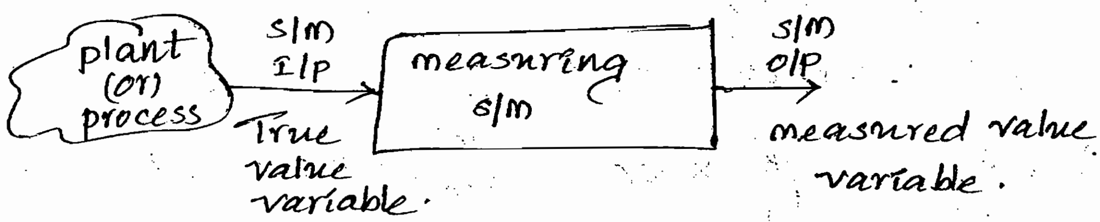
GATE → 6-8M
IES : obj: 50-65M
conv: 50-70M

SYLLABUS :

1. Basics of Measurement s/ms.
2. Error Analysis.
3. Analog instruments.
   - PMMC
   - EMMC
   - MI
   - ESV
   - Thermal inst.
   - Rectifier type inst.
4. Measurement for Resistance :-
   - DC bridge
   - measurement of L, C, M
   - AC bridges.
5. Measurement of power :-
   - DC power measurement
   - AC parameters — 1-φ AC / 3-φ AC
6. Measurement of Energy :
   - potentiometer
   - Pf meter
   - flux meter
   - Inst. t/F.
7. Galvonometer
   - CRO
   - DVM
8. Tansducers (only IES)

Basics of measurements :

1



$A_T = N_T = 3333$ RPM $\qquad A_m = N_m = \boxed{3\,3\,3\,1}$ RPM

Digital display

$$\boxed{\text{Error} = \delta_A = A_m - A_T}$$

$$\boxed{\text{Error} = \text{s/m o/p} - \text{s/m I/p.}}$$

$A_m < A_T \Rightarrow$ Error $= -$ve

$A_m > A_T \Rightarrow$ Error $= +$ve

Ques: Which s/m has more quality ——

(A) $\delta_A = 1$ Amp $\qquad$ (B) $\delta_B = 10$ Amp.

(a) A $\quad$ (b) B $\quad$ (c) A & B $\quad$ (d) can't say (none)

Sol: We can't say without True value. insufficient data

$$\Rightarrow \left[\begin{array}{l} \% \text{ RSE} = \% \text{ relative static error} = \dfrac{A_m - A_T}{A_T} \times 100 \\ \quad (\text{or}) \qquad\qquad = \dfrac{\delta_A}{A_T} \times 100 \\ \% \text{ Limiting error} \Rightarrow \left(\dfrac{A_m}{A_T} - 1\right) \times 100 \\ \% \text{ Accuracy} = (100 - \% \text{ L.E}) \end{array}\right]$$

Ques: Which is more Qlty s/m ——

(A) $\delta_A = 1$ Amp $\qquad$ (B) $\delta_B = 10$ Amp

$A_T = 2$ amp $\qquad$ $B_T = 1000$ Amp

(A) $\% \, RSE = \frac{\delta_A}{A_T} \times 100 = \frac{1}{2} \times 100 = 50\%$.

$\% \, LE = 50\%$.

$\%$ Accuracy $= 50\%$

(B) $\% \, RSE = \frac{\delta_B}{B_T} \times 100 = \frac{10}{1000} \times 100 = 1\%$.

$\% \, LE = 1\%$

$\%$ Accuracy $= 99\%$

Note : The qlty of inst is always decided by % Relative static Error (RSE), the error is always expressed w.r.t true value of the variables. It is also called as Limiting error.

Analog instruments.

⇒ Quantity to be measured

$I \Rightarrow$ (A)

$V \Rightarrow$ (V)

$P \Rightarrow V(t) \cdot I(t) \Rightarrow$ (W)

Energy $= \int P \, dt \Rightarrow$ (E.M)

$\cos\phi \Rightarrow$ P.F meter.

⇒ Working principle :-

- Magnetic field effect
- electromagnetic field effect
- electrostatic field effect
- electromagnetic Induction effect
- Heating effect

(1) Indicating type Inst —

Ex: PMMC — (A), (V)

EMMC — (A), (V), (W)

MI — (A), (V)

OHMmeter — (R)

Megger — (R)

(2) Recording type Inst —

- Cock pit voice recorder (CVR) [in air craft]
- ECG [medical Research & patient monitoring]
- Substation recording inst.
- Seismograph.

(3) Integrated type Inst —

- 1-ϕ EM ⇒ Domestic
- 3-ϕ EM ⇒ Industrial

(4) Null Deflection —

→ potentiometer

→ Galvonometer.

Indicating type inst :—

These are the inst which display the reading only in the time of measurement, it does not have any storage facility, because once we switch off the supply the pointer comes to zero position.

... are the inst's which will record the continous variations of an electrical quantity.

Integrating type : These are the inst's which will give the electrical energy supplied to a consumer, over a specific period of time.

In all indicating type inst, there are three essential components:

1. Deflecting Torque (τ_d)
2. Controlling Torque (τ_c)
3. Damping Torque (T_d)

The torque which is required to move the pointe from its initial position, becoz of continuous current is flowing through the instrument, continuous deflecti torque is delivered on to the moving s/m. so that always the pointer will reads full scale deflection which is undesirable.

2. Controllable torque :

There are two purposes of controlling torque

1. produced o/p $\propto$ i/p.
2. To bring back the pointer to its original position in the absence of i/p.

At steady state both deflecting and controlling torques are equall in magnitude but acting opposite in direction so that the moving s/m produces oscillations, which is undesirable.

3. τ_d: The torque which is required to reduce the no. of oscillations. Damping force is an extra force if it is absent, nothing will happen, it is like a time consuming process ~~but~~ in order to take each reading.

~~Effects~~ :-

$T_d \propto I \to$ only for DC ; $T_d \propto I^2 \Rightarrow$ AC & DC

1. Magnetic field effect : PMMC - Ⓐ, Ⓥ & EMMC - Ⓐ, Ⓥ, Ⓦ
2. Electrostatic field effect : ESV $\Rightarrow T_d \propto V^2 \Rightarrow$ AC & DC
3. Electromagnetic field of attraction / Repulsion effect :

   MI - Ⓐ ; Ⓥ $\Rightarrow T_d \propto I^2 \Rightarrow$ AC , DC
4. Electromagnetic Induction effect : EM $\Rightarrow$ only for AC
5. Heating (or) thermal effect $\Rightarrow$ Bolometer, RTD, thermister, Thermocouple.

   $\hookrightarrow \theta \propto I^2 R$

   $\theta \propto I^2 \Rightarrow$ AC & DC.
6. Chemical effect $\Rightarrow$ DC - Ampere - hour meter.
7. Hall effect $\Rightarrow$ fluxmeter (or) Gaussmeter & poynting vector type - Ⓦ
8. Piezo electric effect $\Rightarrow$ piezo electric T.D.

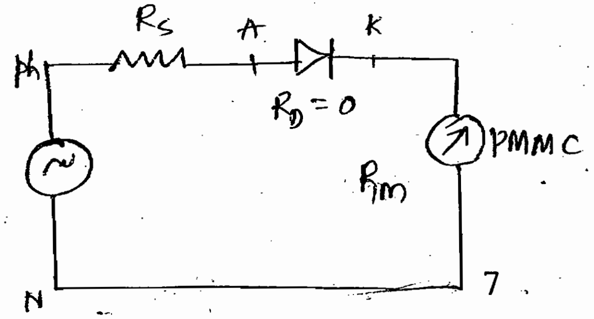
Note : Except PMMC for DC, induction instr's for AC, remaining all other inst's can be working for both AC as well as DC.

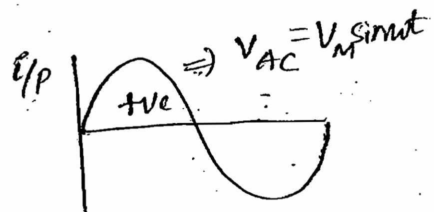
→ The only one inst called PMMC always reads average value and remaining any other inst always reads RMS value including Rectifier type inst.

→ Rectifier type inst's are calibrated in such a manner by multiplying its form factor in order to read the rms value of ac i/p sig.

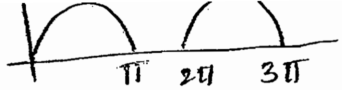
$$\boxed{\text{Reading of Rectifier type inst} = k_f \times \text{PMMC reading}}$$

HWR :





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



$V_{DC} = V_{avg} = \frac{V_m}{\pi}$;

$$K_f = \frac{\text{RMS value of AC I/p sig}}{\text{Avg value of DC o/p sig}} = \frac{V_m/\sqrt{2}}{V_m/\pi} = \frac{\pi}{\sqrt{2}} = 2.22$$

$\boxed{\text{Reading of HWR type inst} = 2.22 \times \text{PMMC reading}}$

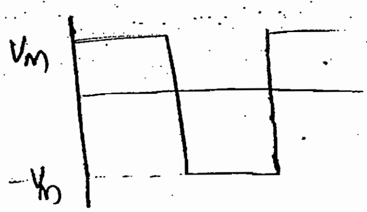
FWR : $V_{AC} = V_{RMS} = \frac{V_m}{\sqrt{2}}$; $V_{DC} = \frac{2V_m}{\pi}$.

$$K_f = \frac{V_m/\sqrt{2}}{2V_m/\pi} = \frac{\pi}{2\sqrt{2}} = 1.11$$

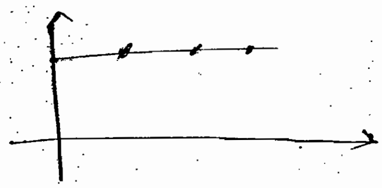
$\boxed{\text{Reading of FWR type inst} = 1.11 \times \text{PMMC reading}}$

Note : If the scale is calibrated by multiplying a form factor of 1.11 it gives correct reading only for AC sinusoidal i/p full wave rectifier, it gives wrong
9 i/p for AC sinusoidal i/p half wave rectifier, square wave i/p, triangular wave i/p and also for sawtooth wave i/p.

Square wave :-



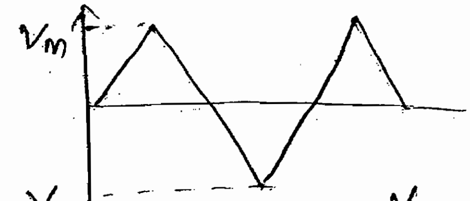
$\Rightarrow$



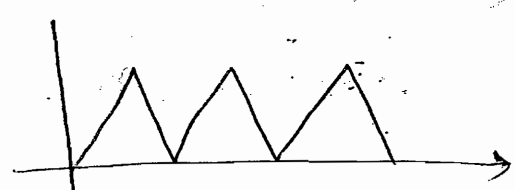
$V_{rms} = V_m$ $V_{avg} = V_m$ $\boxed{K_f = \frac{V_m}{V_m} = 1}$

$\boxed{\text{Reading of rectifier type inst} = 1 \times \text{PMMC meter reading for square wave i/p.}}$

triangular wave ;



$\Rightarrow$



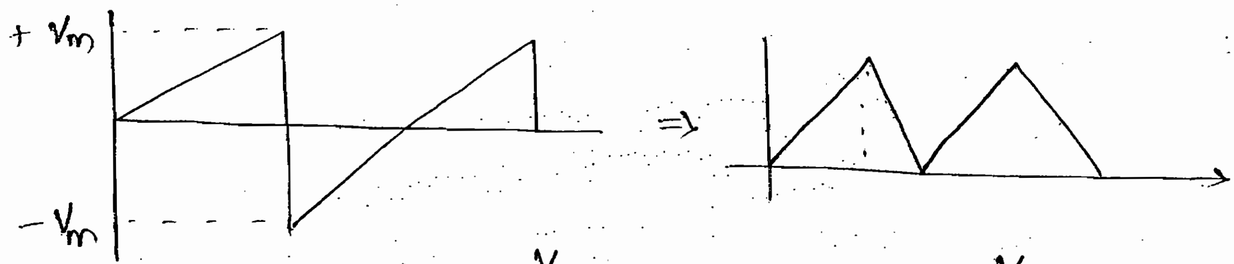
$V_{rms} = \frac{V_m}{\quad}$ $V_{avg} = \frac{V_m}{\quad}$

$/\sqrt{3}$

$V_m/2$

$\boxed{\text{Reading of rectifier type inst for } \Delta^{lar} \text{ wave i/p} = 1.154 \times \text{PMMC meter reading}}$

Sawtooth :-



$$V_{rms} = \frac{V_m}{\sqrt{3}} \qquad V_{avg} = \frac{V_m}{2}$$

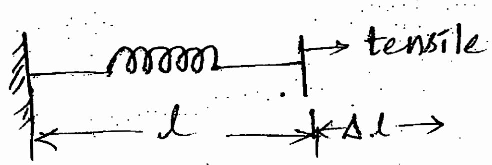
$$K_f = \frac{V_m/\sqrt{3}}{V_m/2} = \frac{2}{\sqrt{3}} = 1.54$$

CONTROL TORQUE :

Control torque is obtained by spring control technique and gravity control technique.

Types of springs :

1. Helical spring

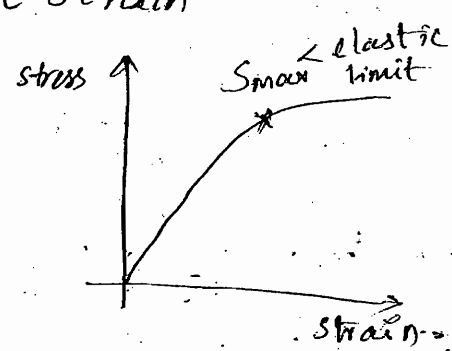


2. spiral spring

$$\text{stress} = \frac{F}{A} \ ; \ \text{strain} = \frac{\Delta l}{l}$$

According to Hook's law ⇒ stess ∝ strain

$$Y = E = \frac{\text{stress}}{\text{strain}} = \frac{F/A}{\Delta l/l} = \frac{F \cdot l}{A \cdot \Delta l}$$



$Y = E$ = young's modulus of elasticity in "N/m^2".

Restoring force ∝ displacement of spring

$F_c \propto x$

$F_c = Kx$ where K = spring constant (or) stiffness constant

$K = F_c/x$ "N/M"

→ Phasor – Bronze → most commonly used material

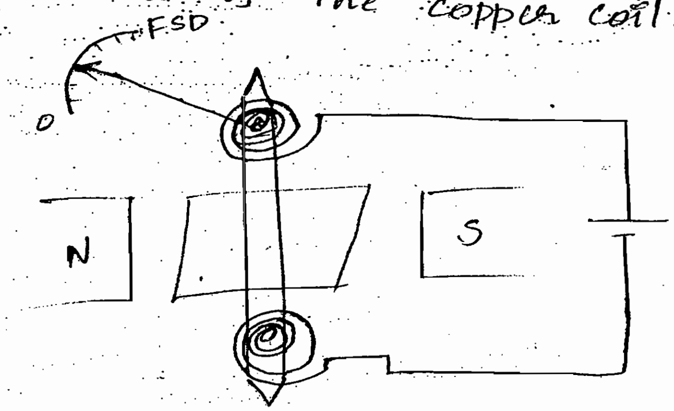
→ Berellium – copper → costly.

Restoring torque ∝ Angular displacement of spring

$T_c \propto \theta$; $T_c = K_c\theta$; $K_c = \frac{T_c}{\theta} = \frac{N-M}{degree}$

→ Spring serves as dual purpose in case of "PMMC", "EMMC" inst:

1. To provide necessary control torque (T_c)
2. It is used as leads of the inst i.e to flow the current into the copper coil & to leave the current out of the copper coil.



whenever spring is broken in these instr always the pointer shows zero deflection.

In case of "MI", "ESV" spring serves as single purpose, whenever spring is broken in these inst's always the pointer swings beyond the full scale.

requirements :

1) spring must be non-magnetic material
2) Max. stress developed in the spring far below the elastic limit
3) whenever spring is used as leads of inst. the area of cross section of the spring must be sufficient in order to carry rated current otherwise spring may suffer from internal heating problem.

Error Analysis :

It error is mentioned by manufacturer known as "Gauranted accuracy error" (GAE).

GAE ⇒ It is always calculated w.r.t FSD.

consider (0-10)A Ammeter, GAE = ± 1% of FSD.

corresponding limiting error is

$$\boxed{\text{reading value} \times \frac{x}{100} = \text{GAE in value}}$$

where $x \Rightarrow$ % limiting error.

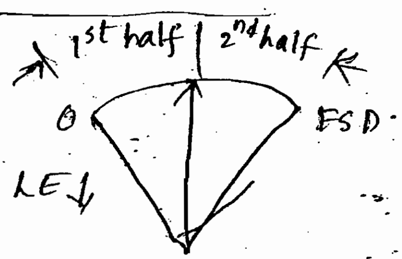
Ex : 1 Amp ± 10% $\Rightarrow 1 \times \frac{x}{100} = \pm 0.1$

$$\boxed{x = \pm 10\%}$$

10 Amp ± 1% $\Rightarrow 10 \times \frac{x}{100} = \pm 0.1$

$$x = \pm 1$$

Limiting error "↓" as in magnitude when the pointer is moving to FSD.



1st half → % LE ↑
→ Accuracy ↓
(100 − % LE)

2nd half → % LE ↓
→ Accuracy ↑

o/p i/p $\frac{}{y}$ $\frac{}{x}$

where $\frac{dx}{x}$, $\frac{dy}{y}$ are % LE on x & y.

$\rightarrow$ $y = x_1^m \cdot x_2^n \Rightarrow \boxed{\frac{\delta y}{y} = \pm\left[m\frac{\delta x_1}{x_1} + n\frac{\delta x_2}{x_2}\right]}$

$\rightarrow$ $x = x_1 + x_2 + x_3$ (or) $x_1 - x_2 - x_3$

$$\frac{\delta x}{x} = \pm\left[\frac{x_1}{x}\frac{\delta x_1}{x_1} + \frac{x_2}{x}\frac{\delta x_2}{x_2} + \frac{x_3}{x}\cdot\frac{\delta x_3}{x_3}\right]$$

$\rightarrow$ $x = x_1 \cdot x_2 \cdot x_3$ (or) $\frac{1}{x_1 x_2 x_3}$ (or) $\frac{x_1}{x_2 x_3}$ (or) $\frac{x_1 x_2}{x}$

$$\frac{\partial x}{x} = \pm\left[\frac{\delta x_1}{x_1} + \frac{\delta x_2}{x_2} + \frac{\delta x_3}{x_3}\right].$$

$\rightarrow$ In case of multiplication (or) division the %LE are simply added. But don't add error in value for.

$R_1 = (100 \pm 6)\,\Omega$ = ~~6%~~ ~~error~~

$R_2 = (50 \pm 2)\,\Omega$

$R_1 + R_2 = (100 \pm 6) + (50 \pm 2)$ Error in value form:

$= 150 \pm 8$

$R_1 - R_2 = (100 \pm 6) - (50 \pm 2) = (50 \pm 8)\,\Omega$

$\rightarrow$ $\parallel el = \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$

differentiate

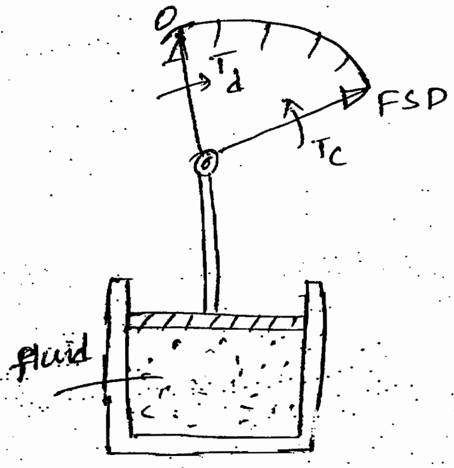
$$\frac{1}{R_{eq}^2}\delta R_{eq} = \frac{1}{r_1^2}\cdot\delta r_1 + \frac{1}{r_2^2}\delta r_2$$

$$\frac{\delta R_{eq}}{R_{eq}} = \pm\left[\frac{R_{eq}}{r_1}\frac{\delta r_1}{r_1} + \frac{R_{eq}}{r_2}\frac{\delta r_2}{r_2}\right].$$

Damping techniques :

There are 3 types of damping technique :

1. Air friction ⇒ MI, EMMC (no pm)
2. Fluid friction ⇒ ESV (no pm & no EM), wall mounted inst
3. Eddy current ⇒ PMMC, Induction type Inst
4. Electro magnetic ⇒ Galvonometer, Fluxmeter.



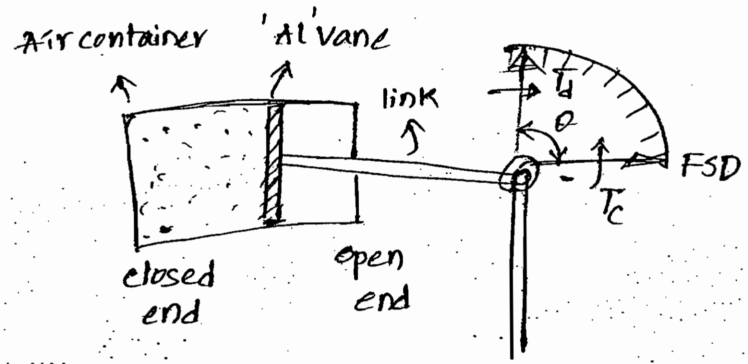


Fig: Air friction Damping.

Fig: Fluid friction damping.

Required ents

1) Air friction damping :-

In a air friction damping technique, an 'Al' vane is attached to the moving s/m with the help of link mechanism and placed inside the air container, so that the friction offered by air will oppose the motion of pointer.

Adv : 1) It requires less maintenance

2) cost is less

3) Repeated no of operations, we can use

2) Fluid friction damping :-

It is the more effective form of damping technique. In this technique an 'Al' vane is attached to the moving s/m and placed the fluid will oppose the motion of the pointer.

DisAdv : Due to leakage of fluid, it is difficult to keep the inst. clean.

2. It requires more maintenance.

3. cost is more

4. can't suitable for repeated no. of operation

5. Every fluid must satisfy the following requirements :

a) Fluid should not evaporate quickly

b) Fluid viscosity should not change with temp

c) Fluid should not have any corrosive action upon the metals of the inst.

d) Fluid must be very good insulator.

3. Eddy current damping :

In order to use this technique there are 3 requirements : 1) permanent magnet

2) conducting material like Al disc.

3) Relative motion b/w them has to exist

**

order of effectiveness :

Eddy current > Fluid friction > Air friction

order of priority :

Eddy current > Air friction > fluid fric

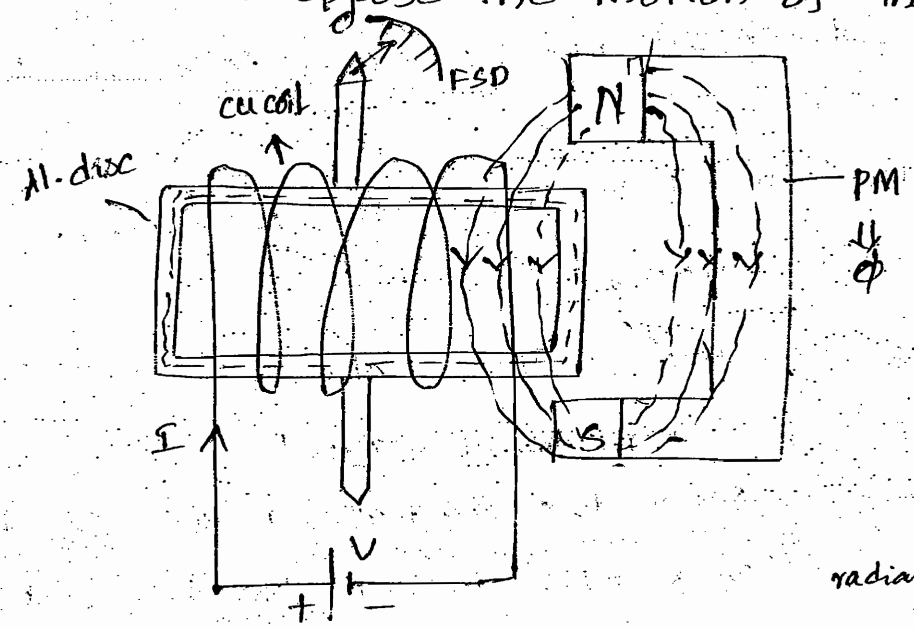
It is the most effective form of technique. In this technique whenever 'Al' former is moving through PM field which cuts the flux produced by

PM. So that an EMF is induced in the

'Al' former is a metallic one which will offer resistance so that produced emf will send some current known as Eddy current, which is circulating through Al disc.

The current which is flowing through metallic portion of the inst known as Eddy current.

Acc. to lenz's law, Always the effect opposes the cause. That means produced Eddy current will oppose the motion of the conductor.



radial → uniform mag. field

PMMC : U-shaped PM (or) concave shape PM (so 360° deflection)

⇓

ALNICO / ALCOMAX

⇓

Hard magnetic material.

⇓

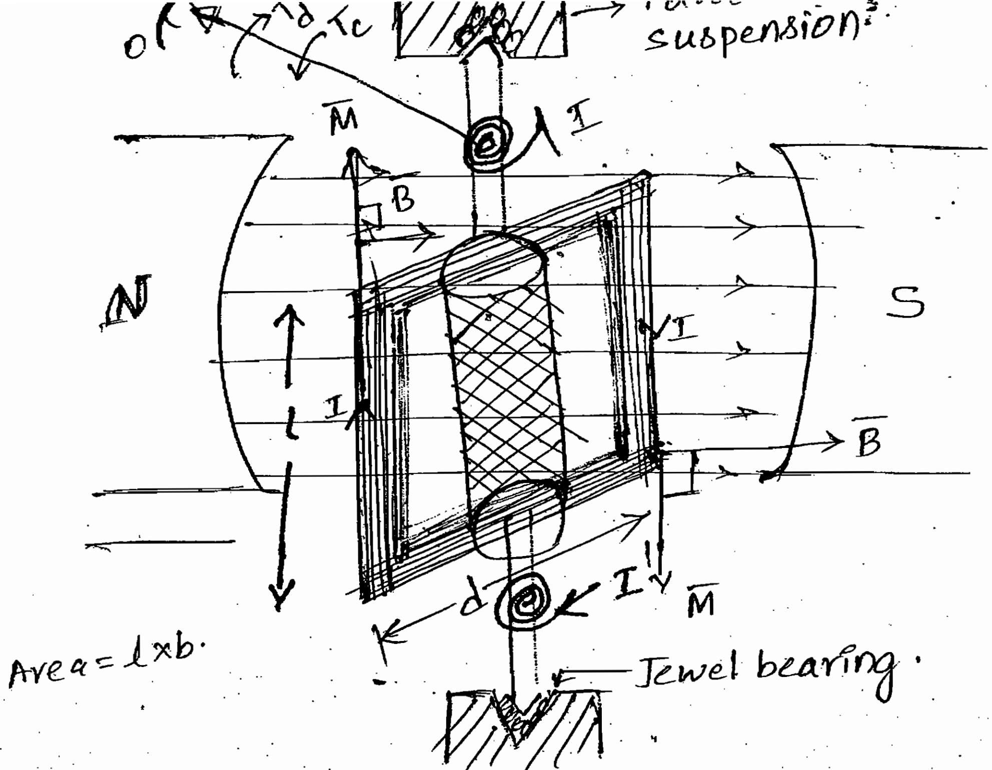
Very high coersive forces

⇓

Very strong internal mag. field

⇓

$B = 0.1\ wb/m^2$ to $1\ wb/m^2$



Area $= l \times b$

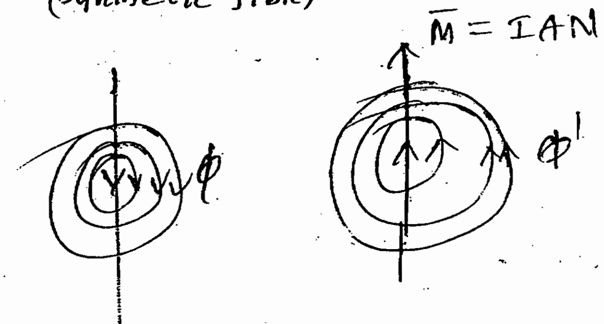
Purpose :

① Iron core (stationary) ⇒ to make magnetic field radi

② Al former ⇒ 1. To provide base for Cu coil.
2. To provide eddy current.

③ Cu coil ⇒ 1. To carry current
2. To produce "τ_d".

④ Jewel bearing ⇒ 1. To avoid wear & tear proble
made up of
"SAPPHIRE"
(synthetic fibre)
2. To reduce friction.



$T_d = \vec{M} \times \vec{B}$
$= |M||B| \cdot \sin \angle \bar{M}\bar{B}$

$T_d = |M||B| \sin 90°$

$T_d = |M| \cdot |B| = IAN \cdot$

$\boxed{T_d = BINA}$

$T_d = BAN \cdot I$

$\boxed{T_d = K_d I}$

~~where~~ where $K_d = BAN$

$K_d = \text{const}$

$T_c = K_c \cdot \theta$

at steady state $\Rightarrow |T_d| = |T_c|$

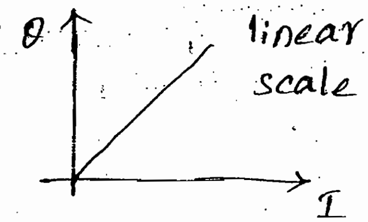
$K_c \cdot \theta = (BAN) \cdot I$

$\therefore \boxed{\theta = \left(\frac{BAN}{K}\right) \cdot I}$

$\therefore \boxed{\theta = \left(\frac{K_d}{K_c}\right) \cdot I}$

$\theta \propto I$

$\boxed{\frac{\theta_2}{\theta_1} \propto \frac{I_2}{I_1}}$



$\therefore$ sensitivity $= \uparrow S = \frac{\Delta\, o/p}{\Delta\, i/p \downarrow}$

$$\boxed{\uparrow S = \frac{\Delta\theta}{\Delta I} = \frac{\theta}{I\downarrow} = \frac{BAN}{K_c}}$$

$S\uparrow \propto B\uparrow$, $S\uparrow \propto A\uparrow$

$S\uparrow \propto N\uparrow$, $S\uparrow \propto \frac{1}{K_c\downarrow}$

Q/E Due to Aging effect : $\boxed{\theta \propto \frac{B}{K_c}}$

① Due to Aging of magnet $\Rightarrow B\downarrow$

② Due to Aging of spring $\Rightarrow K_c\downarrow$

$\theta \propto \frac{B}{K_c}$

$\log\theta = \log(B) - \log(K_c)$

$$\boxed{\frac{\delta\theta}{\theta} = \left(\frac{-\delta B}{B}\right) - \left(\frac{-\delta K_c}{K_c}\right)} \longrightarrow ①$$

If $\frac{\delta\theta}{\theta} = +ve \Rightarrow \uparrow$ If $\frac{\delta\theta}{\theta} = -ve \Rightarrow \downarrow$

For $10^\circ C$ " " $\Rightarrow \frac{\delta_B}{B} = 0.2\%$

For $1^\circ C$ " " $\Rightarrow \frac{\delta_{K_c}}{K_c} = 0.04\%$

For $10^\circ C$ " " $\Rightarrow \frac{\delta_{K_c}}{K_c} = 0.04\%$

Use (1):

$$\frac{\delta_\theta}{\theta} = (-0.2\%) - (-0.4\%)$$

$$= +0.2\% \uparrow$$

$$= +ve$$

Adv:

1. uniform scale $(\because T \propto I)$
2. $T_d \uparrow \propto B \uparrow$

$\left(\frac{T_d \uparrow}{W \downarrow}\right) \uparrow \Rightarrow$ high.

