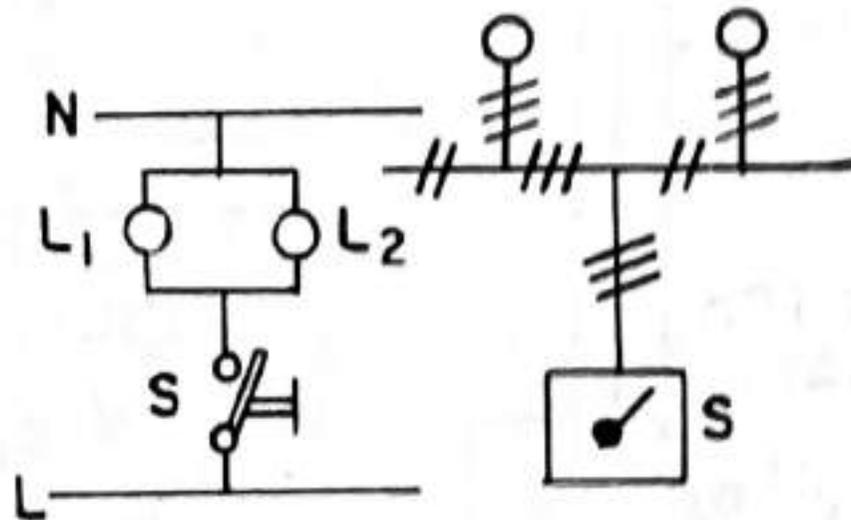
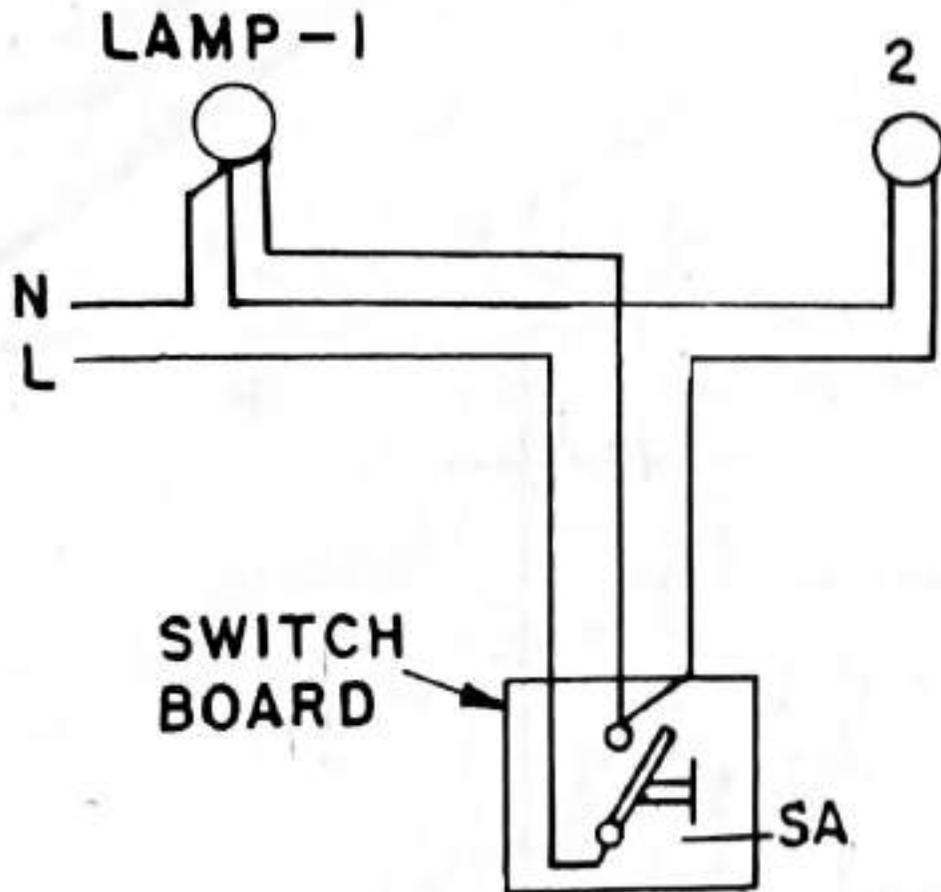
37	DC Series Motor & Generator	
38	DC Shunt Motor & Generator	
39	AC Motor & Generator (Alternator)	
40	Squirrel Cage Induction Motor	
41	Wound rotor Induction Motor	
42	Synchronous Motor & Generator	
43	Starter	
44	Automatic Starters	
45	Star-Delta Starters	
46	Impedance (Z)	
47	Earth, Socket Outlet 3 Pin	
48	Fault, Socket Outlet and Switch Combined 2 Pin	
49	Heater, Push Button Switch	
50	Immersion Heater	
51	Ceiling Fan, Socket Outlet 2 Pin	
52	Bracket Fan, Three Phase Transformer	
53	Exhaust Fan, Single Phase Transformer	
54	Fan Regulator, Plug & Socket	
55	Fire Alarm bell	

56	Fire Alarm Indicator	
57	Diode	
58	Tunnel Diode	
59	LED (Light Emitting Diode)	
60	Zener Diode	
61	Rectifier	
62	PNP Transistor	
63	NPN Transistor	
64	Photo Voltaic Cell	
65	UJT (Unijunction Transistor)	
66	FET (Field Effect Transistor)	
67	Lightning Arrestor	
68	Socket	
69	Wall Socket	
70	3-Pin, 5A Wall Socket	
71	3Pin, 15A Wall Socket	
72	Lamp	
73	Ceiling Rose 2-Plate	
74	Ceiling Rose 3-Plate	

75	Cable Box	
76	Crossing Conductors	
77	Antenna, Connected Conductor	
78	Multimeter, Lightning arrester (L.A.)	
79	Phase indicator meter	
80	Rotary Converter	
81	Buzzer, Energy Meter	
82	Loud speaker	
83	Gap, Silicon Controlled Rectifier	
84	Special Purpose Point	
85	SCR, Circuit Breaker	
86	Wattmeter	
87	Ohmmeter, Neutral link	
88	Brush on Commutator	
89	Battery	
90	SIREN, Cartridge Fuse	
91	Head Phone	
92	Semi Automatic starter	
93	Isolator with Fuse	

Example 11.6. Draw the wiring diagram, schematic diagram and single line diagram of two lights in parallel controlled by one switch.

Solution: See figure 11.6 (a) to (c).

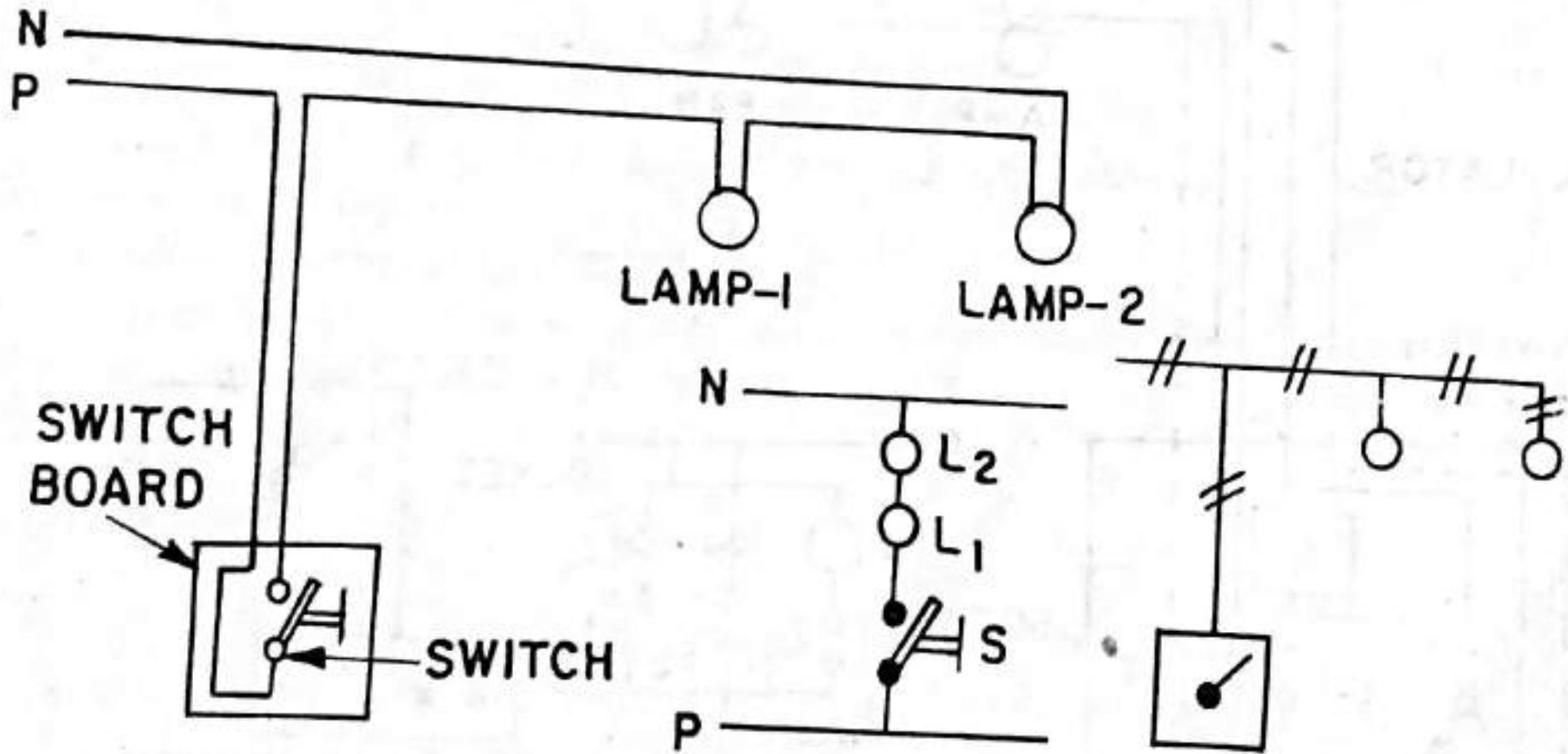


(a) Wiring Diagram (b) Schematic Diagram (c) Single line Diagram

Figure 11.6

Example 11.5. Draw the wiring diagram, schematic diagram and single line diagram of two lights in series controlled by one switch.

Solution: See figure 11.5(a) to (c).



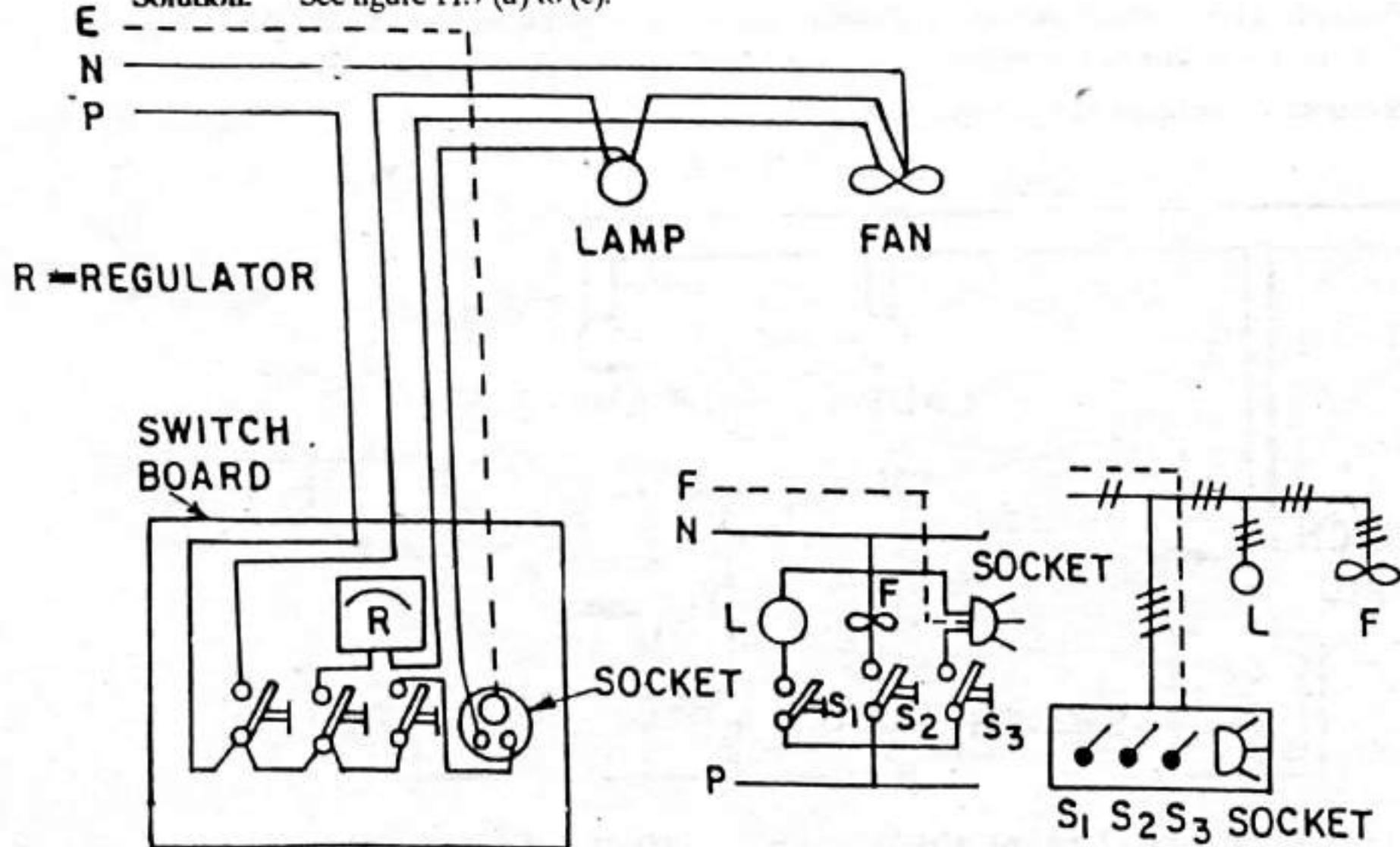
(a) Wiring Diagram (b) Schematic Diagram (c) Single line Diagram

Figure 11.5

JMP

Example 11.7. Draw the wiring diagram, schematic diagram and single line diagram of one light, one ceiling fan with regulator and one 5 ampere, 3 pin plug point, each controlled by individual switches.

Solution: See figure 11.7 (a) to (c).



(a) Wiring Diagram (b) Schematic Diagram (c) Single line Diagram

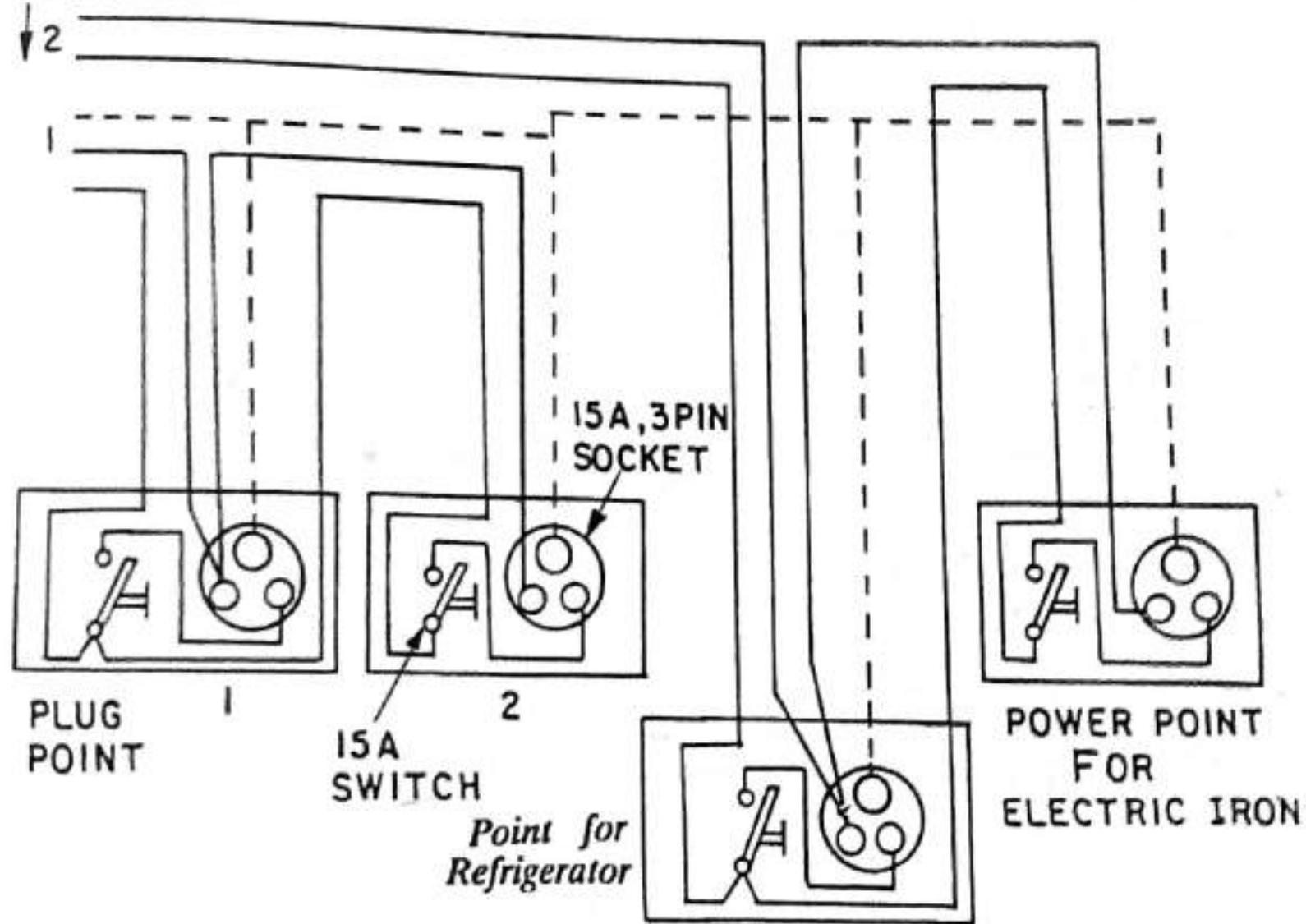
Figure 11.7

Example 11.8. Draw wiring diagram of the following points in a house.

- (i) two power plug points
- (ii) one power point for refrigerator
- (iii) one power point for electric iron

Solution: See figure 11.8.

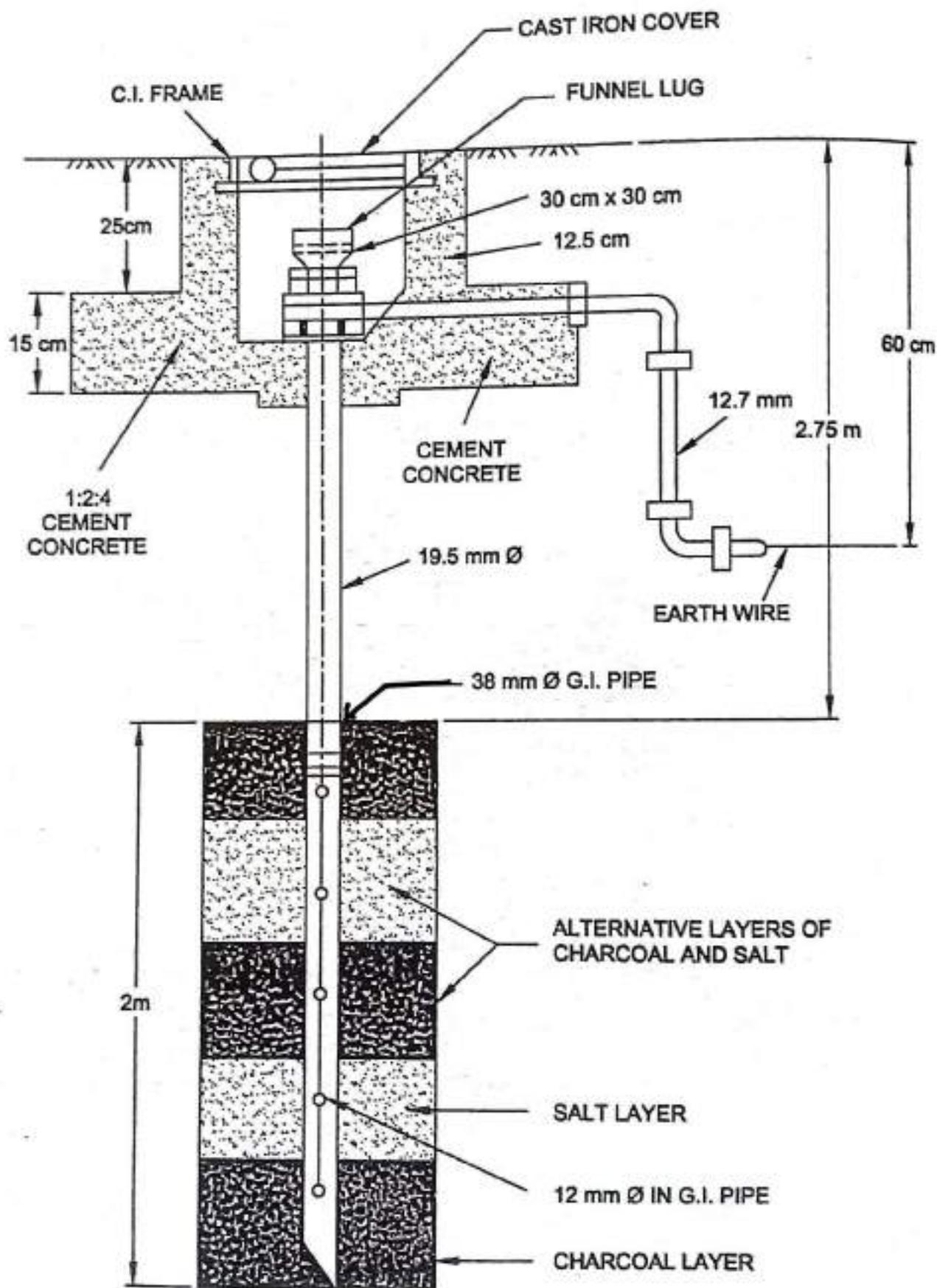
CIRCUITS



Wiring Diagram
Figure 11.8

Q.1 Draw a neat sketch of pipe earthing and also give its dimension.

पाइप अर्थिंग का स्वच्छ रेखाचित्र बनाइए एवं उसका मापन भी लिखिए।



Pipe Earthing

Q.2 Draw a neat sketch of Plate earthing and also give its dimension.