T/W ratio desides sensitivity & friction.

$\left(\frac{T_d}{W}\right) > 1$

3. High sensitivity

$S = 20,000\ \Omega/V$ to $30,000\ \Omega/V$

$= 20\,k\Omega/V$ to $30\,k\Omega/V$ *

4. lesser frictional error

In any inst, the T/W ratio will decide the sensitivity and frictional error. In PMMC inst, becoz of high T/W ratio, sensitivity is very high, reduced frictional errors.

5. Error due to external mag. field known as stray magnetic field error. In a PMMC inst,

mag. ~~field~~ error is lesser.

6. Low power consumption ↓

↳ 20 uw to 200 uwatt *

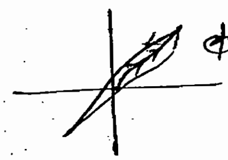
7. No Internal Heating problem.

8. Temp. error is lesser.

⇓

swamping resistor.

9. Hysterisis error is lesser becoz of 'Al' former



$\phi_r \cong 0$ AL former has very thin hysterisis loop.

The word hysterisis means that "the loading energy may not equal to unloading energy."

An PMMC inst, reduced hysterisis error becoz of 'Al' former has very thin hysterisis loop.

10. A long open 360° circular scale available

11. High accuracy.

All errors are lesser in PMMC inst. so that inst has high accuracy.

12. which of the following error is absent in PMMC

a) Temp error b) stray mag. error c) ~~Frictional error~~ ~~d)~~ freq. error

Disadv: 1. works only for DC

2. Costly (due to PM and springs)

3. Delicate constructions.

1. It is used in air craft SIM's & aerospace industries becoz of self shielding property. (becoz high strong M.F)
2. Used as (A), (V)
3. Used in OHM METER Inst.
4. Used in Rectifier Inst.
5. Used in Thermocouple Inst.

Ch 2:

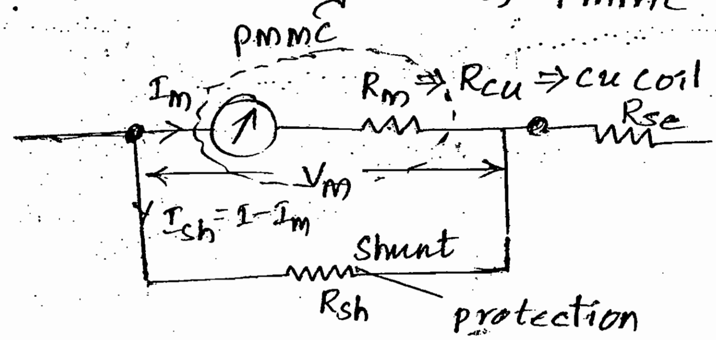
Q3)
$$\begin{bmatrix} 1\ \text{Tesla} = 1\ wb/m^2 \\ 1\ \text{Tesla} = 10^4\ \text{gauss} \end{bmatrix}$$

$$T_d = BINA$$

$$T_d = 200 \times 10^{-3} \times \frac{wb}{m^2} \times 50 \times 10^{-3}\ A \times (100 \times 10 \times 20 \times 10^{-6})\ m^2.$$

$$\boxed{T_d = 200\ \mu N\text{-}m}$$

Simplified diagram of PMMC:



Typically Basic DC-(A): 5 µA.

Basic DC-(A):

1. without any shunt multiplier ⇒ (0-5 µA)
2. with internal shunt multiplier ⇒ (0-200A)
3. with external " " ⇒ (0-500A)

DC-(V):

1. without any series multiplier ⇒ (0-50 mV)
2. With series multiplier20 ⇒ (0-20,000V / 20,000V)

(i) → $S_I = \frac{\Delta\theta}{\Delta I}$ $\frac{mm}{Amp}$ (or) ... /Amp (or) ... /Amp

(v) → $S_V = \frac{\Delta\theta}{\Delta V}$ $\frac{mm}{V}$ (or) Degree/V (or) Radian/V

$$\boxed{S_V = \frac{R_m}{V_{FSD}} \frac{\Omega}{\text{Volt}}} = \frac{1}{\left(\frac{V_{FSD}}{R_m}\right)} \ \Omega/V$$

$$\boxed{\uparrow S_V = \frac{1}{I_{FSD}\downarrow} \frac{\Omega}{\text{Volt}}}$$

Ex: inst: X | inst: Y

$I_{FSD} = 50mA$

$S_x = \frac{1}{I_{FSD}}$ Ω/V

$= \frac{1}{50\times10^{-3}}$ Ω/V

$S_x = 20$ Ω/V

$I_{FSD} = 100mA$

$S_y = \frac{1}{I_{FSD}}$ Ω/V

$S_y = \frac{1}{100\times10^{-3}}$ Ω/V

$S_y = 10$ Ω/V.

$\boxed{S_x > S_y}$

ch2

15) $S_v = \frac{1}{I_{FSD}}$ Ω/V

$= \frac{1}{200\times10^{-6}}$ Ω/V

$= 5$ KΩ/V

$= 5$ Ω/mV.

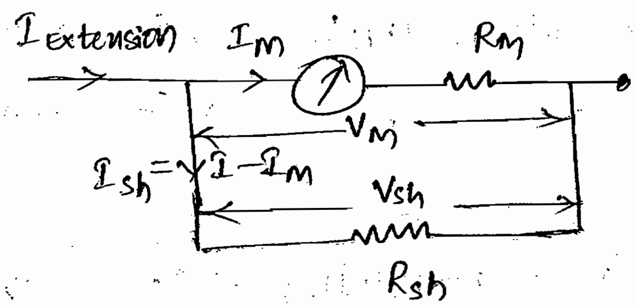
R_{cu} at $t°c = R_{cu\,0°c}[1+\alpha\Delta t]$

I_m at $t°c = \frac{V_M}{R_{cu} \text{ at } t°c}$

R_{sh} at $t°c = R_{sh0}[1+\alpha\Delta t]$

$\boxed{R_{sh} \text{ at } t°c = R_{sh\,0°c}}$

⇒ Extension range of PMMC (A) :-



$\theta \propto I_M$

$\theta \propto I_M \times m$ ← multiplication factor

$\theta \propto I_M \times \frac{I_{ext}}{I_m}$

$\boxed{\theta \propto I_{ext}}$

where $m = \frac{I_{ext}}{...} = \frac{I}{...}$

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

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

$\therefore I_m [R_m + R_{sh}] = I \cdot R_{sh}$

$\therefore \boxed{m = \frac{I}{I_m} = \frac{R_m + R_{sh}}{R_{sh}}}$

$\therefore \boxed{m = 1 + \frac{R_m}{R_{sh}}}$

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

$\therefore R_{sh} = \frac{R_m}{(m-1)}$

Always $\Rightarrow m > 1$

If $m = 1001$, $R_m = 10\,\Omega$

$\therefore R_{sh} = \frac{10\,\Omega}{1001 - 1} = 10\,m\Omega$

$\boxed{R_{sh} \Rightarrow m\Omega}$ *

MANGANIN (or) → DC Inst

CONSTANTAN → AC Inst

↳ lesser cost

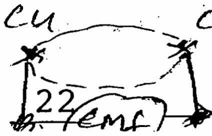
Properties of shunt :-

1. Shunt should carry large currents without excessive rise in temp.
2. Rsh should not vary with time.
3. Rsh should not vary with temp.
4. Shunt should have very low temp coeff
5. shunt should have very low thermal emf with cu

Note :- 1) In case of DC inst. shunt is prepared by MANGANIN, cupper manganin pair can produce a thermal emf is lesser, which does not have any effect on DC inst reading.

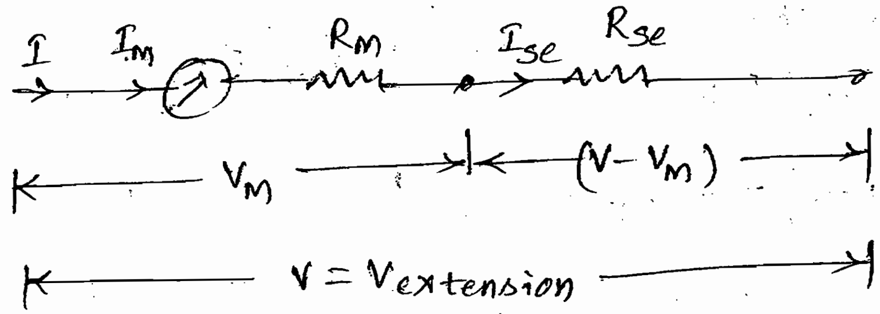
2) In case of AC inst. CONSTANTAN is preffered to prepared for shunt, cu-constantan pair is produce a thermal emf which is in DC nature and it does not have any effect on AC inst. reading.

cu constantan



emf

$AC \Rightarrow I_{RMS} = \sqrt{I_0^2 + \frac{I_1^2}{2}}$



$\theta \propto V_M$

$\theta \propto V_M \times m$

$\theta \propto V_M \times \dfrac{V_{ext}}{V_M}$

$\boxed{\theta \propto V_{ext}}$

where $m = \dfrac{V_{ext}}{V_M} = \dfrac{V}{V_M}$

$\therefore I_M = I_{se}$

$\dfrac{V_M}{R_M} = \dfrac{V - V_M}{R_{se}}$

$\dfrac{R_{se}}{R_M} = \dfrac{V - V_M}{V_M}$

$\dfrac{R_{se}}{R_M} = \dfrac{V}{V_M} - 1$

$\therefore \boxed{m = \dfrac{V}{V_M} = 1 + \dfrac{R_{se}}{R_M}}$

$m - 1 = \dfrac{R_{se}}{R_M}$

$\therefore \boxed{R_{se} = R_M[m-1]}$

Always $\Rightarrow m > 1$

If $m = 1001$, $R_m = 10\Omega$

$R_{se} = 10\Omega[1001 - 1]$

$R_{se} = 10K\Omega$

* $\boxed{R_{se} = K\Omega}$

Q18) $R_m = 100\Omega$.

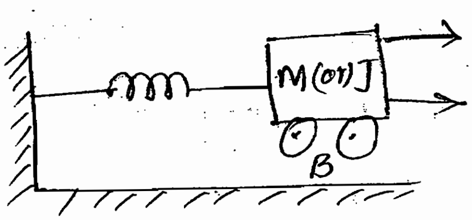
$(0 - 1mA) \hookrightarrow I_m$

$\Downarrow$

$(0 - 100mA) \hookrightarrow I_{ext}$

$\therefore m = \dfrac{I_{ext}}{I_m} = \dfrac{100}{1} = 100$

$R_{sh} = \dfrac{R_m}{m-1} = \dfrac{100}{100-1} = 1.01\Omega$



F_d (or) $T_d \Rightarrow I/p$ 26|2|14

d (or) $\theta \Rightarrow O/p$.

$F_d = M\dfrac{d^2x}{dt^2} + B\dfrac{dx}{dt} + K \cdot d$ (or)

$T_d = J\dfrac{d^2\theta}{dt^2} + B \cdot \dfrac{d\theta}{dt} + K_c\theta$

$F_d(s) = [Ms^2 + Bs + K] \times (s)$

$$\frac{\ }{F_d(s)} = \frac{\ }{s^2+\frac{B}{M}s+\frac{K}{M}}$$

Char. eq^n $s^2+\frac{B}{M}s+\frac{K}{M}=0$

std char. $eq^n \Rightarrow s^2+2\xi\omega_n s+\omega_n^2=0.$

$$\omega_n = \sqrt{\frac{K}{M}} \Rightarrow \boxed{f_n = \frac{1}{2\pi}\sqrt{\frac{K}{M}}}$$

$$2\xi\omega_n = \frac{B}{M} \Rightarrow 2\xi = \sqrt{\frac{K}{M}} = \frac{B}{M\sqrt{M}}$$

$$\boxed{\xi = \frac{B}{2\sqrt{MK}}}$$

$t_s = \frac{4}{\xi\omega_n} = 4T$ ↳ 2% tolera.

$t_s = \frac{3}{\xi\omega_n} = 3T$ ↳ 4% Toleran.

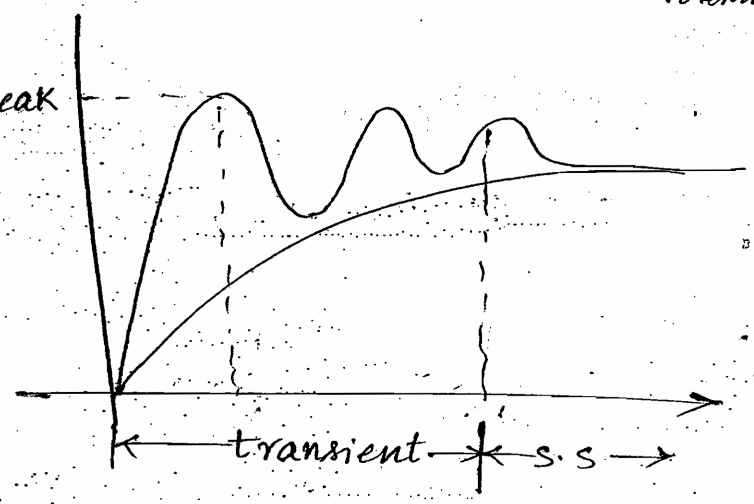
$\xi = 0 \Rightarrow$ Undamped

$\xi = 1 \Rightarrow$ critically

$\xi < 1 \Rightarrow$ underdamped

$\xi > 1 \Rightarrow$ overdamped

$\xi = 0.6$ to 0.8



If $\xi = 0 \Rightarrow T = \frac{1}{\xi\omega_n} = \infty$

Note: All analog inst are second order inst. practically which are used underdamped technique. In a underdamped sl[illegible] the pointer moves to state, it make few oscillations. Whereas in critical damped s/m, the pointer directly moves to steady state without making any oscillations.

Q9] D 12] C 17] $I_m = 50\,\mu A$, $R_m = 500\,\Omega$

$$V_m = I_m R_m = 50\times10^{-6}\times 500 = 25\,mV$$

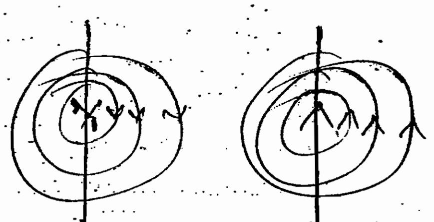
$0 - 25\,mV \rightarrow V_M$

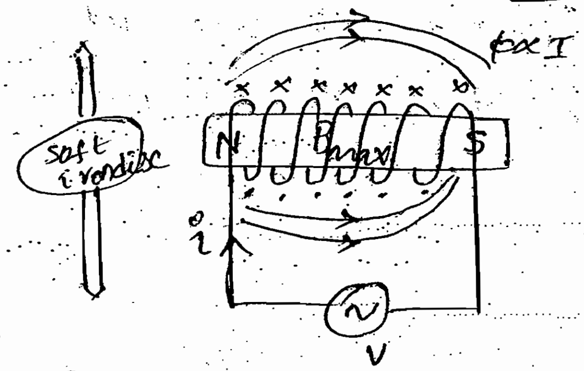
$0 - 10\,V \rightarrow V_{ext}$

$$m = \frac{V_{ext}}{V_M} = \frac{10}{25\times10^{-3}} = 400$$

$$\therefore R_{se} = R_m[m-1] = 500[400-1]$$
$$= 200K - 0.5K$$
$$R_{se} = 199.5\,K\Omega,$$

⇒ Which one of the following inst works on the principle of change in self inductance of a coil — MI inst





$\uparrow$ Reluctance$_{Air}$ = $\frac{MMF}{\phi\downarrow}$

$\downarrow$ Reluctance$_{Iron}$ = $\frac{MMF}{\phi\uparrow}$

$\phi \propto I$

$N\phi = LI$

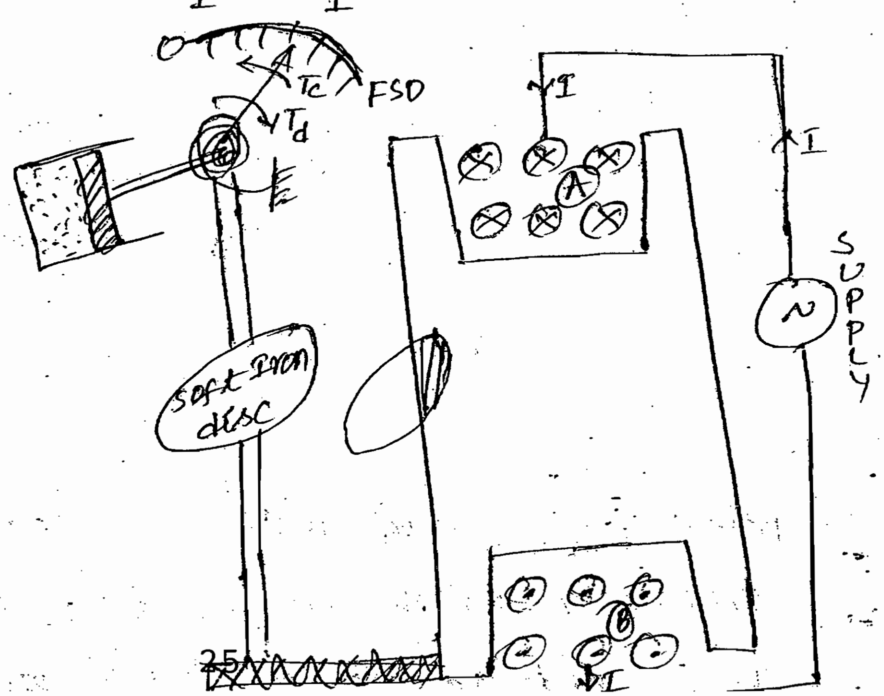
$\therefore L = \frac{N\phi}{I} = \frac{\psi}{I}$

$I \rightarrow \psi \rightarrow L \rightarrow \frac{1}{2}LI^2$

$I' = I + dI$

$\psi' = \psi + d\psi$

$L' = L + dL$



$N\phi = \underbrace{LI}_{\text{variable}}$

diff w.r.t "t"

$$N\frac{d\phi}{dt} = L\frac{dI}{dt} + I\frac{dL}{dt}$$

$$e \cdot dt = LdI + IdL$$

$$\boxed{eI\,dt = LIdI + I^2dL}$$

Energy supplied $= LIdI + I^2dL \rightarrow (1)$

Energy stored $= W_1 = \frac{1}{2}LI^2$

Incremental Energy stored $= W_2 = \frac{1}{2}(L+dL)(I+dI)^2$

∴ change in Energy stored $= \Delta W = W_2 - W_1$

$$\Delta W = \frac{1}{2}(L+dL)(I^2 + dI^2 + 2IdI) - \frac{1}{2}LI^2$$

Neglect higher order diff terms.

$$\therefore \boxed{\Delta W = LIdI + \frac{1}{2}I^2dL} \rightarrow (2)$$

Mech workdone $= dw = T_d \cdot d\theta \longrightarrow (3)$.

Acc. to law of conservation of Energy ⇒

Energy Supplied = Change in Energy stored + Mech. work done.

(1) = (2) + (3)

$$LIdI + I^2dL = LIdI + \frac{1}{2}I^2dL + T_d \cdot d\theta.$$

$$\frac{1}{2}I^2 dL = T_d \cdot d\theta$$

$$\therefore \boxed{T_d = \frac{1}{2}I^2\frac{dL}{d\theta}}$$

→ const

$T_d \propto I^2 \Rightarrow$ AC & DC.

SUPPLY

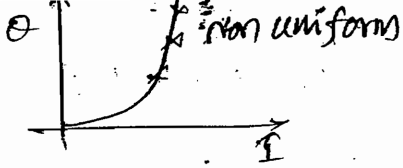
Type of control : Spring

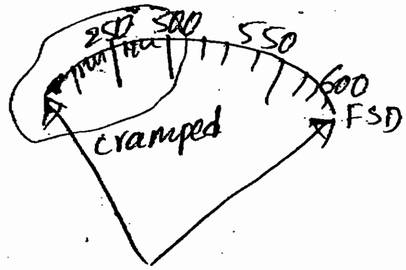
$T_c = K_c \cdot \theta$

At s.s $\Rightarrow |T_d| = |T_c|$

$K_c \cdot \theta = \frac{1}{2} I^2 \cdot \frac{dL}{d\theta}$

$$\boxed{\theta = \frac{I^2}{2K_c} \cdot \frac{dL}{d\theta}} \Rightarrow \text{const.}$$





Adv :-

1. works for both AC & DC.
2. Robust construction.
3. cost is lesser.
4. lesser frictional error (inspite of low T/W) becoz the heavy part of the inst (coil) which is in stationary position.

Disadv :

1. Non uniform scale
2. weak operating field.

$B = 0.006\ wb/m^2$ to $0.0075\ \frac{wb}{m^2}$

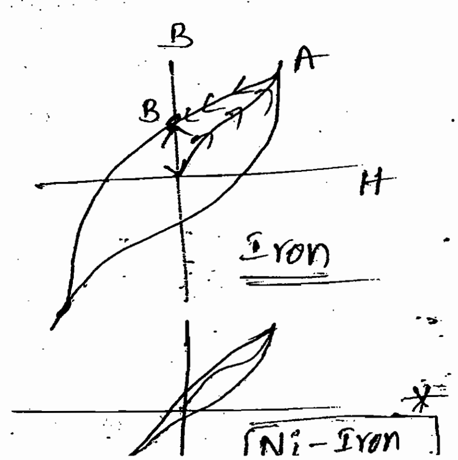
$B = 6\ mwb/m^2$ to $7.5\ mwb/m^2$

3. Low T/W ratio. ∴ sensitivity is lesser

$S = 30\ \Omega/volt$ to $40\ \Omega/V$ *

4. Stray mag. field error is more due to weak mag. field.
5. More power consumption.
6. More internal Heating
7. More Temp. error
8. Hysterisis error is more.

$\boxed{T_d \propto I^2 \frac{dL}{d\theta}}$ ⇒ can't follow perfect square law so accuracy is low.



In case of (V) : $I = \frac{V}{|Z_M|} = \frac{V}{|R_M + j\omega L_M|}$

$$|Z_m| = \sqrt{R_m^2 + \omega^2 L_m^2}$$

$$T_d = \frac{1}{2}\frac{V^2}{Z^2} \cdot \frac{dL}{d\theta} \Rightarrow \boxed{T_d = \frac{V^2}{2\left[R_m^2 + 4\pi^2 f^2 L_m^2\right]} \cdot \frac{dL}{d\theta}}$$

$$T_d \downarrow \propto \frac{V^2 \downarrow}{f^2 \uparrow} \quad \frac{(mV)^2}{(KHz)^2}$$

10. $\dot{W}_e \uparrow \propto B^2 f^2 \uparrow$.

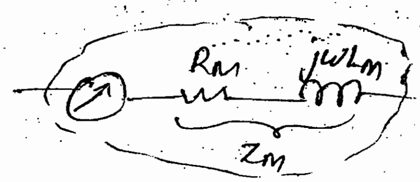
Note:

(1) We never prefer Eddy current damping technique becoz the produced Eddy current will distort the operating field of inst.

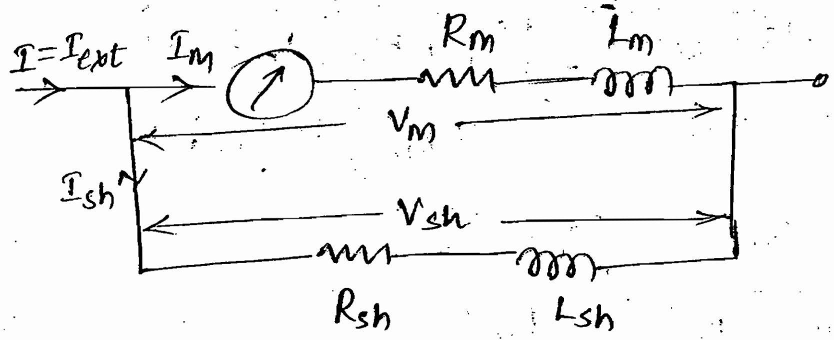
(2) Useful freq range ⇒ "0 – 125 Hz"

Applications

It is mostly preferred in Industries (AC) at power freq range i.e at f = 50 Hz, the inst. accuracy is good.



Simplified diagram :-



$$V_m = V_{sh}$$

$$I_m |Z_m| = I_{sh} |Z_{sh}|$$

$$\frac{I_m}{I_{sh}} = \frac{|R_{sh} + j\omega L_{sh}|}{|R_m + j\omega L_m|}$$

$$\frac{I_m}{I_{sh}} = \sqrt{\frac{R_{sh}^2 + \omega^2 L_{sh}^2}{R_M^2 + \omega^2 L_M^2}}$$

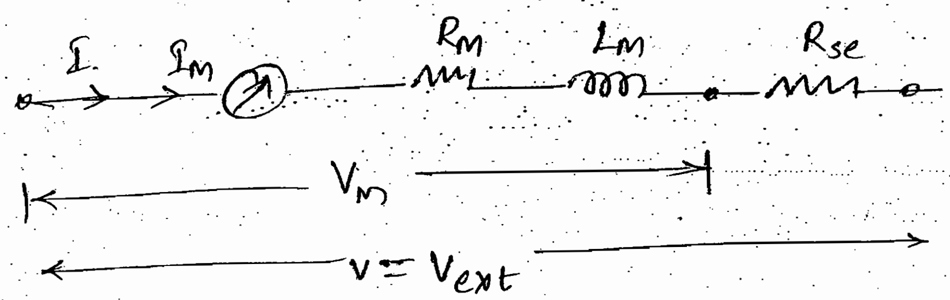
$I_m = f^n$

$$\frac{I_m}{I_{sh}} = \frac{R_{sh}}{R_m}\sqrt{\frac{1+\omega^2\left(\frac{L_{sh}}{R_{sh}}\right)^2}{1+\omega^2\left(\frac{L_m}{R_m}\right)^2}} \Rightarrow \boxed{\frac{I_M}{I_{sh}} = \frac{R_{sh}}{R_M}}$$

$$\text{If } \boxed{\frac{L_{sh}}{R_{sh}} = \frac{L_m}{R_M}} \Rightarrow \boxed{T_{sh} = T_M}$$

Note :
To make the MI Ammeter, independent of supply freq, the shunt ~~type~~ time const should be equal to meter time constant.

⇒ Extension range of MI V/M :-



$$m = \frac{V_{ext}}{V_M} = \frac{I \cdot |Z_{Total}|}{I_M \cdot |Z_M|} = \frac{|(R_M + R_{se}) + j\omega L_m|}{|R_M + j\omega L_M|}$$

$$\frac{V_{ext}}{V_M} = m = \sqrt{\frac{(R_M + R_{se})^2 + \omega^2 L_M^2}{R_M^2 + \omega^2 L_M^2}}$$

$$\therefore V_{ext} = m \cdot V_M$$

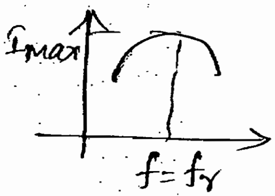
$$V_{ext} = \left(\sqrt{\frac{(R_M + R_{se})^2 + \omega^2 L_M^2}{R_M^2 + \omega^2 L_M^2}}\right) \cdot V_M$$

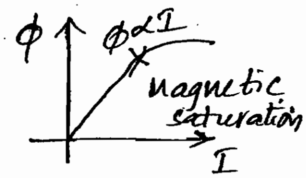
freq error Elimination :-

If capacitor is in series :

RLC Series ckt

If $X_L = X_C \Rightarrow Z = f^n(R)$

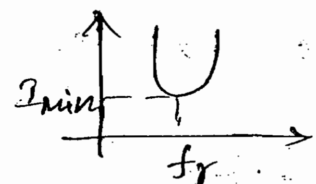


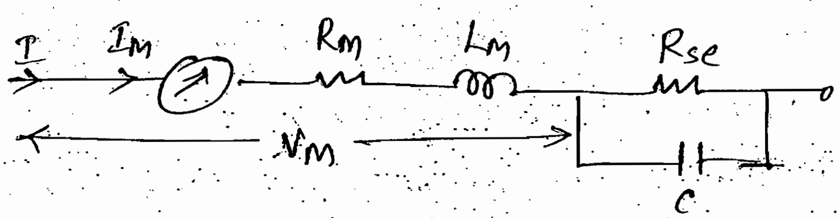


If Capacitor is in llel :

RLC llel ckt

If $X_C = X_L \Rightarrow Z = f^n(R)$





$$Z_{Total} = (R_M + j\omega L_m) + \left(R_{se} \parallel \frac{1}{j\omega C}\right)$$

$$= (R_M + j\omega L_M) + \frac{R_{se} \cdot \frac{1}{j\omega C}}{R_{se} + \frac{1}{j\omega C}}$$

$$= (R_M + j\omega L_M) + \frac{R_{se}}{1 + j\omega C R_{se}} \times \frac{(1 - j\omega C R_{se})}{(1 - j\omega C R_{se})}$$

$$Z_{Total} = (R_M + j\omega L_m) + \frac{R_{se} - j\omega C R_{se}^2}{1 + \omega^2 C^2 R_{se}^2}$$

$$1 \gg \omega^2 C^2 R_{se}^2 \Rightarrow \text{neglect}$$

$$Z_{Total} = (R_M + R_{se}) + j\omega\left[L_m - C R_{se}^2\right]$$

$$L_M - C R_{se}^2 = 0 \Rightarrow \boxed{C = \frac{L_M}{R_{se}^2}} \Rightarrow \text{Theoritically} \Rightarrow \text{Approximately}$$

** $\boxed{C = 0.301 \times \frac{L_M}{n^2}} \Rightarrow$ practically

$\left(10+3\theta - \frac{\theta^2}{4} \right) \times 10^{-6}\ H \quad ; \quad K_c = 25\times10^{-6}\ N\text{-}M/rad.$

diff. w.r.t "θ".

$$\frac{dL}{d\theta} = \left(0 + 3 - \frac{2\theta}{4}\right) \times 10^{-6}\ \frac{H}{rad}$$

$$\theta = \frac{I^2}{2K_c} \cdot \frac{dL}{d\theta} = \frac{(5)^2}{2\times 25\times 10^{-6}\ \frac{N\text{-}M}{rad}} \times \left(3 - \frac{\theta}{2}\right) \times 10^{-6}\ \frac{H}{rad}$$

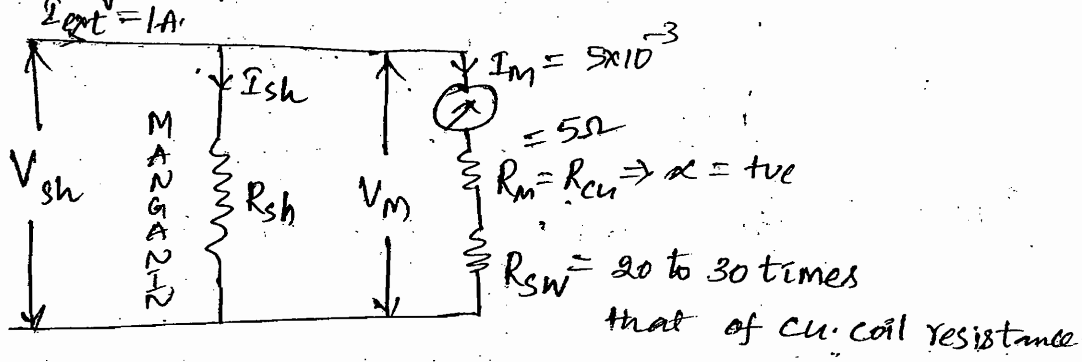
$$2\theta = 3 - \frac{\theta}{2} \Rightarrow 2.5\,\theta = 3 \Rightarrow \boxed{\theta = \frac{6}{5} = 1.2\ rad.}$$

$$\boxed{\theta = 1.2 \times \frac{180^\circ}{\pi} = 68.75^\circ}$$

conv Q1] Ans $\theta = 95.4^\circ$

Q3] Usually in a PMMC, coil is prepared by copper coil, shunt is prepared by manganin, both the materials having different temp. coeff. so that there is a temp. difference exist.

To eliminate the effect of temp difference both shunt and coil is made up of same material. For that a resistance which is added in series with the copper coil, whose char are similar to manganin, whose value around 20 to 30 times that of copper coil resistance.



$$V_M = I_M (R_M + R_{SW})$$

$$V_M = 5\times10^{-3} [5 + 4] = 45\,mV = V_{sh}$$

$$R_{sh} = \frac{V_{sh}}{I_{sh}} = \frac{45 \times 10^{-3}}{0.995} = 45.226 \ m\Omega .$$

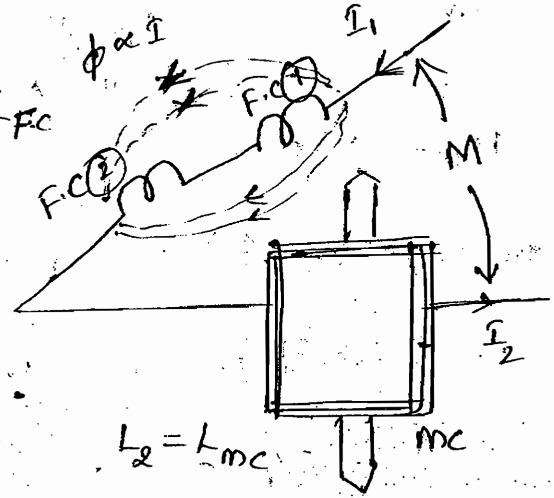
⇒ Which one of the following inst works on the principle of change in mutual inductance ? --- EMMC

$T_d \propto i_1 i_2$

$T_d \propto \phi \, i_2$

$T_d \propto B \cdot i_2$

$$\boxed{L_{eq} = L_1 + L_2 + 2M}$$



In MI inst :

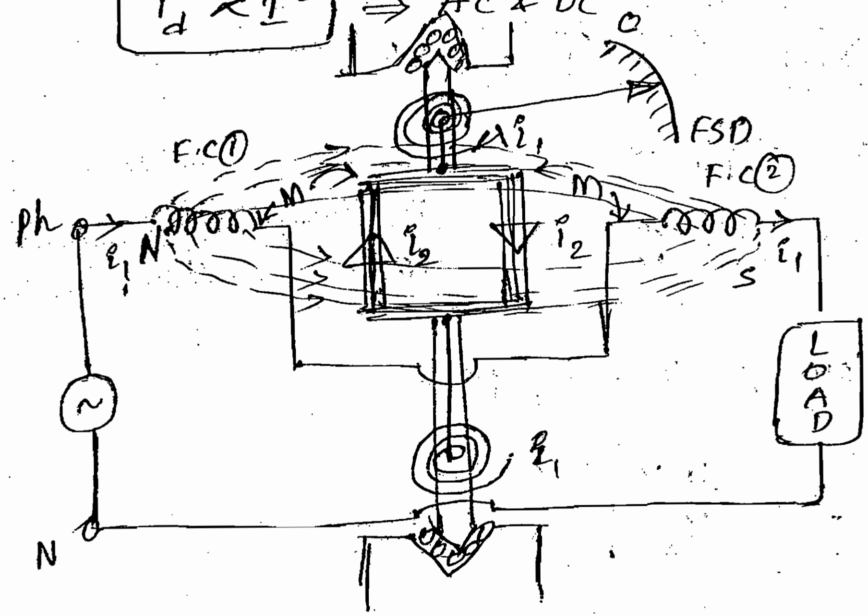
$$T_d = \frac{1}{2} I^2 \frac{d}{d\theta}(L_{eq})$$

$$= \frac{1}{2} I^2 \frac{d}{d\theta}\left[L_1 + L_2 + 2M\right]$$

$$T_d = \frac{1}{2} I^2 \left[0 + 0 + 2 \times \frac{dM}{d\theta}\right]$$

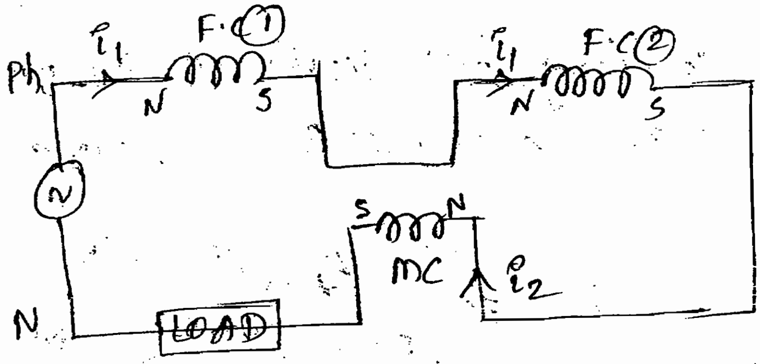
$$\boxed{T_d = I^2 \frac{dM}{d\theta}} \Rightarrow \text{const}$$

$$\boxed{T_d \propto I^2} \Rightarrow \text{AC \& DC}$$



In case of (A) + (V) :- F.C(1) & (2) ...

i.e $i_1 = i_2 = i$ (or) $i_{FC} = i_{MC} = i$

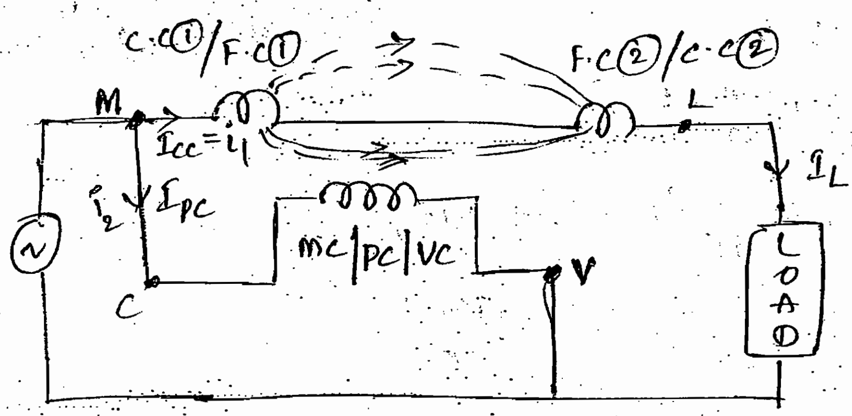


$$\boxed{T_d = i^2 \cdot \frac{dM}{d\theta}}$$ const

$$\boxed{T_d \propto i^2} \Rightarrow \text{AC \& DC}$$

In case of (W) :- F.C(1) & (2), M.C are ||el

$i_1 \neq i_2$ (or) $i_{FC} \neq i_{MC}$



Energy stored in magnetic ckt $\Rightarrow$

$$W = \frac{1}{2} L_1 I_1^2 + \frac{1}{2} L_2 I_2^2 + i_1 i_2 \cdot M$$

diff. w.r.t θ

$$\frac{dW}{d\theta} = 0 + 0 + i_1 i_2 \cdot \frac{dM}{d\theta} \Rightarrow \boxed{\frac{dW}{d\theta} = i_1 i_2 \frac{dM}{d\theta}}$$

Mech. workdone $= dW = T_d \cdot d\theta$

$$\boxed{\therefore T_d = i_1 i_2 \frac{dM}{d\theta}}$$ $\Rightarrow$ const

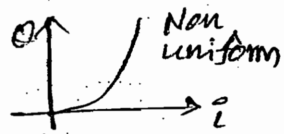
$$\boxed{T_d \propto i_1 i_2}$$

At $s.s \Rightarrow |T_d| = |T_c| \Rightarrow K_c \cdot \theta = i^2 \cdot \frac{dM}{d\theta}$

$$\boxed{\theta = \frac{i^2}{K_c} \cdot \frac{dM}{d\theta}} \Rightarrow \text{EDM-(A)}$$

$\frac{dM}{d\theta} \Rightarrow$ const

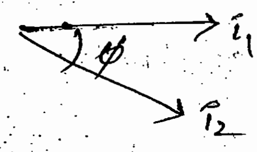
$$\boxed{\theta \propto i^2}$$



$$\boxed{\theta = \frac{i_1 i_2}{K_c} \cdot \frac{dM}{d\theta}} \Rightarrow \text{EDM-(W)}$$

DC

In case of AC supply :-



Let $i_1 = I_{m1} \sin(\omega t) = i_{FC}$

$i_2 = I_{m2} \sin(\omega t - \phi) = i_{MC}$

i_2 lags i_1 by "ϕ" & $\omega = 2\pi f = \frac{2\pi}{T}$.

$$\therefore T_{d\,avg} = \frac{1}{T}\int_0^T \left(i_1 \cdot i_2 \cdot \frac{dM}{d\theta}\right) dt$$

$$T_{d\,avg} = \frac{1}{2T}\int_0^T I_{m1} \cdot I_{m2} \times \left[2\sin(\omega t) \cdot \sin(\omega t - \phi) dt\right] \frac{dM}{d\theta}$$

$$= \frac{I_{m1} \cdot I_{m2}}{2T}\left[\int_0^T \cos\phi \, dt - \int_0^T \underbrace{\cos(2\omega t - \phi)\, dt}_{0}\right] \frac{dM}{d\theta}$$

$$T_{d\,avg} = \frac{I_{m1} \cdot I_{m2}}{2T}\left[\cos\phi \times |t|_0^T - 0\right] \frac{dM}{d\theta}$$

$$T_{d\,avg} = \left(\frac{I_{m1}}{\sqrt{2}}\right)\left(\frac{I_{m2}}{\sqrt{2}}\right) \cdot \cos(\phi) \cdot \frac{dM}{d\theta}$$

$$\boxed{T_{d\,avg} = I_1 \cdot I_2 \cdot \cos(\phi) \cdot \frac{dM}{d\theta}}$$

$$\boxed{T_{d\,avg} = I_{FC} \cdot I_{MC} \cos(\angle I_{FC} \,\&\, I_{MC}) \cdot \frac{dM}{d\theta}}$$

$$\theta = \frac{I_1 \cdot I_2 \cos(\phi)}{K_c} \cdot \frac{dM}{d\theta}$$

Adv :

1. Works for both AC & DC.
2. coils are Air cored type so that hysteresis error is absent
3. Instrument accuracy is high.
4. This inst. is called as: Transfer inst. If any inst. is used for DC without making any calibration, if the same inst is used for AC, if it gives correct reading for both AC & DC known as "Transfer inst". These transfer inst. are used in the calibration of other DC inst. like potentiometer.

Q 6/16 C.

DisAdv :

1. Non uniform scale.
2. Very weak mag. field.

$B = 0.005 \, wb/m^2$ to $0.006 \, wb/m^2$

$B = 5 \, mwb/m^2$ to $6 \, mwb/m^2$

3. $\frac{T_d \downarrow}{W \downarrow} \Rightarrow low \downarrow$
4. low sensitivity in the order of $10\Omega/V$ to $20\Omega/V$.
5. High frictional error.
6. more power consumption
7. more internal heating problem
8. more temp error

10. In case of ⓥ :- $I = \frac{V}{Z}$

$$\boxed{T_d = \frac{V^2}{Z^2} \cdot \frac{dM}{d\theta}} \Rightarrow \text{EDM} - ⓥ$$

$\frac{dM}{d\theta} \rightarrow$ const

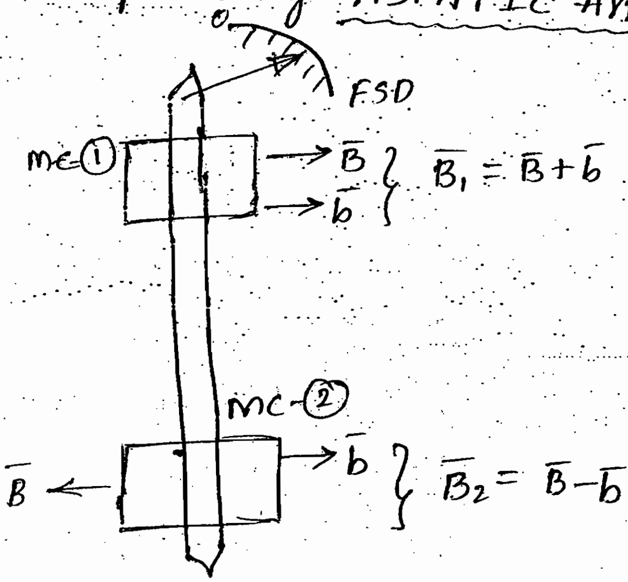
$$\downarrow T_d \propto \frac{V^2 \downarrow}{f^2 \uparrow} \propto \frac{(mV)^2}{(KHz)^2}$$

Inst severily suffer from freq. error.

→ useful freq is (0 – 125HZ)

→ In case of low grade inst, we use upto 1000HZ.

→ even we can use upto 10KHZ freq range by using "ASTATIC Arrangement".



let B → operating field

b → stray mag. field

$\therefore B_{net} = \bar{B}_1 + \bar{B}_2$

$= (B + b) + (\bar{B} - \bar{b})$

$$\boxed{B_{net} = 2\bar{B}}$$

$$\boxed{T_d \propto B_{net} = 2B}$$

Q: What is meant ASTATIC Arrangement?

In a "ASTATIC arrangement", there are two moving coils placed on same spindle (or) shaft, the operating field produced by them is equal in magnitude but opposite in direction.

Adv:

1. The operating fields is double

3. Stray mag. field error is eliminated.

4. Accuracy improves.

5. Freq range can be extended upto 10KHz.

Q. An EDI type inst, the mutual inductance changes uniformly given as $M = -8\cos(\theta + 60°)$ mH. Find the deflecting torque for a current flow of 25mA corresponding to deflection of 30°.

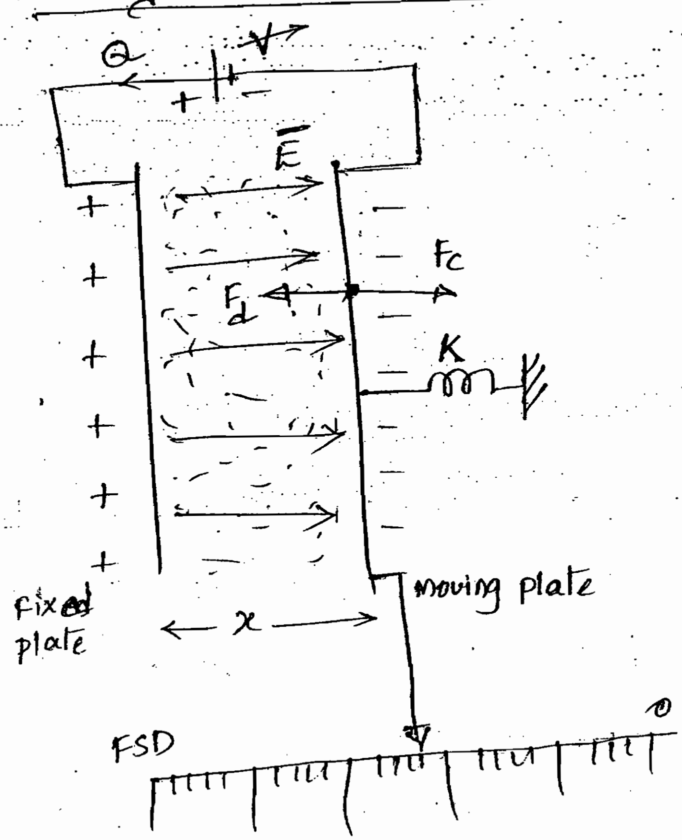
Sol: Given, $M = -8\cos(\theta + 60°)$ mH

differentiate w.r.t "θ"

$$\left.\frac{dM}{d\theta}\right|_{at\ \theta=30} = 8\sin(\theta+60°)\times 10^{-3}\ \frac{H}{rad} = 8\sin(30+60°)\times 10^{-3}$$

$$T_d = I^2 \left.\frac{dM}{d\theta}\right|_{at\ \theta=30°} = (25\times 10^{-3})^2 \times 8\times 10^{-3} = \underline{5\ \mu N\text{-}m}$$

Q: Electrostatic V/m works on the principle of — <u>change in capacitance</u>



$$Q = \overset{\text{variable}}{C}\, V$$

diff on both sides

$$dQ = C\,dV + V\,dC$$

$$V\,dQ = CV\,dV + V^2 dC$$

$$\boxed{\text{Energy supplied} = CV\,dV + V^2 dC} \to (1)$$

$$\text{Energy stored} = W_1 = \frac{1}{2}CV^2$$

change in Energy stored $= \Delta W = W_2 - W_1$

$$\boxed{\Delta W = CV\,dV + \frac{1}{2}V^2 dC} \longrightarrow (2)$$

Mech. workdone $= dW = F_d \cdot dx \longrightarrow (3)$

Acc. to law of conservation of Energy,

Energy Supplied = change in Energy stored + Mech. work done.

$$(1) = (2) + (3)$$

$$CV\,dV + V^2 dC = CV\,dV + \frac{1}{2}V^2 dC + F_d \cdot dx$$

$$\frac{1}{2}V^2 dC = F_d \cdot dx \Rightarrow \boxed{F_d = \frac{1}{2}V^2 \left(\frac{dC}{dx}\right)} \Rightarrow \text{const}$$

$$\therefore \boxed{F_d \propto V^2} \Rightarrow \text{AC \& DC}$$

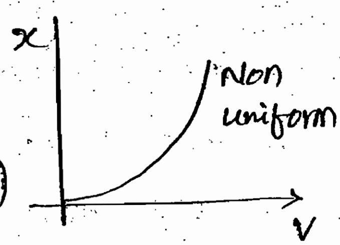
Type of control : Helical spring $\Rightarrow \boxed{F_c = K \cdot x}$

At S.S $\Rightarrow |F_d| = |F_c|$

$$K_c\, x = \frac{1}{2}V^2 \frac{dC}{dx}$$

$$\boxed{x = \frac{V^2}{2K_c} \cdot \left(\frac{dC}{dx}\right)} \Rightarrow \text{Const}$$

$$\therefore x \propto V^2$$



$$C = \frac{A\epsilon}{x} = \frac{A\epsilon_0 \epsilon_r}{x}$$

$$F_d = \frac{1}{2}V^2 \frac{dC}{dx} = \frac{1}{2}V^2 \frac{C}{x} = \frac{1}{2}V^2 \frac{A\epsilon/x}{x}$$

$$F_d = \frac{1}{2}V^2 \frac{A\epsilon}{x^2}$$

$$\boxed{V = \sqrt{\frac{2F_d \cdot x^2}{A\epsilon}}} \Rightarrow \text{Kelvin Absolute Electrometer.}$$

If any inst gives the magnitude of the measured Qty in terms of physical constants of the inst, is known as obsolute inst. These obsolute inst's are kept at international standard laboratories which are used for calibration of other inst.

Ex:

1. Kelvin absolute electrometer ⇒ used to measure V
2. Rayleigh current balance meter ⇒ I
3. Lorentz Force method ⇒ R
4. Tangent (G)meter → used for Detection purpose.

Adv :—

1. Works for both AC & DC
2. No mag. field is present in their working s/m. so that stray mag. field error is absent.
3. Hysteresis error is absent
4. This inst practically draws zero current from the supply s/m. i.e low power consumption
5. No internal heating problem
6. No temp. error.
7. wave form and freq errors are unimportant

   All errors are lesser. ∴ Inst has higher accuracy
8. This Inst is best suitable for measurement of high vlg in the order of 500V to 220KV.

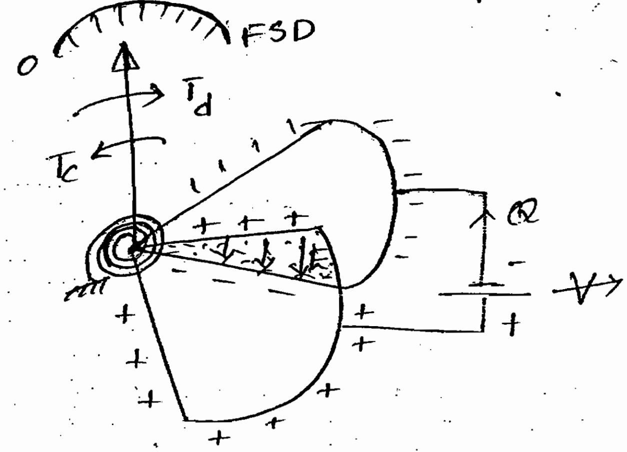
   $F_d \propto V^2 \propto (KV)^2$

Disadv :—

1. Non-uniform scale.
2. can't suitable for measurement of low vlg
2. for Measurement of current

5. size of inst is more.
6. Not robust i.e mech. not strong.

Case (2) : With circular plates



Area =

Energy supplied $= CVdV + V^2dC \rightarrow (1)$.

Incremental energy stored $= W_2 = \frac{1}{2}(C+dC)(V+dV)^2$

change in energy stored $= \Delta W = W_2 - W_1$

$$\Delta W = CVdV + \frac{1}{2}V^2dC \rightarrow (2)$$

Mech. workdone $= dW = T_d \cdot d\theta \rightarrow (4)$

Acc. to law of conservation of energy,

Energy supplied = change in Energy stored + Mech. workdone.

$$(1) = (2) + (4)$$

$$CVdV + V^2dC = CVdV + \frac{1}{2}V^2dC + T_d \cdot d\theta$$

$$\frac{1}{2}V^2dC = T_d \cdot d\theta.$$

$$\therefore \boxed{T_d = \frac{1}{2}V^2 \cdot \frac{dC}{d\theta}} \Rightarrow \text{const}.$$

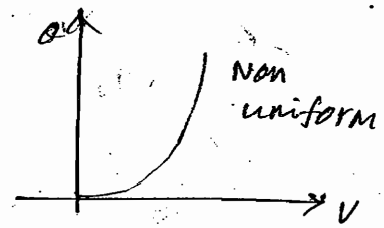
$\boxed{T_c = K_c\theta}$

At s.s $\Rightarrow |T_d| = |T_c|$

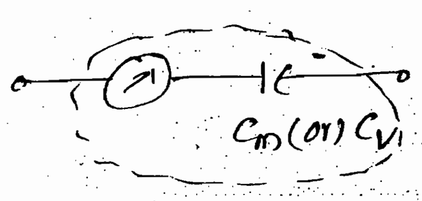
$$K_c \cdot \theta = \frac{1}{2} V^2 \cdot \frac{dc}{d\theta}$$

$$\boxed{\theta = \frac{V^2}{2K_c} \cdot \frac{dc}{d\theta}} \Rightarrow \text{const.}$$

$\theta \propto V^2$



Simplified diagram :-



C_m or $C_v \to$ meter capacitance w.r.t FSD

Q: (0 - 2000 V) ESV changes uniformly its capacitance from 42 PF to 54 PF. To extend the meter range upto 20,000 V by using external capacitor then find the value of capacitance required.

Sol: (0 - 2000) V $\to V_M$

0 - 20,000 V $\to V_{ext}$

- 42 PF to 54 PF $\Rightarrow C_m$

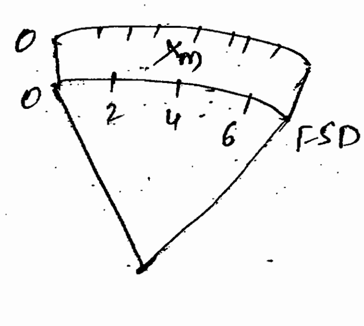
$$\therefore m = \frac{V_{ext}}{V_M} = \frac{20000}{2000} = 10$$

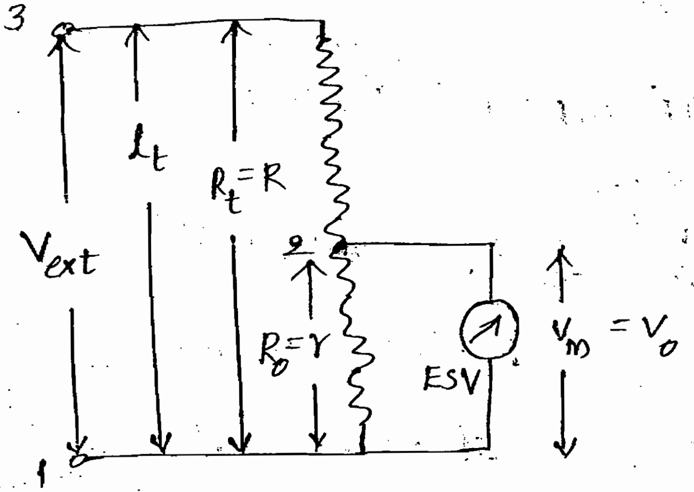
$$C_s = \frac{54\,PF}{10-1} = 6\ PF$$

$\Rightarrow$ Extension range of ESV :-

The extension range is obtained by using

1. Potentiometer method
2. Series capacitor (or) External capacitor.
3.





Length ratio = V/g ratio = resistance ratio

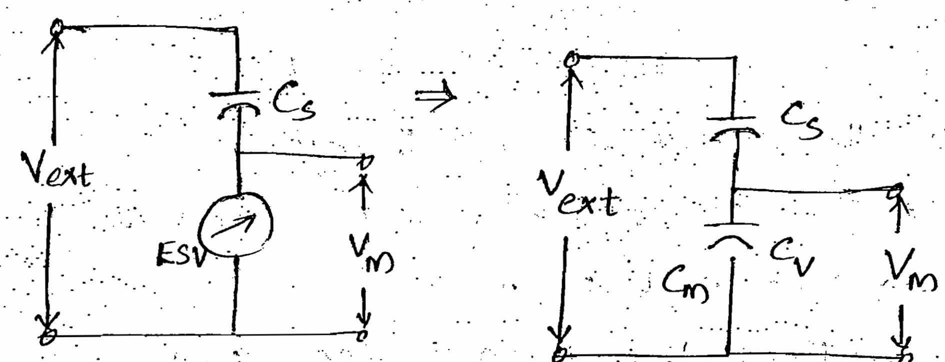
$$\frac{x}{4} = \frac{V_m}{V_{ext}} = \frac{r}{R}$$

$$\therefore \boxed{m = \frac{V_{ext}}{V_m} = \frac{R}{r}}$$

$$\therefore V_{ext} = m \cdot V_m$$

$$\boxed{V_{ext} = \left(\frac{R}{r}\right) \cdot V_m}$$

2. By using series capacitor :-



Let $C_s \rightarrow$ series capacitor

$$\therefore V_m = V_{ext} \times \frac{C_s}{C_s + C_m}$$

$$\therefore m = \frac{V_{ext}}{V_m} = \frac{C_s + C_m}{C_s}$$

$$m = \frac{V_{ext}}{V_m} = 1 + \frac{C_m}{C_s}$$

$$m - 1 = \frac{C_m}{C_s} \Rightarrow \boxed{C_s = \frac{C_m}{m-1}}$$

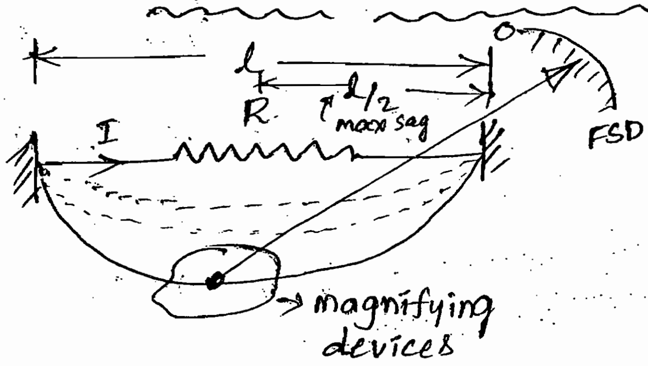
Q: Which of the following inst work on the principle of heating effect — Thermal instrument

(slow)

response — Thermal inst.