प्लेट अर्थिंग का स्वच्छ रेखाचित्र बनाइए एवं उसका मापन भी लिखिए।

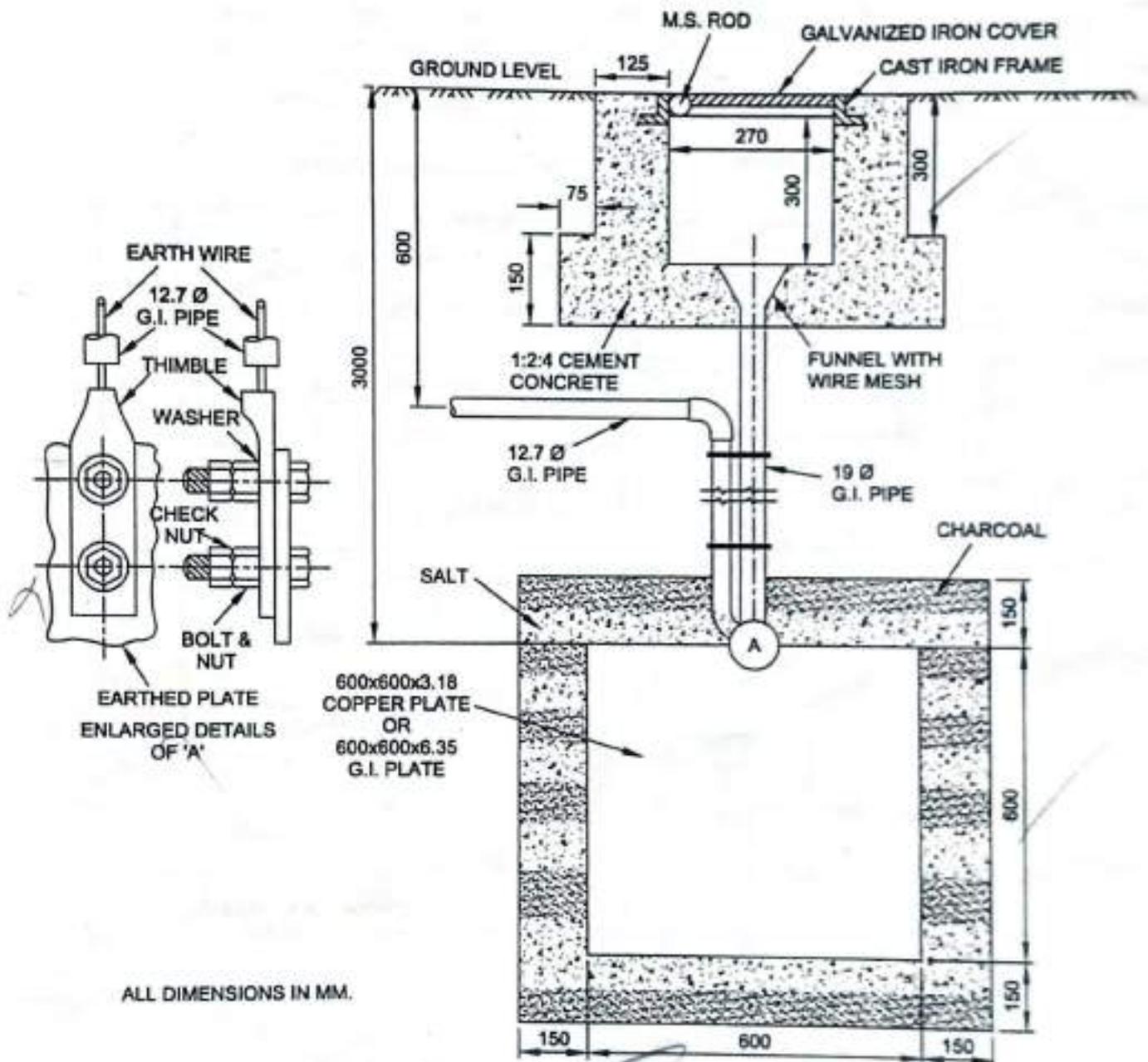
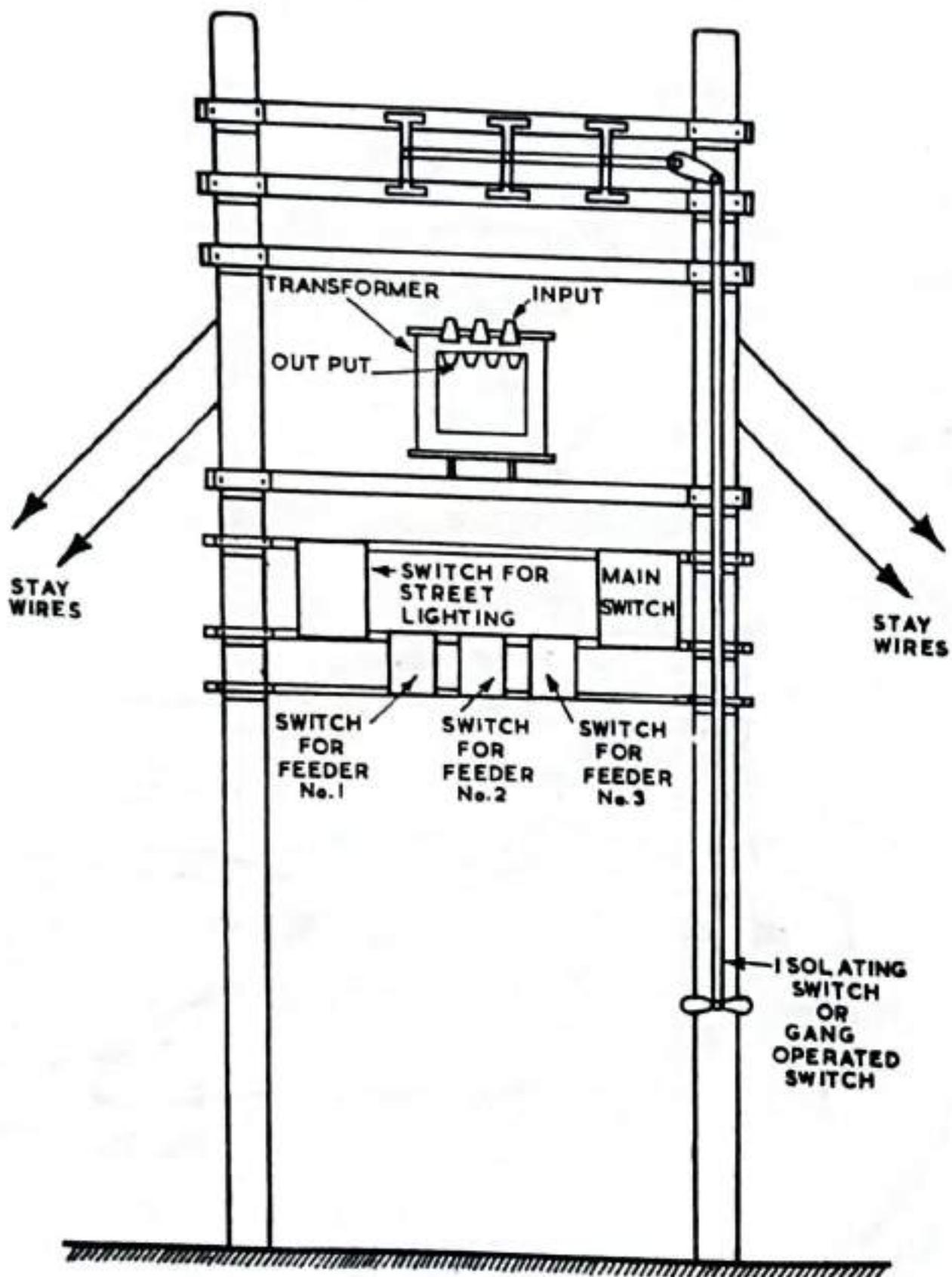


Plate Earthing
Fig. 12.12.

Q.3 Draw the diagram of pole mounted substation.
पोल माउंटेड सबस्टेशन का चित्र बनाइये।

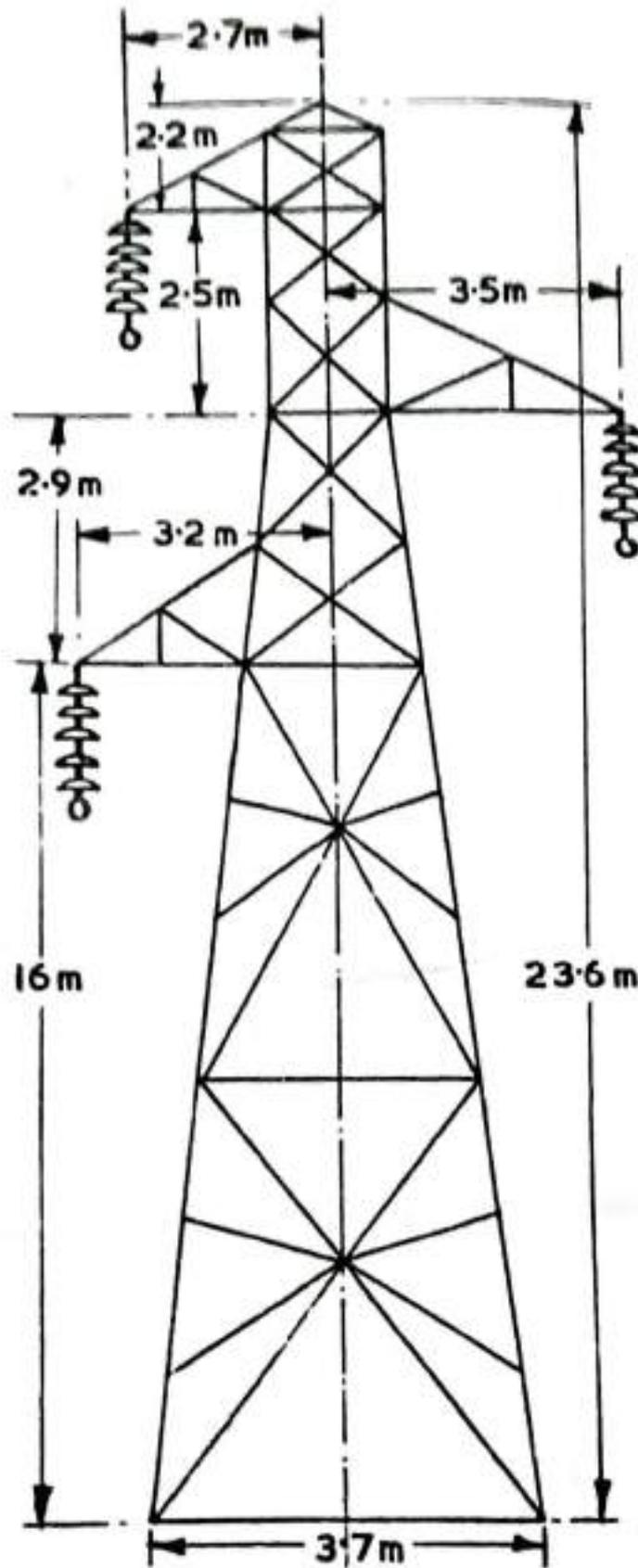


Pole-mounted Sub-Station

Bharat Nirmalkar Sir

Q.4 Draw the diagram of steel tower of 66 kV single circuit transmission line.

66 kV सिंगल सर्किट ट्रांसमिशन लाइन के स्टील टावर का आरेख बनाएं।

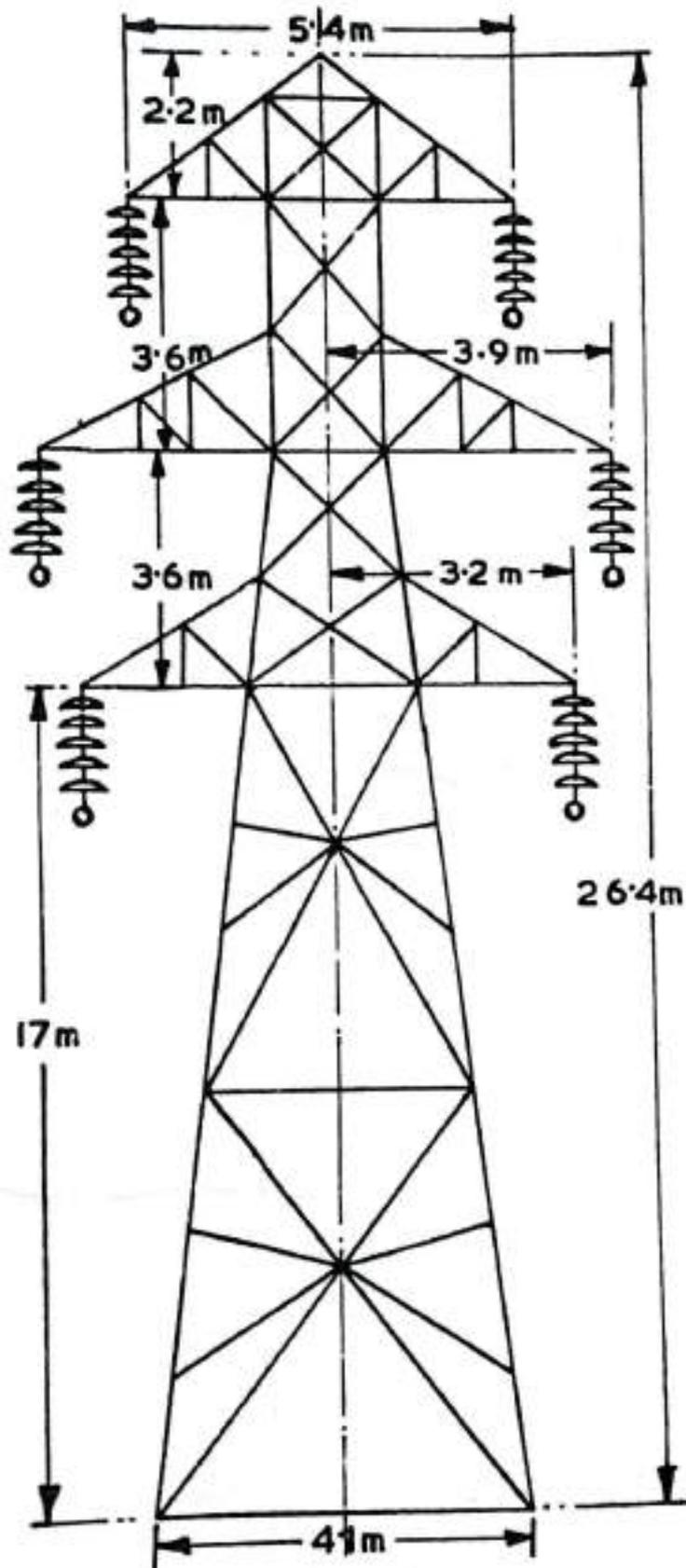


66 kV Steel Tower (Single Circuit)

Bharat Nirmalkar Sir

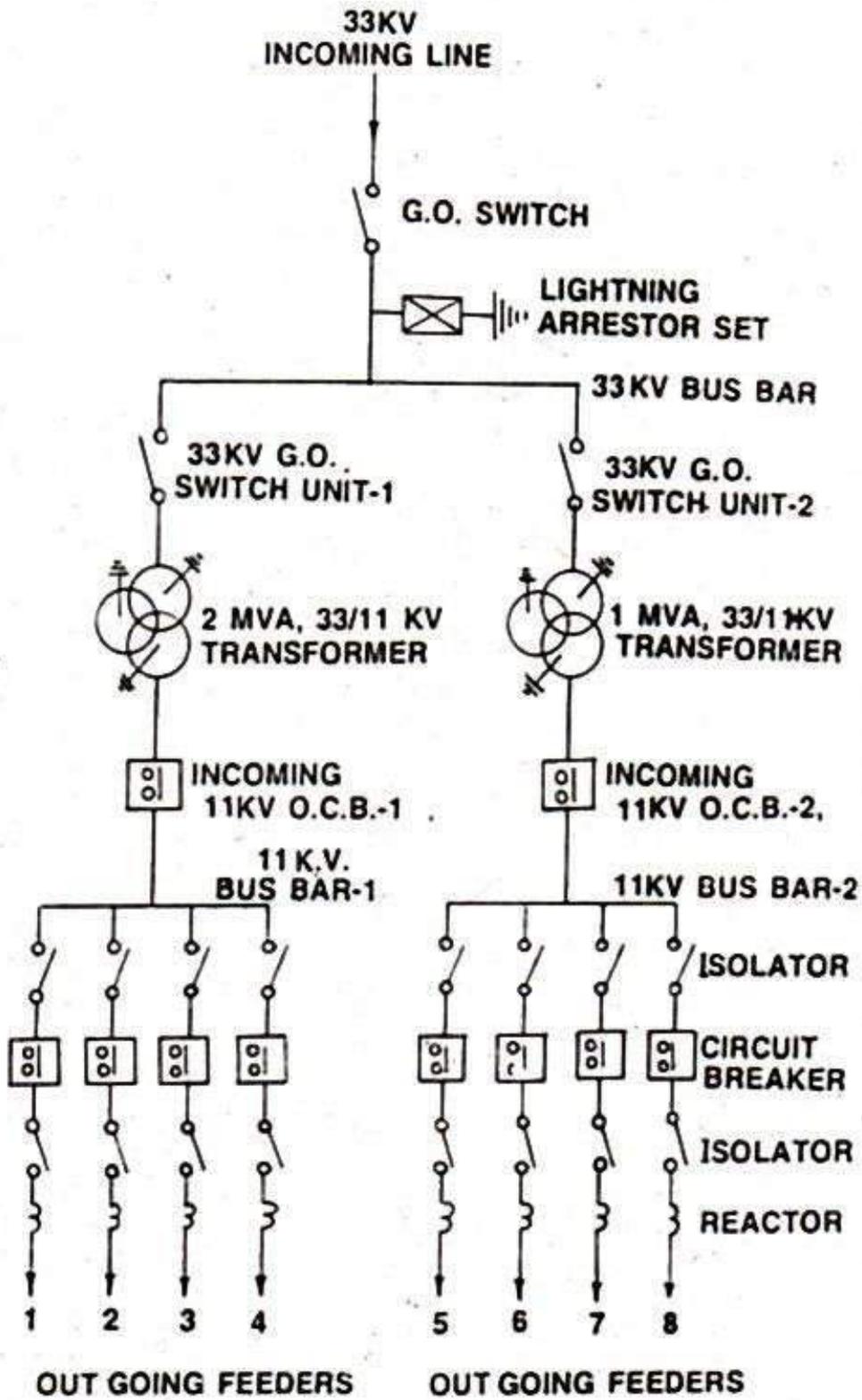
Q.5 Draw the diagram of steel tower of 66 kV Double circuit transmission line.

66 KV डबल सर्किट ट्रांसमिशन लाइन के स्टील टावर का चित्र बनाएं।



66 kV Steel Tower (Double Circuit)

Q.6 Draw a single line diagram of 33/11 kV substation.
33/11 kV सबस्टेशन का सिंगल लाइन डायग्राम बनाइये।

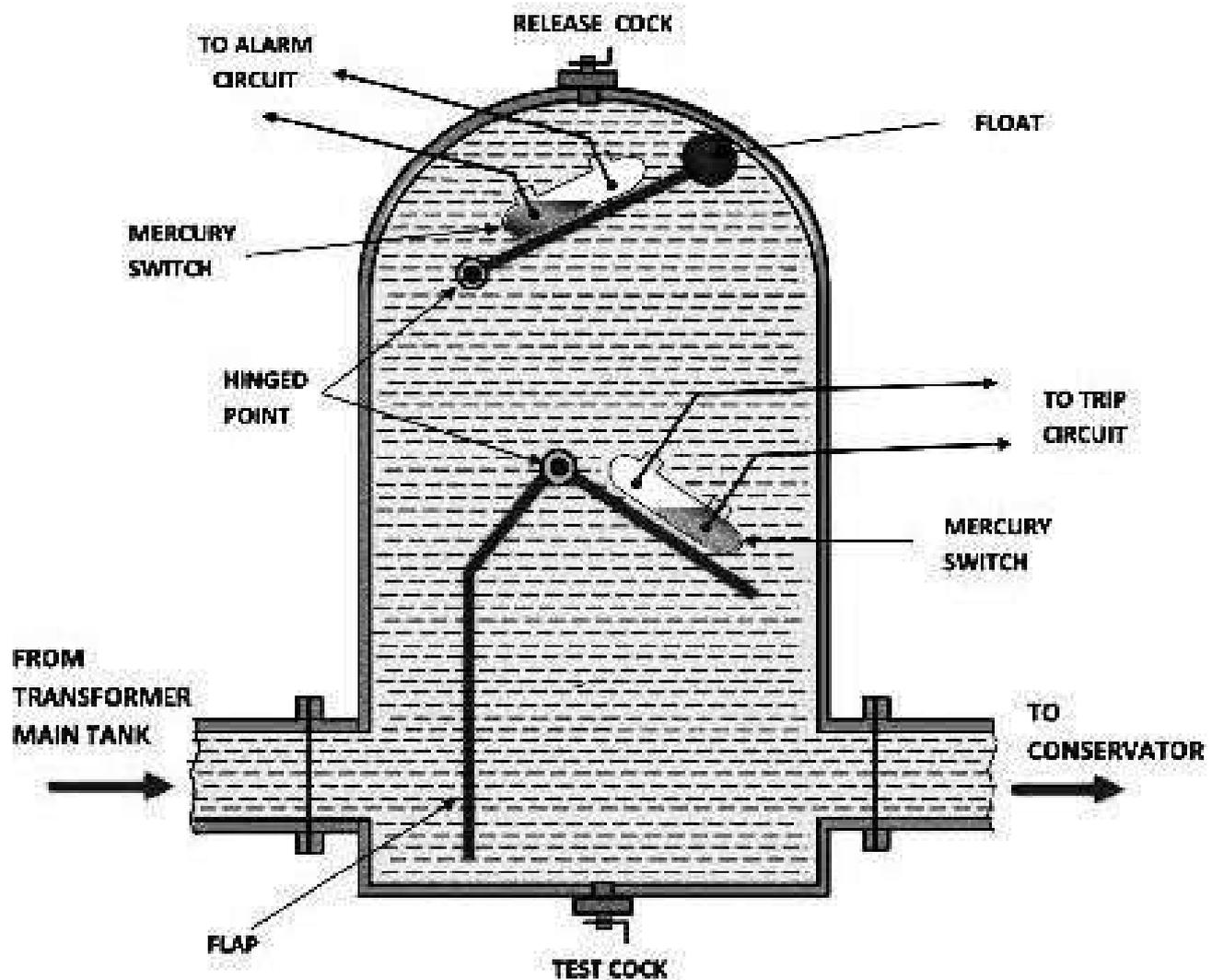


चित्र 9.14 33/11 kV सब-स्टेशन का सिंगल लाइन डायग्राम

Bharat Nirmalkar Sir

Q.7 Draw the diagram of Buchholz Relay.

बुकोल्ज रिले का चित्र बनाइये।



Q.8 Draw connection of CT and PT for measurement of current and voltage.