THERMAL INSTRUMENT

→ RF inst.
→ True RMS meter.



$$L_T = l_0[1+\alpha \Delta t]$$

$$L_T - l_0 = l_0 \cdot \alpha \cdot \Delta t$$

$$\Delta l = l_0 \cdot \alpha \cdot \Delta t$$

$$\boxed{\Delta l = l \cdot \alpha \cdot \Delta t}$$

$\theta \propto$ sag $\propto \Delta l \propto \Delta t \propto$ Heat $\propto I^2 R$

$\boxed{\theta \propto I^2} \Rightarrow$ AC & DC

Let R be the resistance of the wire

I be the current flowing through the wire

H be the rate of heat generation in watts

$\Delta t \rightarrow$ rise in temp. in °C.

$S_a \longrightarrow$ Heat dissipating surface area in m^2

$U \longrightarrow$ coeff of Heat dissipation in watt/$m^2 \times$ °C.

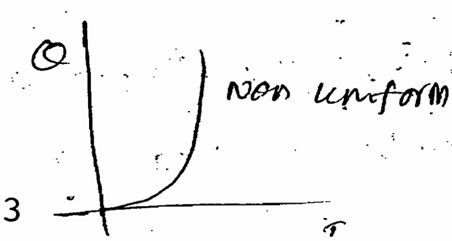
$\alpha \longrightarrow$ coeff of Linear expansion /°C.

$$U = \frac{H}{S_a \times \Delta t} \Rightarrow \boxed{\Delta t = \frac{H}{U \cdot S_a}}$$

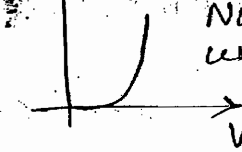
$$\Delta l = l\alpha \Delta t = l\alpha \frac{H}{US_a}$$

$$\boxed{\Delta l = \frac{l\alpha}{US_a} \times I^2 R} \Rightarrow \text{Hot wire inst.} \quad \text{— (A)}$$

$\therefore \theta \propto I^2$



$$\boxed{\Delta l = \frac{l\alpha}{US_a} \times \frac{V^2}{R}} \Rightarrow \theta \propto V^2$$



Non uniform.

Adv:

1. Works for both AC & DC.
2. No mag. field is present so that stray Mag. field erro is absent.
3. Hysteresis error also absent.
4. No reactance term is present. so that freq error is absent. so that these inst is used upto radiofreq range. i.e upto 50MHz.
5. Thermal inst are also known as Radio freq inst.
   " " True RMS meters.
6. These inst " " "Transfer inst".

Disadv:

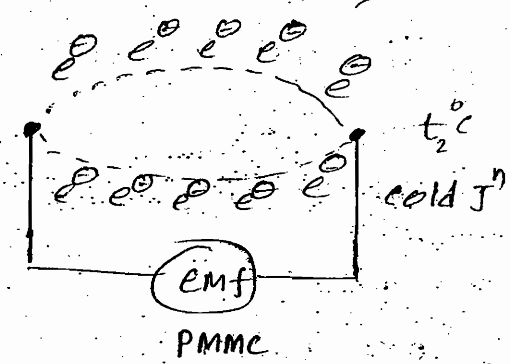
1. Non-uniform scale
2. Difficult construction
3. Ambient (surrounding) temp will effect the actual readings of the inst. so that inst accuracy is lesser.
4. It have min overloading capability around 150% of full scale.
6. More power consumption
7. Not robust
8. Suffer's from skin effect when using at higher freq's, to reduce the skin effect, tubular cond are used or preferred when the current carrying capability greater than 3 Amps.

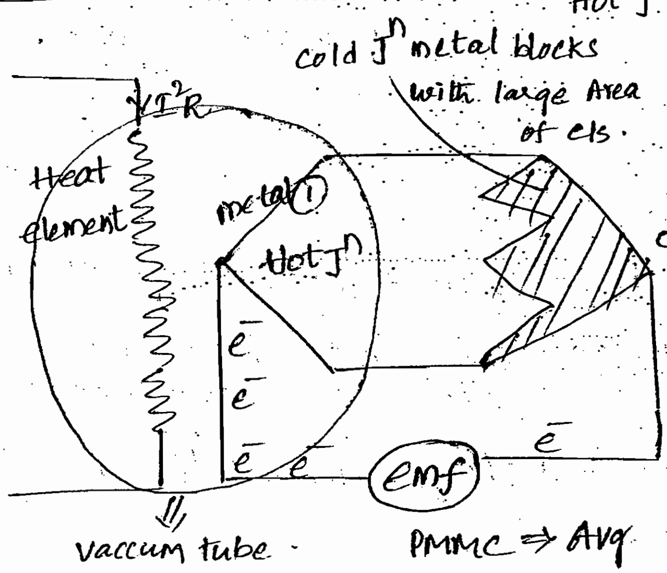
⇒ THERMOCOUPLE INSTRUMENT :-

Thermocouple works on the principle of "Seebeck effect", wherever there are two dissimilar metals are maintained at two different temp namely Hot Junction and cold Junction. so that there is some electron flow is observed from hot Junction to cold junction known as seebeck effect.

The produced electron flow unidirectional which is ~~unidirection~~ DC nature detected by PMMC.

$$\boxed{emf \propto \Delta t \propto Heat \propto I^2R}$$



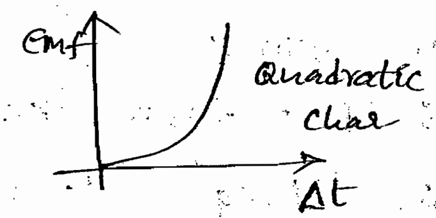


Cu ⟷ constantant
Fe ⟷ constantan
platinum ⟷ Rhodium
chromel ⟷ Alluemel

contact 1) conduction process

Non contact { 2) - convection
3) Radiation

$$emf = e = a \cdot \Delta t + b \cdot \Delta t^2$$



$a \rightarrow$ constant (or) $S_{thermocouple}$

$$a = \frac{emf}{\Delta t} \cdot \frac{\mu volt}{^\circ C}$$

PSU**
$$\boxed{a = 40 \frac{\mu Volt}{^\circ C} \text{ to } 50 \frac{\mu Volt}{^\circ C}}$$

thermocouple

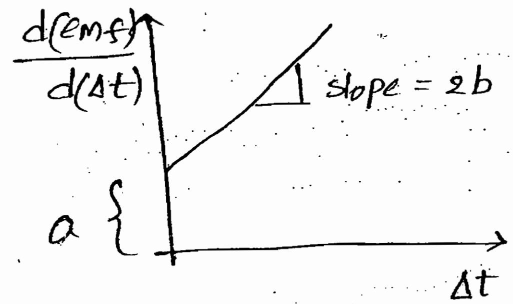
** PSU

$$\boxed{b = \frac{emf}{\Delta t^2} - \mu\, volt/{}^{\circ}C^2}$$

$$\boxed{b = \frac{\mu volt}{{}^{\circ}C^2} \quad (or) \quad 2\ \mu\, volts/{}^{\circ}C^2}$$

** PSU

$$\boxed{\frac{d(emf)}{d(\Delta t)} = a + 2b \cdot \Delta t}$$



Temp. range : upto 1100°C ⇒ In general even we can use upto 2000°C.

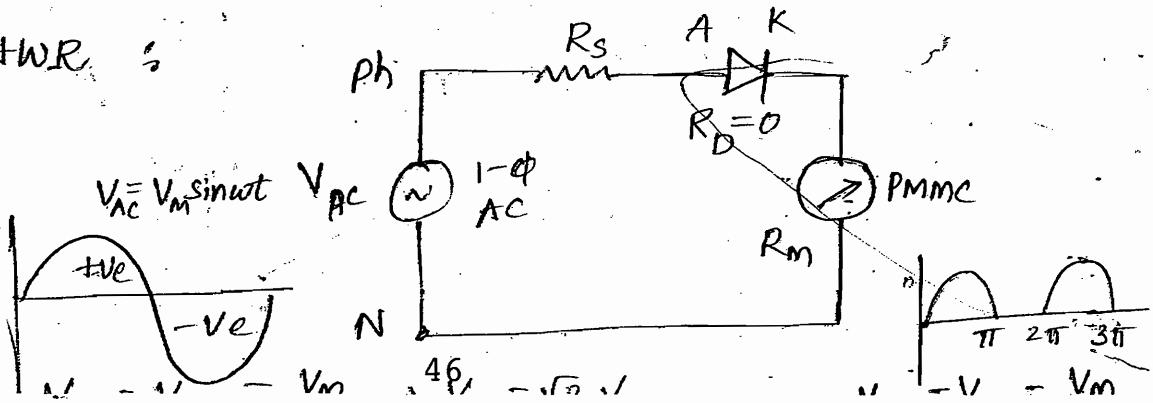
Note : In thermocouple type inst. the produced thermal emf is very small in the order of micro or milli volts, which is in DC nature detected by PMMC [Avg] but scale is calibrated to read rms value of AC current flowing through heater element.

⇒ Rectifier Type Instruments :— ✓ Imp for GATE

Based on usage of diodes rectifier type inst classified as :

1. HWR 2. FWR

1. HWR :



$V_{DC} = \frac{V_m}{\pi} = \frac{\ }{\pi} V_{AC}$

$$\boxed{V_{DC} = 0.45\, V_{AC}}$$

$$\boxed{I_{AC} = \frac{V_{AC}}{R_s + R_m}}$$

$$I_{DC} = \frac{V_{DC}}{R_s + R_m}$$

$$\boxed{I_{DC} = 0.45 \times \frac{V_{AC}}{R_s + R_m}}$$

$I_{DC} = 0.45\, I_{AC}$

$$\frac{1}{(I_{AC})_{FSD}} = 0.45 \times \frac{1}{(I_{DC})_{FSD}}$$

$$\boxed{S_{AC\,HWR} = 0.45\, S_{DC}}$$

$\Downarrow$

$$R_s + R_m = 0.45 \times V_{AC} \times \frac{1}{I_{DC}}$$

$$R_s + R_m = 0.45 \times V_{AC} \times S_{DC}$$

GATE definite (Q)

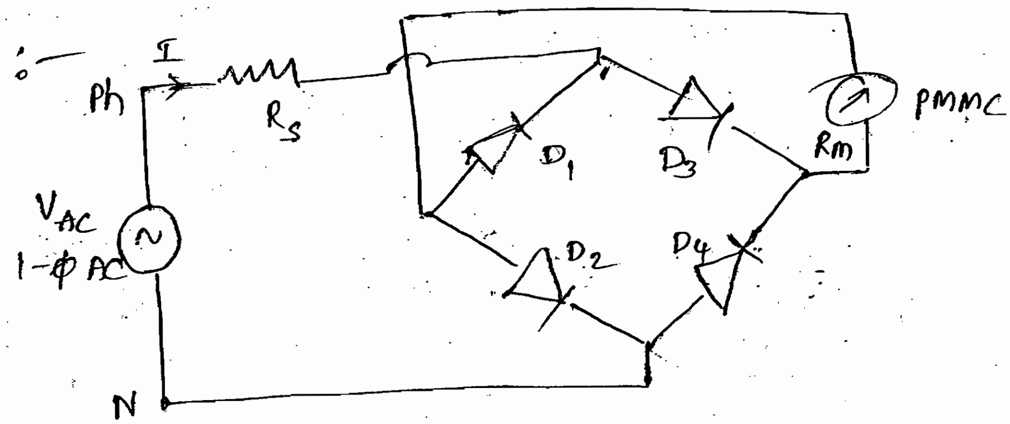
$$\boxed{R_s = 0.45 \times V_{AC} \times S_{DC} - R_m}$$ $\Rightarrow$ Ideal diode HWR

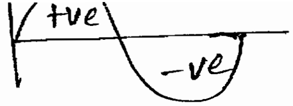
$$\boxed{R_s = 0.45 \times V_{AC} \times S_{DC} - R_m - R_D}$$ $\Rightarrow$ practical diode HWR.

$$K_f = \frac{V_M/\sqrt{2}}{V_M/\pi} = \frac{\pi}{\sqrt{2}} = 2.22$$

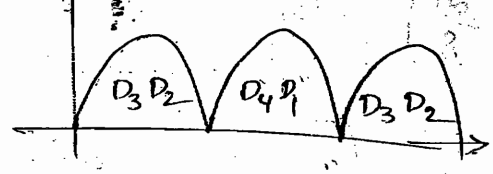
$$\boxed{\text{Reading of HWR type inst} = 2.22 \times \text{PMMC reading}}$$

2) FWR :-





$\Rightarrow$



$V_{AC} = V_{RMS} = \frac{V_m}{\sqrt{2}} \Rightarrow \boxed{V_m = \sqrt{2}\, V_{AC}}$

$V_{DC} = V_{Avg} = \frac{2V_m}{\pi}$

$V_{DC} = \frac{2V_m}{\pi} = \frac{2\sqrt{2}}{\pi} V_{AC}$

$= 2 \times 0.45 V_{AC}$

$\boxed{V_{DC} = 0.9\, V_{AC}}$

$\boxed{I_{AC} = \frac{V_{AC}}{R_s + R_m}}$

$I_{DC} = \frac{V_{DC}}{R_s + R_m}$

$\boxed{I_{DC} = 0.9 \times \left(\frac{V_{AC}}{R_s + R_m}\right)} \Rightarrow R_s + R_m = 0.9 \times V_{AC} \times \frac{1}{I_{DC}}$

$R_s + R_m = 0.9 \times V_{AC} \times S_{DC}$

$\boxed{I_{DC} = 0.9 \times I_{AC}}$

$\boxed{R_s = 0.9 \times V_{AC} \times S_{DC} - R_m}$ Ideal FWR

$\boxed{R_s = 0.9 V_{AC} \times S_{DC} - R_m - 2R_D}$ practi FWR

$\frac{1}{(I_{AC})_{FSD}} = 0.9 \times \frac{1}{(I_{DC})_{FSD}}$

Imp $\boxed{S_{AC\ FWR} = 0.9 \times S_{DC}}$

$\Downarrow$

$S_{AC\ FWR} = 2 \times (0.45 S_{DC}) = 2\, S_{AC\ HWR}$

$\boxed{S_{AC\ HWR} : S_{AC\ FWR} : S_{DC} = 0.45 : 0.9 : 1}$

$K_f = \frac{V_m/\sqrt{2}}{2V_m/\pi} = \frac{\pi}{2\sqrt{2}} = \frac{2.22}{2} = 1.11.$

$\boxed{\text{Reading of FWR type inst} = 1.11 \times \text{PMMC reading}}$.

$\frac{19}{7}$) B

$\frac{21}{8}$] $I_m = 45\times10^{-3}\ A$;

$V_{AC} = 100KV$

$$\boxed{I_{DC} = 0.9\left(\frac{V_{AC}}{R_s+R_M}\right)} \quad R_M \to 0$$

$$= 0.9\times\frac{V_{AC}}{X_C+0} = 0.9\times\frac{V_{AC}}{|1/j\omega C|}$$

$$I_{DC} = 0.9\times V_{AC}\times|j2\pi fC|$$

$$C = \frac{I_{DC}}{0.9\times V_{AC}\times 2\pi f}$$

$$C = \frac{45\times10^{-3}}{0.9\times100\times10^{3}\times2\pi\times50} = 1590\ PF$$

$$\boxed{C = 15.90\times10^{-10}\ F}$$

$\frac{20}{8}$]

$$I_{DC} = 0.9\times\frac{V_{DC}}{R_s+R_m}$$

$$1\times10^{-3} = 0.9\times\frac{100}{R_s+100}$$

$$R_s+100 = \frac{90}{10^{-3}} \Rightarrow R_s+0.1K = 90K.$$

$$\boxed{R_s = 89.9\ K\Omega}$$

Q A (0–1000V) ($\hookrightarrow V_{FSD}$) VM has a sensitivity of 1000 V/Ω, Find the meter current ~~for~~ at half full scale deflection

Sol:

$$S_V = \frac{R_m}{V_{FSD}}\ \Omega/V$$

first calculate R_m=? then proceed

$$1000\ \frac{\Omega}{V} = \frac{R_M}{1000\,V} \Rightarrow \boxed{R_M = 1000\ K\Omega}$$

(1) I_M at FSD $= \frac{V_{FSD}}{R_m} = \frac{1000}{1000K} = 1mA.$

(2) I_M at Half FSD $= \frac{\frac{1}{2}V_{FSD}}{R_M} = 0.5mA.$

(3) I_M at $\frac{1}{5}$th FSD $= 0.2mA.$

$$S_V = \frac{1}{I_{FSD}}$$

$$I_{FSD} = \frac{1}{S_V} = \frac{1}{1000}$$

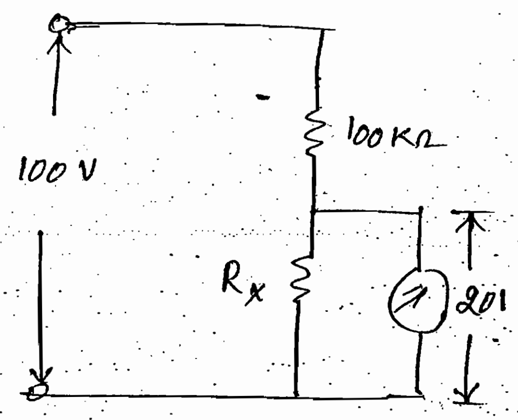
$$\boxed{I_{FSD} = 1\,mA}$$

⇒ A (0–100V) V/M has a sensitivity of 500 Ω/V, connected in the ckt shown in below fig, meter reads 20 Volts and find the value of R_s.

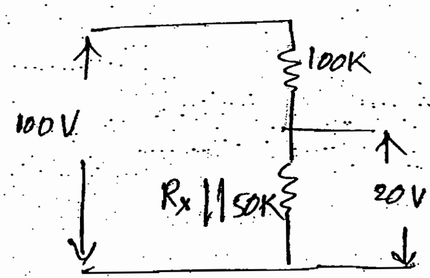
Sol: (0–100V) ; $S_V = \frac{500\,\Omega}{Volt}$
↳ V_{FSD}

$$\Rightarrow S_V = \frac{R_m}{V_{FSD}}$$

$$\Rightarrow 500 = \frac{R_m}{100\,V} \Rightarrow \boxed{R_m = 50\,K\Omega}$$



⇓



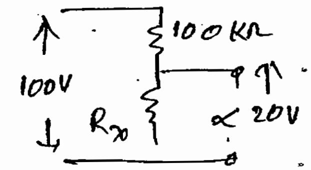
$$20V = 100V \times \frac{(R_x \parallel 50K)}{100K + (R_x \parallel 50K)}$$

$$(0.2)(100K) + (0.2)(R_x \parallel 50K) = (R_x \parallel 50K)$$

$$20K = (0.8)(R_x \parallel 50K)$$

$$25K = \frac{R_x \cdot 50K}{R_x + 50K} \Rightarrow \boxed{R_x = 50\,K\Omega}$$

In the above problem if it is Ideal V/M, the value of R_x = 25 KΩ.



$$20 = 100 \times \frac{R_x}{R_x + 100}$$

$$\Rightarrow \boxed{R_x = 25\,K\Omega}$$

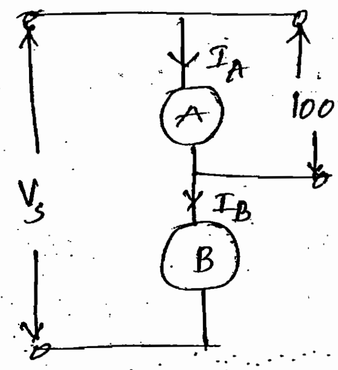
DC source "A" meter has a full scale value of 100 V has a resistance of 100 Ω/V, "B" meter has total resistance of 15000 Ω.

ⓐ Find B meter reading

ⓑ current flowing through meters.

ⓒ Find source vlg.

Given,



(0-100V) ↳ V_{FSD}

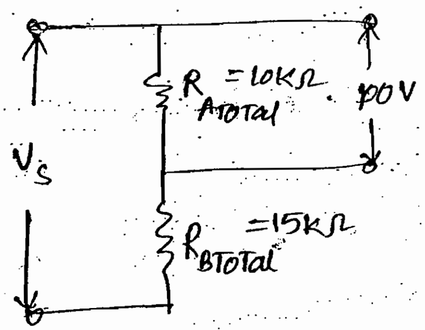
$R_A = 100\ \Omega/V$

$R_{A\,Total} = 10k\Omega$

$R_{B\,Total} = 15k\Omega$

① $I_A = \dfrac{V_A}{R_{A\,Total}}$

$I_A = \dfrac{100}{10K} = 10\ mA = I_B$



② $V_B = I_B R_{B\,Total}$

$= 10\,m \times 15\,K$

$V_B = 150\ V$

③ $V_s = V_A + V_B$

(or) $V_s = 100 + 150 = 250\ V$

$V_s = I_A \left[R_{A\,total} + R_{B\,Total}\right]$

... of Resistance :

Resistance is classified as 3 types only for the purpose of Measurement.

1. Low resistance [$< 1\Omega$]
2. Medium " [1Ω to $100k\Omega$ or 1Ω to $0.1M\Omega$]
3. High resistance [$> 100k\Omega$ or $> 0.1 M\Omega$]

Ex ① : Arm. w/g resistance, Series field w/g resistance, shunt resistance of (A), Diode F.B. resistance, link resistance, compensating w/g resistance, slide wire resistance.

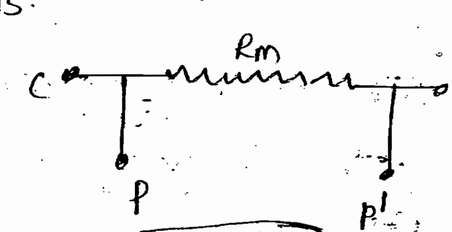
Ex ② : Shunt field w/g resistance, Resistance of heating element, All electrical Apparatus.

Ex ③ : Insulation resistance of insulators,
" " of Dielectrics,
" " of cable,
power diode R.B resistance
series multiplier Resistance of (V)
E/p impedance of CRO
" " FET
" " OPAMP

Error present in the measurement of Low resistance :

1. Error due to contact resistance
2. Error due to Resistance of leads.
3. Error due to temp.
4. Error due to thermal emf.

4 point method or 4 probe method



where $cc' \rightarrow$ current t/m's

$R = \frac{V_{PP'}}{}$

1. Error due to leakage current, which are carried by guard wire

2. Error due to specimen capacitance $\boxed{\text{cable = cond + dielectric}}$.
i.e Initially a large amount of charging current flows on the application of direct v/g to the cable.

3.

Q: Which one of the following method is used to measure low resistance?

a. A-V method b. potentiometer c. Kelvin double bridge. ✓d. All

none is given

⇒ Measurement of medium resistance :-

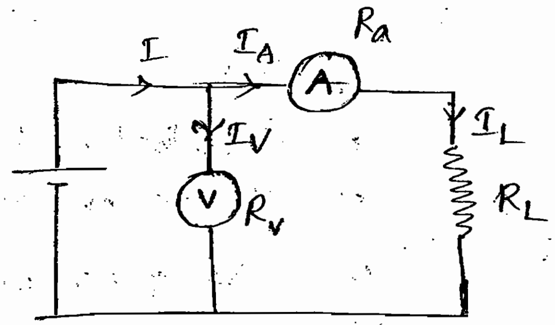
1. V-A method
2. Substitution
3. OHM meter
4. WHEATSTONE

⇒ Measurement of High resistance :-

1. Loss of charge method
2. Direct deflection method
3. Mega-OHM bridge "
4. Meggar method.

<u>Note</u> Never connect Ⓐ as llel, if it is connected, the Ⓐ going to get damaged.

V - A Method.



Take $\boxed{R_{True} = R_L}$

$$R_m = \frac{V}{A} = \frac{I_a R_a + I_L' R_L}{I_a}$$

$$\boxed{\therefore I_a = I_L}$$

$$\boxed{R_m = R_L + R_a}$$

$$\boxed{R_m = R_T + R_a}$$

$$\text{Error} = R_m - R_L = R_a$$

$$\text{Error} = +ve \Rightarrow R_m > R_L$$

$$\%\ \text{Error} = \frac{R_m - R_T}{R_T} \times 100$$

$$= \frac{R_m - R_L}{R_L} \times 100$$

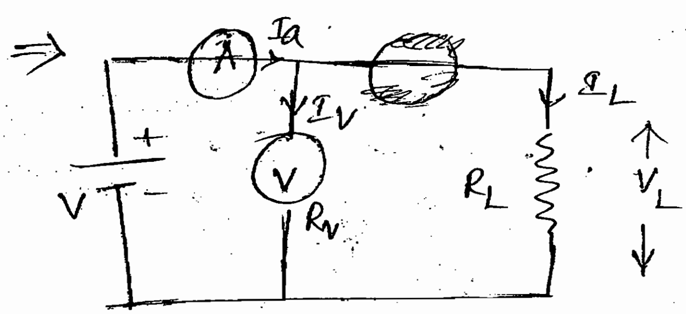
$$\boxed{\%\ \text{Error}\downarrow = \frac{R_a}{R_L\uparrow} \times 100}$$

Ideally $\Rightarrow R_a = 0$

Note :

V - A method is best suitable for measurement of Large value of "R" in medium resistance range; produced error is +ve becoz of A connected on Load side, ideally A resistance is zero but practically not possible. It is only known as "Loading effect of A".

$\Rightarrow$



Take $\boxed{R_{True} = R_L}$

$$R_m = \frac{V}{A} = \frac{V_L}{I_a} = \frac{V_L}{I_L + I_V}$$

$$R_m = \frac{V_L}{\frac{V_L}{R_L} + \frac{V_L}{R_V}} = \frac{1}{\frac{1}{R_L} + \frac{1}{R_V}}$$

$$\boxed{\frac{1}{R_m} = \frac{1}{R_L} + \frac{1}{R_V}}$$

$$\boxed{R_m = \frac{R_L \cdot R_V}{R_L + R_V}}$$

$$(1+x)^{-1} = 1 - \frac{x}{1!} + \frac{x^2}{2!} + \cdots$$

$$R_m = \frac{\;\cdots\;}{R_V\left[1+\frac{R_L}{R_V}\right]} = R_L\left[1+\frac{R_L}{R_V}\right]^{-1}$$

$$R_m = R_L\left[1-\frac{R_L}{R_V}\right] = R_L - \frac{R_L^2}{R_V}$$

$$\boxed{\text{Error} = R_m - R_L = \frac{-R_L^2}{R_V}}$$

Error $= -ve \Rightarrow R_m < R_L$

$$\%\,\text{Error} = \frac{R_m - R_L}{R_L}\times 100 = \frac{-R_L^2/R_V}{R_L}\times 100$$

$$\boxed{\%\,\text{Error}\downarrow = \frac{\downarrow R_L}{R_V}\times 100}$$

Ideally $\Rightarrow R_V = \infty$.

Note :-

(A)-(V) Method is best suitable for measurement of Low value of Resistance, produced error -ve becoz of (V) connected on load side.
Ideally (V) resistance $\to \infty$ practically not possible.
⇓
"Loading effect of (V)"

Note : Error in (V)-(A) method = Error in (A)-(V) method

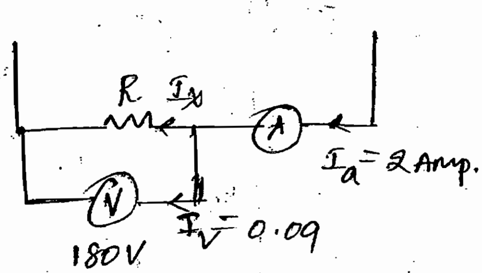
$$|R_a| = \left|\frac{-R_L^2}{R_V}\right|$$

**

$$\boxed{\therefore R_L = \sqrt{R_a R_V}}$$

In order to get equal error in both the methods, the condition should be

25/22) **A-V method :-**



$$R_m = \frac{(V)}{(A)} = \frac{180\,V}{2A} = 90\,\Omega$$

$$R_T = \frac{(V)}{I_x} = \frac{180}{1.91} = 94.24\,\Omega$$

$$\therefore I_V = \frac{(V)}{R_V} = \frac{180}{2000} = 0.09$$

$$I_x = I_a - I_V = 1.91\,A$$

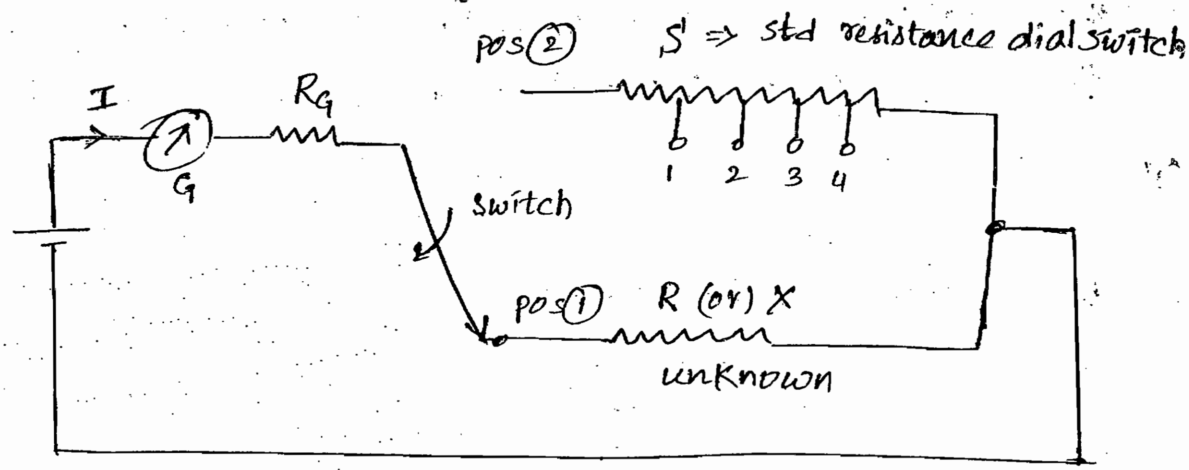
$$\%\,\text{Error} = \frac{90-94.24}{94.24}\times 100 = -4.5\%$$

$\Rightarrow$ Exact

$$= \frac{\ldots}{R_V} \times 100 = \frac{\ldots}{2000} \times 100$$

$= -4.71\% \Rightarrow$ Approx.

⇒ Substitution method :-



case(1): Switch is moved to pos-(1) $\Rightarrow \theta_1 \propto I_1 = \dfrac{E}{R_G + R} \rightarrow (1)$

case(2): " pos-(2) $\Rightarrow \theta_2 \propto I_2 = \dfrac{E}{R_G + S} \rightarrow (2)$

Let $\theta_1 \rightarrow$ Deflections of (G) with unknown resistance

$\theta_2 \rightarrow$ " known "

$$\frac{Eq(1)}{Eq(2)} \Rightarrow \frac{\theta_1}{\theta_2} = \frac{R_G + S}{R_G + R}$$

$$R_G + R = \frac{\theta_2}{\theta_1}\left[R_G + S\right]$$

$$\boxed{R = \frac{\theta_2}{\theta_1}\left[R_G + S\right] - R_G}$$

Adv : It is one of the best method to use in practical ckts.

DisAdv : The main drawback of this method is the choice of availability of std Resistance dial switch.

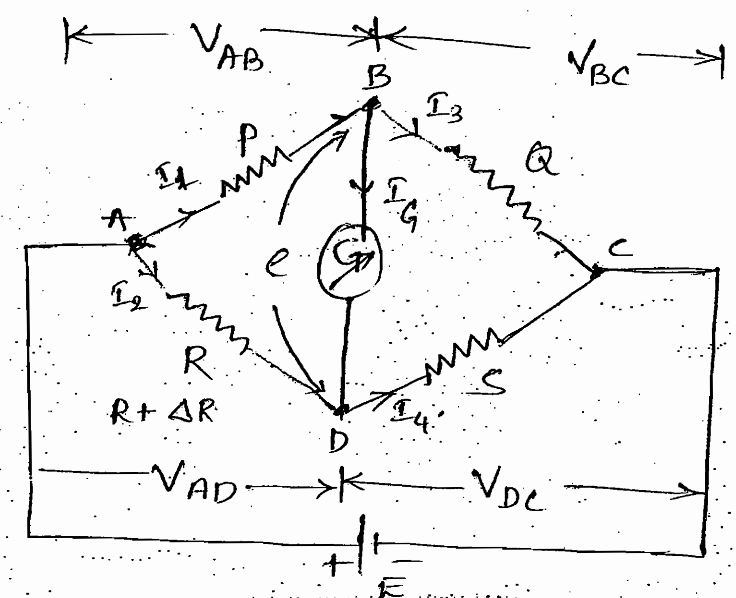
2. Change in battery emf due to more current carrying capacity

3. Change in battery Emf due to aging effect

method, $R_G = 200\Omega$; $S = 100K\Omega$; Q with unknown resistance, the deflection of (G) is 46 divisions on the scale with known resistance 40 divisions on the scale. Find the value of unknown Resistance.

Sol: $R = \frac{40}{46}\left[200 + 100K\right] - 200 = 86.93K\Omega$

⇒ Wheatstone bridge method :-



It is used to measure medium resistances most accurately in the order of 100Ω to $10K\Omega$.

P, Q ⇒ ratio Arm resistances

R, S ⇒ " " "

P, Q, S ⇒ known resistances

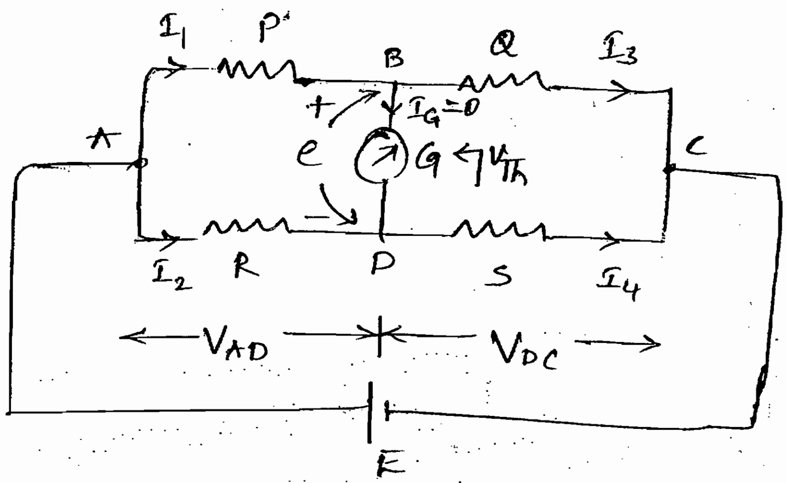
R ⇒ unknown "

Type of detector ⇒ D'Arsonal (G)

Type of supply ⇒ DC battery

↳ Weston std. cell

$I_{G} = 0 \; ; \quad I_1 = I_3 \; ; \quad I_2 = I_4 .$



$$V_{AB} = V_{AD} \qquad\qquad V_{BC} = V_{DC}$$

$$I_1 P = I_2 R \rightarrow (1) \qquad\qquad I_3 Q = I_4 S \rightarrow (2)$$

$$\frac{\text{Eq}(1)}{\text{Eq}(2)} \Rightarrow \frac{\cancel{I_1} P}{\cancel{I_3} Q} = \frac{I_2 R}{I_4 S} \Rightarrow \boxed{\frac{P}{Q} = \frac{R}{S}} \rightarrow (A)$$

$$\boxed{PS = QR}$$

$$\boxed{R = \frac{P}{Q} \times S}$$

$$* \; S_{\text{Detector}} = S_V = \frac{\text{change in Deflection}}{\text{change in v/g}} = \frac{\Delta\theta}{\Delta V} = \frac{\Delta\theta}{e}$$

$$\boxed{\Delta\theta = e \cdot S_V}$$

$$* \; S_{\text{Bridge}} \uparrow = \frac{\text{change in Deflection}}{\text{unit change in resistance}} = \frac{\Delta\theta}{(\Delta R / R)\downarrow}$$

$$\boxed{S_B = \frac{e \cdot S_V \cdot R}{\Delta R}} \rightarrow (3)$$

$$e = V_{AD} - V_{AB} = E\left[\frac{R}{R+S} - \frac{P}{P+Q}\right]$$

$$\boxed{e = V_{Th} = E\left(\frac{R+\Delta R}{R+\Delta R+S} - \frac{P}{P+Q}\right)} \longrightarrow (4)$$

Add 1 on both side to eq (A),

so that $1 + \frac{Q}{P} = \frac{S}{R} + 1$

$$\frac{P+Q}{P} = \frac{R+S}{R}$$

$$\boxed{\frac{P}{P+Q} = \frac{R}{R+S}} \longrightarrow (5)$$

Subs. Eq (5) in Eq (4),

$$e = E\left(\frac{R+\Delta R}{R+\Delta R+S} - \frac{R}{R+S}\right)$$

$$= E\left(\frac{S \cdot \Delta R}{(R+S)^2 + \underbrace{\Delta R(R+S)}_{\text{neglected}}}\right)$$

$\because (R+S)^2 >> \Delta R(R+S)$

$$\boxed{e = E \cdot \frac{S \cdot \Delta R}{R^2 + S^2 + 2RS}} \longrightarrow (6)$$

Sub eq (6) in eq (3), we get

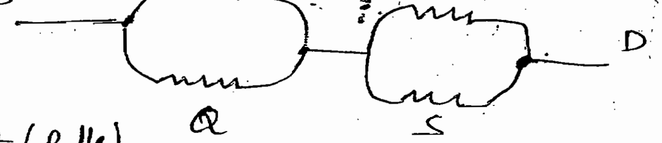
$$\boxed{S_B = E \cdot \frac{S_V \cdot R_s}{R^2 + s^2 + 2R_s}}$$

$$\boxed{S_B = E \times \frac{S_V}{\frac{R^2}{R_s} + \frac{s^2}{R_s} + \frac{2Rs}{R_s}}}$$

Imp $$\boxed{S_B = E \times \frac{S_V}{\frac{R}{S} + \frac{S}{R} + 2}}$$

Condition for obtaining max. sensitivity, If $\frac{R}{S} = 1 \Rightarrow R = S$

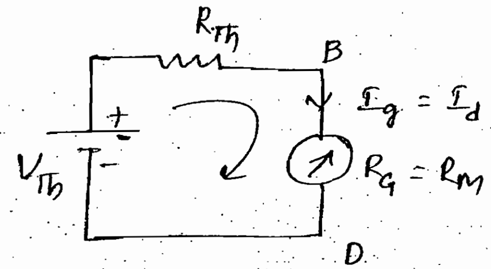
Imp $$S_{B_{max}} = E \cdot \frac{S_V}{4}$$



$$R_{Th} = (P \| Q) + (R \| S)$$

$$\boxed{R_{Th} = \frac{P \cdot Q}{P+Q} + \frac{R \cdot S}{R+S}}$$

$$\boxed{V_{Th} = E\left[\frac{R+\Delta R}{R+\Delta R+S} - \frac{P}{P+Q}\right]}$$



$$\boxed{I_g = I_d = \frac{V_{Th}}{R_{Th} + R_G}}$$

Ideally $\Rightarrow R_G = 0$.

$$\boxed{I_g = I_d = \frac{V_{Th}}{R_{Th}}}$$

Case (i) : $P = Q = S = R$

$$R_{Th} = (R \| R) + (R \| R) = R$$

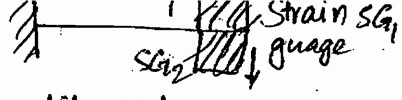
$$V_{Th} = E\left[\frac{R+\Delta R}{R+\Delta R+R} - \frac{R}{R+R}\right]$$

$$V_{Th} = E\left[\frac{R+\Delta R}{2R+\Delta R} - \frac{1}{2}\right]$$

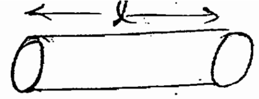
$$V_{Th} = E\left[\frac{\Delta R}{4R + \underbrace{2\Delta R}_{\text{neglect}}}\right] \quad \because 4R >> 2\Delta R$$

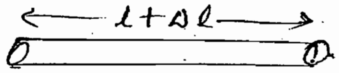
$$\boxed{V_{Th} = \frac{E}{4} \cdot \frac{\Delta R}{R}} \Rightarrow \text{Quarter bridge}$$

$$\boxed{S_{Quarter} = \frac{V_{Th}}{(\Delta R/R)} = \frac{E}{4}}$$



Cantilever beam





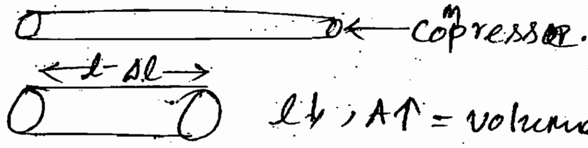
$l\uparrow, A\downarrow$

Volume $= l \times A$.

$$l' = l + \Delta l$$

$$R' = R + \Delta R$$

$$\text{strain} = \frac{\Delta l}{l} = +ve.$$



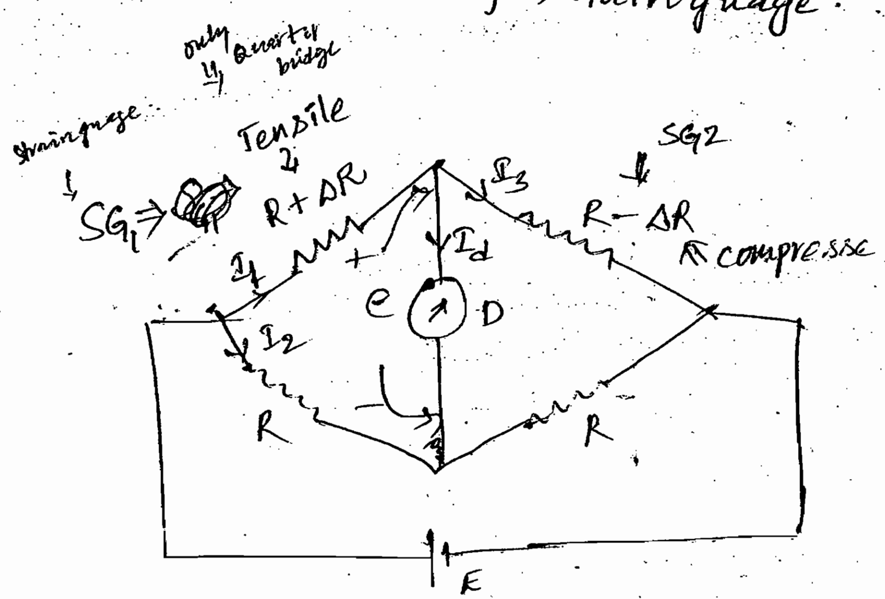
$l\downarrow, A\uparrow =$ volume

$$l' = l - \Delta l$$

$$R' = R - \Delta R \;, \quad \text{strain} = \frac{\Delta l}{l} = -ve$$

Quarter bridge :-

The change of resistance occurs in one of the arm of the wheat stone bridge due to applied tensile force, the remaining arms of the bridge is same known as "Quarter bridge", the produced strain is measured by "strain guage".



Half bridge.

$$V_{Th} = \frac{E}{2} \times \frac{\Delta R}{R}$$

$$\boxed{S_H = \frac{V_{Th}}{(\Delta R/R)} = \frac{E}{2}}$$

$$\boxed{S_H = 2 S_a}$$

Case(iii) : Full Bridge.

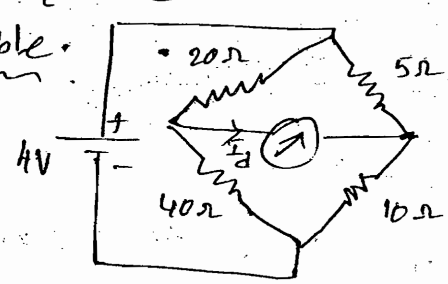
$$\boxed{V_{Th} = \frac{E}{1} \times \frac{\Delta R}{R}}$$

$$\boxed{S_F = \frac{V_{Th}}{\Delta R/R} = \frac{E}{1}}$$

$$\boxed{S_F = 2 S_H = 4 S_a}$$

$$\boxed{S_a : S_H : S_F = 1 : 2 : 4}$$

⇒ Find the current flowing through G if the G internal resistance is double.



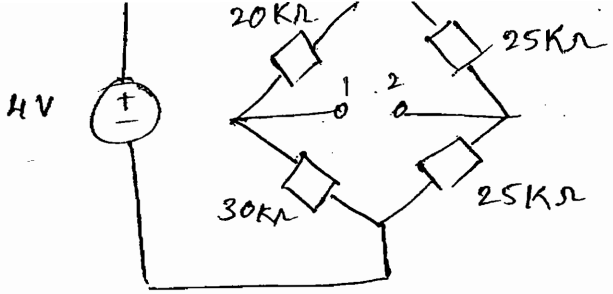
$I_g = 0$ (bridge is balanced)

⇒ Find the v/g b/w the terminal 1 & 2 as shown in fig

2) Find the Resistance b/w t/m 1 & 2.

3) If the G is connected b/w t/m 1 & 2 Find the current flow

4) If the sensitivity of G is 0.5 mm/μA. Find the deflections of shown fig G



Sol: (1) $V_{12} = V_{Th} = 4\left[\frac{20K}{20K+30K} - \frac{25K}{25K+25K}\right]$

$V_{Th} = -0.4$ volts.

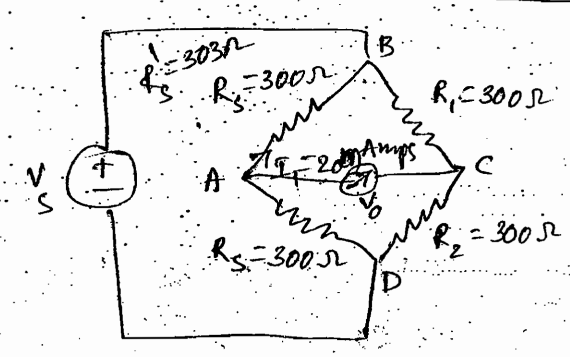
(2) $R_{Th} = R_{12} = (20K \| 30K) + (25K \| 25K) = 24.5K\Omega$

(3) $I_g = \frac{V_{Th}}{R_{Th}} = \frac{-0.4}{24.5\times10^3} = -16.32\ \mu Amp.$

(4) $S_{I_g} = \frac{\Delta\theta}{I_g} = \Delta\theta = S_{I_g} \times I_g \Rightarrow \Delta\theta = 0.5\frac{mm}{\mu A}\times 16.32\ \mu A$

$\boxed{\Delta\theta = 8.16\ mm}$

⇒ strain guage problem:



$R_s' = 300 + 1\% = 300 + \left(\frac{1}{100}\times 300\right)$

$R_s' = 303\Omega$

$V_{AB} = I_1 R_s = 20\times10^{-3}\times 300 = 6V.$

$\therefore V_s = 2V_{AB} = 2\times6 = 12V$

$V_{Th} = V_0 = \frac{E}{4}\times\frac{\Delta R}{R}$

$V_0 = \frac{12}{4}\times\frac{3}{300} = 30\ mV$

↳ Exact.

Method-(2)

$V_{Th} = 12\left[\frac{303}{303+300} - \frac{300}{300+300}\right]$

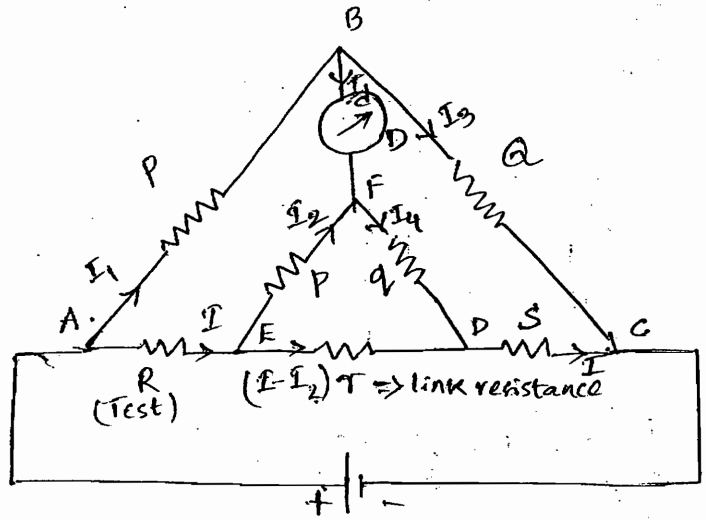
$V_{Th} = 29.85\ mV.$

↳ Approx

Q5/20] C   Q10] A CAREY – foster (Comparision, Resistance, equal)

9) C   21) d   17) d

24) a   (c)



It is used to measure ~~is used to measure~~ the low resistances with most accurately in the order of 0.1 μΩ to 1Ω. This bridge consist of link resistance connected b/w test resistance (unknown) and known resistance (std), so that which can measure low resistances more accurately.

bridge is under balanced condition,

$$I_d = 0, \quad I_1 = I_3, \quad I_2 = I_4$$

Apply KVL in "ABFEA" loop,

$$I_1 P - I_2 p - I \cdot R = 0$$

$$\boxed{I_1 P = I_2 p + IR} \rightarrow (1)$$

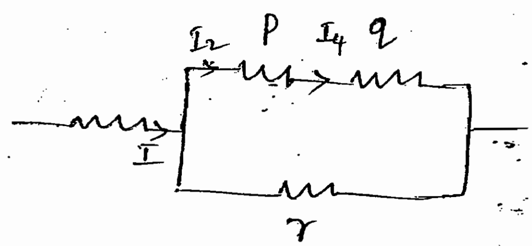
Apply KVL in "BCDFB" loop,

$$I_3 Q - I \cdot S - I_4 q = 0$$

$$\boxed{I_3 Q = I_4 q + IS} \rightarrow (2)$$

$$\therefore \boxed{I_2 = I_4 = I \times \frac{r}{p+q+r}} \rightarrow (3)$$

$\Leftarrow$



$$\frac{eq(1)}{eq(2)} \Rightarrow \frac{I_1 P}{I_3 Q} = \frac{I \cdot \frac{pr}{p+q+r} + IR}{I \cdot \frac{qr}{p+q+r} + I \cdot S}$$

$$\boxed{R = \frac{P}{Q} \times S + \frac{qr}{p+q+r}\left[\frac{P}{Q} - \frac{p}{q}\right]}$$

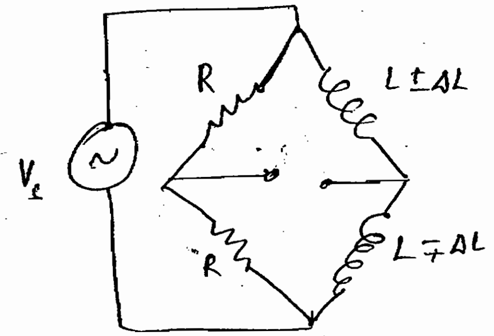
Case (1): If $\frac{P}{Q} = \frac{p}{q} \Rightarrow \boxed{R = \frac{P}{Q} \times S}$

Case (2): If $r = 0 \Rightarrow \boxed{R = \frac{P}{Q} \times S}$

By shorting link resistance, we can convert the Kelvin double bridge into wheatstone bridge so that we can measure medium resistances.

Q13] C. 14] B.

11)



$$V_{01} = V_S\left[\frac{R}{R+R} - \frac{(L\pm\Delta L)}{(L\pm\Delta L)+(L\mp\Delta L)}\right]$$

$$= V_s\left[\frac{1}{2} - \frac{L}{2L} \mp \frac{\Delta L}{2L}\right]$$

$$= V_s\left[\frac{1}{2} - \frac{1}{2} \mp \frac{1}{2}\times 0.1\right]$$

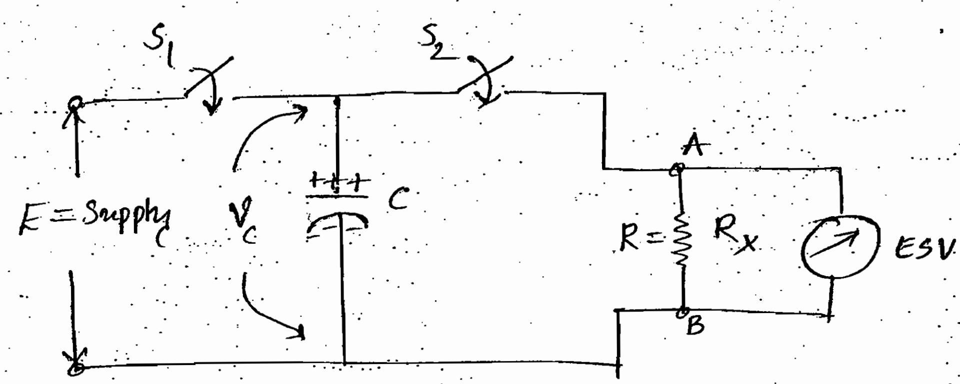
$$\boxed{V_{01} = \mp 0.05 V_s}$$

$$\frac{\Delta L}{L} = 0.1$$

Half bridge : $V_{Th} = V_{02} = \frac{E}{2} \times \frac{\Delta R}{R} = \frac{V_s}{2} \times \frac{\omega \Delta L}{\omega L} = \frac{V_s}{2} \times 0.1$

$$\boxed{V_{02} = 0.05 V_s}$$

⇒ Loss of charge method :— Best method to measure high Resistance



case ① : S_1 is closed ; S_2 is opened

"C" is charged

case ② : S_1 is opened ; S_2 is closed

"C" is discharged exponentially.

ckt behaves like a discharging RC ckt

$v_c = v = E \cdot e^{-t/\tau}$ where $\tau = RC$

$$\frac{v}{E} = e^{-t/\tau}$$

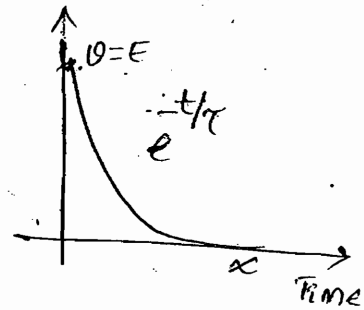
$\frac{E}{v} = e^{t/\tau}$ Apply "log" on both side

$$\ln\left(\frac{E}{V}\right) = \ln e^{(t/\tau)} \Rightarrow \boxed{\ln\left(\frac{E}{V}\right) = \frac{t}{\tau} = \frac{t}{RC}}$$

$$\therefore \boxed{R = \frac{t}{C \times \ln\left(\frac{E}{V}\right)}}$$

$$\ln(x) = \log_e x = 2.303 \log_{10}(x)$$

$$R = \frac{t}{2.303 \times C \log_{10}(E/V)}$$



** gate

$$\boxed{R = \frac{0.4343\, t}{C \times \log(E/V)}} \quad t \to \text{sec}.$$

At $t = 0$ sec $\Rightarrow v = E$

At $t = \infty$ sec $\Rightarrow v = 0$

Adv : It is one of the best method to use in practical ckt to measure the insulation resistance of underground cable.

Dis : The main drawback of this method, to measure the high v/g an electrostatic Ⓥ is required across insulation resistance, which works on the principle of change in capacitance so that the meter capacitance will affect the actual capacitance of the ckt.

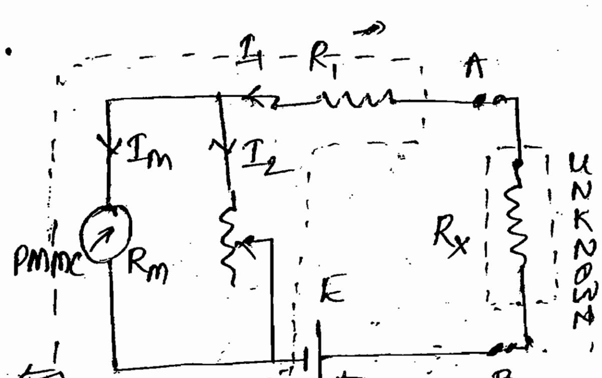
OHMmeter :- Appl. of pmmc

* It is an indicating inst. becoz which consist of PMMC meter.

* Most commonly used meter in industries, series type OHMmeter.

$R_1 \rightarrow$ current limiting R

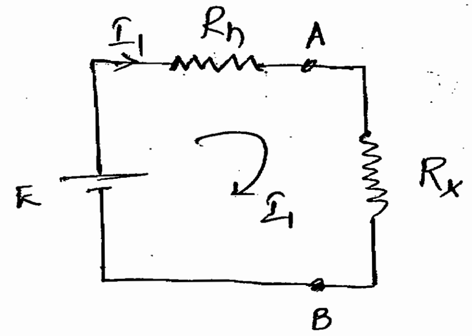
P



Equivalent resistance $= R_h$

Working battery

$$\boxed{R_h = \frac{R_2 \cdot R_m}{\ldots} + R_1}$$



$$\boxed{I_1 = \frac{E}{R_h + R_x}}$$

$$I_m = \frac{I_1 \cdot R_2}{R_2 + R_m}$$

$$\boxed{I_m = \left(\frac{E}{R_h + R_x}\right)\left(\frac{R_2}{R_2 + R_m}\right)} \rightarrow (1)$$

Case (1) : $O.C \Rightarrow R_x = \infty$

$$\boxed{I_1 = 0 \Rightarrow I_m = 0}$$

Case (2) : $S.C \Rightarrow R_x = 0$

$$\boxed{I_1 = I_{SC} = \frac{E}{R_h}}$$

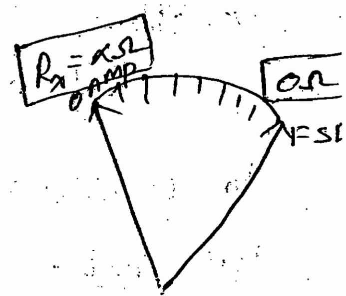
$$\boxed{I_{m\,FSD} = \frac{E}{R_h}\left(\frac{R_2}{R_2 + R_m}\right)} \rightarrow (2)$$

$$\theta \propto \frac{1}{R_{TEST}} \propto \frac{1}{R_x}$$

If $R_x = \infty\Omega \Rightarrow \theta = 0^{\circ}$

If $R_x = 0\Omega \Rightarrow \theta = FSD$

** scale : $\infty\Omega$ to 0Ω



$$\frac{Eq(1)}{Eq(2)} \Rightarrow \boxed{\frac{I_m}{I_{m\,FSD}} = \frac{R_h}{R_h + R_x}}$$

Let $S \Rightarrow$ fraction of FSD

$$S = \frac{I_m}{I_{m\,FSD}}$$

$$\frac{1}{S} = \frac{R_h + R_x}{R_h}$$

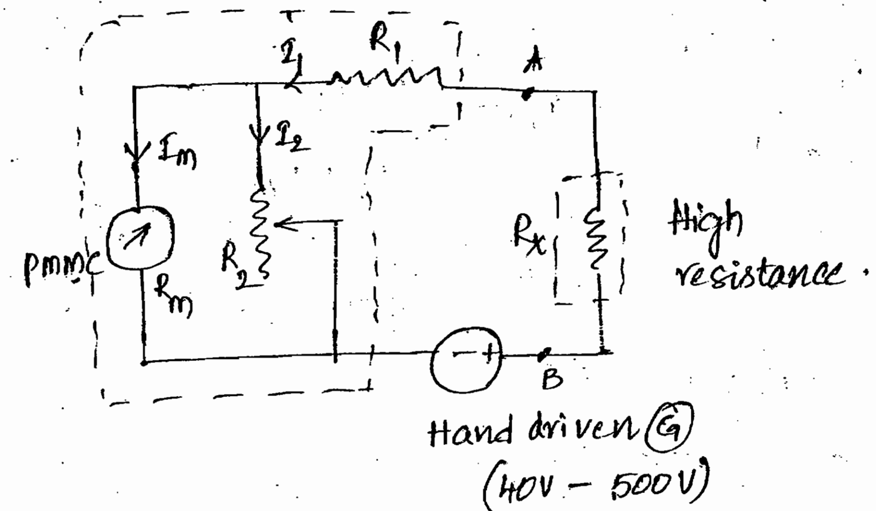
$$\frac{1}{S} = 1 + \frac{R_x}{R_h}$$

$$\boxed{R_x = R_h\left[\frac{1}{S} - 1\right]}$$

Application : 1. It is used to measure the resistance of field coils of Electrical m/c's,

2. Used to measure ...

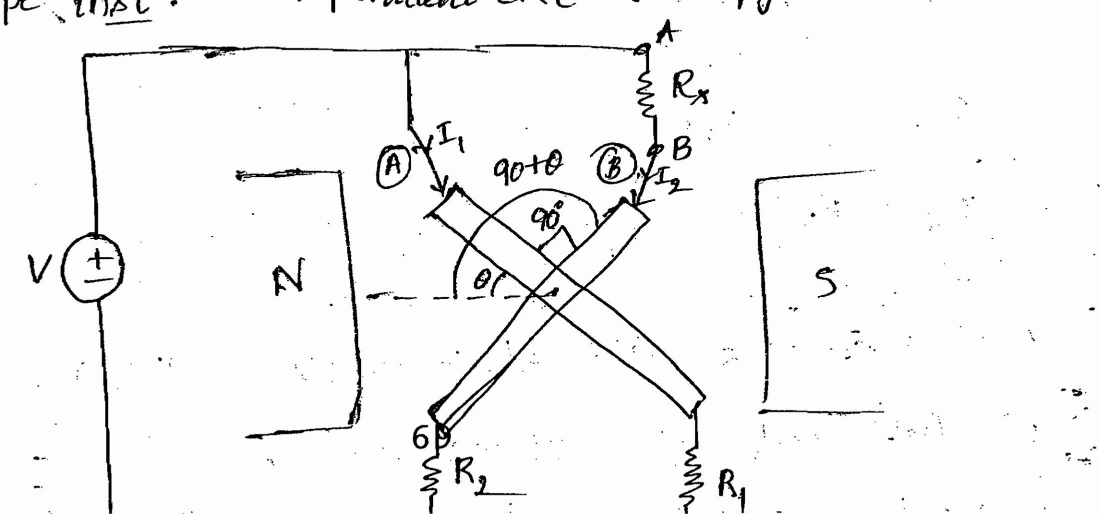
Meggar :– is a ratio type ohmmeter.