धार एवं विभव के मापन हेतु प्रयुक्त सी. टी. एवं पी. टी. का कनेक्शन चित्र बनाइए।

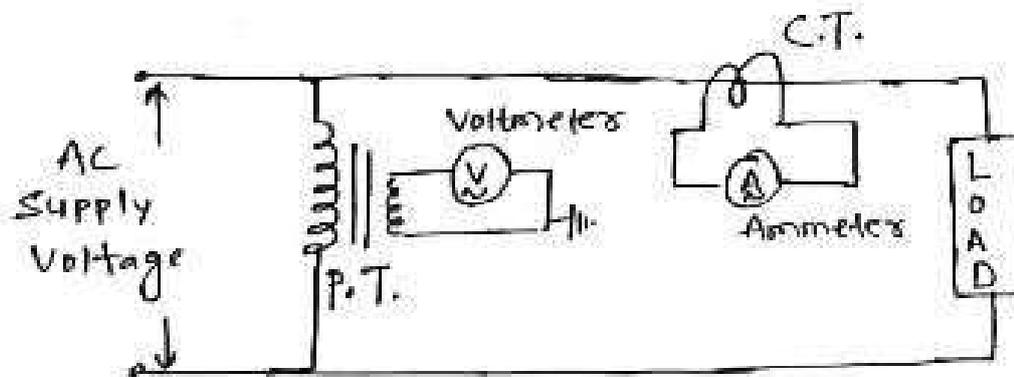


Fig:- Circuit Diagram of measurement of voltage & current using CT & PT.

Bharat Nirmalkar Sir

Q.9 Draw the connection diagram for extension range of voltmeter and ammeter by using series/shunt multiplier and CT/PT.

सी. टी. पी. टी. एवं सिरीज / शण्ट के द्वारा वोल्टमीटर व एमीटर के परास वृद्धि के लिए कनेक्शन डायग्राम बनाइए।

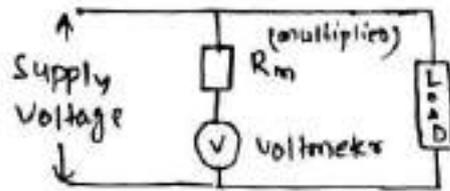


Fig (a) :- Extension the Range of voltmeter Using series multiplier.

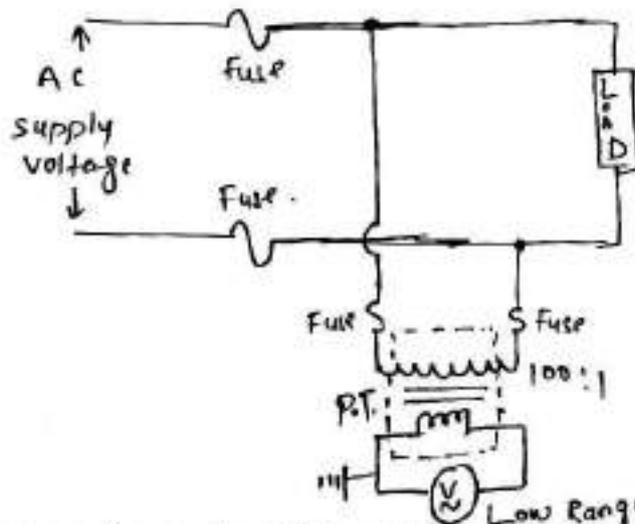
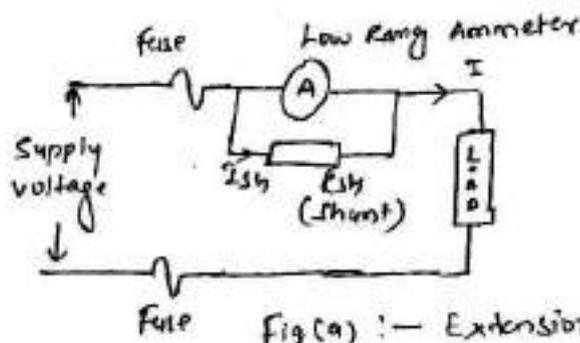
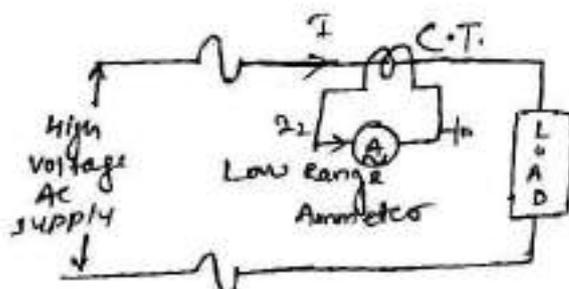


Fig.(b) Extension of Range of voltmeter using P.T.



Fig(a) :- Extension the Range of Ammeter using Shunt.



Fig(b) :- Extension the Range of Ammeter using C.T.

Q.1 Draw the different parts of 2MVA Transformer.

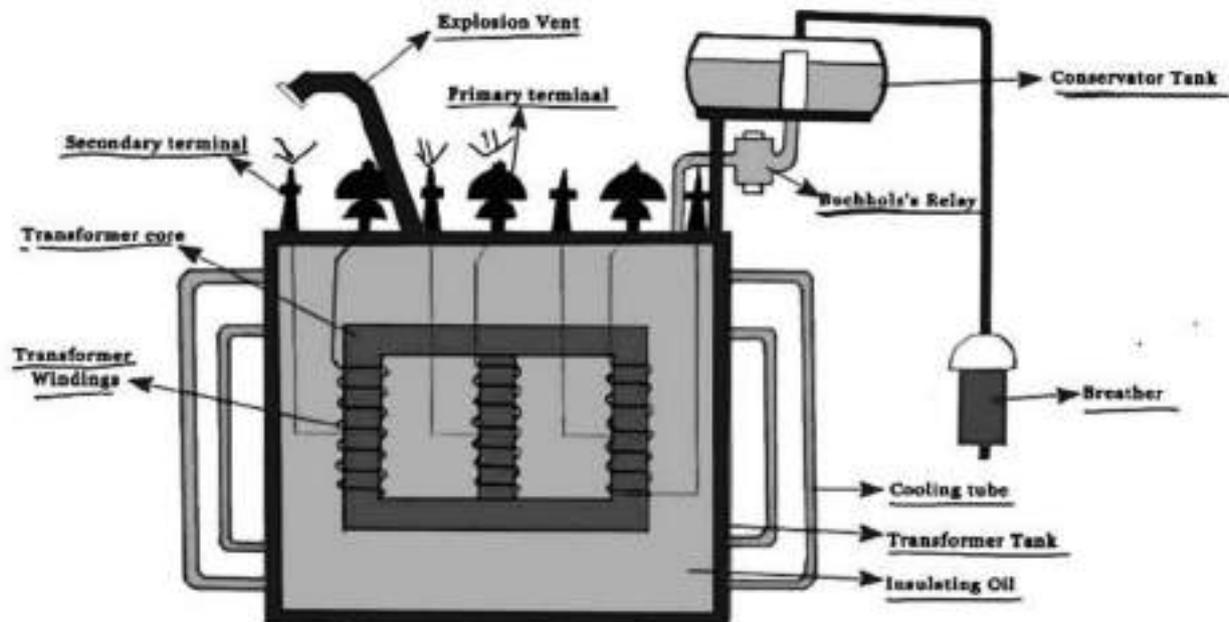


Fig. - Parts of 2MVA Transformer

Q.2 Draw cross-sectional view of assembled DC machine.

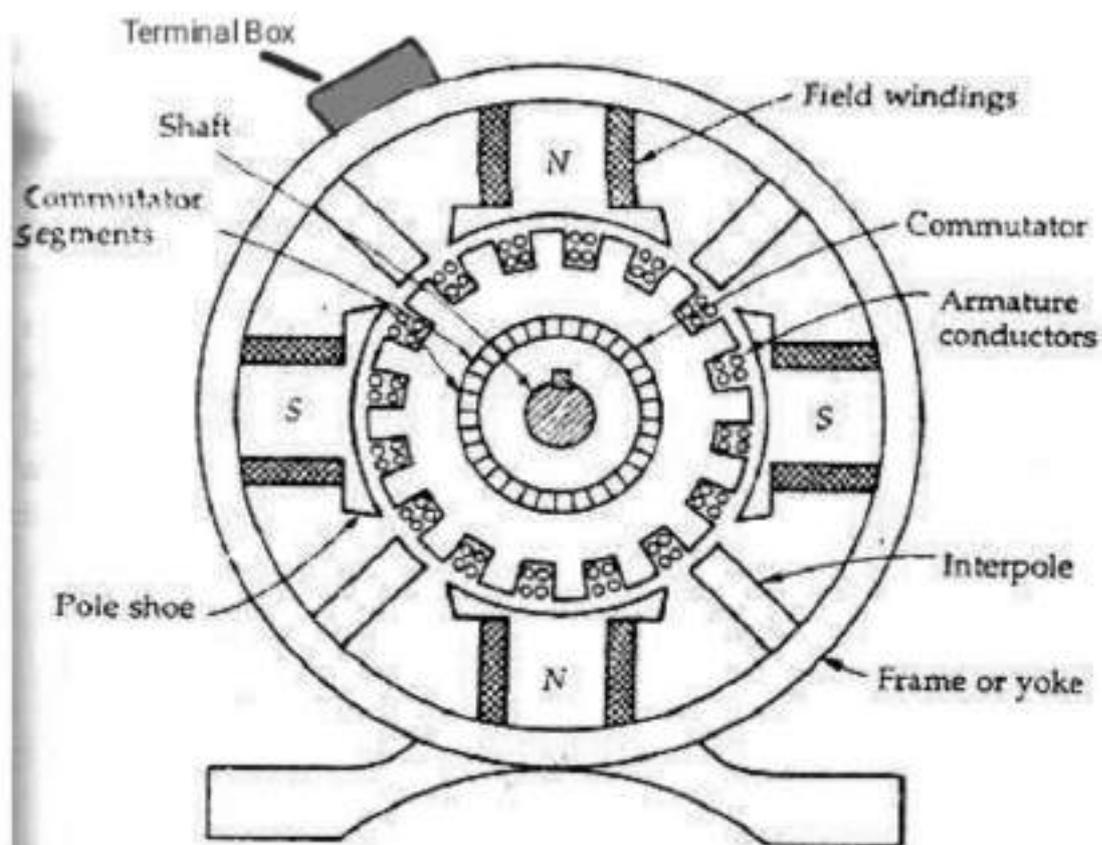
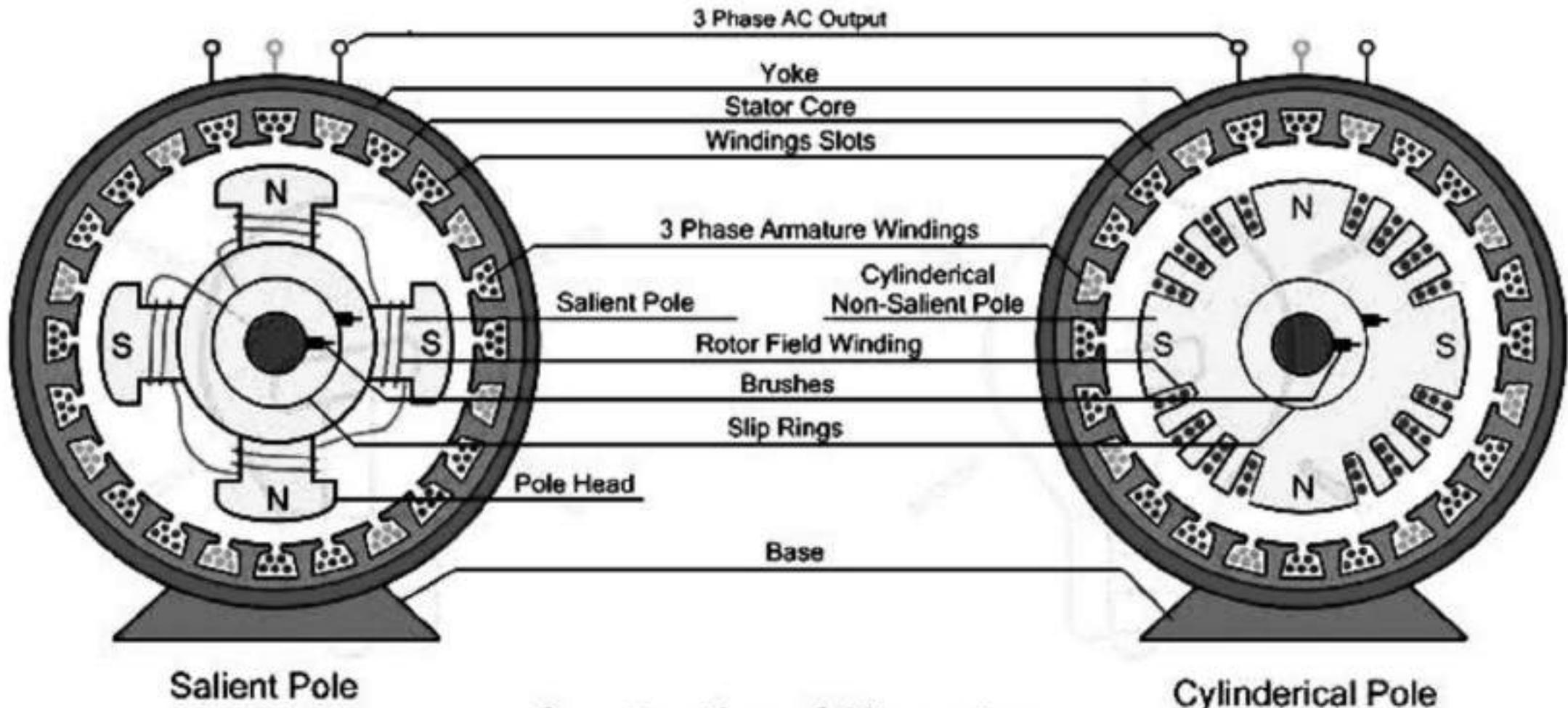


Fig. Cross section of DC machine

Q.3 Draw the diagram of construction of 3 phase alternator.

or

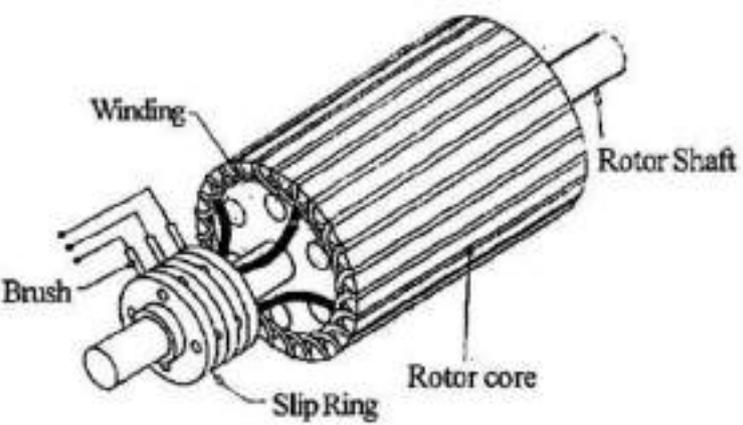
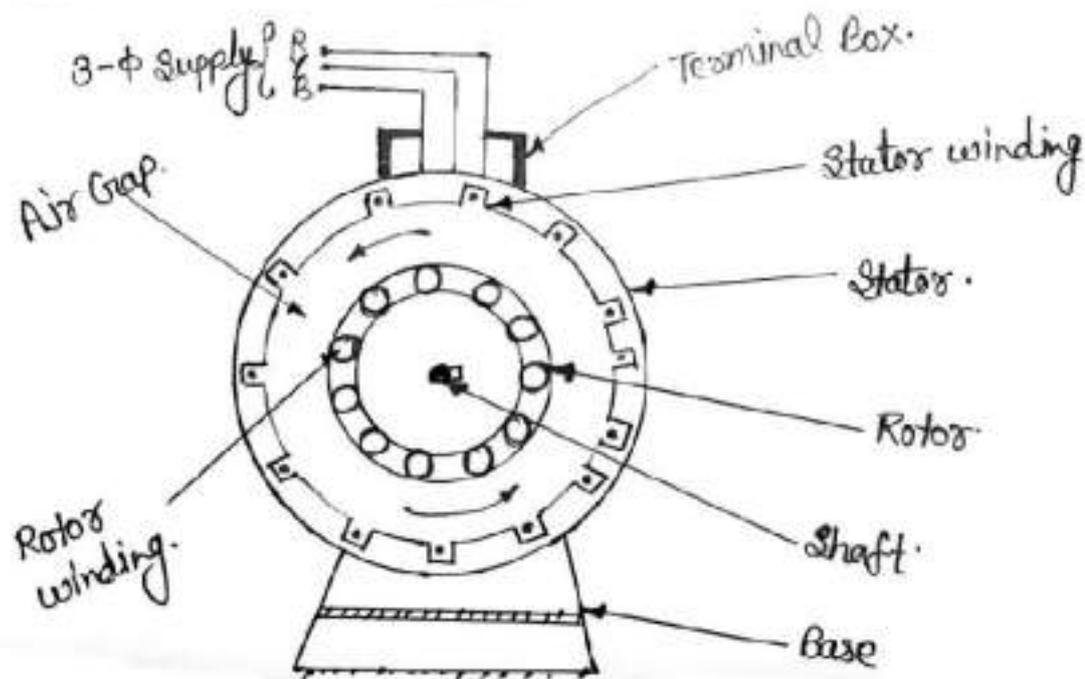
Draw the diagram of cylindrical & salient pole rotor.



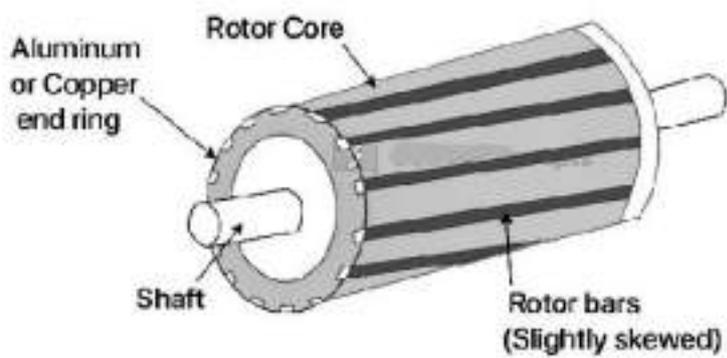
Construction of Alternator

Q.4 Draw the diagram of construction of 3 phase induction motor & different types of the rotor.

3- ϕ Induction motor की संरचना:-



Slip Ring Type Rotor



Squirrel Cage Rotor

Fig : Construction of 3 phase Induction motor & different types of rotor of Induction motor

Q.5 Draw the control and power wiring of DOL Starter.

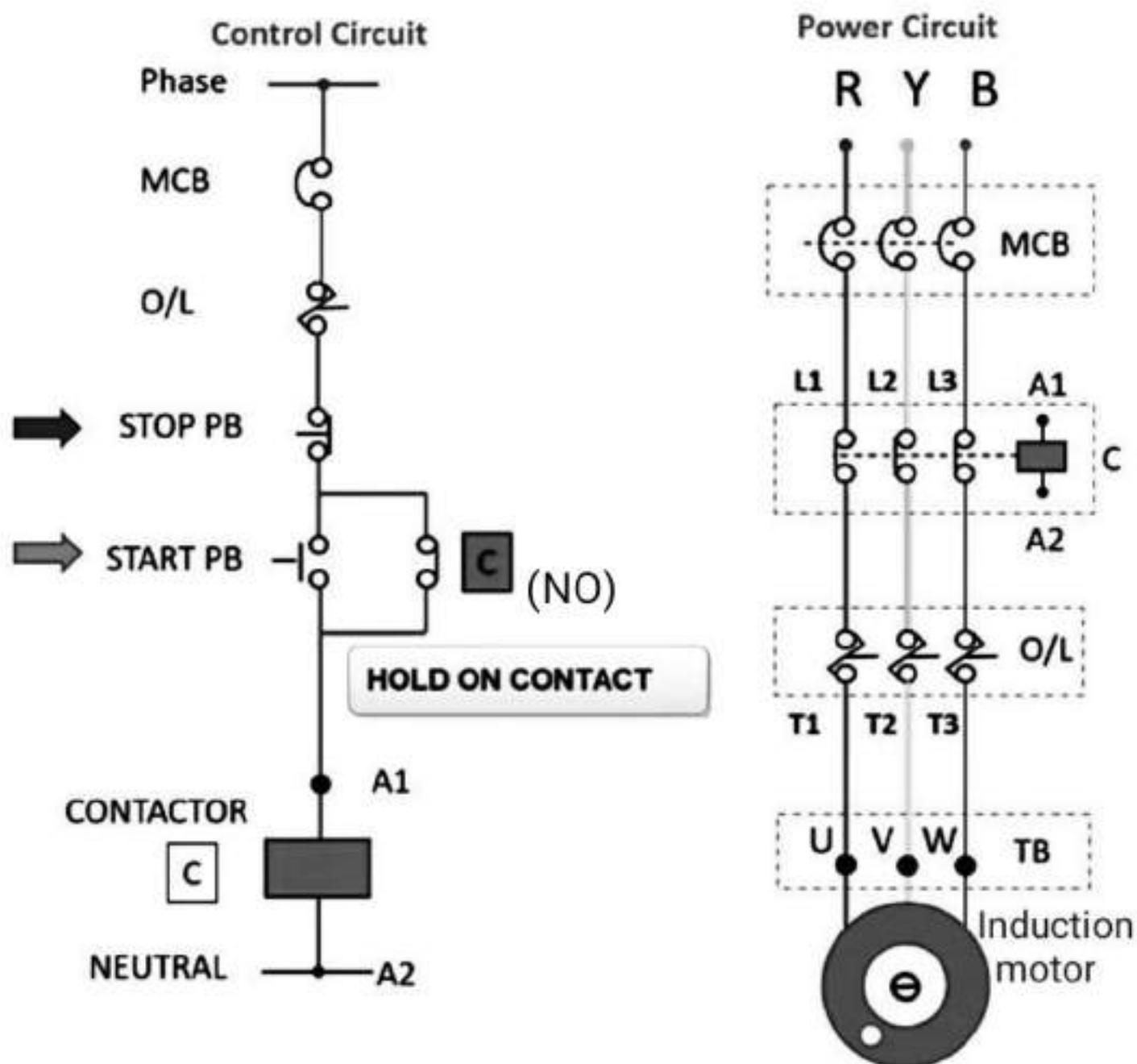
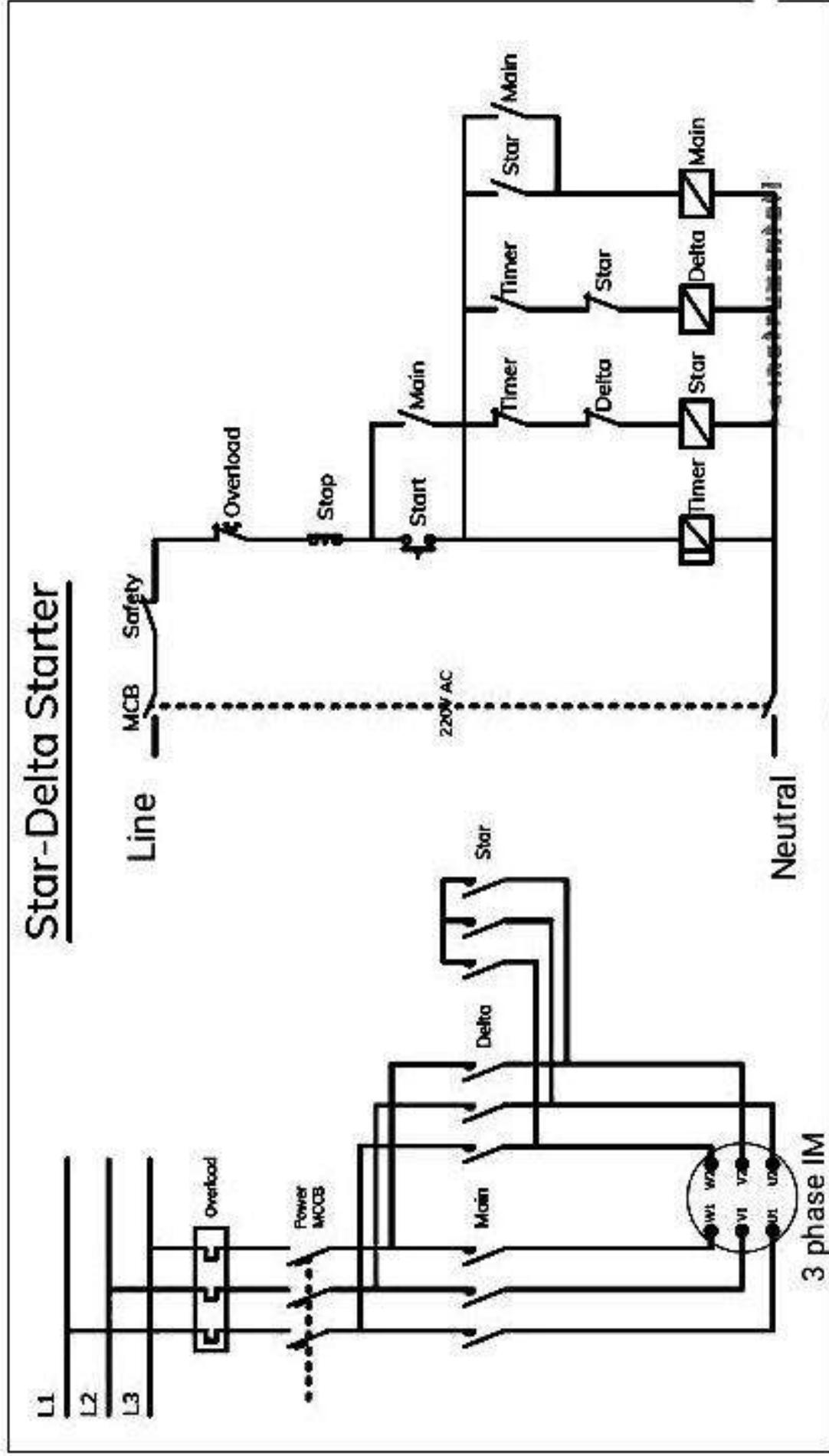


Fig : Control wiring & Power wiring of DOL Starter of the Induction machine.