Meggar is a ratio type ohmmeter, which consist of a working battery replaced by hand driven (G), which is used to generate the sufficient vlges in order to produce the proper deflection.

The min. vlg required in a meggar inst around 40 volts. The hand driven (G) generates vlges in the order of 500V to 1000V are also possible.

Meggar is a indicating inst. It is a direct reading inst. It is also called moving coil type inst. Equivalent ckt of Meggar :-



d_A d_B

$$BI_1 l \sin(\theta) = BI_2 l \sin(90+\theta)$$

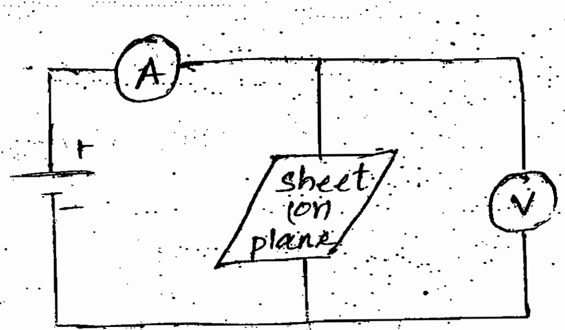
$$\tan(\theta) = \frac{I_2}{I_1}$$

Very small values of "θ"

$$\tan(\theta) = \theta = \frac{I_2}{I_1} = \frac{V/R_2+X}{V/R_1}$$

$$\theta = \frac{R_1}{R_2+R_x} \Rightarrow \boxed{\theta \propto \frac{1}{R_x}}$$

→ Direct deflection method :-



$$R_m = \frac{V}{A} = \rho_s \cdot \frac{l}{A}$$

$$R_m = \frac{V}{A} = \rho_s \times \frac{1\,\text{unit}}{1\,\text{unit}}$$

It is used to measure the <u>surface resistance</u> of an insulating material, for that the material is taken in the form plate or sheet, the sheet dimensions are 1 unit ~~in~~ length and 1 unit ~~of~~ area of cross section.

4.

⇒ Comparision b/w DC & AC bridges :-

DC bridges	AC bridges.
1. Used to measure (R) only	1. Used to measure L, C, M, f
2. Type of Detector :- ↳ D'Arsonel (G)	2. Type of Detector :- (a) Vibrational (G) ⇒ Power freq ↳ * f = 5Hz to 1000Hz (b) Head phones ⇒ Audio freq (or) ↳ * f = 250Hz to 3KHz 4KHz Telephone detectors (c) Tunable Amplifier ⇒ R.F. rang ↳ * f = 10Hz to 100 KHz.
3. Type of supply : ↳ DC battery ↳ Weston std cell	3. Type of supply : ↳ AC supply. It is generated by using crystal oscillator and electronic oscillators. (a) Fixed free oscillators ⇒ upto f = 1000Hz power o/p = 1 watt. (b) Crystal oscillator : upto 100 KHz ; power o/p = 7W (c) Microphone Hummer : f = 500 Hz to 3000 Hz ; 1W (d) Interrupters : f = 50 Hz to 100Hz ; 1W

4. Only magnitude balance

$\boxed{P/Q = R/S}$

$, M, f$

er freq

z

freq

3KHz

4KHz

R.F. rang

Hz.

using

electronic

upto

=1000Hz

watt.

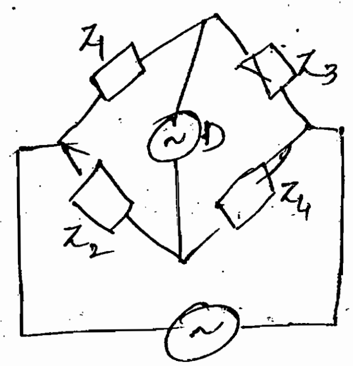
o/p = 7W

z ; 1W

z ; 1W

(e) Alternator ⇒ more power o/p

4. Magnitude & phase angle balance



$$\bar{Z}_1 \bar{Z}_4 = \bar{Z}_2 \bar{Z}_3$$

$$|Z_1| \angle\theta_1 \cdot |Z_4| \angle\theta_4 = |Z_2| \angle\theta_2 \cdot |Z_3| \angle\theta_3$$

$$|Z_1||Z_4| \angle\theta_1 + \theta_4 = |Z_2||Z_3| \angle\theta_2 + \theta_3$$

Magnitude balance :

$$\boxed{|Z_1| = \frac{|Z_2||Z_3|}{|Z_4|}}$$

phase angle :

$$\angle\theta_1 + \theta_4 = \angle\theta_2 + \theta_3$$

$$\boxed{\angle\theta_1 = \angle\theta_2 + \theta_3 - \theta_4}$$

If $\angle\theta_1 = 0^\circ \Rightarrow$ Pure R

If $\angle\theta_1 = 90^\circ \Rightarrow$ Pure L

$\angle\theta_1 = 0$ to $90^\circ \Rightarrow$ R & L

$\angle\theta_1 = -90^\circ \Rightarrow$ pure C

$\angle\theta_1 = -90^\circ$ to $0^\circ \Rightarrow$ R & C , Q1/10 In the above prob. unknow "Z" consist of R & L parameter in series. Find the value of R & L = ?

$$Z_4 = \frac{Z_2 Z_3}{Z_1} = \frac{400\angle 90^\circ \times 300\angle 0^\circ}{200\angle 60^\circ}$$

$$\boxed{Z_4 = 600\angle 30^\circ}$$

⇓

R & L

$$|Z| \angle \theta = R + j\omega L$$

$$\boxed{|Z|\cos(\theta) + j|Z|\sin(\theta) = R + j\omega L}$$

$$R = |Z|\cos(\theta) = 600\cos(30^\circ) = 519.6\Omega$$

$$L = \frac{|Z|\sin\theta}{2\pi f} = \frac{600\sin(30^\circ)}{2\pi \times 50} = 0.95H$$

3] Case ①: $\angle\theta_1 + \theta_4 = \angle\theta_2 + \theta_3$

$$\begin{array}{llcll} \text{Case ①}: & 0 \text{ to } 90^\circ & 0^\circ = & 0 \text{ to } 90 & 0 \quad ✓ \\ \text{Case ②}: & 0 \text{ to } 90^\circ & 0 \text{ to } 90^\circ = & 0^\circ & 0 \quad \times \\ \text{Case ③}: & 0^\circ \text{ to } 90^\circ & 0 \text{ to } 90^\circ = & 0^\circ & 0^\circ \quad \times \\ \text{Case ④}: & 0^\circ \text{ to } 90^\circ & 0^\circ = & 0^\circ \text{ to } 90^\circ & 0^\circ \quad ✓ \end{array}$$

⇒ Which one of the following method is used to measure the self inductance of the coil?

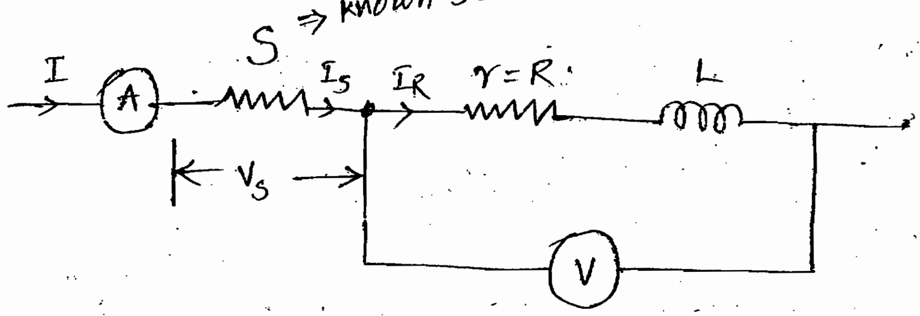
less accurate becoz loading effect
a) V-A method
b) 3-Ⓥ method
c) 3-Ⓐ method

d) Maxwells Inductance bridge
e) Maxwell L-C bridge.
f) Hay's bridge
g) Owen's
h) Anderson

Comparision methods ⇓ More accurate

* All

(1) V – A method :—



$(A) \Rightarrow I = I_R = I_S$

$V_S = I_S \cdot S$

$V_S = (A) \cdot S$

$(V) = I_R\,[R + jwL]$

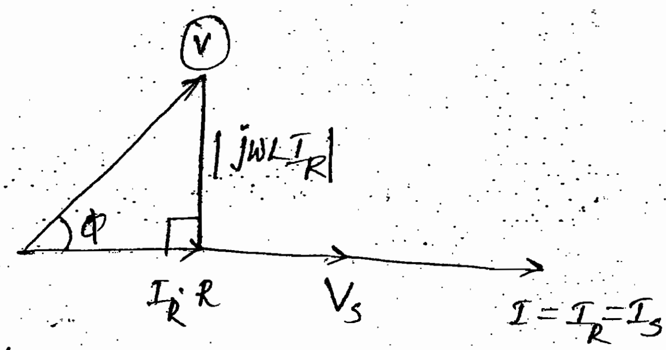
$(V) = I_R R + jwL I_R$

$\bar{I}_R$ lags (V) by "ϕ"

(V) leads $I_R = I$ by "ϕ"

V_S is inphase with $I_S = I$

$$\cos(\phi) = \frac{I_R \cdot R}{(V)}$$



$$\boxed{R = \frac{(V)}{(A)} \cdot \cos\phi}$$

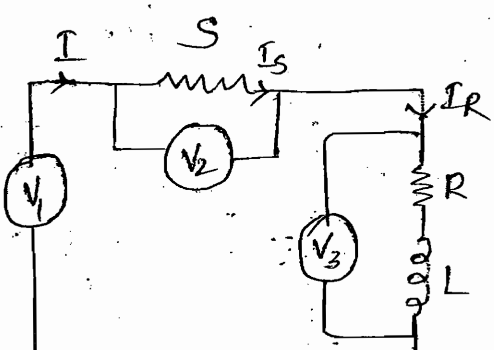
⇓

AC potentiometer.

$$\sin(\phi) = \frac{|jwLI_R|}{(V)}$$

$$\boxed{L = \frac{(V)}{(A)} \; \frac{\sin(\phi)}{2\pi f}}$$

(2) 3-(V) method :



$\Rightarrow I = I_R = I_S$

$$I_S = \frac{V_2}{S} = I_R = I$$

$$\Rightarrow \bar{V}_1 = \bar{V}_2 + \bar{V}_3$$

$$V_1^2 = V_2^2 + V_3^2 + 2V_2V_3\cos\phi$$

gate

$$\boxed{p.f = \cos(\phi) = \frac{V_1^2 - V_2^2 - V_3^2}{2V_2V_3}}$$

$$\Rightarrow \cos(\phi) = \frac{I_R R}{V_3}$$

$$R = \frac{V_3}{V_2/S} \times \cos(\phi)$$

$$\boxed{R = \frac{V_3}{V_2} \times S \cdot \cos(\phi)}$$

$$\Rightarrow \sin(\phi) = \frac{|jωL I_R|}{V_3}$$

$$L = \frac{V_3}{V_2/S} \times \frac{\sin(\phi)}{\omega} \Rightarrow \boxed{L = \frac{V_3}{V_2} \times S \times \frac{\sin\phi}{2\pi f}}$$

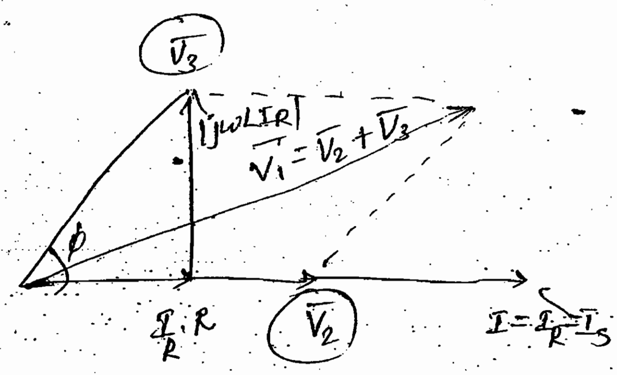
$\Rightarrow V_3 = I_R(R + j\omega L)$?

$$V_3 = I_R R + j\omega L I_R$$

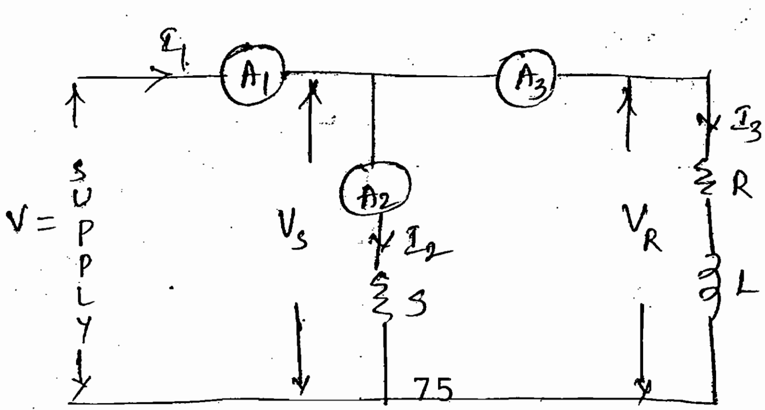
I_R lags V_3 by "ϕ"

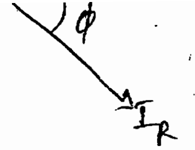
V_3 leads $I_R = I$ by "ϕ"

V_2 is inphase with $I_S = I$



③ 3-(A) method :-





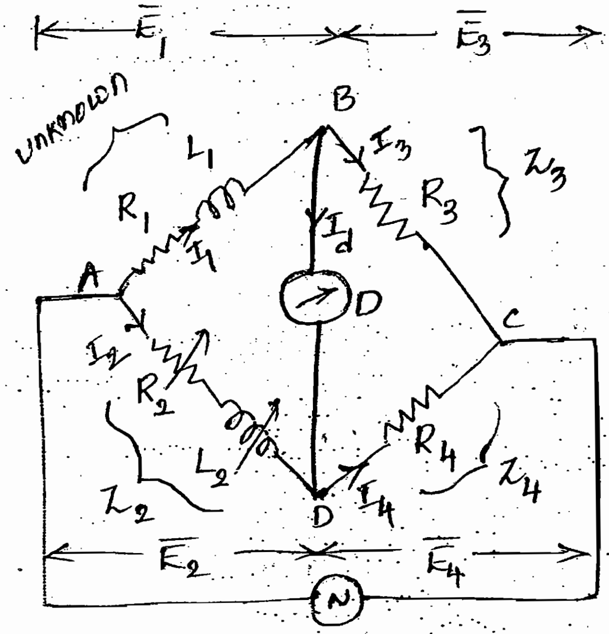
$I_1 = I_2 + I_3$

$$\boxed{I_1^2 = I_2^2 + I_3^2 + 2 I_2 I_3 \cos(\phi)}$$

$$\boxed{p.f = \cos\phi = \frac{I_1^2 - I_2^2 - I_3^2}{2 I_2 I_3}}$$

$*I$

(4) Maxwells inductance bridge :-



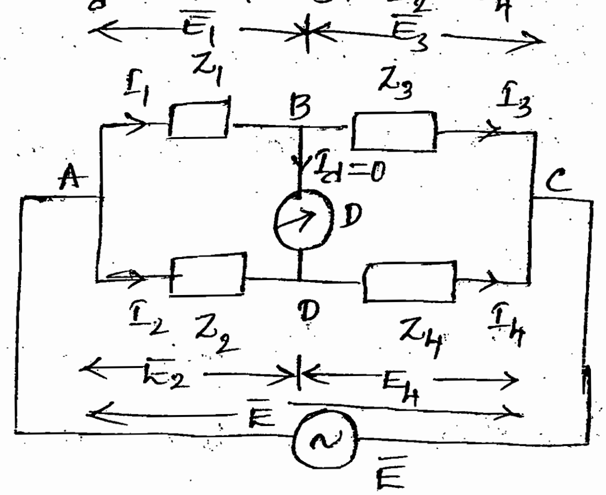
$I_R = I_S$

same →

$\bar{E}$; AC supply.

Bridge is under balanced condition,

$I_d = 0$, $I_1 = I_3$, $I_2 = I_4$



$$\bar{E}_1 = \bar{E}_2 \; ; \; \bar{E}_3 = \bar{E}_4$$

$$\bar{E} = \bar{E}_1 + \bar{E}_3 \quad , \quad \bar{E} = \bar{E}_2 + \bar{E}_4$$

$$\bar{E}_1 = I_1 Z_1 = I_1 R_1 + j\omega L_1 I_1 \; ; \; \bar{E}_2 = I_2 Z_2 = I_2 R_2 + j\omega L_2 I_2$$

$$R_1R_4 + j\omega L_1 R_4 = R_2R_3 + j\omega L_2 R_3$$

Real part :- $R_1 R_4 = R_2 R_3$

$$\boxed{R_1 = \frac{R_2 R_3}{R_4}}$$ common

Img. part :- $L_1 R_4 = L_2 \cdot R_3$

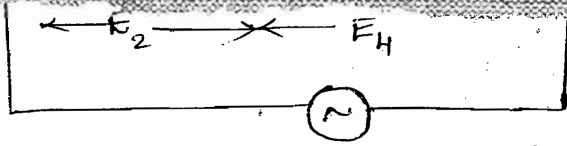
$$\boxed{L_1 = L_2 \cdot \frac{R_3}{R_4}}$$ common

Adv :

1. Balanced eq's are simple
2. Balanced eq's are independent of Supply freq
3. Cost of bridge is lesser becoz no variable capacitor present.

Dis :-

1. This bridge can't suitable for measurement of Q-factor of inductive coils becoz there is no variable capacitor.

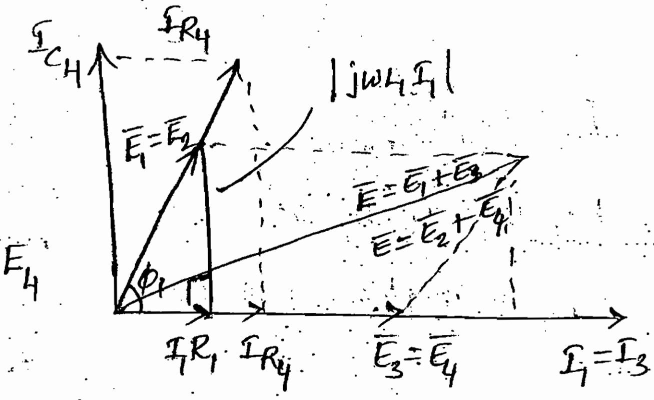


same

I_2 is inphase with E_2

I_{C_4} leads $E_{C_4} = E_4$ by 90°

I_{R_4} is inphase with $E_{R_4} = E_4$



So $\bar{Z}_3 \bar{Z}_4 = \bar{Z}_2 \bar{Z}_3$

$$(R_1 + j\omega L_1)\left(R_4 \parallel \frac{1}{j\omega C_4}\right) = R_2 R_3$$

Real part:

$$\boxed{R_1 R_4 = \frac{R_2 R_3}{R_4}}$$

Imag. part:

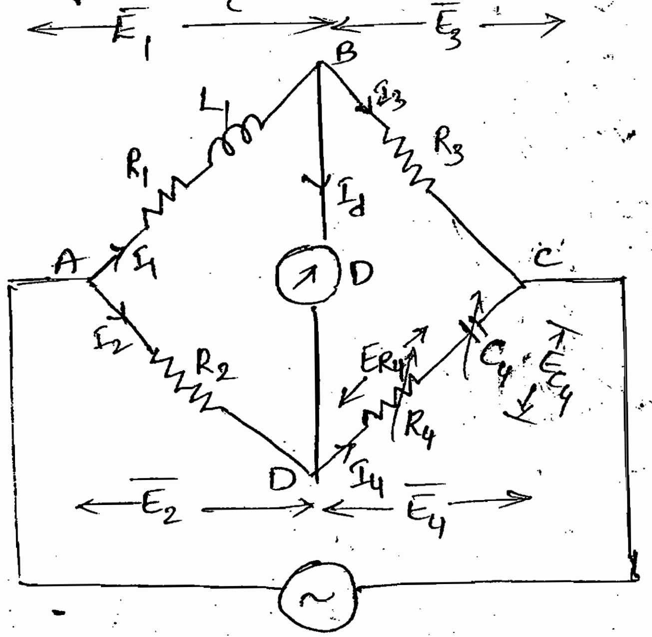
$$\boxed{L_1 = R_2 R_3 C_4}$$

$$Q\text{-factor} = \frac{\omega L_1}{R_1} = \omega \times \frac{R_2 R_3 C_4}{R_2 R_3 / R_4} = \omega R_4 C_4$$

$$\boxed{Q\text{-factor} = \omega R_4 C_4}$$

$Q < 1 \Rightarrow$ low Q

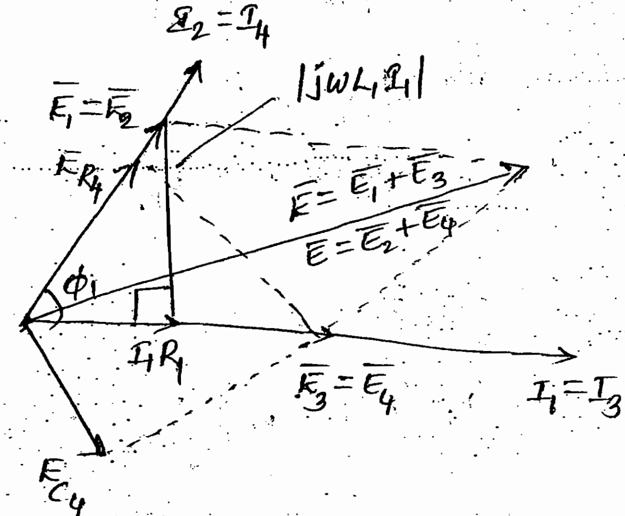
Hay's bridge :-



$\overline{E}_4 = \overline{E}_{C_4} + \overline{E}_{R_4}$

E_{C_4} lags I_4 by 90^0

E_{R_4} is in phase with I_4



Balanced condition :

$$\overline{Z}_1 \overline{Z}_4 = \overline{Z}_2 \overline{Z}_3$$

$$(R_1 + j\omega L_1)\left(R_4 + \frac{1}{j\omega C_4}\right) = R_2 R_3$$

$$(R_1 + j\omega L_1)\left[\frac{1 + j\omega R_4 C_4}{j\omega C_4}\right] = R_2 R_3$$

$$(R_1 - \omega^2 L_1 R_4 C_4) + j\omega\left[L_1 + R_1 R_4 C_4\right] = j\omega R_2 R_3 C_4$$

Real part

$$\boxed{R_1 = \omega^2 L_1 R_4 C_4} \rightarrow (1)$$

Img. part

$$\boxed{L_1 + R_1 R_4 C_4 = R_2 R_3 C_4} \rightarrow (2)$$

subs eq(1) in eq(2),

$$L_1 + \omega^2 R_4^2 C_4^2 L_1 = R_2 R_3 C_4$$

$$\therefore \boxed{L_1 = \frac{R_2 R_3 C_4}{1+\omega^2 R_4^2 C_4^2}} \rightarrow (3)$$

Subs. eq(3) in eq(1),

$$\therefore \boxed{R_1 = \frac{\omega^2 R_2 R_3 R_4 C_4^2}{1+\omega^2 R_4^2 C_4^2}} \rightarrow (4)$$

$$Q = \frac{\omega L_1}{R_1} = \frac{1}{\omega R_4 C_4} \Rightarrow Q = \frac{1}{\underline{\omega R_4 C_4}} \Rightarrow Q \propto \frac{1}{10^3 \times 10^{-6}} \propto 10^3$$

$$\Rightarrow \boxed{Q > 10 \Rightarrow \text{High } Q}$$

$$\therefore \downarrow (\omega R_4 C_4)^2 = \frac{1}{Q^2 \uparrow} \Rightarrow 1 >> \frac{1}{Q^2} \Rightarrow \text{neglect}$$

$$L_1 = \frac{R_2 R_3 C_4}{1+\underbrace{\frac{1}{Q^2}}_{\text{neglect}}} \Rightarrow \boxed{L_1 = R_2 R_3 C_4}$$

$I_1 = I_3$

$$R_1 = \frac{\omega^2 R_2 R_3 R_4 C_4^2}{1+\underbrace{\frac{1}{Q^2}}_{\text{neglect}}} \Rightarrow \boxed{R_1 = \omega^2 R_2 R_3 R_4 C_4^2}$$

Q4] c — uncommon one select

Adv : 1) Balanced eq^n are complex

2) Balanced eq^n are not independent of supply freq.

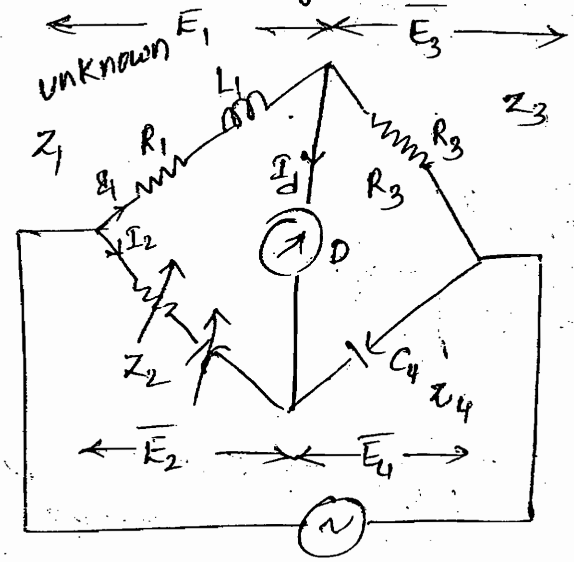
3) Bridge can't suitable for the measurement of Q-value is low.

4) Bridge is high costly.

5) Bridge is used to measure high Q-value

Note: By selecting large value of Q-factor we can make the balanced eq^n independent of supply freq.

⇒ Owen's Bridge : 2-C bridge.



Balanced condition, $\bar{Z}_1 \bar{Z}_4 = \bar{Z}_2 \bar{Z}_3$

$$(R_1 + j\omega L_1)\left(\frac{1}{j\omega C_4}\right) = \left(R_2 + \frac{1}{j\omega C_2}\right) R_3$$

$$\frac{R_1 + j\omega L_1}{j\omega C_4} = \frac{(1 + j\omega C_2 R_2) R_3}{j\omega C_2}$$

$$R_1 C_2 + j\omega L_1 C_2 = R_3 C_4 + j\omega R_2 R_3 C_2 C_4$$

Real part

$$\boxed{R_1 = \frac{R_3 C_4}{C_2}}$$

Img. part :

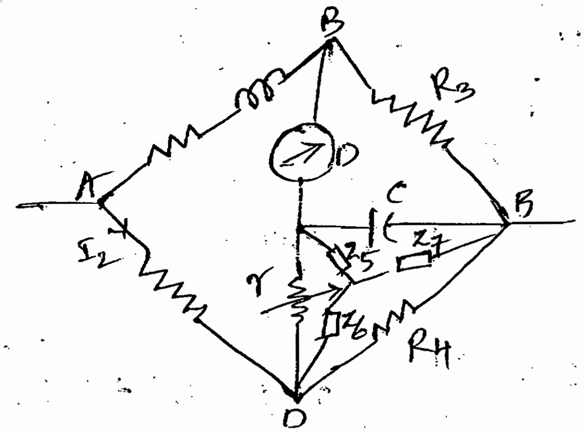
$$\boxed{L_1 = R_2 R_3 C_4}$$

$$\boxed{Q\text{-factor} = \frac{\omega L_1}{R_1} = \omega R_2 C_2}$$ ⇒ medium – Q

$$\boxed{1 < Q < 10}$$

phasor diagram :–

Anderson Bridge :-

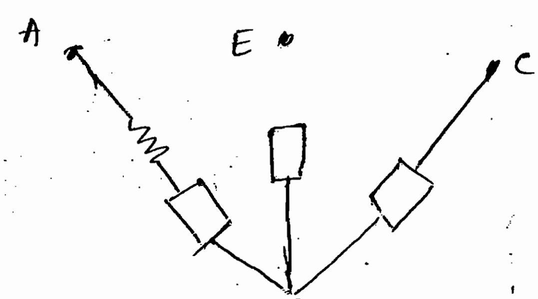


⇒ It is a 5 t/m or point bridge, we can obtain faster balance condition by varying variable resistance connected in series with the Detector.

⇒ Bridge consist of fixed capacitor, by varying variable 'R', under balanced condition, bridge is suitable for measurement of Q-factor of very low Q-coils.

⇒ To analyze the bridge, convert Δ → Y n/w.

$$Z_5 = \frac{r \cdot \frac{1}{j\omega C}}{r + R_4 + \frac{1}{j\omega C}} \qquad Z_6 = \frac{r \cdot R_4}{r + R_4 + \frac{1}{j\omega C}} \qquad Z_7 = \frac{R_4 \times \frac{1}{j\omega C}}{r + R_4 + \frac{1}{j\omega C}}$$



$\to Z_1 Z_4 = (Z_2 + Z_6) Z_3$

$$(R_1 + j\omega L_1)\left[\frac{R_4 \times \frac{1}{j\omega C}}{r + R_4 + \frac{1}{j\omega C}}\right] = \left[R_2 + \frac{r R_4}{r + R_4 + \frac{1}{j\omega C}}\right] R_3$$

Real part :

Remember same Max-L, Max-L-C, Anderson

$$\boxed{R_1 = \frac{R_2 R_3}{R_4}}$$

Img. part :

$$\boxed{L_1 = \frac{C R_3}{R_4}\left[r(R_2 + R_4) + R_2 R_4\right]}$$

Note: This bridge can measure the ~~capacitance~~ Inductance in terms of ~~inductance~~ capacitance.