Q. 6 Draw the power and control wiring of Star-Delt Starter of 3 phase induction motor.



(a) Power Wiring

(b) Control Wiring

Winding Techniques

Example 6.5. Develop a simple lap winding for a D.C. machine having 32 armature conductors, and 4 poles. Also show equalizer ring.

Solution: For construction it is necessary to find out the back pitch and front pitch. In case of simple lap winding these can be calculated by using the following formulas:

$$\frac{y_b + y_f}{2} = \frac{Z}{P} \quad \dots(1)$$

$$y_b - y_f = \pm 2 \quad \dots(2)$$

(where Z indicates total number of conductors and P indicates number of poles.)

In this example

So $Z = 32$ and $P = 4$

$$\frac{y_b + y_f}{2} = \frac{32}{4}$$

and $y_b - y_f = 2$ (for Progressive Winding)

or $y_b + y_f = 16$

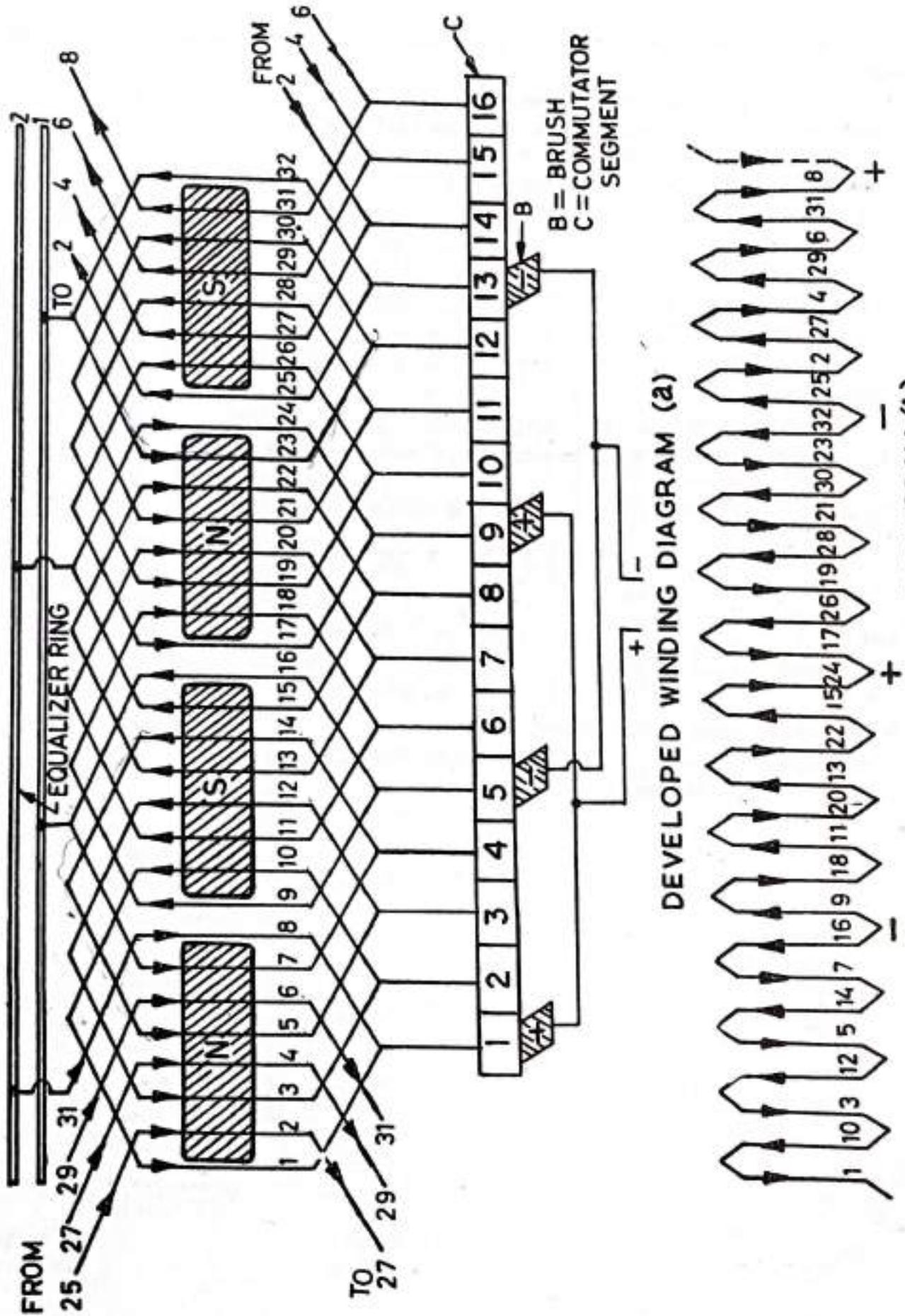
and $y_b - y_f = 2$

or $2y_b = 18$

$$y_b = \frac{18}{2} = 9 \quad \text{hence } y_f = 7$$

Table

S.No.	Back side $y_b = 9$	Front side $y_f = 7$	S.No.	Back side $y_b = 9$	Front side $y_f = 7$
1.	$1 + 9 = 10$	$10 - 7 = 3$	9.	$17 + 9 = 26$	$26 - 7 = 19$
2.	$3 + 9 = 12$	$12 - 7 = 5$	10.	$19 + 9 = 28$	$28 - 7 = 21$
3.	$5 + 9 = 14$	$14 - 7 = 7$	11.	$21 + 9 = 30$	$30 - 7 = 23$
4.	$7 + 9 = 16$	$16 - 7 = 9$	12.	$23 + 9 = 32$	$32 - 7 = 25$
5.	$9 + 9 = 18$	$18 - 7 = 11$	13.	$25 + 9 = 2$ (34)	$2 - 7 = 27$ (34)
6.	$11 + 9 = 20$	$20 - 7 = 13$	14.	$27 + 9 = 4$ (36)	$4 - 7 = 29$ (36)
7.	$13 + 9 = 22$	$22 - 7 = 15$	15.	$29 + 9 = 6$ (38)	$6 - 7 = 31$ (38)
8.	$15 + 9 = 24$	$24 - 7 = 17$	16.	$31 + 9 = 8$ (40)	$8 - 7 = 1$



6.10.2 Commutator Segments

Each armature coil should be connected to one commutator segments by taking end connections, see figure 6.31(a).

6.10.3 Equivalent Ring Diagram and Brushes

Ring diagram can be drawn by placing the connected conductors together instead of placing the conductors as in the main diagram. See figure 6.31(b). This diagram is being employed to find out the position of the brushes. Generally the direction of the emf generated in the conductors under the influence of north pole is taken downward and under the south pole it is taken upward. So meeting point of the emf of two conductors will indicate the place of positive brushes while the separating point will indicate the place of negative brush. After finding out the position of the positive and negative brushes on the ring diagram, transfer these to corresponding points on the main winding diagram and provide the required number of brushes on the commutator segments.

6.10.4 Equalizer Rings

The number of equalizer rings depends upon the size of machine. A very large armature may have as many as 10 equalizer rings. However connections to each equalizer should be equal to half the number of poles. Figure 6.31(a) shows the provision of two such equalizer rings.

Example 6.6. Develop a simple Lap Winding for a D.C. machine having 36 armature conductors and 6 poles.

Solution :

$$\frac{y_b + y_f}{2} = \frac{36}{6} \text{ or } y_b + y_f = 12$$

and

$$y_b - y_f = 2 \text{ (for Progressive winding)}$$

So

$$2y_b = 14$$

∴

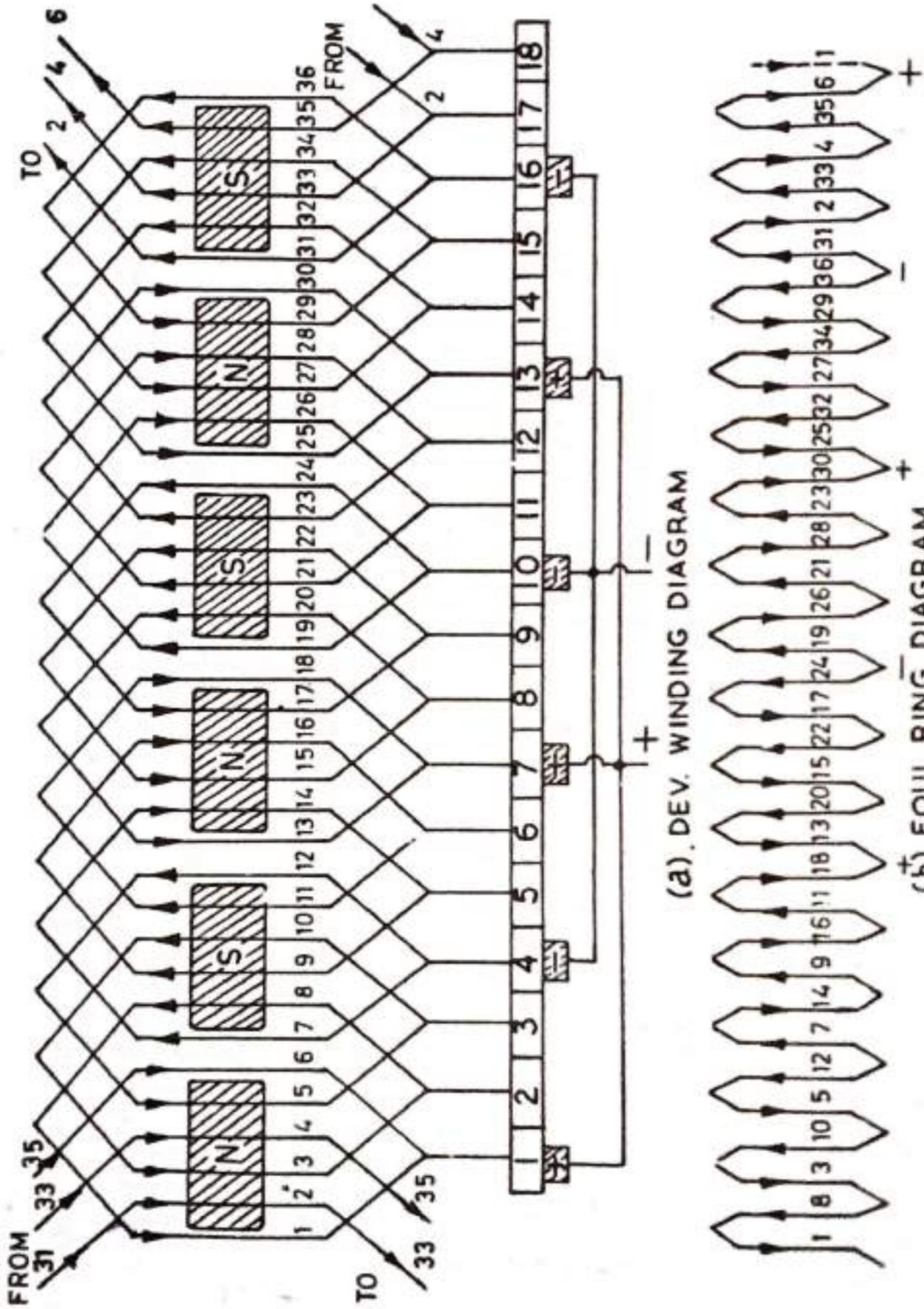
$$y_b = 7$$

and

$$y_f = 5$$

Table

S.No.	Back side $y_b = 7$	Front side $y_f = 5$	S.No.	Back side $y_b = 7$	Front side $y_f = 5$
1	$1 + 7 = 8$	$8 - 5 = 3$	10	$19 + 7 = 26$	$26 - 5 = 21$
2	$3 + 7 = 10$	$10 - 5 = 5$	11	$21 + 7 = 28$	$28 - 5 = 23$
3	$5 + 7 = 12$	$12 - 5 = 7$	12	$23 + 7 = 30$	$30 - 5 = 25$
4	$7 + 7 = 14$	$14 - 5 = 9$	13	$25 + 7 = 32$	$32 - 5 = 27$
5	$9 + 7 = 16$	$16 - 5 = 11$	14	$27 + 7 = 34$	$34 - 5 = 29$
6	$11 + 7 = 18$	$18 - 5 = 13$	15	$29 + 7 = 36$	$36 - 5 = 31$
7	$13 + 7 = 20$	$20 - 5 = 15$	16	$31 + 7 = 2$	$2 - 5 = 33$
8	$15 + 7 = 22$	$22 - 5 = 17$	17	(38) $33 + 7 = 4$	(38) $4 - 5 = 35$
9	$17 + 7 = 24$	$24 - 5 = 19$	18	(40) $35 + 7 = 6$	(40) $6 - 5 = 1$
				(42)	



(a). DEV. WINDING DIAGRAM

(b) EQUI. RING DIAGRAM

Simple Lap Winding

Figure 6.32

6.10.4 Wave winding. This type of winding is most suitable for machines of high voltage and low current rating. The following points must be remembered in case of Wave Winding:

- (i) y_b and y_f should be nearly equal to pole pitch.
- (ii) In this type of winding both pitches i.e. y_b and y_f , may be equal to each other, or there may be difference of two.
- (iii) y_b and y_f should always be odd number.
- (iv) For the separate winding in case of Duplex wave winding the commutator segments, number of the coils and commutator pitch should be even.
- (v) While calculating the pitches, if in the first formula + ve sign is taken, then the winding will be known as progressive winding, but if - ve sign is taken, then the winding will be known as retrogressive winding. Although in either case y_b may be greater or less than y_f .
- (vi) The number of commutator segments should be equal to the number of coils or equal to half the number of conductors, in single turn coils.
- (vii) The number of parallel path in wave winding will be equal to two. So whatever the number of poles, only two brushes will be provided, however these may be increased to four.
- (viii) Total voltage induced i.e. E will be equal to voltage induced in one conductor multiplied by the number of conductors per parallel path i.e. $Z/2$.
- (ix) Total current of the machine will be equal to current flowing in one conductor or in one parallel path multiplied by two.

Example 6.9. Develop simple wave winding for a D.C. machine having 34 armature conductors and 4 Poles.

Solution : y_b and y_f can be calculated by using the following formulae

$$\frac{y_b + y_f}{2} = \frac{Z \pm 2}{P} \quad \text{---(1)}$$

$$y_b - y_f = \pm 2 \quad \text{---(2)}$$

$$y_b = y_f \quad \text{---(3)}$$

$$\frac{y_b + y_f}{2} = \frac{34 + 2}{4} \text{ (for Progressive winding)}$$

$$y_b + y_f = 18 \quad \text{taking } y_b = y_f$$

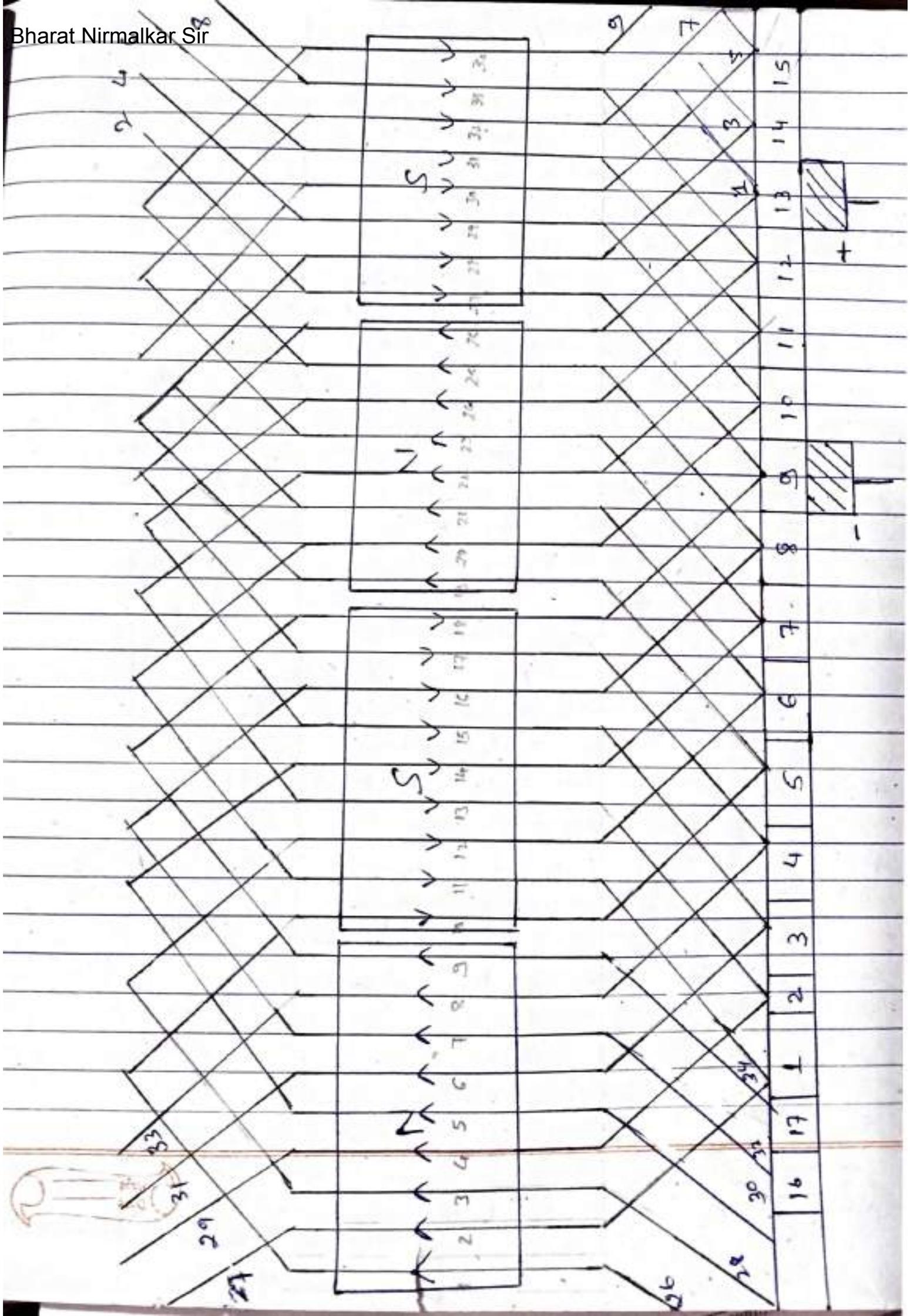
$$y_b = 9 \quad \text{and } y_f = 9$$

or
So

or
hence

Table

S.No.	Back side $y_b = 9$	Front side $y_f = 9$	S.No.	Back side $y_b = 9$	Front side $y_f = 9$
1.	1 + 9 = 10	10 + 9 = 19	10.	27 + 9 = 2 (36)	2 + 9 = 11
2.	19 + 9 = 28	28 + 9 = 3 (37)	11.	11 + 9 = 20	20 + 9 = 29
3.	3 + 9 = 12	12 + 9 = 21	12.	29 + 9 = 4 (38)	4 + 9 = 13
4.	21 + 9 = 30	30 + 9 = 5 (39)	13.	13 + 9 = 22	22 + 9 = 31
5.	5 + 9 = 14	14 + 9 = 23	14.	31 + 9 = 6 (40)	6 + 9 = 15
6.	23 + 9 = 32	32 + 9 = 7 (41)	15.	15 + 9 = 24	24 + 9 = 33
7.	7 + 9 = 16	16 + 9 = 25	16.	33 + 9 = 8 (42)	8 + 9 = 17
8.	25 + 9 = 34	34 + 9 = 9 (43)	17.	17 + 9 = 26	26 + 9 = 1 (35)
9.	9 + 9 = 18	18 + 9 = 27			



SIMPLEX WAVE WINDING:

Developed diagram of a simplex 2-layer wave wound armature winding for a 4-pole generator with 26 armature conductors.

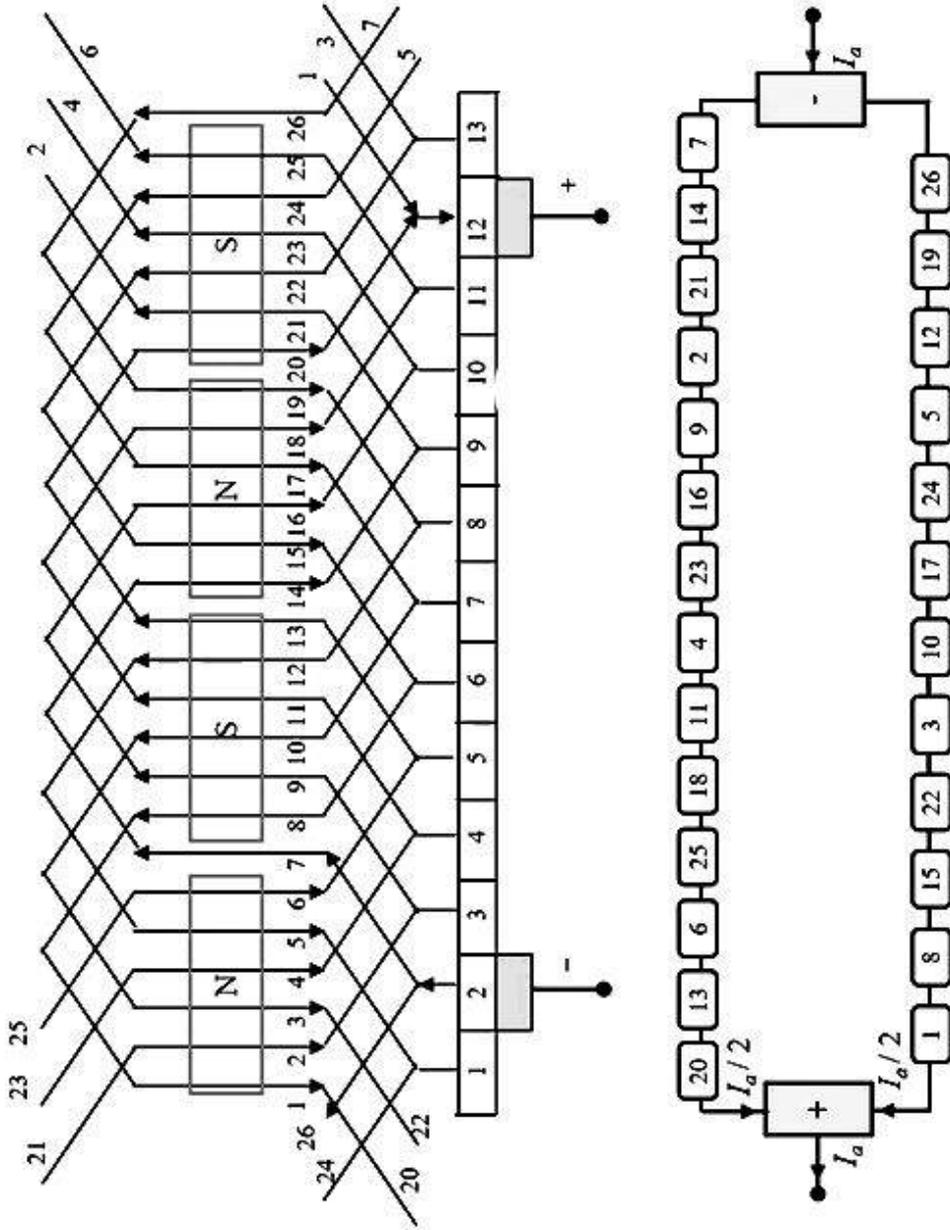
Here, $Y_A = (26 \pm 2) / 4 = 6$ or 7 .

Taking $Y_A = 7$, we have $Y_B = Y_F = 7$.

WINDING TABLE:

Sr. No.	Back connection	Front connection
1	1 to $(1 + 7) = 8$	8 to $(8 + 7) = 15$
2	15 to $(15 + 7) = 22$	22 to $(22 + 7) = 29 = 29 - 26 = 3$
3	3 to $(3 + 7) = 10$	10 to $(10 + 7) = 17$
4	17 to $(17 + 7) = 24$	24 to $(24 + 7) = 31 = 31 - 26 = 5$
5	5 to $(5 + 7) = 12$	12 to $(12 + 7) = 19$
6	19 to $(19 + 7) = 26$	26 to $(26 + 7) = 33 = 33 - 26 = 7$
7	7 to $(7 + 7) = 14$	14 to $(14 + 7) = 21$
8	21 to $(21 + 7) = 28 = 28 - 26 = 2$	2 to $(2 + 7) = 9$
9	9 to $(9 + 7) = 16$	16 to $(16 + 7) = 23$
10	23 to $(23 + 7) = 30 = 30 - 26 = 4$	4 to $(4 + 7) = 11$
11	11 to $(11 + 7) = 18$	18 to $(18 + 7) = 25$
12	25 to $(25 + 7) = 32 = 32 - 26 = 6$	6 to $(6 + 7) = 13$
13	13 to $(13 + 7) = 20$	20 to $(20 + 7) = 27 = 27 - 26 = 1$

DIVISION OF CURRENT IN SIMPLEX WAVE WINDING



4.1 Illumination fixtures: types and internal circuit diagram

प्रकाश का योजनामूर्तिक उपयोग करके चौराई गौर्दर्यापरक या व्यावहारिक प्रकाश उत्पन्न करता illumination or प्रदीपि कहलाता है।

प्रदीपि के अन्तर्गत कृत्रिम प्रकाश स्रोती एवं प्राकृतिक प्रकाश स्रोती - सौली का अक्षुचित प्रयोग किया जाता है।

Types of illumination fixtures

1) Ambient lighting or illumination (परिवेश प्रकाश व्यवस्था) →

Bright, powerful illumination that lights up a room in its entirety general lighting or now mostly known as "ambient" lighting is made for a single purpose: to provide you with uniform levels of illumination over the entire space completely independently from other lighting sources.

→ Fixtures most often used to supply generally ambient lighting are:

- Ceiling mounted fixtures
- LED downlights
- Track lights
- wall-mounted fixtures
- Floor lamp

2) Task lighting or illumination →

Few things can serve as a more worthy addition than effective task lighting specially tailored for the task you are about to complete. whether you are about to indulge in productive computer work, enjoy cooking a delicious meal or simply sit

-back and relax with a good book, nothing will aid you better as a task lighting.

→ Types of fixtures that provide Task lighting -

- Desk lamps or portable lamps
- Undercabinet and slimline bars and extrusions
- Downlights or directional gimbal recessed fixtures
- Pendant lighting

3) Accent lighting →

In general, accent lighting shines upon three time as much light on the focal point as much light on the focal point as ambient lighting provides to emphasize it. Have a higher output and narrower beam angle to focus the light only where required. This is a requirement to create a noticeable contrast with the ambient lighting that will guide your gaze where it must go.

Types of fixtures that provide Accent lighting.

- wall-mounted fixtures
- Tape and extrusion
- Directional recessed fixture or downlight
- Track light

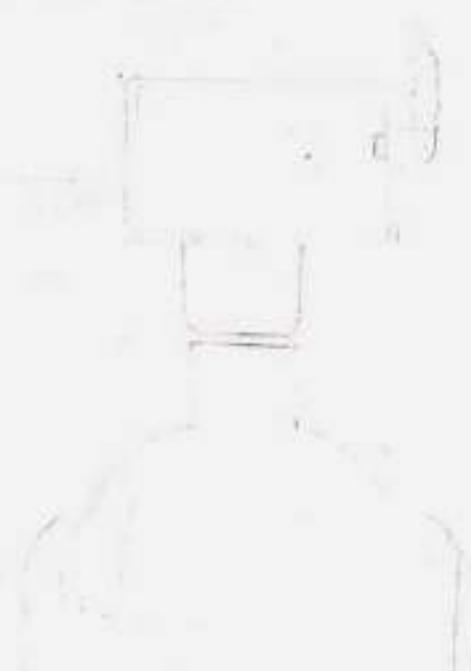
4) Decorative lighting (अनावरी प्रकाश व्यवस्था) →

When it comes to decorative lighting, just like its name implies, it is all about

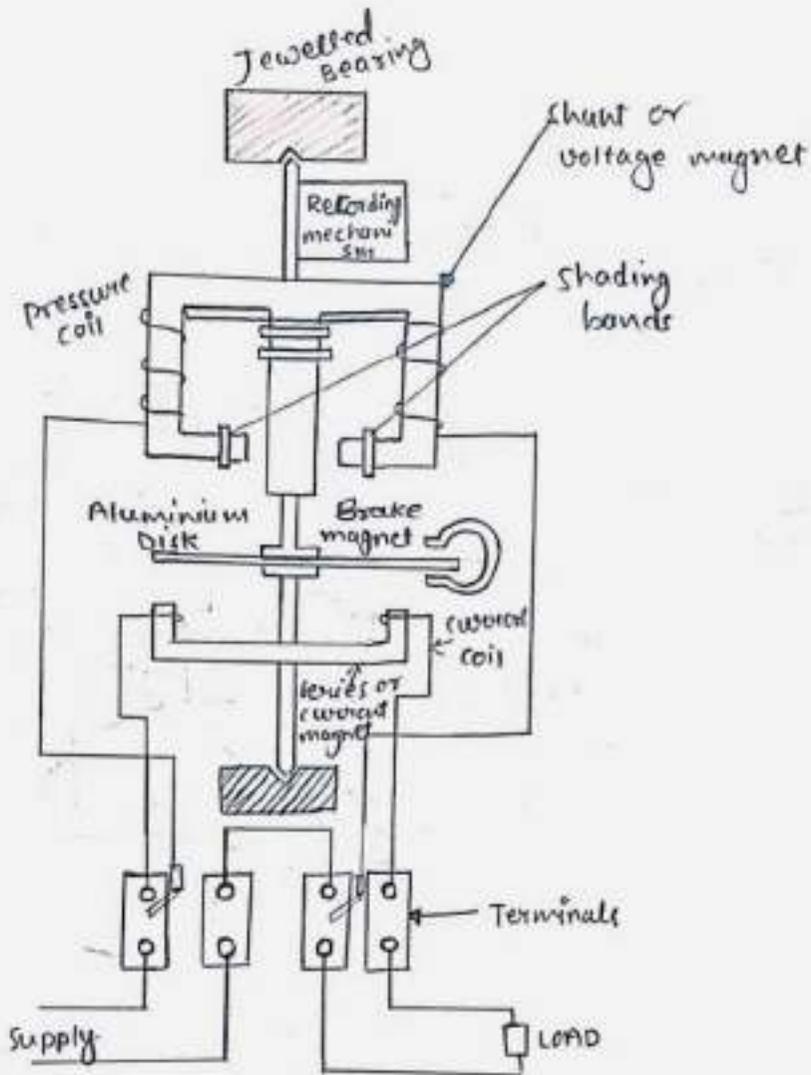
making a strong statement. Before choosing it, make sure to think of the 'direct, upwork, or downwards lighting colour, and size to really achieve the effect that you have in mind.

Types of Decorative Lighting:

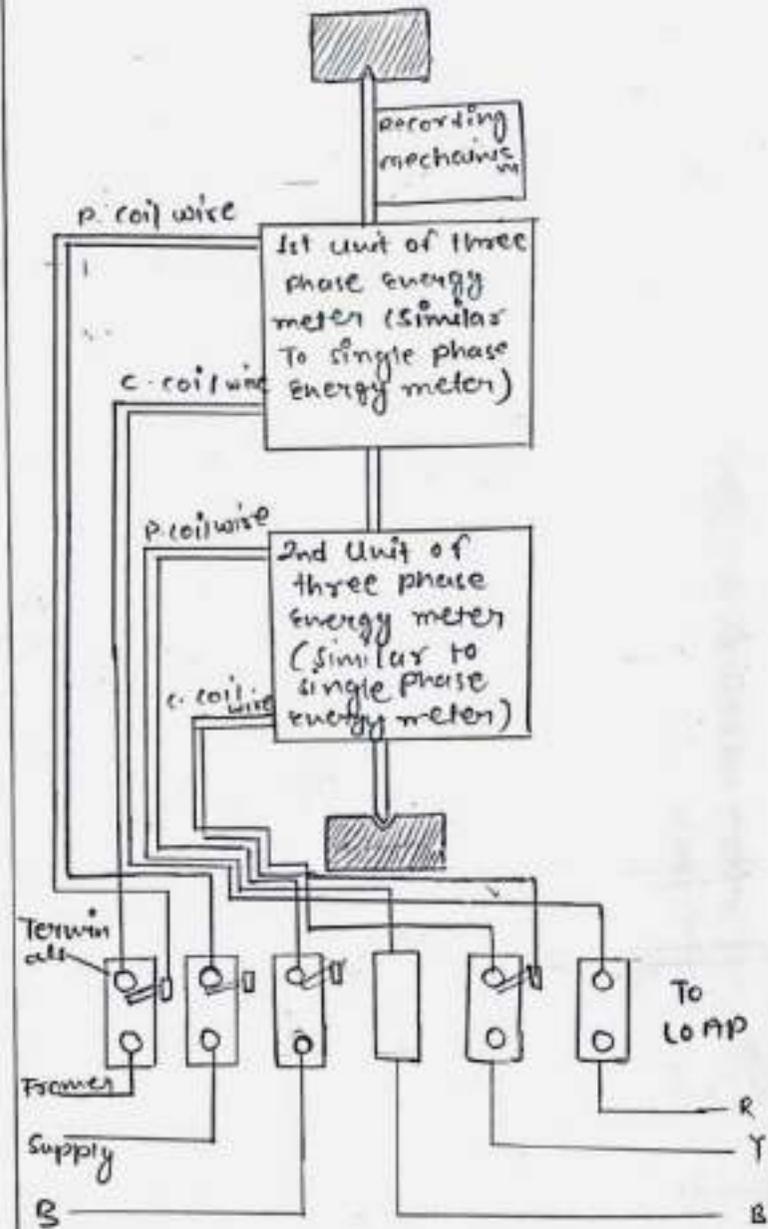
- Pendant lighting
- Wall sconces
- Table and floor lamps
- ceiling fans with light kits



4.3 Single Phase induction type Energy meter & Three Phase Energy meter

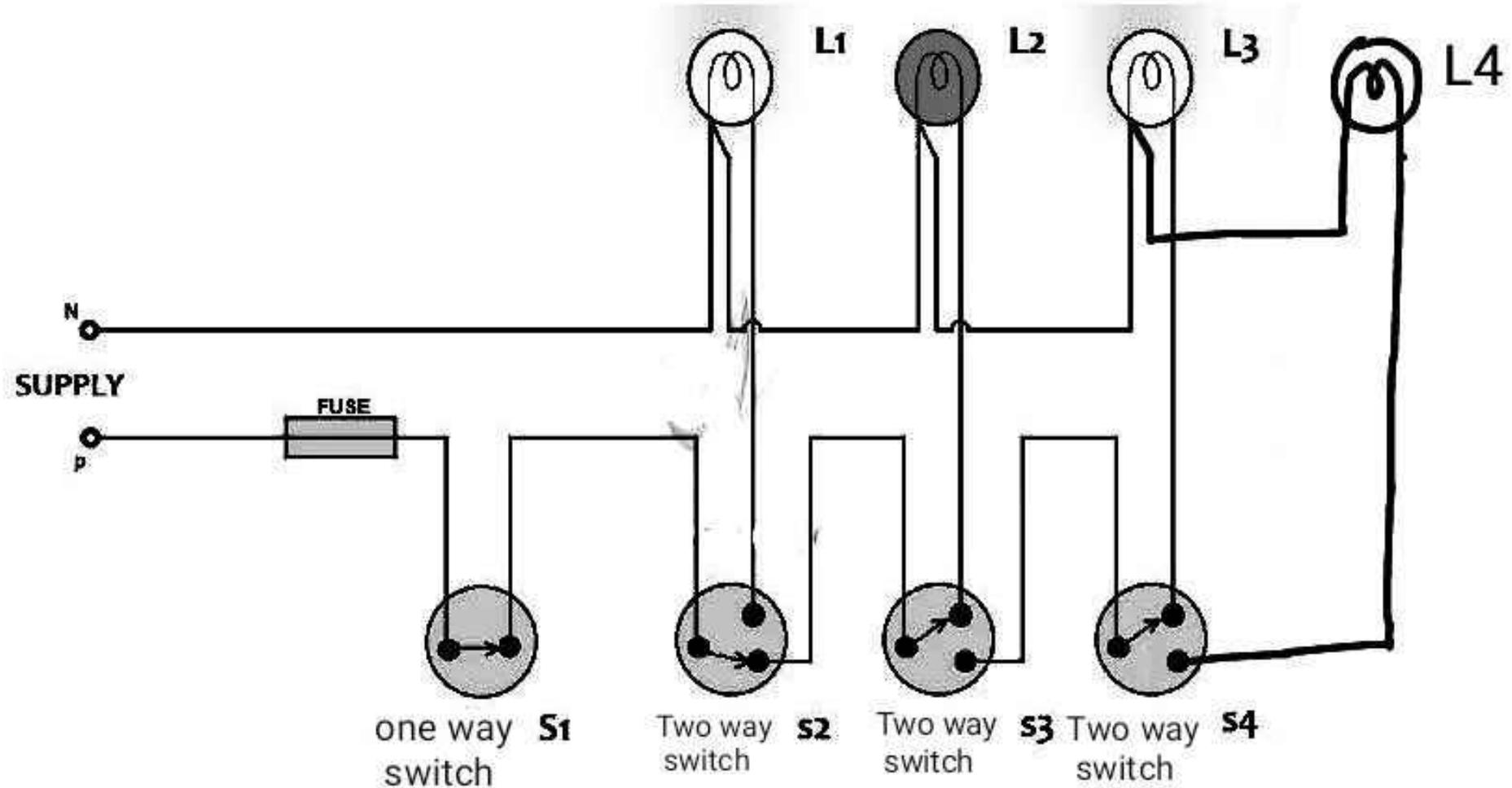


(a) Single Phase Energy Meter



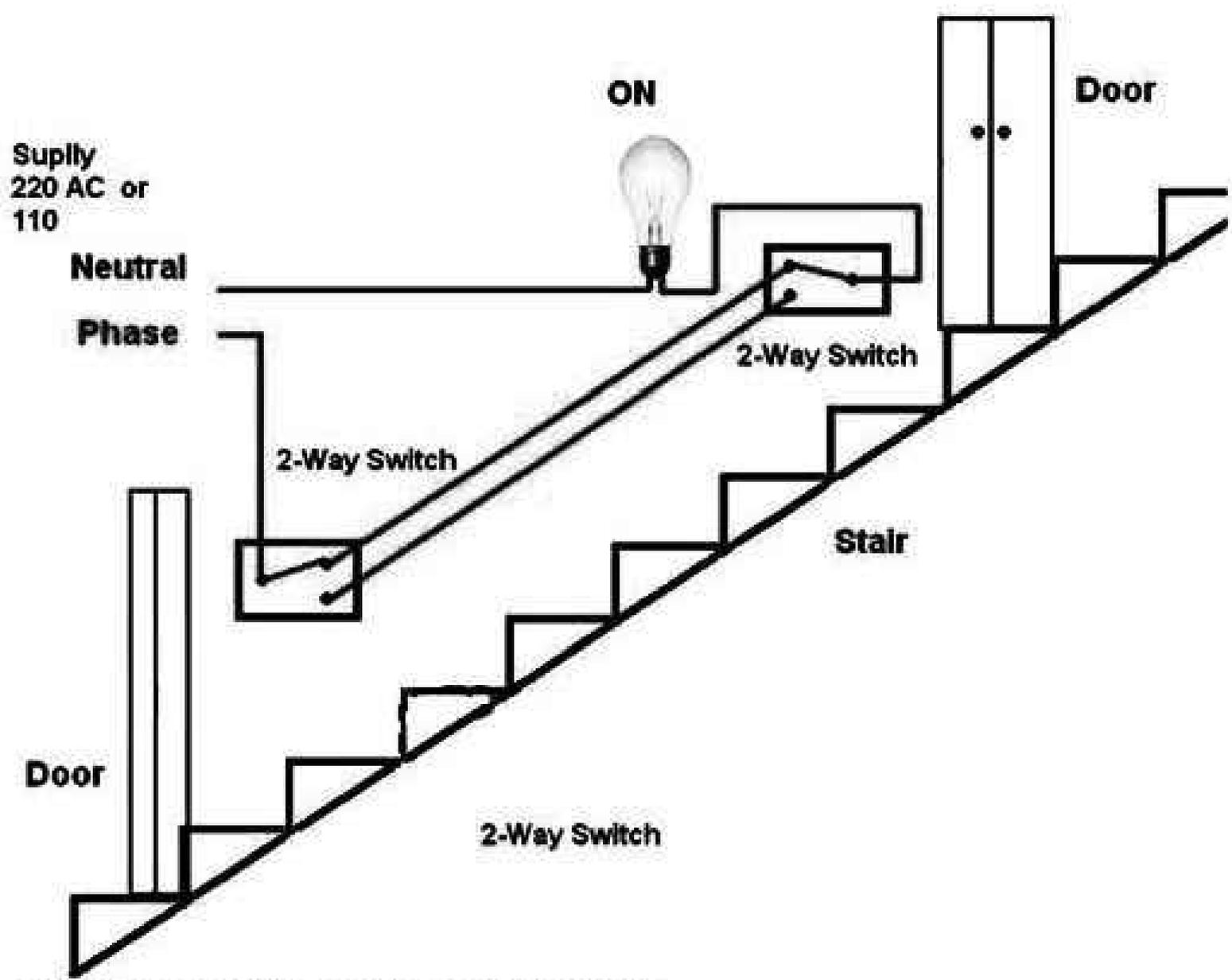
(b) Three Phase Energy Meter

Q. Draw the diagram of long corridor wiring (Godown wiring)



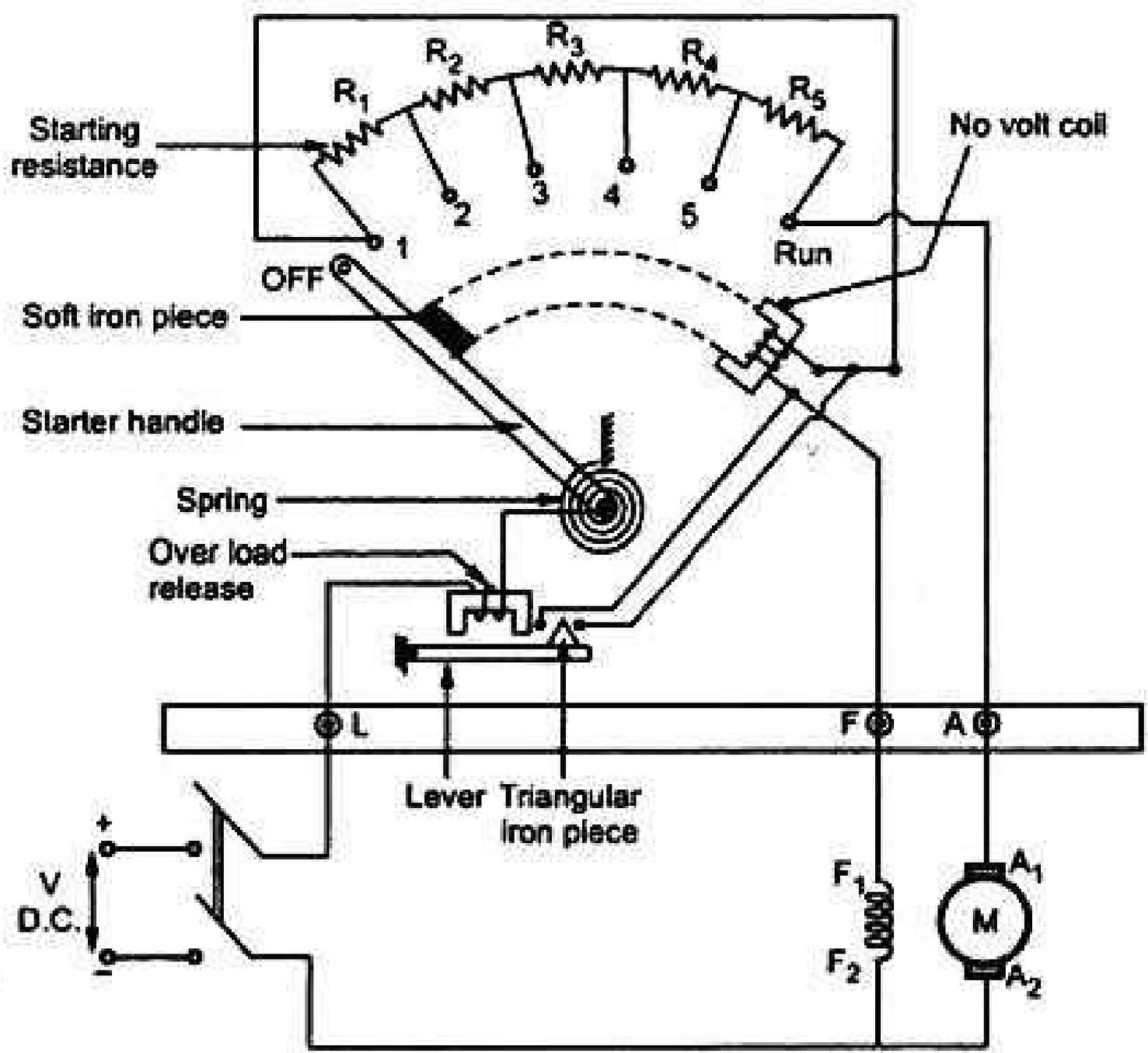
Godown Wiring diagram.