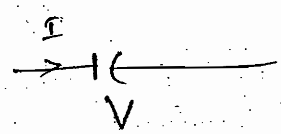
Q which one of the following factor is used to measure the Qualitiness of capacitive instrument?

a) Q-factor ~~b)~~ D-factor c) E-factor d) F-factor.

Q which one of the following bridge is used to measure the capacitance?

a) Desauty b) Modified Desauty c) Schering ~~d)~~ All

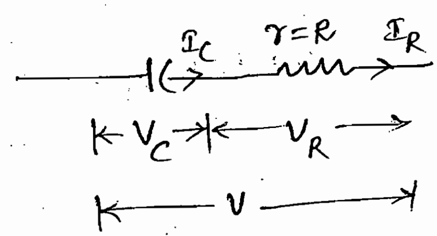
pure capacitor



- → No power loss
- → No power dissipation
- → loss angle $\delta = 0$
- → D-factor $= 0$

$$\boxed{\tan\delta = 0}$$

impure capacitor

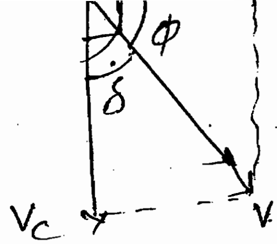


$I = I_C = I_R$

$\bar{V} = \bar{V}_R + \bar{V}_C$

$$\text{D-factor} = \tan\delta = \frac{V_R}{V_C} = \frac{I_R R}{I_C X_C} = \omega RC$$

$$\boxed{\text{D-factor} = \omega RC}$$

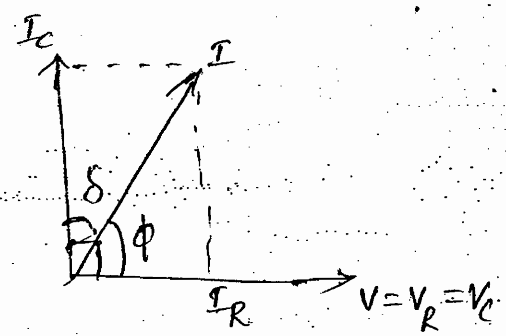


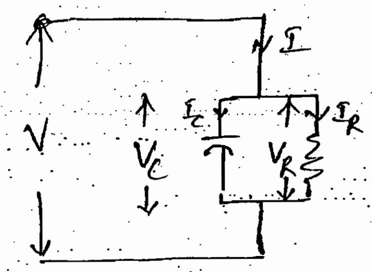
$\delta \rightarrow$ Loss angle

$\delta + \phi = 90^{\circ} \Rightarrow \phi = 90 - \delta$

$$\boxed{\text{lossy p.f} = \cos\phi = \cos(90-\delta) = \sin(\delta)}$$

$\Rightarrow$ Find the Dissipation factor for UG cable and draw the equivalent ckt.





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

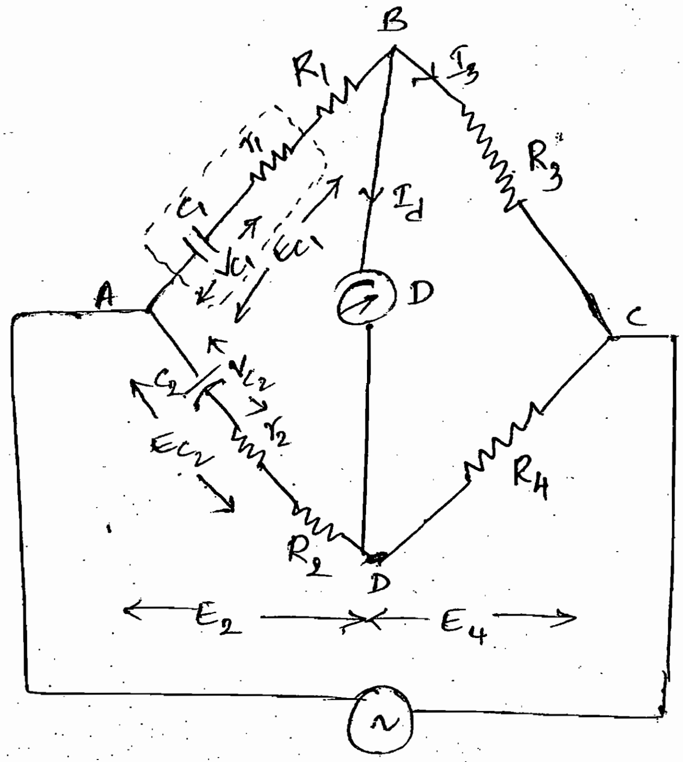
$V = V_R = V_C$ $\quad$ $V = V_R = V_C$

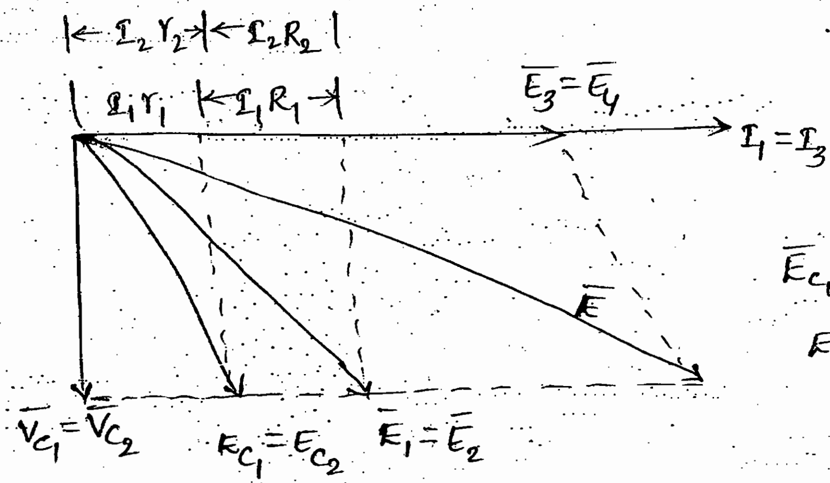
$\phi + \delta = 90^{\circ} \Rightarrow \boxed{\delta = 90 - \phi}$

$$D\text{-factor} = \tan(\delta) = \frac{I_R}{I_C} = \frac{V_R/R}{V_C \times |j\omega C|} = \frac{1}{\omega RC}$$

$\Rightarrow$ Modified De-sauty bridge :-

It is used to measure capacitance and D-factor of pure capacitors as well as impure capacitors whereas Desauty's bridge is used to estimate the capacitance and D-factor of pure capacitors only.





$\overline{E_{C_1}} = \overline{V_{C_1}} + \overline{I_1 r_1}$

$E_1 = E_{C_1} + I_1 R_1$

- Balanced cond, $\overline{Z_1}\,\overline{Z_4} = \overline{Z_2}\,\overline{Z_3}$

$$\left[R_1 + \left(r_1 + \frac{1}{j\omega C_1}\right)\right] R_4 = \left[R_2 + \left(r_2 + \frac{1}{j\omega C_2}\right)\right] R_3$$

Real part :

$$(R_1 + r_1) R_4 = (R_2 + r_2) R_3$$

$$\boxed{r_1 = \frac{R_3}{R_4}(R_2 + r_2) - R_1}$$

$$\boxed{D\text{-factor} = \omega r_1 C_1}$$

Img. part

$$\frac{R_4}{j\omega C_1} = \frac{R_3}{j\omega C_2}$$

$$\boxed{C_1 = C_2 \cdot \frac{R_4}{R_3}}$$

Bridge :-

Substitute $r_1=0$, $r_2=0$ in the modified Desauty bridge.

Balanced condition $\Rightarrow$ $\bar{Z}_1\bar{Z}_4 = \bar{Z}_2\bar{Z}_3$

$$\left[R_1+\left(0+\frac{1}{j\omega C_1}\right)\right]R_4 = \left[R_2+\left(0+\frac{1}{j\omega C_2}\right)\right]R_3 .$$

Real part :

$(R_1+0)R_4 = (R_2+0)R_3$

$$\boxed{R_1R_4 = R_2R_3}$$

img. part :

$$\frac{R_4}{j\omega C_1} = \frac{R_3}{j\omega C_2}$$

$$\therefore \boxed{C_1 = C_2\frac{R_4}{R_3}}$$

same for 3 bridges

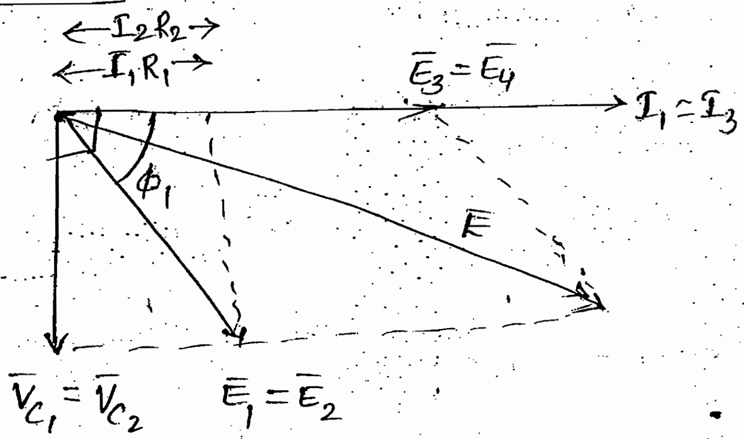
D-factor $= \omega r_1 C_1$

$$\boxed{D\text{-factor} = 0}$$

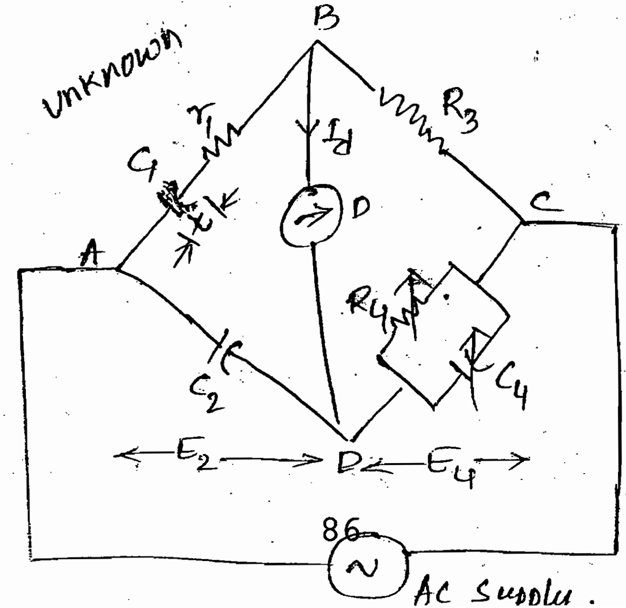
$I_1 r_1$

$-I_1R_1$

$E_1 = V_{c_1} + I_1R_1$



Schering bridge :-



Let $C_2 \rightarrow$ std compressed air capacitor (pure C no dielectric losses)

* It is used to measure the unknown capacitance
* It is used to measure the thickness of dielectric sheets
* It is used to measure permitivity of dielectric sheets
* It is used to measure dielectric power loss.
* It is used to measure lossy p.f
* It is used to measure D-factor
* It is used to measure the capacitance of UG cable.
* To check the healthyness of insulators used in p.s
* To check the healthyness of busings used in t/F.

From Balanced cond, $\bar{Z}_1\bar{Z}_4 = \bar{Z}_2\bar{Z}_3$

$$\left(r_1 + \frac{1}{j\omega C_1}\right)\left(R_4 \,\|\, \frac{1}{j\omega C_4}\right) = R_3 \times \frac{1}{j\omega C_2}$$

$$\boxed{r_1 = R_3 \cdot \frac{C_4}{C_2}} \qquad \boxed{C_1 = C_2 \cdot \frac{R_4}{R_3}}$$

$$\boxed{\text{D-factor} = \omega r_1 C_1}$$

$$\text{D-factor} = \omega \times R_3 \frac{C_4}{C_2} \times C_2 \times \frac{R_4}{R_3}$$

$$\boxed{\text{D-factor} = \omega R_4 C_4}$$

$$\tan\delta = \omega R_4 C_4$$

$$\boxed{\delta = \tan^{-1}(\omega R_4 C_4)}$$

circular plates $\Rightarrow A = \frac{\pi d^2}{4}$

$$C_1 = \frac{A\epsilon}{t} = \frac{A\epsilon_0\epsilon_r}{t}$$

$$\boxed{t = \frac{A\epsilon}{C_1}}$$

$$\boxed{\epsilon = \frac{C_1 t}{A}}$$

Very small values of "δ" $\Rightarrow \delta = \tan(\delta)$

$$\boxed{\text{lossy p.f} = \sin(\delta) = \delta = \tan(\delta) = \text{D-factor}}$$

no dielectric losses)

itance

electric sheath

sheath

$$\therefore \cos(\phi) = \frac{r_1}{|Z_1|} = \frac{r_1}{\left| r_1 + \frac{1}{j\omega C_1} \right|}$$

$$\boxed{\cos(\phi) = \frac{r_1}{\sqrt{r_1^2 + \frac{1}{\omega^2 C_1^2}}}}$$

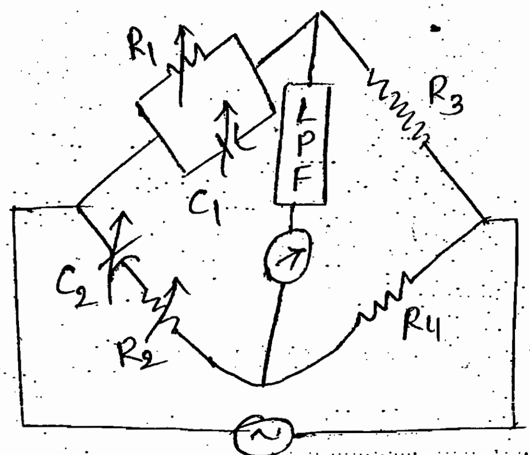
→ Which one of the following bridge is freq sensitivity bridge?

⇒ Wein's Rabinson Bridge :-

UG cable.

in

n t/F



It is used to measure the unknown freq, unknown capacitance, as freq ~~detecting~~ determining element in the harmonic distortion analyser.

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

$\epsilon_0 \epsilon_r$

It is used as freq. determining element in the notch filter application.

Note: is suitable only for sinusoidal sigs and for other sig's it may not get balance easily.

This bridge is more sensitive to harmonics, if any harmonic content is present in the i/p supply, bridge never lead to ~~be~~ Null balance condition. In order to get balance cond, a eliminate the harmonics.

$\rightarrow$

23)

Balanced condition, $\bar{Z}_1 \bar{Z}_4 = \bar{Z}_2 \bar{Z}_3$

$$\left(R_1 \| \frac{1}{j\omega C_1}\right) R_4 = \left(R_2 + \frac{1}{j\omega C_2}\right) R_3 .$$

Real part :

$$R_3 - \omega^2 R_1 R_2 C_1 C_2 R_3 = 0$$

$$R_3 \left[1 - \omega^2 R_1 R_2 C_1 C_2\right] = 0$$

$$\boxed{\omega = \frac{1}{\sqrt{R_1 R_2 C_1 C_2}}} \quad \boxed{f = \frac{1}{2\pi \sqrt{R_1 R_2 C_1 C_2}}}$$

If identical resistance & capacitance

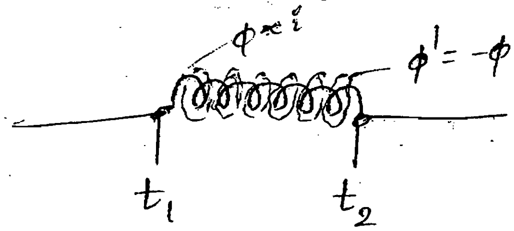
$$\left.\begin{array}{l} \text{If } R_1 = R_2 = R \\ \text{If } C_1 = C_2 = C \end{array}\right\} \Rightarrow \boxed{\therefore f = \frac{1}{2\pi RC}} \quad \& \quad \frac{R_4}{R_3} = \frac{R}{R} + \frac{C}{C}$$

$$\boxed{\frac{R_4}{R_3} = 2}$$

<u>Note</u>: In All AC bridges, every Junction or node to the ground there is a capacitance formed known as earth capacitance which will affect the actual Capacitance of the bridge. To eliminate the effect of node to earth capacitance, <u>WAGNER</u> earthing device is used.

$C_2' = C_2 \| C_{earth}$

⇒ Wire wound resistors :—



$\phi' = -\phi$ ⇒ Bifilar wlg.

$\phi \propto i$

$N\phi \propto Li$

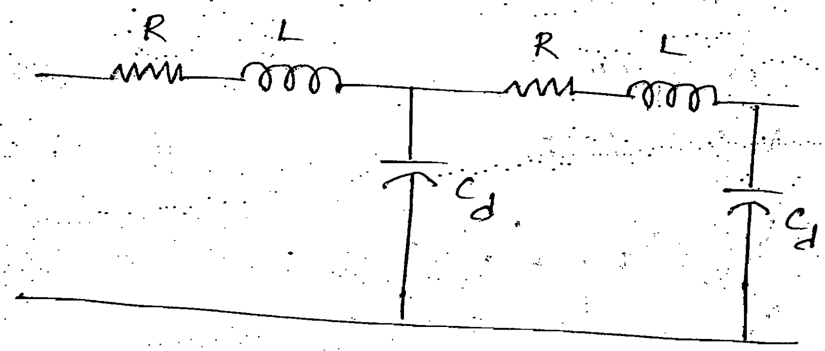
$L = \frac{N\phi}{i} = \frac{\psi}{i}$

$\uparrow X_L = 2\pi \uparrow f L$

23) d

All wire wound resistors will exhibit the inductive and capacitive properties when we are using it with high freq's. To eliminate the effect of Residual inductances a wire which is placed over the wire wound resistors which can produce a flux equal in magnitude but opposite in direction to that of flux produced in wire wound resistor known as "Bifilar wlg".

Equivalent ckt of wire wound Resistor:



C_d → distributed (or) self capacitance of coil.

Which one of the following is used to measure Mutual inductance?

a) Heaviside mutual inductance bridge.

b) CAMPBELL's modified " "

c) Heaviside – CAMPBELL equal ratio bridge

d) CAREY-FOSTER & Heydweillers bridge.

~~e) All~~

to

Known

actual

effect

thing

1 Gearth

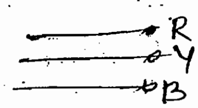
Measurement of power

$$P = \frac{dW}{dt} = \frac{d}{dt}(V \cdot Q) = V \cdot \frac{dQ}{dt} = V \cdot i \quad \text{VoltAmp (or) } \frac{\text{Joule}}{\text{sec}} \text{ (or) watt}$$

power

- DC power
  - ($P_{dc} = V_{DC} \cdot I_{DC}$)
  - 1. (V) – (A) method
  - 2. (A) – (V) "
  - 3. EDM – (W)
- AC power
  - 1-ϕ AC
    - Real power
      - $P = V_{ph} I_{ph} \cos\phi$
      - $P = V_L I_L \cos\phi$
    - Reactive power
      - $Q = V_{ph} I_{ph} \sin\phi$
      - $Q = V_L I_L \sin\phi$
  - 3-ϕ AC
    - Real power
      - $P = 3 V_{ph} I_{ph} \cos\phi$
      - $P = \sqrt{3} \, V_L I_L \cos\phi$
    - Reactive power
      - $Q = 3 V_{ph} I_{ph} \sin\phi$
      - $Q = \sqrt{3} \, V_L I_L \sin\phi$

Q



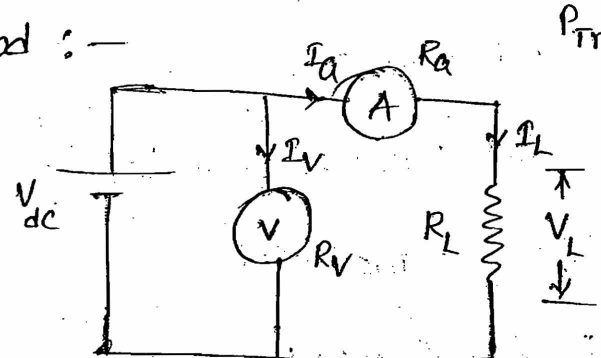
Y	Δ
$V_L = \sqrt{3} V_{ph}$	$V_L = V_{ph}$
$I_L = I_{ph}$	$I_L = \sqrt{3} I_{ph}$
LV, HI	HV, LI

more insulation required

DC power Measurement :

1. (V) – (A) method :–

$P_{True} = V_L I_L$



$P_m = (V) \cdot (A)$

$P_M = (V_L + I_a R_a) I_a$

$P_m = V_L \cdot I_L + I_a^2 R_a$

$$\boxed{P_m = P_T + I_a^2 R_a}$$

$P_m \quad P_T \quad I_a R_a$

Error = +ve $\Rightarrow P_m > P_T$

$$\% \text{ Error} = \frac{P_m - P_T}{P_T} \times 100 = \frac{\cancel{I_a} R_a}{\cancel{I_L} V_L} \times 100 \quad \because I_a = I_L$$

$$\boxed{\% \text{ Error} \downarrow = \frac{R_a}{R_L \uparrow} \times 100}$$

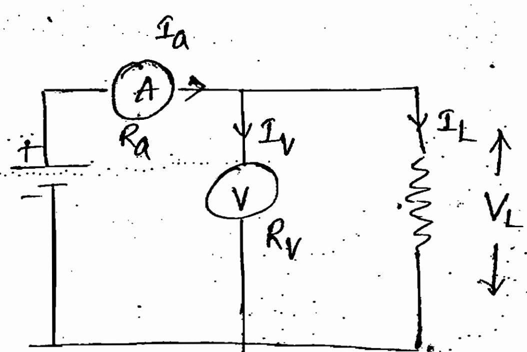
Ideally $R_a = 0$

Q: Measurement of power by using (A)-(V) method the possible error is ___

a) Remain same b) +ve c) -ve d) none.

2. (A)-(V) method :-

$P_{True} = V_L I_L$



$I_a = I_L + I_V$

$P_m = (V) \cdot (A) = V_L \cdot I_a$

$P_m = V_L [I_L + I_V]$

$P_m = V_L I_L + V_L \times \frac{V_L}{R_V}$

$$\boxed{P_m = P_T + \frac{V_L^2}{R_V}}$$

$$\text{Error} = P_m - P_T = \frac{V_L^2}{R_V}.$$

Error = +ve $\Rightarrow P_m > P_T$

$$\% \text{ Error} = \frac{P_m - P_T}{P_T} \times 100$$

$$\% \text{ Error} = \frac{V_L^2 / R_V}{V_L I_L} \times 100$$

$$\boxed{\% \text{ Error} \downarrow = \frac{I_V}{I_L \uparrow} \times 100}$$

$$\boxed{\% \text{ Error} \downarrow = \frac{R_L \downarrow}{R_V} \times 100}$$

Note

In order to get equal error in both the methods, condition should be? Error

(V)-(A) — Error in (A)-(V)

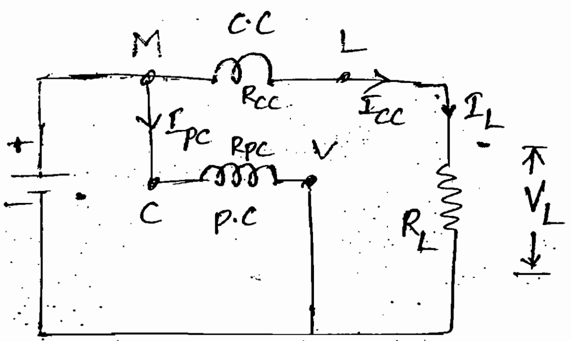
Method Method

$$|I_a^2 R_a| = \left|\frac{V_L^2}{R_V}\right| \Rightarrow |I_L^2 R_a| = \left|\frac{V_L^2}{R_V}\right|$$

$$\Rightarrow \boxed{R_a = \left(\frac{V_L}{I_L}\right)^2 \times \frac{1}{R_V}} \quad **$$

③ EDM Wattmeter method :–

a) (V) – (A) method



M-C short connection:

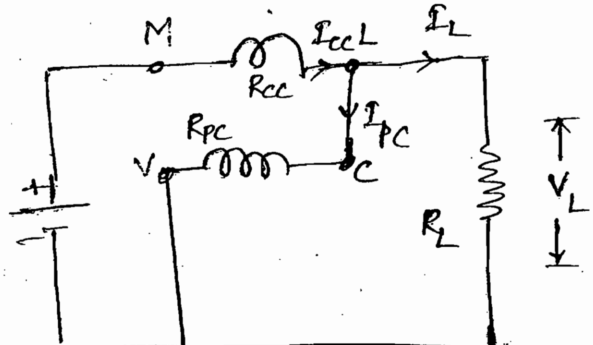
Error $= P_m - P_T = I_L^2 R_{cc}$

$$\boxed{I_{cc} = I_L}$$

$$P_m = P_T + I_{cc}^2 R_{cc}$$

$$\boxed{P_m = P_T + I_L^2 R_{cc}}$$

b) (A) – (V) method :–



L-C short connection:

$$P_m = P_T + \frac{V_{pc}^2}{R_{pc}}$$

$$P_m = P_T + \frac{V_L^2}{R_{pc}}$$

$$\boxed{I_{cc} = I_L + I_{pc}}$$

Error $= P_m - P_T = \frac{V_L^2}{R_{pc}}$

1. Error due to pressure coil inductance.
2. Error due to inter turn capacitance of P.C.
3. Error due to current coil resistance.
4. Very weak operating field so that stray magnetic field error is more pronounced, it can be eliminated by providing ASTATIC arrangement
5. More power consumption.
6. More internal heating problem.
7. Temp. error is more.
8. Error due to coil connections.
9. Error due to low power factor of the loads i.e in case of LPF Loads an ordinary (W) can't indicate proper reading.

Case(i):

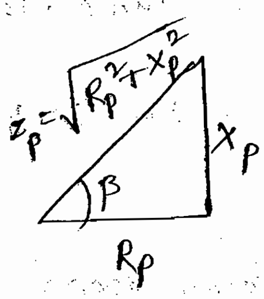
Error due PC inductance for lagging loads:

Let $Z_{pc} = R_p + jX_p$; $Z_{pc} \Rightarrow$ PC impedance.

$$|Z_p| = \sqrt{R_p^2 + X_p^2} \;\; \& \;\; \beta = \tan^{-1}\left(\frac{X_p}{R_p}\right)$$

Let $\beta \rightarrow$ Impedance Angle of P.C

$$\therefore \cos(\beta) = \frac{R_p}{Z_p}$$



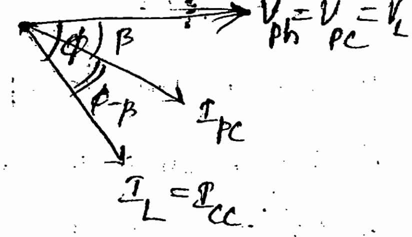
$$\therefore \boxed{Z_p = \frac{R_p}{\cos(\beta)}}$$

I_{pc} lags $V_{pc} = V_L$ by "β"

I_L lags V_L by "ϕ"
lead

$$\therefore I_{pc} = \frac{V_{pc}}{\;} = \frac{V_L}{\;}$$

$\angle I_{pc} \ \& \ I_{cc} = \phi - \beta$



$$T_d = I_{pc} \cdot I_{cc} \cos(\angle I_p \ \& \ I_{cc}) \cdot \frac{dM}{d\theta}$$

$$\boxed{T_d = \frac{V_L \cdot I_L \cdot \cos(\beta) \cdot \cos(\phi - \beta)}{R_p} \frac{dM}{d\theta}} \rightarrow (2)$$

Q1:

$$C.F \times P_M = P_T \Rightarrow \boxed{C.F = \frac{P_T}{P_M}}$$ correction factor

$$\frac{Eq(1)}{Eq(2)} \Rightarrow \boxed{\frac{P_T}{P_M} = C.F = \frac{\cos(\phi)}{\cos(\beta) \times \cos(\phi - \beta)}}$$ $\Leftarrow$ conv.(5)

$$\boxed{C.F\downarrow = \frac{\cos\phi}{\cos(\beta\uparrow) \times \cos(\phi - \beta)\uparrow}}$$

Always $\Rightarrow C.F < 1 \Rightarrow$ lag.

$$\% \text{ Error} = \frac{P_M - P_T}{P_T} \times 100 = \left(\frac{P_M}{P_T} - 1\right) \times 100$$

$$\% \text{ Error} = \left(\frac{1}{C.F} - 1\right) \times 100$$

$$\% \text{ Error} = \left[\frac{\cos(\beta)\cos(\phi - \beta)}{\cos(\phi)} - 1\right] \times 100$$

$$\boxed{\% \text{ Error}\uparrow = [\tan\phi \cdot \tan\beta\uparrow] \times 100}$$

$$\boxed{\text{Error} = +ve \Rightarrow P_M > P_T}$$

Note :

1. In case of lagging loads becoz of error due to pressure coil inductance, always the inst reads high produced error is +ve always correction factor less than 1.

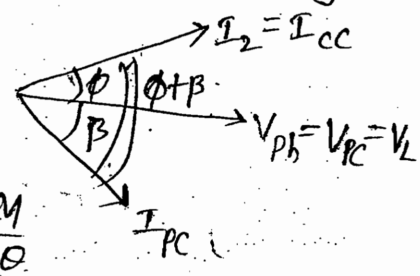
$I_h = V_{PC} = V_L$

... can't indicate proper reading in case of LPF loads even though PC & C.C's are fully excited, the produced torque is lesser, Error due to PC inductance tends to be large, which increases appreciably with decrease in P.F.