Q. Draw the diagram of staircase wiring using two way switch.



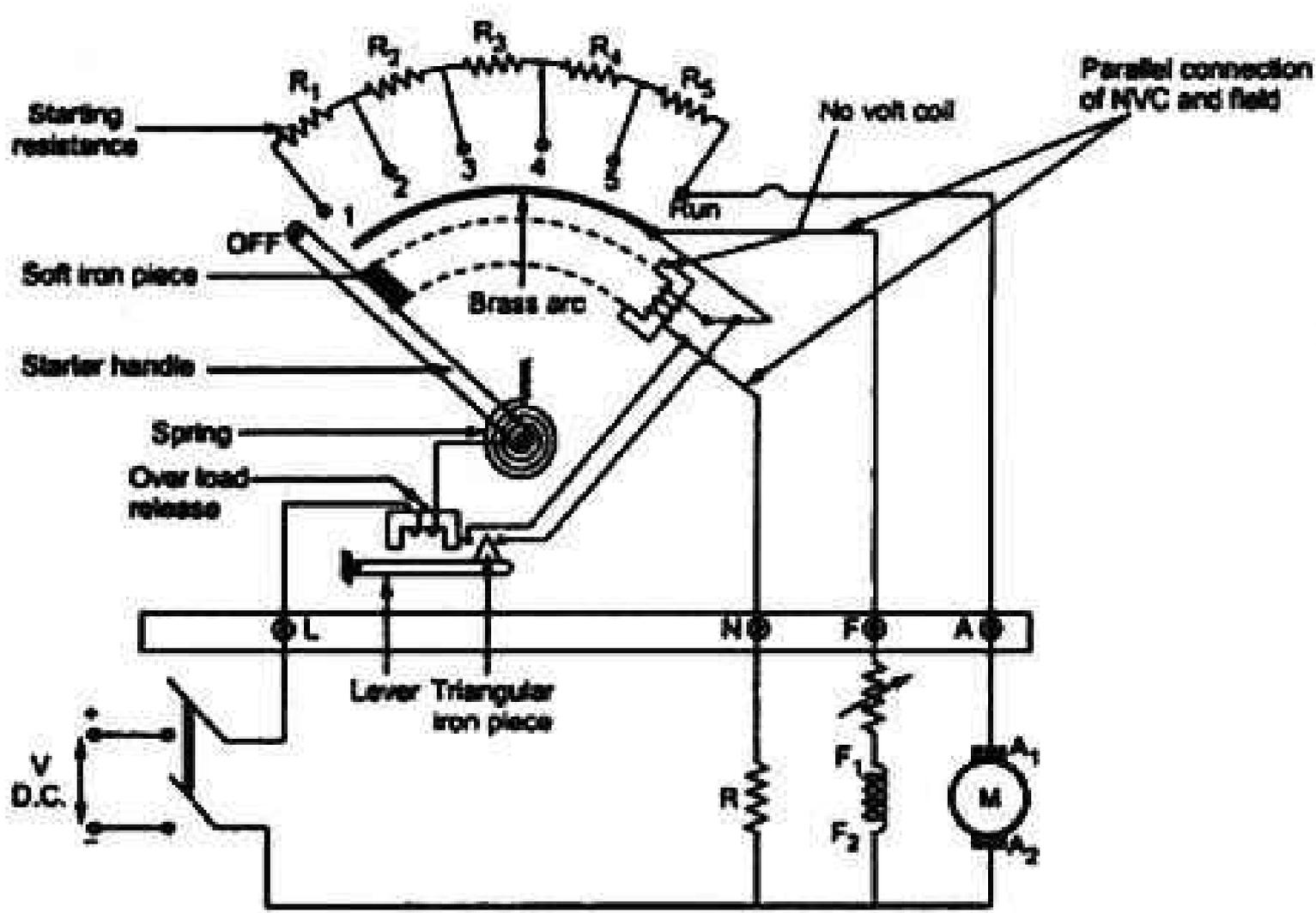
Stair case wiring circuit diagram

Q. Draw the diagram of 3 point starter for DC motor.



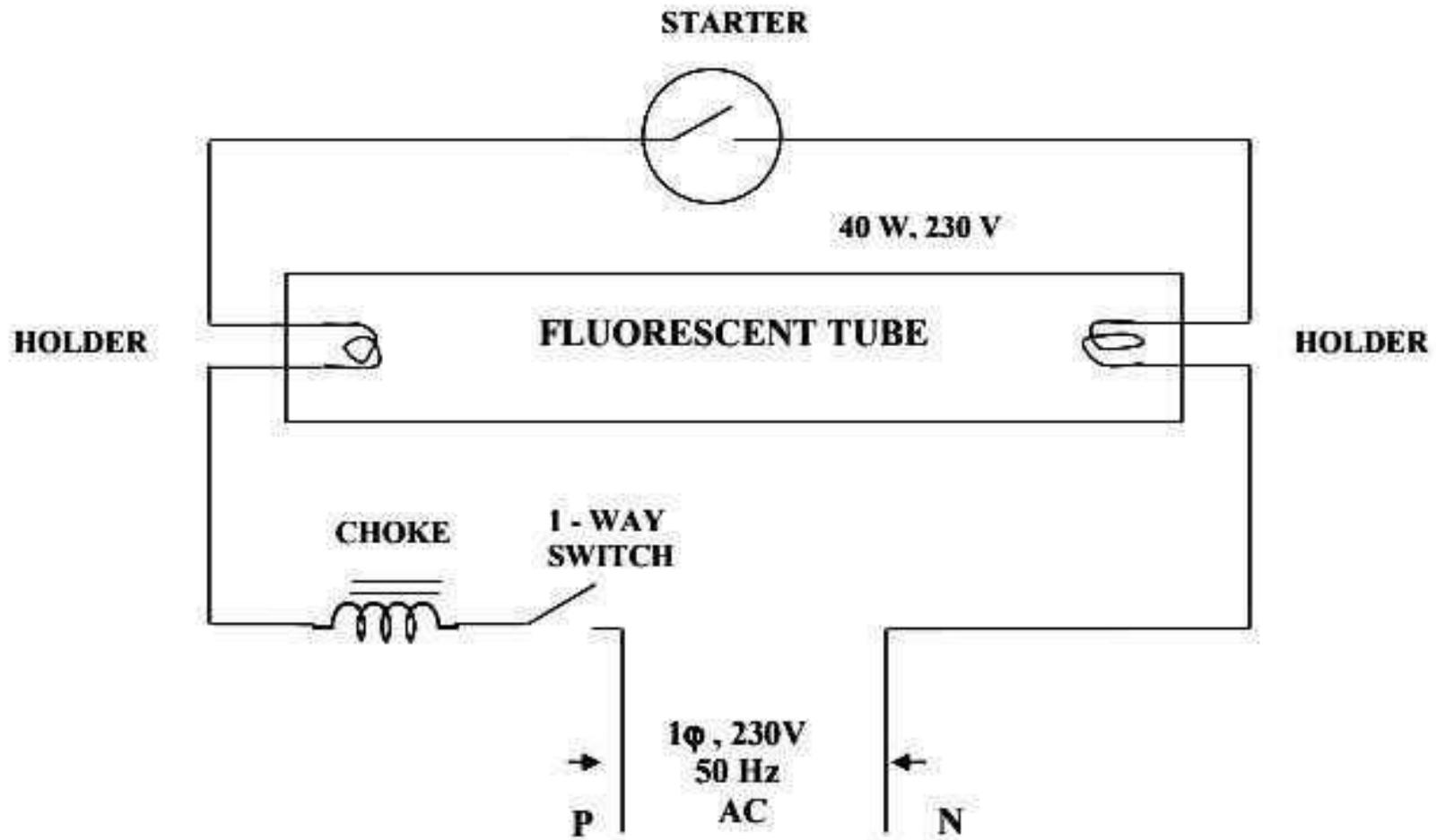
3 point starter

Q. Draw the diagram of 4 point starter for DC motor.



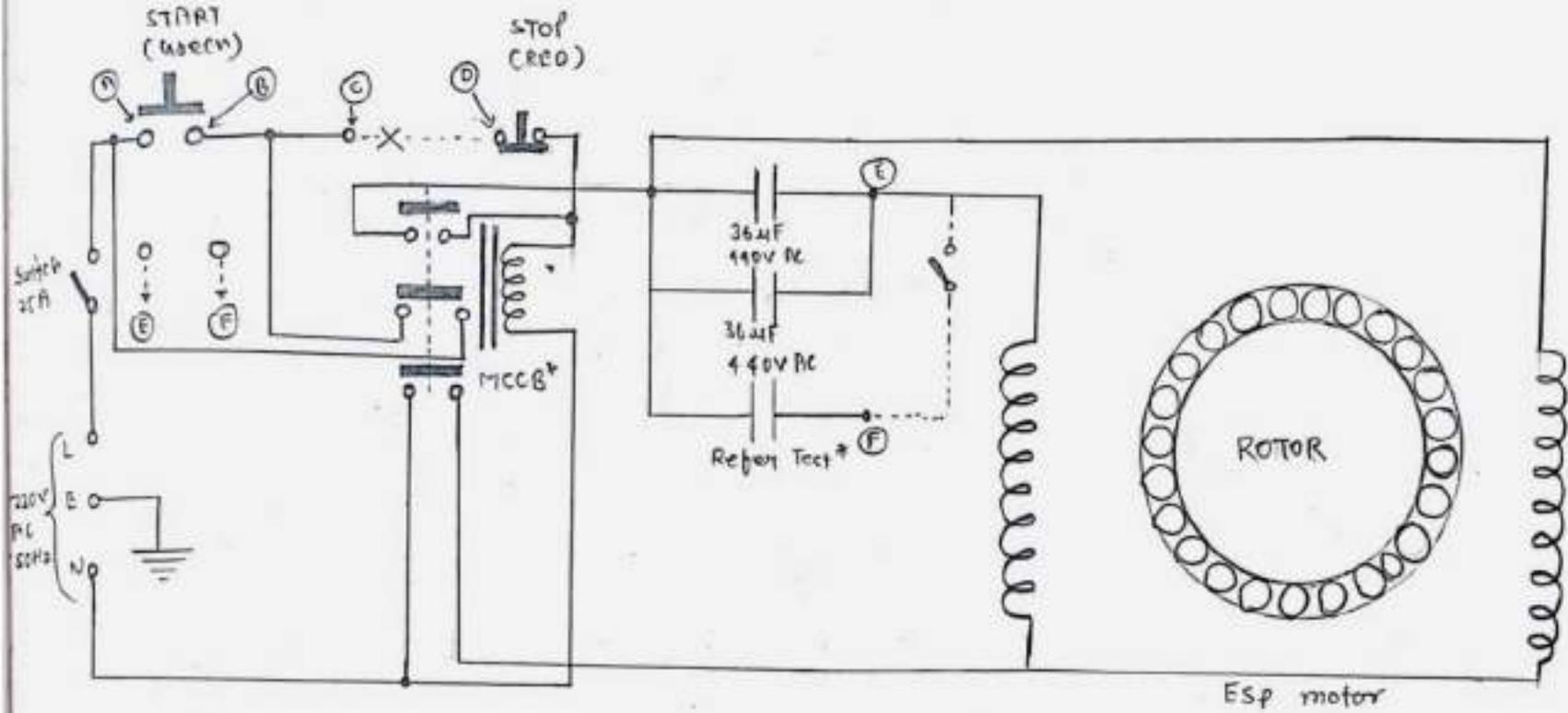
Four Point Starter

Q. Draw connection diagram of fluorescent tubelight.

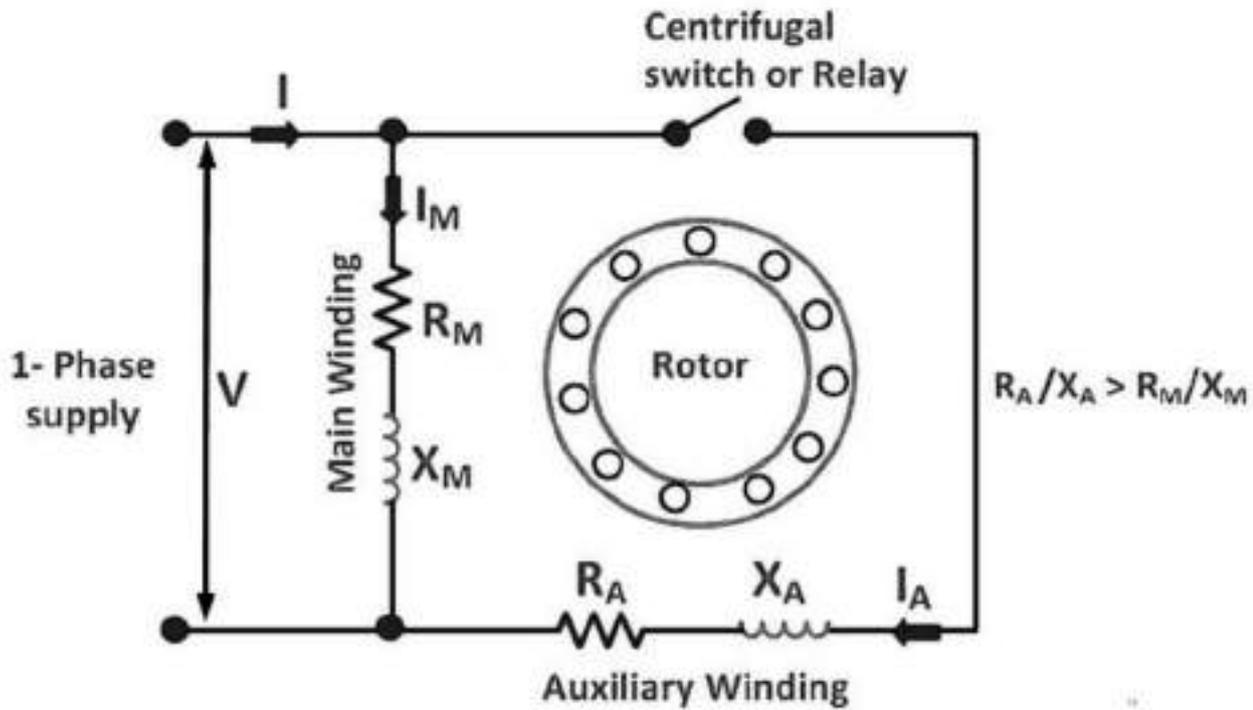


wiring diagram of fluorescent lamp

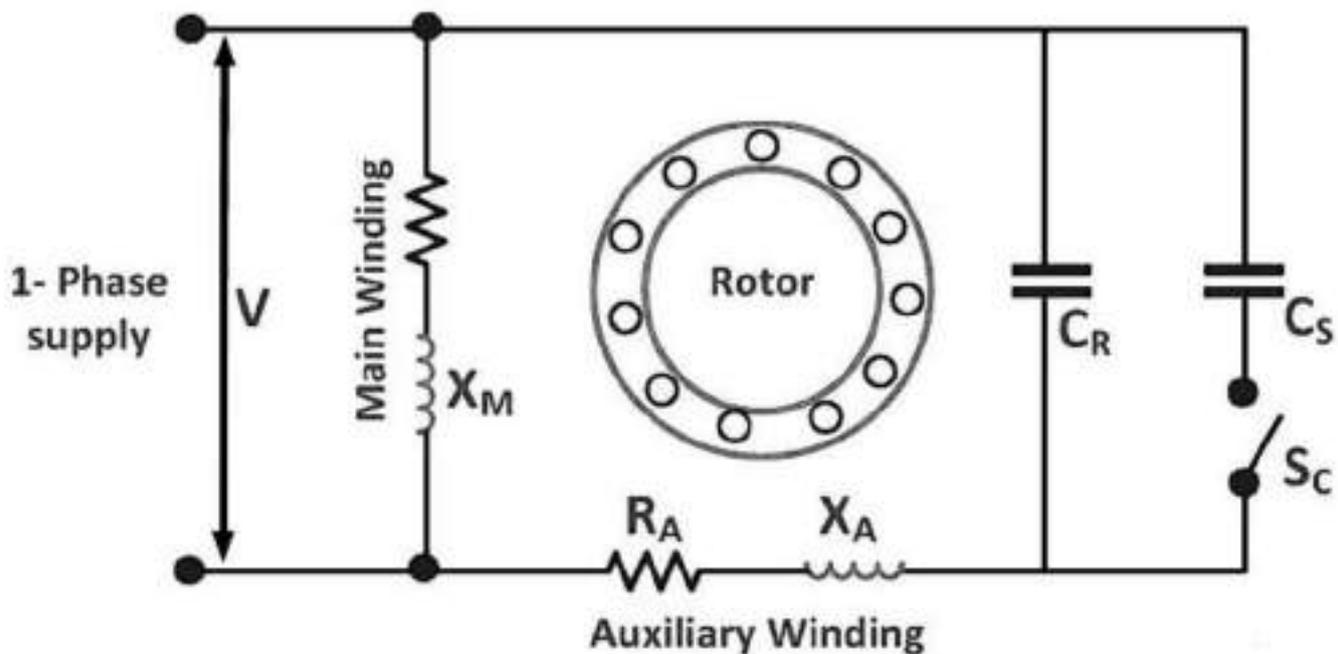
u.s wiring Diagram of Submersible and centrifugal pumps.



Q. Draw the diagram of Resistance start & capacitor start and capacitor run single phase induction motor.



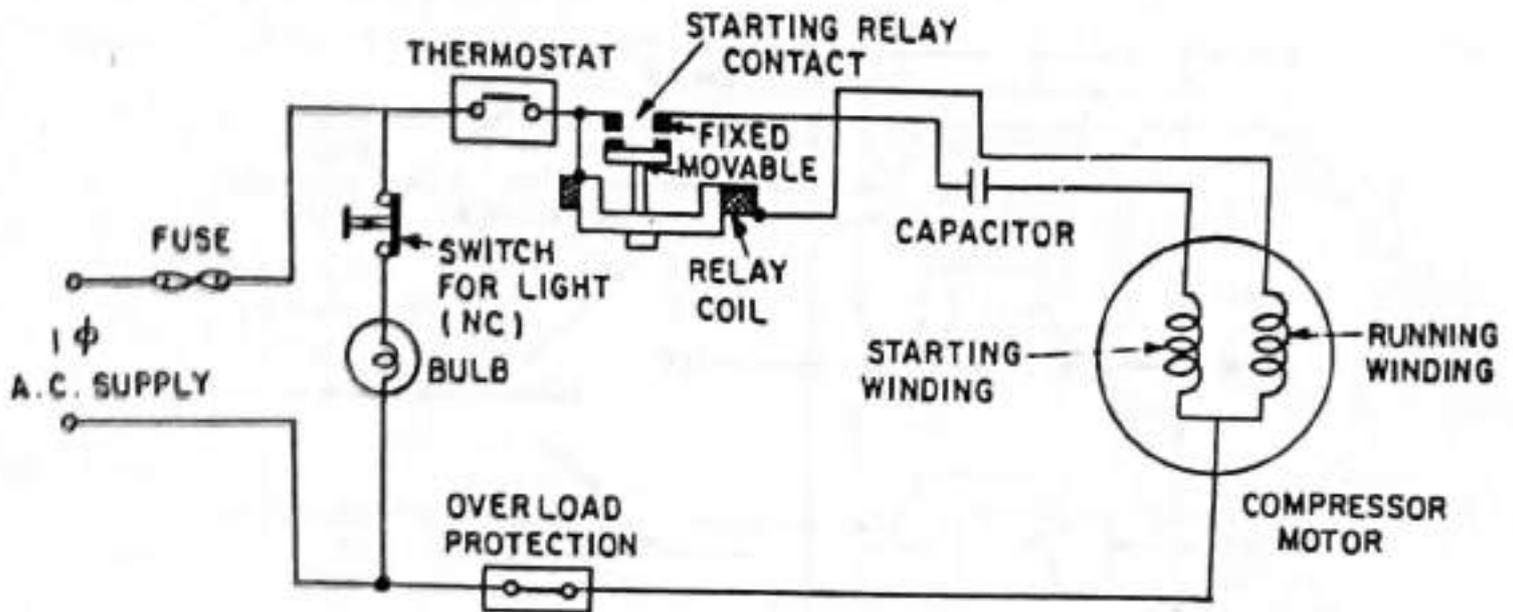
(a) Resistance start single phase IM



(b) Capacitor Start capacitor run motor.

Example 11.59. Draw the electrical circuit diagram of the "Domestic Refrigerator".

Solution : See figure 11.59.

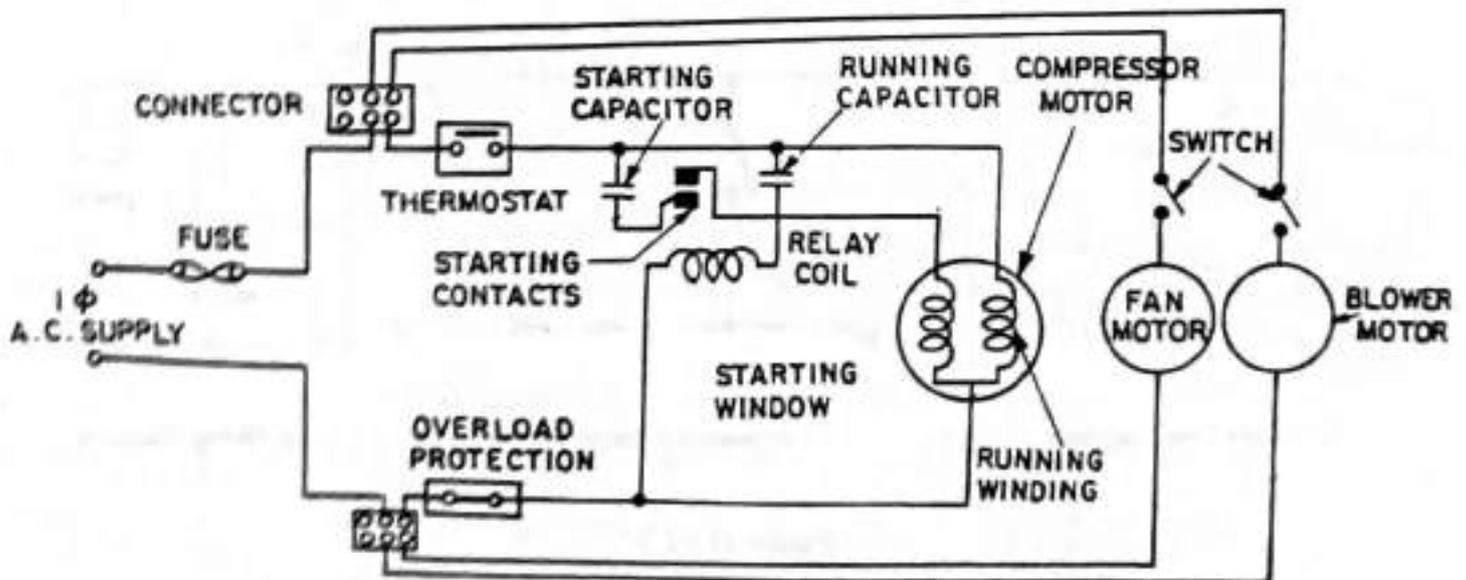


Electrical Circuit of Domestic Refrigerator

Figure 11.59

Example 11.60. Draw the electrical circuit diagram of the window type "Air Conditioner".

Solution : See figure 11.60.



Electrical Circuit of Domestic Air Conditioner

Figure 11.60

Example 11.14. Draw the wiring diagram of double staircase wiring by using looping system.

Solution: See figure 11.14 (a) to (d).

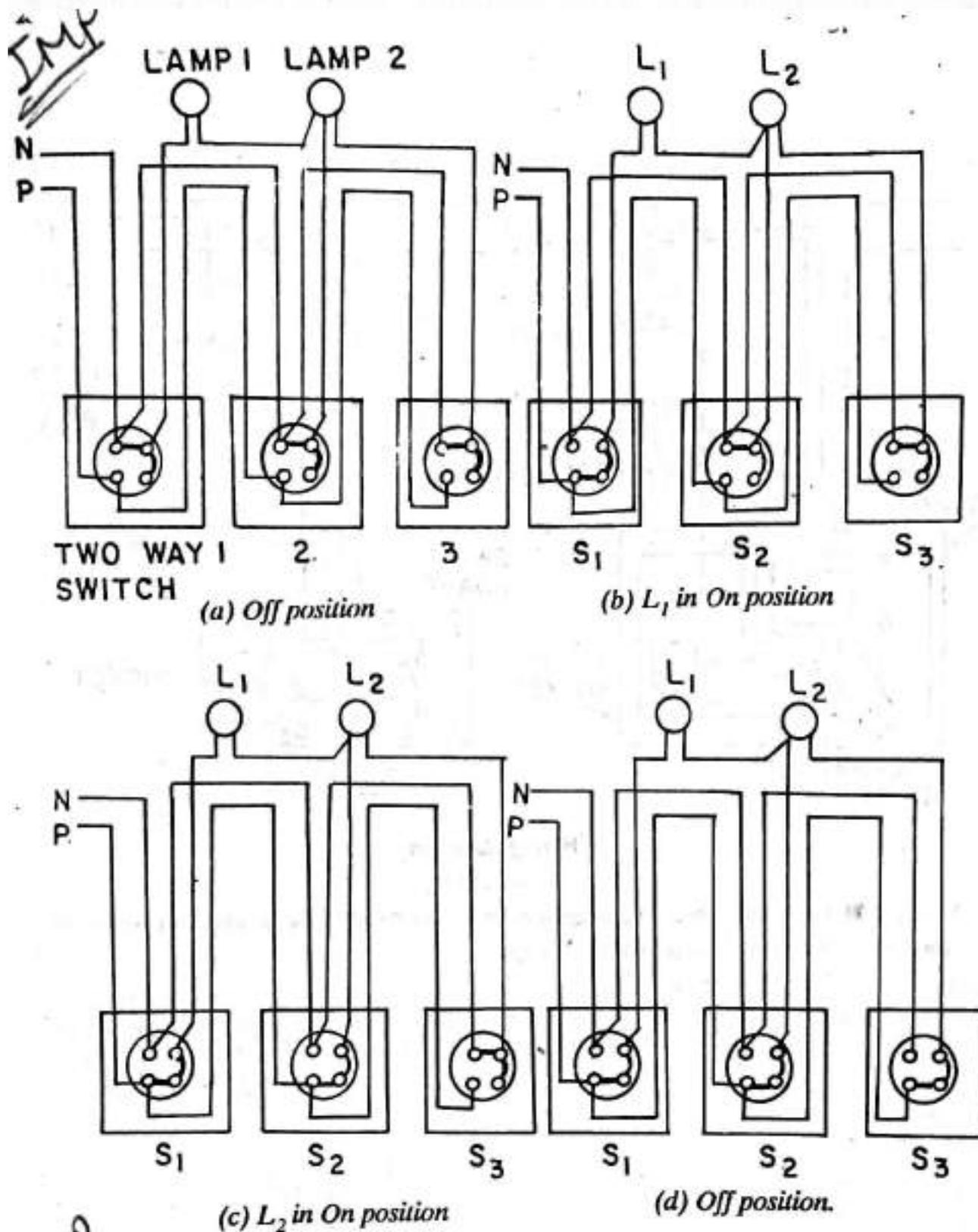


Figure 11.14

Example 11.15. Draw the wiring diagram in looping system for a lighting circuit, generally required for a long corridor or a godown.

Solution: (i) See figure 11.15 (a).

In this wiring diagram any number of persons can enter the corridor or godown at any end, and operate the lights one by one.

(ii) See figure 11.15(b). In this wiring diagram it will not be possible for two persons to enter the corridor at the same end and perform the whole procedure one after the other, and also the circuit will not function when the master switch is in "OFF" position.

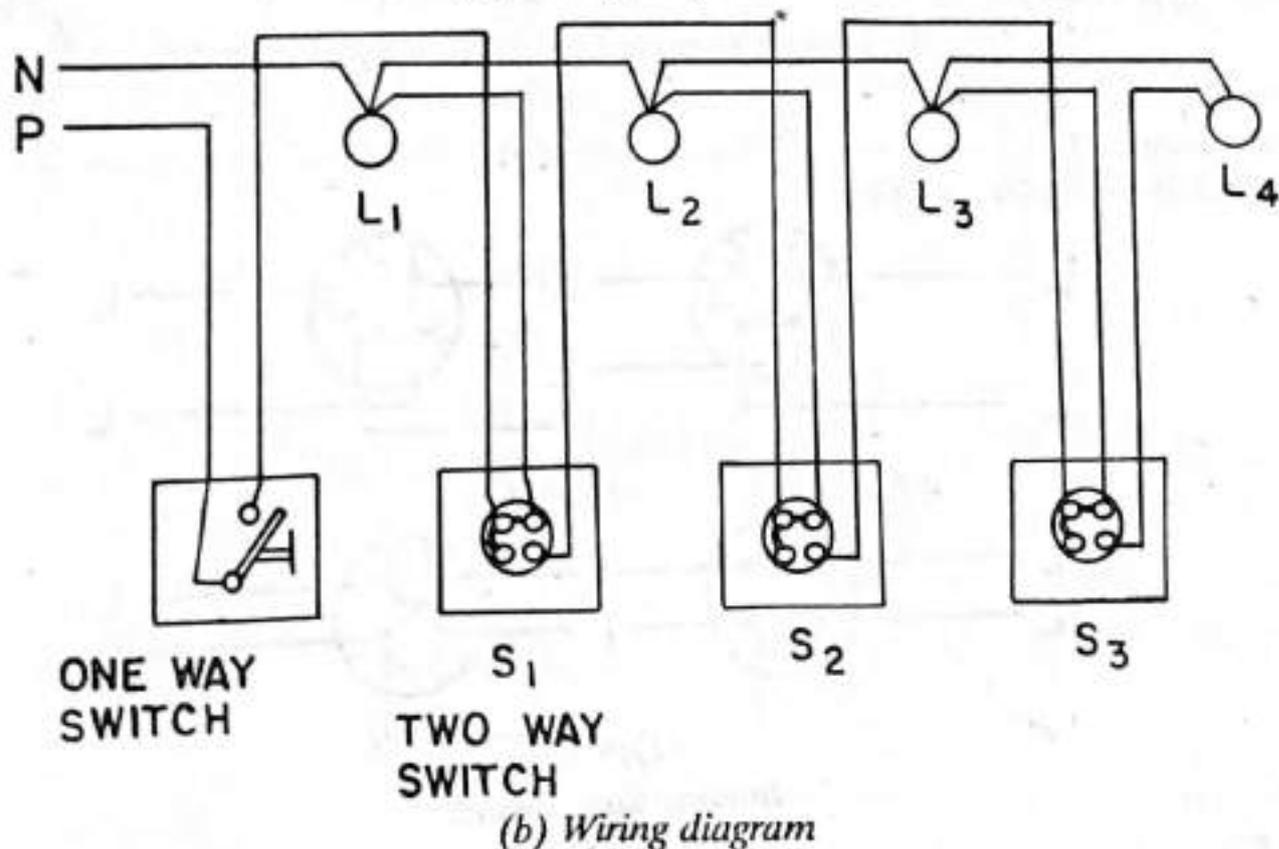
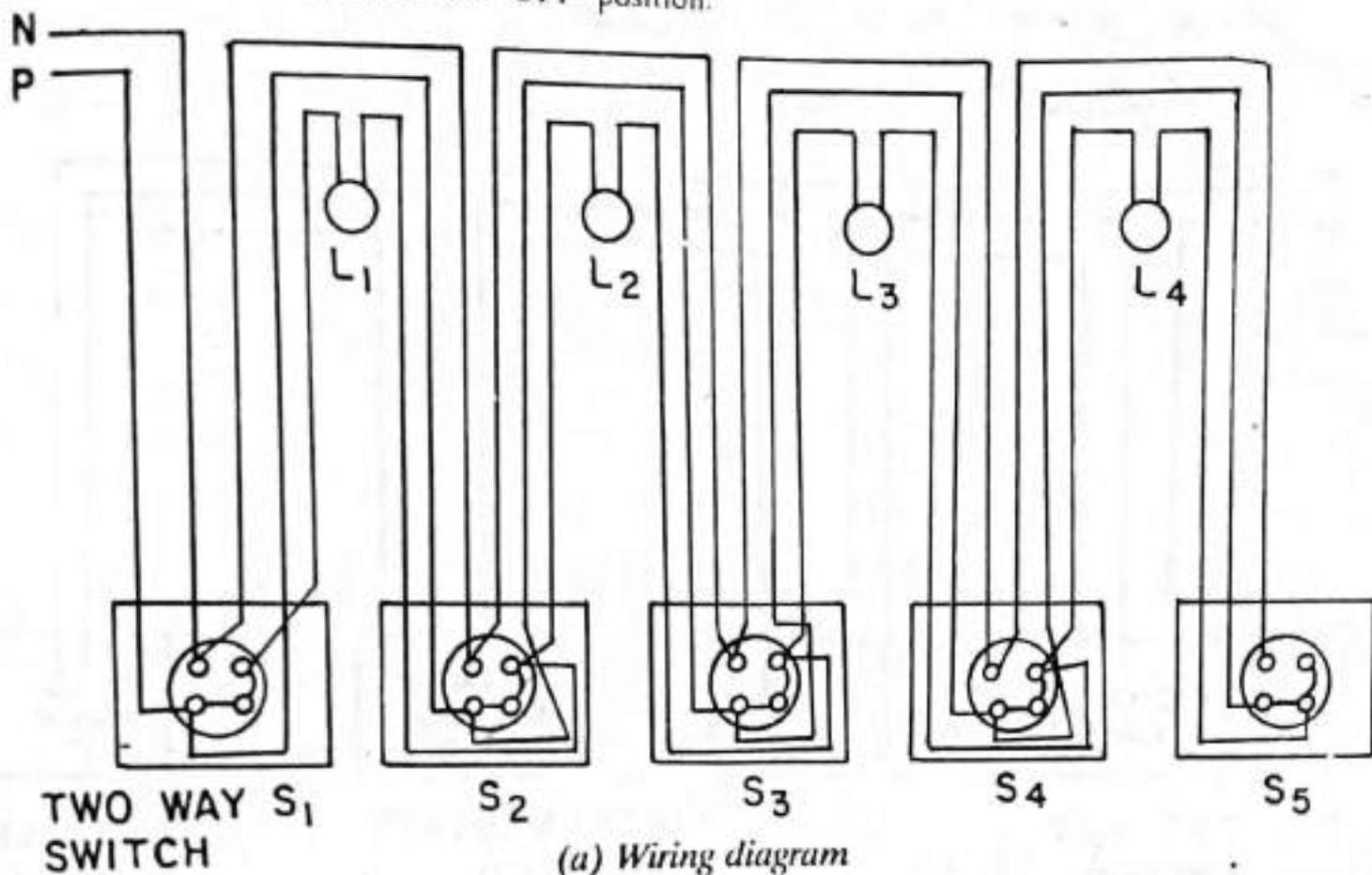


Figure 11.15

Unit - 5th CAD

CAD? CAD का अर्थ होता है, Computer aided Drawing या Drafting. यह एक ऐसी विधि है जिसके द्वारा किसी भी ड्राइंग को कंप्यूटर के पर्दे पर प्रदर्शित किया जा सकता है। Engineering में मशीन अभियंता की ड्राइंग तथा Layouts को भी CAD के द्वारा बनाया जा सकता है।

CAD में ड्राइंग भी संशोधित है जिससे किसी भी Products की ड्राइंग बनायी जा सकती है।

CAD प्रक्रिया में डिजाइन की आवश्यकता जैसे - Part का निर्देशन तथा निर्देशांक, पैमाने की संवर्ध, रंग की विशेषता आदि CAD system में Input द्वारा संप्रेषित किए जा सकते हैं। साथ ही जका अंतर्दीक्षा भी किया जा सकता है।

CAD में ड्राइंग के निम्न कार्य हैं:-

① Dimensioning करना तथा Tolerance के साथ Orthographic projection देना है।

② Assemble Drawing बनाना है।

③ एक Part list बनाना है जिसमें पहले का नाम, संख्या तथा अन्य विशेषता दिया जाता है।

④ Drawing में Machine के tolerance के लिए चिह्न देना है।

⑤ यह Drafting ड्राइंग के कटे भाग sectioning करता है।

⑥ Technical list circle के लिए Isometric view तथा Assembly को प्रिन्ट करता है।

- इस प्रकार Drafting में बने ड्राइंग को CAD द्वारा storage में रखा जा सकता है। जिससे इसमें आवश्यकता अनुसार संशोधित किया जा सकता है।

*CAD में निम्नलिखित Commands होते हैं।

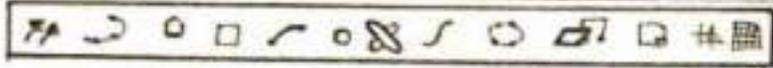
① Plot Command → यह एक Command बनता है जिस पर विभिन्न Commands को Lines पर plots या prompts देना जाता है। इसमें Layout Name, page set तथा output device name Find की जा सकती है।

② Zoom Command → यह Real time में Active रूप में Drawing को show करने में उपयुक्त है, जो कि इस command द्वारा controlled है। इसमें निम्न options होते हैं।

- | | |
|-----------------|----------------|
| a) Zoom window | e) Zoom Object |
| b) Zoom dynamic | f) Zoom in |
| c) Zoom scale | g) Zoom out |
| d) Zoom Center | h) Zoom all |
| | i) Zoom Extent |

③ Draw Command → यह Common Drawing में रेखा, वक्र, दीर्घवक्र, अर्ध वृत्त आदि विभिन्न रूपों में उपलब्ध है। इसमें निम्न स्पष्टीकरण होते हैं →

- | | | |
|------------|----------|-------------|
| ① Line (—) | ① Spline | ① Regions |
| ② Pline | ② Elipse | ② M text |
| ③ Polygon | ③ Insets | ③ Hatch |
| ④ Arc | ④ Blocks | ④ Reveser |
| ⑤ Circle | ⑤ Joins | ⑤ Rectangle |



④ Layers → यह Command रेखा पर नई layer निर्धारित करने में, रंग चुनने में, नाम को परिभाषित करने में, रेखा के भार को find करने में, तथा Angle 'C' Show करने में यह Layer command काम आता है। Dialog Box layer को सम्मिलित होता है।

⑤ Ortho → इस Command के द्वारा कर्सेट को Horizontal & Vertical direction में परिवर्तन कर देता है।

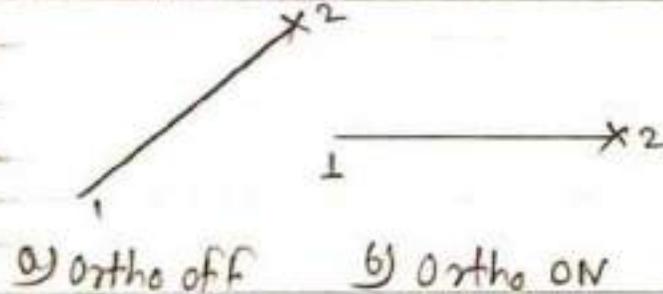


Fig → Ortho command

⑥ Object snap command → यह command एक प्रत्यक्ष AutoCAD का command होता है। जिसका उपयोग रेखा की गति बदलने में किया जाता है।

कई बार Drawing को ऐसे point पर start करना पड़ता है जो select करने में कठिन होता है। इस स्थिति में यह Command उपयोग होता है। इसके लिए पहले Object snap command को ON करने है। फिर किसी भी Diagram (Circle, Rectangle या किसी भी lines) का mid point लेने में जिससे यह Command उनके center lines को अर्थात् center points को Detect करेगा है। जब इस Command को ON किया जाता है तो निम्न symbols प्राप्त होते हैं →

- Intersection - Square symbol
- Mid point of line - Triangular symbol
- center of circle - Circular symbol
- Quarter point of line - Square in shape

⑦ Editing Commands → Drawing बनाने सम्मर्थ होने के बाद किसी Object अथवा रेखा को उसे modify करने के लिए इस Commands का use किया जाता है। इसे Editing command कहते हैं। इससे रेखा की गतिविधियों को सुदृढ़ी भी जा सकता है। इस प्रकार Modify की यह प्रकार Editing कहलाती है।
 में Editing commands निम्न हैं →

- | | |
|----------|-----------|
| ① Erase | ⑦ Filter |
| ② Copy | ⑧ Chamfer |
| ③ Move | ⑨ Offset |
| ④ Arrow | ⑩ Rotate |
| ⑤ Mirror | ⑪ Trim |
| ⑥ Break | ⑫ Extend |

⑧ Text command ⇒ एक इस option command से किसी ड्राइंग Space के संदर्भ जो कुछ भी लिखा जाता है, Text Command कहलाता है। इस Text command की सहायता से हम किसी भी ड्राइंग का नाम method तथा scale के साथ उसका कुछ विवरण भी लिख सकते हैं। इसके Text को use textbox बनाने में किया जाता है।
 में Text मुख्यतः दो प्रकार के होते हैं ⇒

① Single line text ⇒ इस Option के प्रयोग से किसी Text को एक ही line पर लिखा जाता है। इससे दूसरे line का उपयोग नहीं किया जा सकता है।

Syntax - Command - Text or M text
 Specify start point (SL/ML/Justify) - M L
 "Enter the text"
 ④ Multiline Text ⇒ Text को एक से अधिक line में लिखने में प्रयोग है। जिस कि पैराग्राफ नाम से होता है। इसे M-text

Syntax of Command - Text or M-text
 Specify start point (SL/ML/Justify) - M L
 "Enter Text"
 Dimensioning ⇒ प्रत्येक ड्राइंग में उसकी लंबाई, चौड़ाई, ऊंचाई, डिग्री की स्थिति आदि की जानकारी जो कि उसके विवरण में आवश्यक होती है। इस जानकारी को ही show कराने Dimensioning कहलाती है।

Dimensioning के Main parts मुख्य अवयव निम्न हैं ⇒
 ① Extension line - यह line Extension show करता है।
 ② Dimension line - यह विमांकन करता है।
 ③ Arrow head line - यह विमांकन की स्थिति Arrow head के द्वारा दर्शाता है।

Note ⇒ इस Command को use करने के लिए पहले plot command में DIM लिखकर prompt किया जाता है।

किसी भी ड्राइंग में Dimensioning की महत्व भूमिका होती है। क्योंकि यही ड्राइंग के सही आकार व आकृति को अंकन करता है। बिना Dimensioning के Drawing को Complete नहीं माना जा सकता है।

- Types of Dimensioning ⇒
- ① Linear Dimension
 - ② Radial Dimension
 - ③ Diametric Dimension
 - ④ Angular Dimension

① Linear Dimension \Rightarrow इस विभाजन का उपयोग किसी भी straight line के Dimension के लिए कर सकते हैं। इसे Dimension line युक्त line के समान होता है।

में मुख्यतः निम्न प्रकार के होते हैं \Rightarrow

i) Horizontal Dimension \Rightarrow जब किसी रेखा को विभाजन करते हैं तो उसे Horizontal Dimension करते हैं।

ii) Vertical Dimension \Rightarrow जब ऊर्ध्व रेखा को विभाजन करते हैं तो उसे Vertical Dimension करते हैं।

iii) Aligned Dimension \Rightarrow इसके कुछ विशेष line के Dimensioning में Aligned dimension करते हैं।

② Radia Dimension \Rightarrow इसका उपयोग किसी भी वृत्तीय चाप, स्पर्श रेखा अदि को दशानि में किया जाता है। इस Dimension में विभाज की Value के सामने R लिखा होता है।

Syntax \Rightarrow
Command - DIM \downarrow
DIM - Rad \downarrow

"Select Arc or circle select"
Dimension test <50> -50 \downarrow

③ Dimetric Dimension \Rightarrow इस Dimension का उपयोग किसी भी वृत्त की त्रिज्या को दशानि में किया जाता है। इसके dimension value के सामने ϕ लिखा होता है।

④ Angular Dimension \Rightarrow इस विधि में किसी भी दो रेखाओं के बीच के कोण तथा वृत्त के किसी चाप केन्द्र पर बनने वाली कोण को दशानि जा सकता है।

Syntax & Command - DIM
 DIM - Angular
 select arc line - select line AB
 select second line = select AC - 100
 B Dimension text < 00 > - 00

Coordinate entry → Autocad में निर्देशांक की (coordinates की) स्थिति को

निर्दिष्ट करने के लिए Co-ordinate entry का उपयोग किया जाता है। यह अंतर्निहित अवस्थाओं को समझने में हमारा सहाय लेकर help करता है। अर्थात् यह प्रक्रिया time taken होती है।

इसमें सापेक्ष Command देने के लिए →

- ① Select the menu item insert > Graphic > line
- ② Determine the starting point manually and press [Enter].....
- ③ Select the menu item options > Relative Co-ordinate input.
- ④ In the Relative co-ordinate input dialog, you can specify the position of the end point.
- ⑤ Click [OK].

Autocad Screen layout & Interface →

Screen layout → मूल रूप से Autocad में screen layout एक 2d स्थान का प्रतिनिधित्व करता है, जहाँ उपयोगकर्ता ड्राइंग बोर्ड के आकार का विशिष्ट कद चयन करता है और title block को edit कर सकता है। और एक ही समय में कई दृश्य देख सकता है। Autocad में उपयोगकर्ता को प्रकार के विंगल आइकन का उपयोग करके चित्र बनाने के लिए प्लुग प्रोविड है।

CAD में प्रत्येक layout 4 areas में divide होता है →

- ① Drawing area
- ② Command area
- ③ Menubar area.
- ④ Tool bar area

इन चारों areas में विभिन्न प्रकार के various components होते हैं।

Interface → Autocad Interface एक ribbon का user interface का है जिसमें panel और tab में व्यवस्थित विभिन्न Autocad Command शामिल है। tab काफी powerful होता है। क्योंकि उनके पास Command के panel के साथ-साथ विजय भी होते हैं। उपयोग के लिए यदि आप एक hatch वस्तु का चयन करते हैं तो एक contextual tab प्रकट होता है।

Co-Ordinate system for Autocad

Co-Ordinate system for autocad. 2D व 3D coordinates को निर्धारित करने में प्रयोग किया जाता है। जो स्थिति Co-ordinates पर होता है। x, y, z और z के coordinates संभावित रूप से भी गणितीय स्थान तर्क है। वे एक मतमाना आदितीय मूल $(0,0,0)$ के साथ स्थित हैं।

Angular measurement of autocad

Autocad में कौन एक माप के माप को दो रेखाओं के बीच या एक रेखा के भीतर मकर द्वारा angular measurement करता है। इसके लिए, →

Ribbon Home tab > Utilities panel, expand the measure drop-down and click the measure angle tool. Select two lines an arc or a circle.

Point specification

Point object को बनाने के लिए point command का प्रयोग किया जाता है। जो Object Snap के रूप में कार्य करता है। जिसका माप Object को Snap कर सकता है। आप किसी भी बिंदु के लिए 2D और 3D स्थान निर्दिष्ट कर सकता है। इस Command का प्रयोग करने के लिए बस FO लक्ष्य कर enter करें Drawing area पर क्लिक करें जिसमें Point दिखाए देता है।

Drawing Aids

Drawing aids menu में कई कमांड होते हैं जो मौजूदा Objects पर आधारित सर सर lines या Rectangle बनाते हैं, या Drawing पर Drafting को तेज और आसान बनाने के लिए मौजूदा Object को बनाने बनाते हैं।

Some Imp Drawing aids

- | | |
|----------|---------------|
| ① Grid | ③ Object snap |
| ② Snap | ④ Zoom & PAN |
| ⑤ Units | ⑥ Limits |
| ⑦ Layers | ⑧ Linetype |

① Grid → Grid command का उपयोग समान या असमान मैगिन और इन्वियर Space में points या lines की series को display करने के लिए किया जाता है। इस Command को function key F7 से Grid mode को toggle करते हैं।

② Snap → Snap command का उपयोग समान या असमान एक करके और जानकारी को packs file में संग्रहित करने में किया जाता है। जो किसी भी Object को निर्धारित और सज्ज कराने के लिए Snap command का उपयोग किया जाता है। यह Command function key F9 Snap mode को toggle करते हैं।

③ Object snap → इस Command का उपयोग ड्राइंग की गरि लक्षित में किया जाता है।

④ Zoom & Pan →

i) Zoom → यह Command ड्राइंग को Zoom in तथा Zoom out करने में प्रयुक्त Command है।

ii) Pan → जब आप माउस को अपनी ड्राइंग के सारे ओर घुमाते हैं तो माउस के हील को दबाए रखते पर Pan command operate होता है।

⑤ Units → यदि 1000 के एक घण्टे में मापने के लिए एक आयाम का उपयोग करते हैं तो इसका मतलब है कि भले ही CAD Drawing cm, mm पर हो तो मंड का माप जान भी 1000 पर अपरिमेय है।

Autocad में प्रयुक्त निम्न Commands प्रयुक्त हैं →
 इंच, फीट, मील, cm, mm, Km, m, गज, Å
 इनका अभाव, unitless आदि।

⑥ Limits → Autocad में Limits command का उपयोग Drawing area पर Drawing part में एक invisible Rectangle limit निर्धारित करने के लिए किया जाता है। यह Grid display और point को Limit करता है।

⑦ Layer → इस फंक्शन में प्रयुक्त Command है। यह Dialog box के माध्यम से चलता है।

⑧ linetype → इस Command में $\text{Ctrl} + \text{L}$ बटन पर enter key press की जाती है। linetype में 25-5 वर्त तक शामिल हो सकता है।

Link

Modify commands or Edit Command

① Erase command → इस Command का उपयोग किसी भी Autocad के diagram के अनिश्चित part को हटाया जा सकता है।
 process to use →

- 1) Select erase Command
- 2) Select diagram
- 3) Rightclick.
- 4) OK.

② Copy command → यह प्रश्न उत्तर, या diagram की प्रतिलिपी बनाता है।

Process → ① select copy command

② Select diagram

③ Right click

④ Base point में

⑤ एकाधिक प्रतियाँ बनाएँ।

⑥ Enter करें।

③ Move command → किसी परिवर्तन में उपयुक्त है।

Process → Same as above.

④ Rotate command → Clockwise / anti-clockwise direction में changing करने के लिए यह command उपयुक्त होता है। process - Same as above.

⑤ Scale → पैमाना बताने के लिए यह command उपयुक्त है।
Process → Same.

⑥ Stretch → यह Command द्वाारा में कुछ भाग को मूल आकार में जोड़ने के लिए उपयुक्त है।
Process → Same.

⑦ Array → यह Command किसी भी वस्तु या Diagram की कई प्रतियाँ बनाता है। यह समान आकार या पैमाने वाली वस्तुओं की एकाधिक प्रतियाँ बना सकता है।

Process → ① Select command

② Select diagram

③ Right click

④ Select Rectangle table

⑤ Modify array reference

Printing & Plotting of Diagram or Drawing

एक Plotting शैली एक वैकल्पिक विधि है जो निर्धारित करने के लिए प्रारंभिक बल्ड या फॉन्ट में plot की जाती है। plot शैली को किसी बल्ड या फॉन्ट पर assign करना plot करते समय एक linewidth और lighttype जैसे गुणों को override करता है। plot शैली से कौन plot की गई वस्तुओं की उपस्थिति उदाहरण के लिए

एक printing शैली इस command से भी plotting के बाद keyboard पर ctrl + P द्वारा या command line पर PLOT type की शुरुआत करें। इसके अलावा में plot window खुल जायेगी। जिसमें pdf के लिए DWG का select करें।

Creating basic drawings

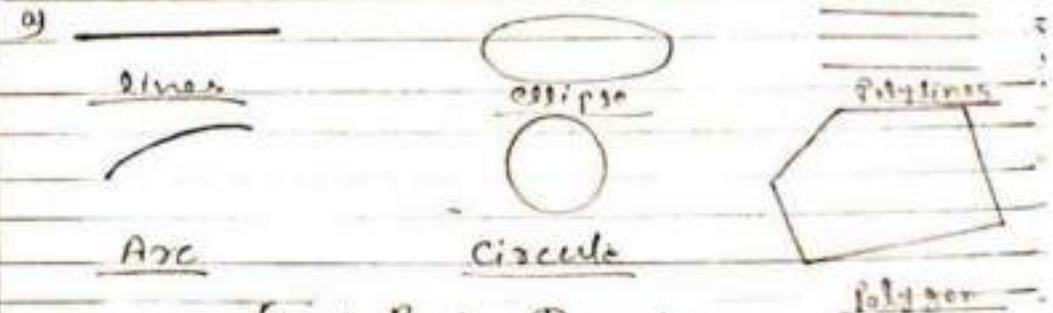


Fig 1 Basic Drawings

CAD के लाभ \Rightarrow

- ① Architecture \Rightarrow BIM (Building Information ^{Model})
- ② Product Design \Rightarrow Industrial Design
- ③ Graphic design \Rightarrow 2D, 3D
- ④ Engineering \Rightarrow उपकरणों के निर्माण में
- ⑤ productivity बढ़ता है।
- ⑥ Errors कम होता है।
- ⑦ DDT (Direct Design transfer)
- ⑧ सस्ता Prototyping
- ⑨ Easily Alternation \Rightarrow सुधार उपकरण आसानी
- ⑩ Quality improvement errors को solve
- ⑪ आसानी से sharing Informations easy
- ⑫ Marketing

*3 Methods of arc making \Rightarrow

Arc command \Rightarrow यह Command Arc बनाने में प्रयोग है। सामान्यतः CAD में 3 प्रकार के parameters से Arc बनाया जाता है।

① 3-point arc \Rightarrow यह जो बिना पर तीन बिंदु लेना चाही उस बिंदु बनाता है। जिससे एक \downarrow पाठ्य शिखि तथा तीसरा केंद्र बिंदु के बनाता है। तथा एक जो दूसरा बिंदु चाप के circular value को निर्धारण चाप लिखा जाता है।

② Start, center \Rightarrow इस विधि में स्टार्ट या center point होता है अंगीय तीसरा point कोण जीवा की लंबाई हो सकता है।

③ Start, End \Rightarrow चाप के Start & End Point होता है। इससे चाप को निर्दिष्ट दिशा या कोण या केंद्र बिंदु द्वारा पूरा किया जाता है। \rightarrow 

Commands \Rightarrow

① Chamfer \Rightarrow इस Command द्वारा वस्तुओं के कोने को तैयार किया जा सकता है।

- Process \Rightarrow
- ① select chamfer
 - ② type 1 चुने
 - ③ enter
 - ④ type 2 चुने
 - ⑤ enter
 - ⑥ select diagram 1
 - ⑦ select diagram 2

② Fillet \Rightarrow सीधे कोने को गोल करने में \rightarrow

- Process \Rightarrow
- ① select fillet
 - ② type r चुना
 - ③ enter
 - ④ Value of r
 - ⑤ enter
 - ⑥ 1 2 diagram से।

③ Trim \Rightarrow Trim करने में जिसका किनासा दूसरे लाइन में हो उसे काटने Trim करते हैं।

- Process \Rightarrow
- ① editing panel से trim select करें
 - ② Double enter
 - ③ Intersect line Double click
 - ④ enter

Two Methods of Drawing a circle :-

Circle :- एक circle बनाने की कई विधियाँ हैं।
इसे center point & radius of circle, या
circle command से mouse से मदद से select कर,
याँ सभी तरह displayable, 2 सही विस्तार विधि पाते हैं।

- ① Center point & Radius
- ② Center point & Diameter
- ③ 3 point & अक्षर पर निर्भर लेना
- ④ 2 Point \Rightarrow end-point & diameter of circle
- ⑤ TTR (Tangent Tangent Radius) \Rightarrow two line of tangent are a circle
- ⑥ TTT (Tangent Tangent Tangent) \Rightarrow 3 tangent & 6 point

UNIT - 05

S.1

CAD का मतलब - C = stand for computer
A = stand for Added
D = stand for Drafting

CAD = computer Added Drafting.

एक ऐसी विधि है जिसमें किसी वस्तु की ड्राइंग कम्प्यूटर के पर्दे पर प्राप्त होती है। Engineering में मशीन अवयवों की ड्राइंग तथा ले-आउट बनाया जाता है।

CAD के कार्यों के साथ ड्राफ्टिंग का संयुक्त रूप है। जिसमें उत्पाद ड्राइंग बनायी जाती है। CAD प्रक्रिया में डिजाइन पैरामीटर की जानकारी जैसे - view का निर्देशांक, रेखा की लंबाई, वृत्त की त्रिज्या आदि CAD system को Input Device द्वारा अंप्रेषित किए जाते हैं तथा साथ ही साथ स्क्रीन पर ड्राइंग का अंतर्लीकन किया जाता है। ड्राइंग को आवश्यकतानुसार ठीक किया जाता है। जब ड्राइंग को अंतिम रूप से मान लिया जाता है तो एवम् CAD Drafting Package निम्नलिखित कार्य करता है -

- (1) Dimension or with tolerance orthographic projection करना।
- (2) कटे हुए भाग में sectioning करना।
- (3) Assembly or assembly Drawing बनाना।
- (4) पार्ट लिस्ट बनाना जिसमें प्रत्येक भाग का नाम विवरण, पदार्थ तथा आवश्यक संख्या दी गई हो।
- (5) Drawing में machining or tolerance अंकित अंकित करना।
- (6) तकनीकी बुची वृत्त के लिए Isometric view तथा विस्तृत assembly बनाना।
इस प्रकार बनायी गई drawing को CAD

ड्राइंग को स्टोरेज में रखा जाता है, तथा आवश्यकता अनुसार उसे खोलकर देखा जाता है।

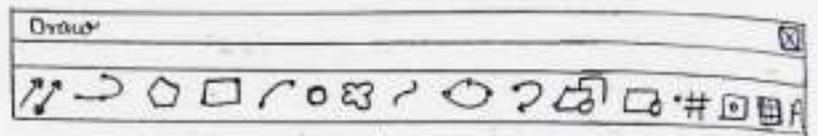
ड्राइंग को आवश्यकता अनुसार Plotted फ्लॉडिंग किया जाता है। CAD screen पर ग्राफिक भावना बनता है जिसमें designer design के बारे में गलत करता है तथा आवश्यक संशोधन और फेरबदल आसानी से कर सकता है। अंत में यह कहा जा सकता है कि CAD system का उपयोग graphic क्षमताओं को उन्नत करती है। इससे designer अपनी विचारधारा design में सरलता से संशोधन एनिमेशन कार्य design में गहनता कार्य आसानी का उपयोग फॉन्ट तथा अन्य अतिपेनशील विशेषताओं को परिकल्पित करता है।

* Plot → इसके द्वारा कमांड लॉइन पर प्लॉट प्रॉम्प्ट प्राप्त होता है। इसमें से अडट, लेम, पैज और असेटिंग तथा माइक्रोफुट डिवाइस लेम जात कर सकते हैं।

* Zoom → यह Real time में सक्रिय रूप में ड्राइंग को प्रदर्शन को नियंत्रित करता है। इसमें निम्नलिखित option मिले हैं-

- (a) Zoom window,
- (b) Zoom dynamic,
- (c) Zoom scale,
- (d) Zoom center,
- (e) Zoom object,
- (f) Zoom In,
- (g) Zoom out,
- (h) Zoom all,
- (i) Zoom Extent,

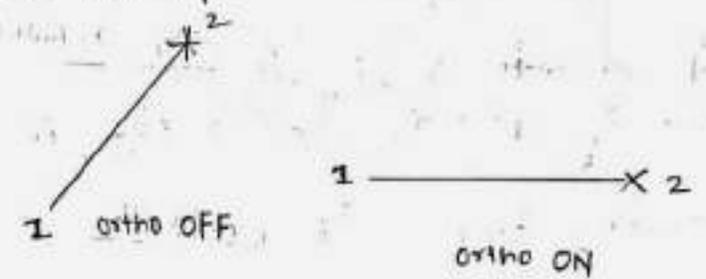
* Draw:- यह ड्राइंग में रेखा चला, अक्ष, अक्षरे, दीर्घवृत्त आदि निर्मित करता है। इसमें निम्नलिखित उप-निर्देश उपलब्ध हैं -



- (a) Line
- (b) Pline
- (c) Polygon
- (d) Arc
- (e) Circle
- (f) Spline
- (g) Ellipse
- (h) Insect
- (i) Block
- (j) Point
- (k) Revealed
- (l) Batch

* Layers:- यह निर्देश रेखा पर कई layer निर्मित करने का चुनने का प्रकार को परिभाषित करके रेखा के भार, layer के Plot status तथा कोन भी लेयर प्रदर्शित करना है। यह चुनने के काम आता है। संकेतक वॉलम लेयर के सहायक होता है।

* Ortho:- Ortho Command के द्वारा कर्सर की horizontal और Vertical direction में प्रतिबंध कर देता है।



* Object Snap Command → यह एक महत्वपूर्ण Auto CAD कमांड होता है

जिसका उपयोग Drawing की गति बढ़ाने में किया जाता है।

कई बार Drawing की किसी किसी point में शरत करना पड़ता है जो detect करने में कठिन होता है इस स्थिति में object snap command को ON किया जाता है। इसके माध्यम से कुछ points जैसे circle के center किसी line के mid point दो line के बीच के intersection की आसानी से detect कर लिया जाता है। जब object snap को ON किया जाता है तो निम्न तरह के symbol प्राप्त होते हैं -

- Intersection -  ← square symbol
- mid point of line -  ← Triangle symbol
- Center of circle -  ← Circular symbol
- Quater point of line -  ← Square in shape

* Editing Commands → Drawing बनाने समय यदि कोई object अक्षर्य रह

जाये तो उसे modify करने के लिए जो Commands का use किया जाता है उसे Editing Commands कहते हैं। इसके Drawing को सुधारा जा सकता है। modify करने की प्रक्रिया Editing कहलती है।

- कुछ Editing commands के उदाहरण हैं -
- ① Erase ② Array ③ Fillet ④ Rotate
 - ⑤ Copy ⑥ Mirror ⑦ Chamfer ⑧ Trim
 - ⑨ move ⑩ Break ⑪ Offset ⑫ Extend

* Text Command → Drawing space के अन्दर ही कुछ भी लिखा जाता है वह

Text कहलाता है। Text की सहायता से हम Drawing का नाम method तथा scale लिख सकते हैं। Text का use title box बनाने में भी किया जाता है।

Text मुख्यतः दो प्रकार के होते हैं -

- ① Single line text (SL)
- ② multiline text (ML)

① Single line text → जब इस option का उपयोग किया जाता है तो text को केवल एक ही लाइन पर लिखा जा सकता है text लिखने के बिचे दूसरे line का उपयोग नहीं करते हैं।

Syntax - Command - Text
Specify start point - (SL/ML/justify)
- SL ← style
Enter the text -

② Multiline text - जब इस option का उपयोग किया जाता है तो text को एक से अधिक lines पर लिखा जा सकता है। Text का बहुत सारे पैराग्राफ बनाकर लिख सकते हैं। Text को बहुत सारे lines में लिखना ही multiline या M-text कहलाता है।

Syntax - Command - Text or M Text
Specify start point (SL/ML/justify) - ML
Enter the text

10/11
Dimensioning

Dimensioning :- प्रत्येक ड्राइंग में अपनी लंबाई, चौड़ाई, ऊंचाई, दूरी की स्थिति माप की जानकारी जो कि उसके निर्माण में सहायक होती है, विमांकन (Dimensioning) कहलाती है। Dimensioning के सहायक उपकरण रेखा, विमांकन रेखा (Dimension line), चिह्न होते हैं। Command prompt में DIM लिखकर विमांकन का अधीन किया जा सकता है।
किसी भी Drawing में Dimension की अत्यंत भूमिका होती है Dimension के त्रुटि से object के अही आकार व आकृति का पता लगाया जा सकता है। बिना Dimensioning के Drawing को Complete नहीं माना जा सकता है।

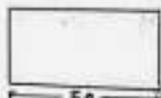
Types of Dimension -

① Linear Dimension :- इस विमांकन का उपयोग किसी भी Straight line के Dimension के लिए कर सकते हैं। इसमें Dimension line मुख्य तारण के समानांतर होता है।

अंका Symbol  है।

ये मुख्यतः निम्न प्रकार के होते हैं।

(i) Horizontal - Dimension → जब किसी क्षैतिज रेखा (Horizontal line) का विमांकन करते हैं तो उसे Horizontal Dimension कहते हैं।



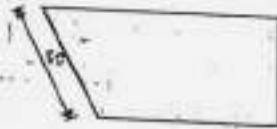
(ii) Vertical Dimension :- जब किसी उर्ध्वाधर रेखा (Vertical line) का Dimension करते हैं उसे Vertical Dimension कहते हैं।



(iii) Aligned Dimensioning :- जब किसी झुके हुए रेखा (Inclined) का Dimension करते हैं तो उसे Aligned (Inclined) Dimension कहते हैं।



(iv) Rotated Dimension :- इस प्रकार के Dimension में Dimension line त extension line कुछ कोण पर बने होते हैं।



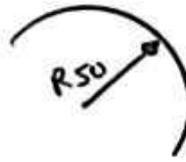
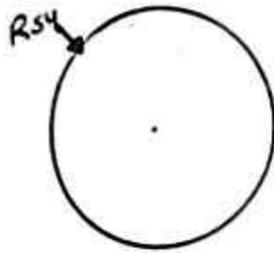
② Radial Dimension → इस विमांकन का उपयोग किसी भी वृत्त या चाप की रेखा को दर्शाने के लिए किया जाता है। इसमें विमांकन में Dimension value के आकार लिखा जाता है।

Syntax Command - Dim ↓

Dim - Rad ↓

select Arc or circle select

Dimension text <50> -50 ←



③ Dimetric Dimension :- इस विमांकन का उपयोग किसी भी वृत्त की व्यास की दृष्टि के लिए किया जाता है। इसके विमांकन value के सामने ϕ लिखा होता है।

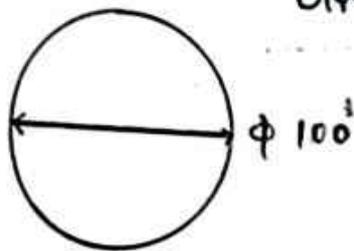
Syntax

Command - Dim ←

Dim - Dia ←

select circle - select

Dimension text <100> - ←



④ Angular Dimension → इस विधि में किसी भी दो रेखाओं के बीच के कोण को तथा वृत्त के किसी चाप केन्द्र पर बनने वाले कोण को दर्शाया जा सकता है।

Syntax

Command - Dim ←

Dim - Angular ←

select Arc, line - select line AB ←

select 2nd line - select AC -60 ←

B Dimension text <60> -60 ←