Q15]

case (2): Error due to P.C inductance for leading

$\angle I_{PC} \ \& \ I_{CC} = \phi + \beta$.



$$\cancel{C.F =} \ T_d = \frac{V_L I_L \cdot \cos\beta \cdot \cos(\phi+\beta)}{R_p} \frac{dM}{d\theta} \rightarrow (3)$$

$$\boxed{C.F = \frac{\cos\phi}{\cos\beta \times \cos(\phi+\beta)}}$$

Always $\Rightarrow$ CF > 1 $\Rightarrow$ LEAD.

$$\% \text{ Error} = \frac{P_m - P_T}{P_T} \times 100$$

$$\boxed{\% \text{ Error} = -[\tan(\phi) \cdot \tan(\beta)] \times 100}$$

$$\boxed{\text{Error} = -ve \Rightarrow P_m < P_T}$$

Note: $\% \text{ Error} = \frac{P_m - P_T}{P_T} \times 100 = +[\tan\phi - \tan\beta]$

$$P_m - P_T = \left[\frac{\sin\phi}{\cos\phi} \times \tan(\beta)\right] \times V_L I_L \cos\phi$$

to

$\boxed{P_m = P_T + V_L I_L \sin\phi \cdot \tan(\beta)}$ & $\boxed{P_m = P_T - V_L I_L \sin\phi \tan\beta}$

high

$\hookrightarrow$ +ve $\Rightarrow$ LAGGING LOAD

$\hookrightarrow$ -ve $\hookrightarrow$ LEADING

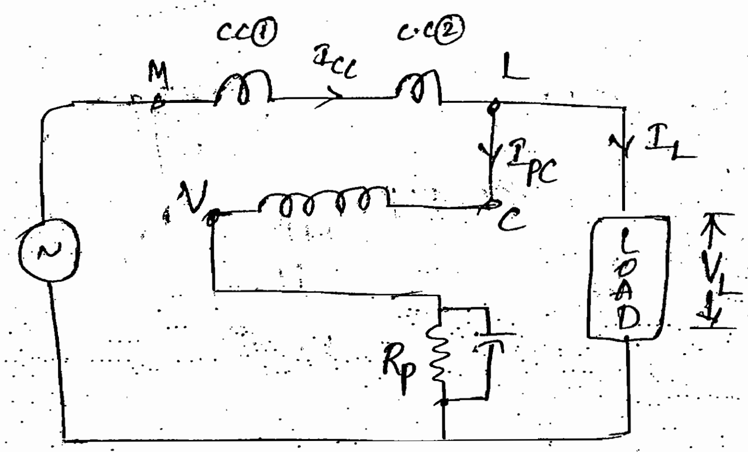
or

Remedy : Error due to P.C inductance can be eliminated by connecting a capacitor in ||el with R_p whose value, $C = \frac{0.41 L_p}{R_p^2}$ ⇒ practical ⇒ Exact.

$\boxed{C = \frac{L_p}{R_p^2}}$ ⇒ Theoritical ⇒ Approx

⇒ Error due to coil connections :-

a) L-C short connection :-

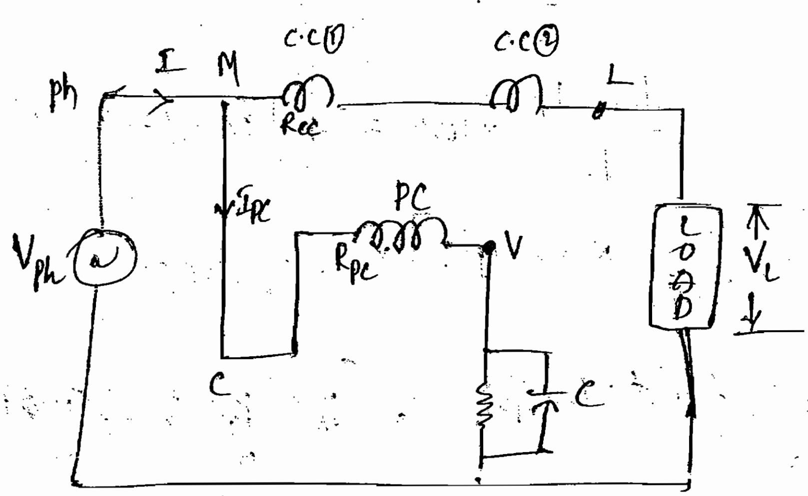


$$P_M = V_{pc} \cdot I_{cc} \cdot \cos(\phi) = V_{pc} \left[I_L + I_{pc} \right] \cdot \cos(\phi)$$

$$P_{LC\,short} = V_L I_L \cos\phi + V_{pc} \cdot I_{pc} \cos(\phi)$$

$$P_{LC\,short} = P_T + V_{pc} \cdot I_{pc} \cdot \cos(\phi)$$

b) M-C short connection :-



$P_m = V_{pc} \cdot I_{cc} \cdot \cos\phi$

$P_{MC\,short} = V_L I_L \cos\phi$

$P_{MC\,short} = P_T$

wlg is required in order to compensate the power loss is pressure coil.

Compensated coil is placed over the c.c connected in series with pressure coil, so that flux produced in c.c due to p.c current (ϕ_{pc}) can be cancelled out.

Compensated coil produces flux is equal in magnitude but opp in direction to that of flux produced in c.c due to ~~by~~ p.c current. (ϕ_{pc}).

pending

1. An ordinary (W) can't indicate correct reading in case of LPF load.

$T_d \propto V_{PC} \cdot I_{CC} \cos\phi$

$\theta \propto \cos\phi$

$\theta \propto p.f$

2. Error due to pressure coil inductance increases appreciably with decrease in p.f.

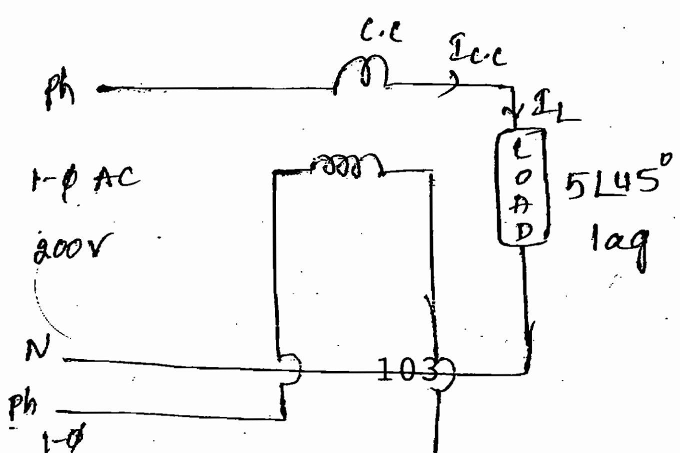
$\%\ \text{Error} = +\left[\tan(\phi) \cdot \tan(\beta)\right] \times 100$.

Special features of LPF (W):

1. PC must be connected on Load side.
2. Compensating coil is connected to compensate the power loss in pressure coil.
3. A capacitor is connected across R_p to cancel the inductive reactance of p.c.
4. ~~An~~ ~~order~~ ~~to~~ PC resistance is slightly reduced so that corresponding torque reduces.

$$T_d \uparrow = \frac{V_{PC} \cdot I_{cc} \cdot \cos\phi}{\downarrow R_p} \frac{dM}{d\theta}$$

Q) Find the (W) reading from the following diagram:



Sol: $I_{cc} = I_L = \dfrac{200\angle 0}{5\angle 45^\circ} = 40\angle -45^\circ$

ref always $\rightarrow V_{PC} = 100\angle 0^\circ$

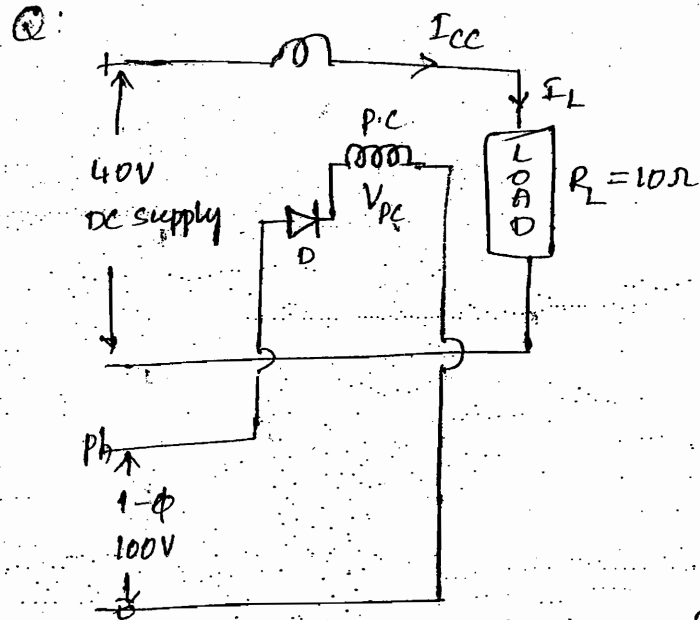
$$\angle V_{PC} \,\&\, I_{cc} = (0^\circ) - (-45^\circ) = 45^\circ$$

$$P = V_{PC} \cdot I_{cc} \cdot \cos(\angle V_{PC} \,\&\, I_{cc})$$

$$P = 100 \times 40 \times \cos(45^\circ)$$

$$\boxed{P = 2.82\ KW}$$

Q:



Sol $\Rightarrow I_{cc} = I_L = \dfrac{40}{10} = 4A$

$$V_{PC} = V_{DC} = \frac{V_M}{\pi} = \frac{\sqrt{2}}{\pi} V_{AC}$$

$$= 0.45 V_{AC}$$

$$V_{PC} = 0.45 \times 100 = 45V$$

$$P = V_{PC} \cdot I_{cc} = 45 \times 4$$

$$\boxed{P = 180\,W}$$

$\frac{8}{12}$)

$$I_L = \frac{200\angle 0^\circ}{5\angle 36.6^\circ} = 40\angle -36.86$$

$$CT = \frac{50}{5} \Rightarrow 50A - 5$$

$$40\angle -36.86 - ?$$

$$\boxed{I_{cc} = 4\angle -36.86}$$

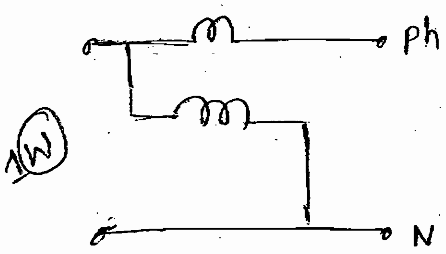
$$V_{PC} = 200\angle 0^\circ$$

$$\angle V_{PC} \,\&\, I_{cc} = (0^\circ) - (-36.86^\circ) = 36.86^\circ$$

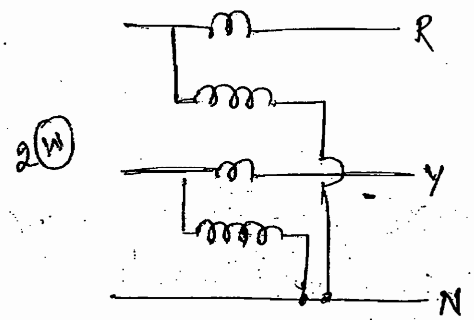
$$P = 200 \times 4 \times \cos(36.86^\circ)$$

$$\boxed{P = 640\,W}$$

1-ϕ, 2-wire s/m :



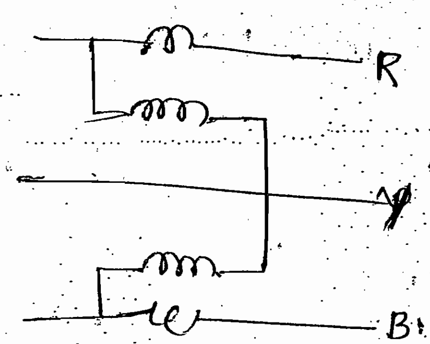
2-ϕ, 3-wire s/m:



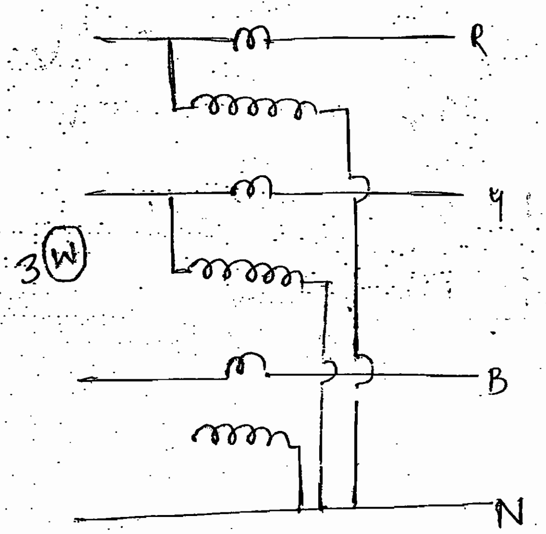
3-ϕ, 3 wire $\Rightarrow$ 2 (W)
unbalanced (or) balanced.

$\Rightarrow$ 3

3



3-ϕ, 4-wire s/m :

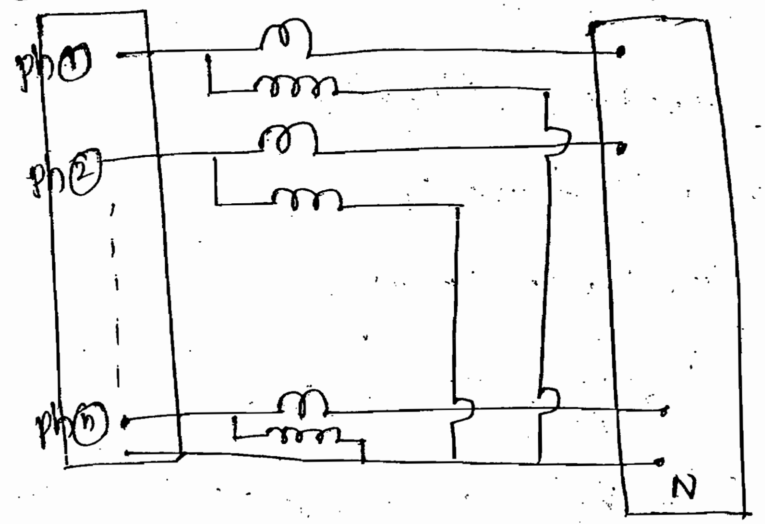


3-ϕ, 4-wire 1 (W)
balanced s/M

Acc to BLONDEL's theorem in a N-ϕ s/M, if there is neutral available ; no. of wattmeters required is n

* If there is no neutral point is available, no of wattmeters required is $(n-1)$

BLONDEL's ph THEOREM :



⇒ 3-ϕ Real power measurement by 2-(W) method.

(or)

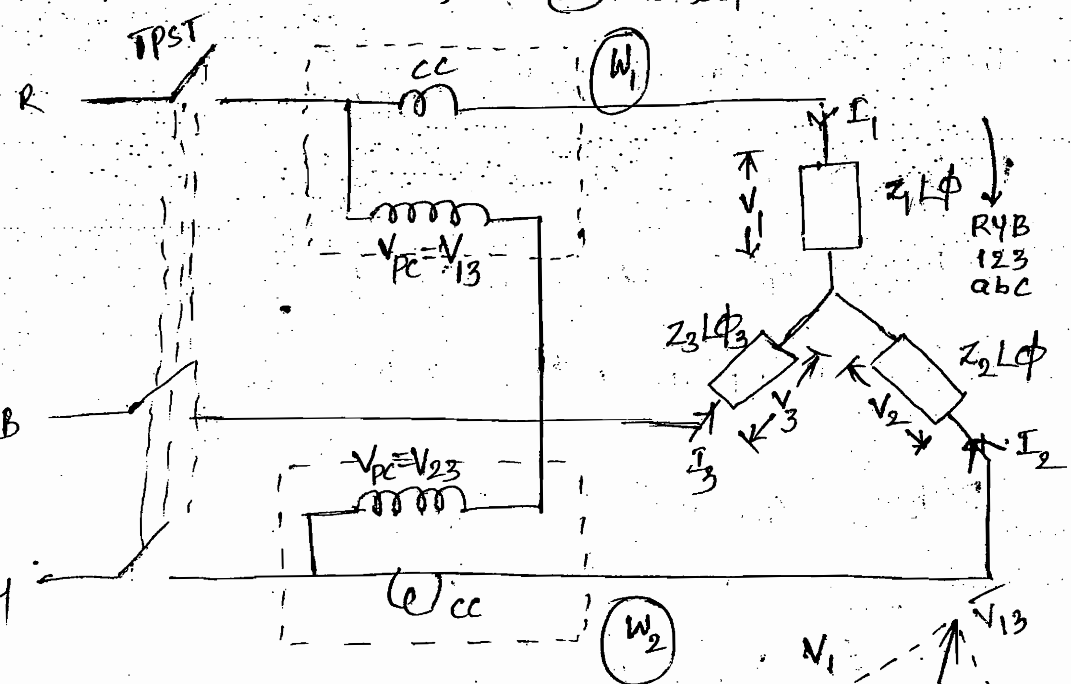
3-ϕ Reactive power measurement by 2-(W) method.

(or)

P.F of the load by 2-(W) method

(or)

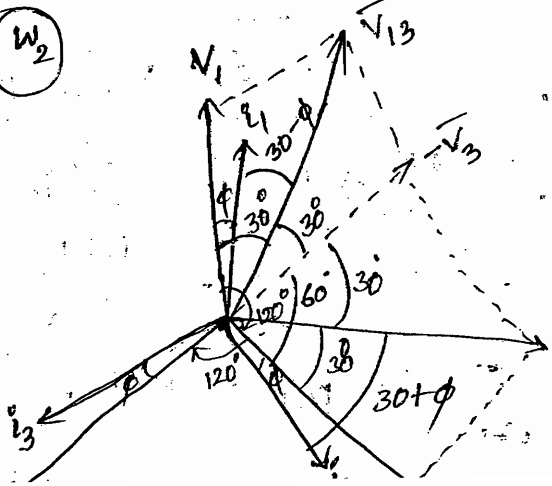
phase angle of Load by 2-(W) method



if

$$\bar{V}_{13} = \bar{V}_1 - \bar{V}_3$$

$$V_{13} = \bar{V}_1 + -\bar{V}_3$$



let $V_1 = V_2 = V_3 = V_{ph}$

let $I_1 = I_2 = I_3 = I_{ph}$

$W_1 \Rightarrow P_1 = V_{PC} \cdot I_{CC} \cdot \cos \angle V_{PC} \,\&\, I_{CC}$

$\therefore P_1 = V_{13} \cdot I_1 \cdot \cos \angle V_{13} \,\&\, I_1$

$$\boxed{P_1 = \sqrt{3}\, V_{ph} \cdot I_{ph} \cdot \cos(30-\phi)} \rightarrow (1)$$

$W_2 \Rightarrow P_2 = V_{23} \cdot I_2 \cdot \cos(\angle V_{23} \,\&\, I_2)$

$$\boxed{P_2 = \sqrt{3}\, V_{ph}\, I_{ph} \cos(30+\phi)} \rightarrow (2)$$

$$P = P_1 + P_2 = \sqrt{3}\, V_{ph} I_{ph} \left[\cos(30-\phi) + \cos(30+\phi)\right]$$

$$P = \sqrt{3}\, V_{ph} I_{ph} \times 2\cos(30^\circ) \cos(\phi)$$

$$\boxed{P = P_1 + P_2 = 3\, V_{ph} I_{ph} \cos(\phi)} \longrightarrow (3)$$

Acc. to BLONDEL'S theorem, the total power consumed by the load is the sum of W readings.

$$P_1 - P_2 = \sqrt{3}\, V_{ph} I_{ph} \left[\cos(30-\phi) - \cos(30+\phi)\right]$$

$$P_1 - P_2 = \sqrt{3}\, V_{ph} I_{ph} \times 2\sin(30^\circ) \times \sin\phi$$

$$\boxed{P_1 - P_2 = \sqrt{3}\, V_{ph} I_{ph} \cdot \sin\phi} \longrightarrow (4)$$

$$P_1 - P_2 = \frac{3\, V_{ph} I_{ph} \sin\phi}{\sqrt{3}} = \frac{Q}{\sqrt{3}}$$

$$\boxed{\therefore Q = \sqrt{3}\left[P_1 - P_2\right]}$$

$$\frac{Eq(4)}{(3)} \Rightarrow \tan\phi = \frac{\sqrt{3}\left[P_1 - P_2\right]}{P_1 + P_2} \Rightarrow \phi = \tan^{-1}\left(\frac{\sqrt{3}\left[P_1 - P_2\right]}{P_1 + P_2}\right)$$

$$\Rightarrow \phi = \tan^{-1}\left[\frac{Q}{P}\right]$$

$$p.f = \cos\phi = \cos\left[\tan^{-1}\left[\frac{\sqrt{3}\left[P_1 - P_2\right]}{P_1 + P_2}\right]\right]$$

$$P.F = \cos\phi = \frac{P}{\sqrt{P^2+Q^2}} = \frac{P}{S}.$$

⇒ In 3-φ power measurement by 2-W method, one of the (W) reads, another (W) reads zero then the nature of load ?

⇒ In the above problem, 2-W readings are equal in magnitude with opposite in sign then the nature of load ?

ϕ	$\cos(\phi)$	$P_1=\sqrt{3}V_pI_p\cos(30-\phi)$	$P_2=\sqrt{3}V_pI_p\cos(30+\phi)$	Relation b/ P_1 & P_2
$\phi=0^\circ$	1 ⇒ UPF	$P_1=\frac{3}{2}V_{ph}I_{ph}$	$P_2=\frac{3}{2}V_{ph}I_{ph}$	$P_1=P_2$
$\phi=30^\circ$	p.f = 0.866 lag	$P_1=\sqrt{3}V_{ph}I_{ph}$	$P_2=\frac{\sqrt{3}}{2}V_{ph}I_{ph}$	$P_2=P_1/2$
$\phi=60^\circ$	p.f = 0.5 lag	$P_1=\frac{3}{2}V_{ph}I_{ph}$	$P_2=0$	P_1=reads, P_2=
$\phi=75^\circ$	p.f = 0.259	$P_1=1.22\,V_{ph}I_{ph}$	$P_2=-0.44V_{ph}I_{ph}$	P_1=reads, P_2=-
$\phi=90^\circ$	p.f = 0 ZPF	$P_1=\frac{\sqrt{3}}{2}V_{ph}I_{ph}$	$P_2=\frac{-\sqrt{3}}{2}V_{ph}I_{ph}$	$P_1=-P_2$, P_2=-

<u>Note:</u>

$$\left.\begin{array}{c} 0 < p.f < 0.5 \\ (or) \\ 60^\circ < \phi < 90^\circ \end{array}\right\} \Rightarrow P_2 = -Ve$$

4/10) $P_1 = 10.5KW$; $P_2 = -2.5KW$

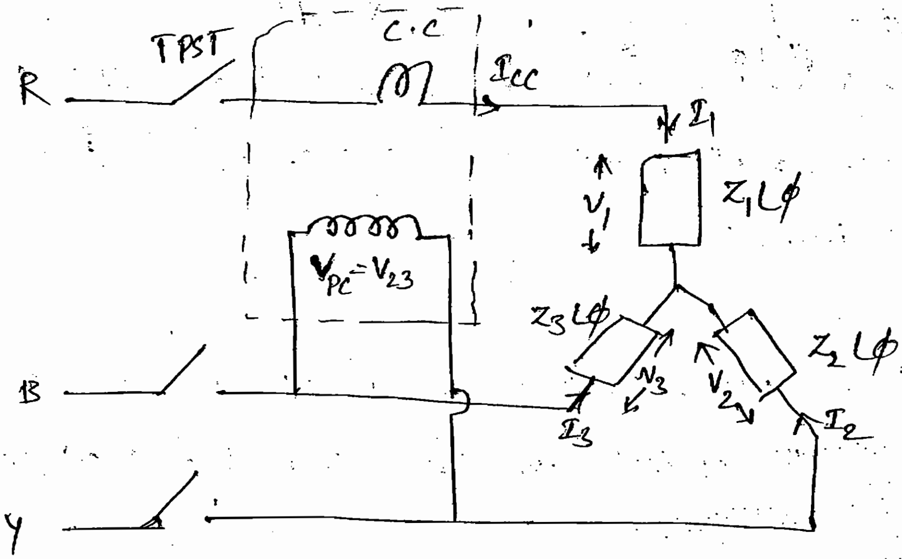
① $P = P_1+P_2 = 8KW$ ② $Q=\sqrt{3}(P_1-P_2) = 13\sqrt{3}$ KVAR

③ $\phi = \tan^{-1}\left(\frac{Q}{P}\right) = 70.4^\circ$ ④ $P.f = \cos(70.4) = 0.334$

5/10) $P_1 = 3KW$; $P_2 = -1KW$ ⇒ Before " "
$P_2 = 1KW$ ⇒ After reversing c.c

① $P = P_1+P_2 = 4KW$ ② $Q=\sqrt{3}(P_1-P_2) = 4\sqrt{3}$ KVAR

③ $\phi = \tan^{-1}\left(\frac{Q}{P}\right) = 73.89$ ④ $P.f = \cos(73.89) = 0.277$



$$W \Rightarrow V_{PC}\, I_{CC} \cdot \cos \angle V_{PC} \;\&\; I_{CC}$$

$$W \Rightarrow V_{23} \cdot I_1 \cdot \cos \angle V_{23} \;\&\; I_1$$

$$W \Rightarrow \sqrt{3}\, V_{ph}\, I_{ph} \cos(90-\phi)$$

$$\boxed{W \Rightarrow \sqrt{3}\, V_{ph}\, I_{ph} \sin(\phi)}$$

Total Reactive power = Q

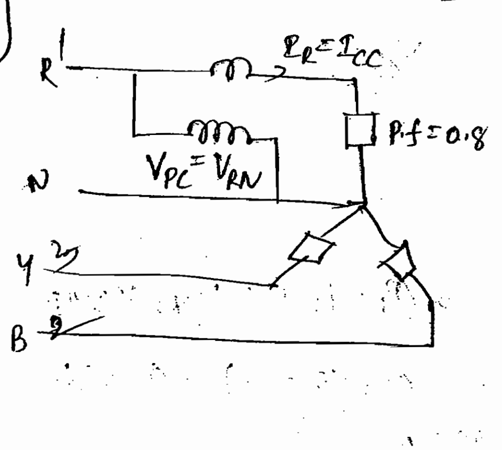
$$Q = 3 V_{ph} I_{ph} \sin(\phi)$$

$$Q = \sqrt{3} \left[\sqrt{3}\, V_{ph} \cdot I_{ph} \cdot \sin\phi \right]$$

$$\boxed{Q = \sqrt{3}\,[W]}$$

Q9

Q11]



$$P = V_{PC} \cdot I_{CC} \cdot \cos(\phi)$$

$$P = V_{RN} \cdot I_R \cdot \cos(\phi)$$

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

$$400 = V_{ph} I_{ph} \times 0.8$$

$$\boxed{V_{ph} I_{ph} = 500}$$

$$W = \sqrt{3} \times 500 \times 0.6 = 519.6$$

Assume RYB phase sequence

$$V_R = V_{RN} = V_{Ph} \angle 0^\circ = \frac{V_L}{\sqrt{3}} \angle 0^\circ = \frac{415}{\sqrt{3}} \angle 0^\circ$$

$$V_y = V_{YN} = V_{Ph} \angle -120^\circ = \frac{V_L}{\sqrt{3}} \angle -120^\circ = \frac{415}{\sqrt{3}} \angle -120^\circ$$

$$\boxed{V_{PC} = V_B = V_{BN}} = V_{Ph} \angle -240^\circ = \frac{V_L}{\sqrt{3}} \angle -240^\circ = \frac{415}{\sqrt{3}} \angle -240^\circ$$

$$V_{RY} = V_{RN} - V_{YN} = \frac{415}{\sqrt{3}} \angle 0^\circ - \frac{415}{\sqrt{3}} \angle -240^\circ$$

$$= \frac{415}{\sqrt{3}} \left[1.5 + j\frac{\sqrt{3}}{2}\right] = 415 \angle 30^\circ$$

$$I_{cc} = \frac{V_{RY}}{Z\angle\phi} = \frac{415\angle 30^\circ}{100\angle 36.86^\circ} = 4.15\angle -6.86^\circ$$

$$V_{PC} = V_{BN} = \frac{415}{\sqrt{3}} \angle -240^\circ$$

$$\angle V_{PC} \,\&\, I_{cc} = (-240^\circ) - (-6.86^\circ) = -233.14$$

$$P = V_{PC} \cdot I_{cc} \cdot \cos(\angle V_{PC} \,\&\, I_{cc})$$

$$P = \frac{415}{\sqrt{3}} \times 4.15 \times \cos(-233.14^\circ)$$

$P = -597\,W \Rightarrow$ RYB sequence.

$P = +597\,W \Rightarrow$ RBY "

Q9) $V_L = V_{ph}$; Assume abc phase sequence.

$$V_{ab} = V_{Ph} \angle 0^\circ = V_L \angle 0^\circ = 400\angle 0^\circ$$

$$V_{PC} = V_{bc} = V_{Ph} \angle -120^\circ = V_L \angle -120^\circ = 400 \angle -120^\circ$$

$$V_{ca} = V_{Ph} \angle -240^\circ = V_L \angle -240^\circ = 400 \angle -240^\circ$$

$$I_{cc} = \frac{V_{ca}}{Z_2} = \frac{400\angle -240^\circ}{100\angle 0^\circ} = 4\angle -240^\circ$$

$$V_{PC} = 400 \angle -120^\circ$$

$$\angle V_{PC} \,\&\, I_{cc} = (-120^\circ) - (-240) = +120^\circ$$

$$P = V_{PC} \cdot I_{cc} \cdot \cos(\angle V_{PC} \,\&\, I_{cc}) = 400 \times 4 \times \cos(+120) = -800 \Rightarrow abc$$

Potentiometer is a length comparision ~~de~~ device. Becoz of Null balance condition, it has more accuracy.
It consist of a working battery which can supply a working current flowing through Rheostat and slidewire.

slide wire is prepared by platinum, Gold, silver alloy. Sliding contact is prepared by copper, silver, Gold alloy. Sliding contact should not have any spark problem.
The working current is adjusted by using Rheostat so that current flowing through slide wire is also adjusted.
To find the unknown Emf, connected in the ckt shown in below fig. which consist of operating switch 's' which is in close position. The G key switch Q3
is in open position. Keep on adjust, the working 4
current flowing through slide wire so that v/g drop across slide wire is also adjusted. At one instan particular instant if the G switch is closed,
the G show zero deflection known as Null balance 7]
condition. ~~End~~

Calculating of unknown Emf is nothing but v/g drop across AC portion of length of the slide wire - Q

let $1\,cm = 1\Omega$; $200\,cm = l_{AB} \Rightarrow R_{AB} = 200\Omega$

length ratio = voltage ratio = Resistance ratio

$$\frac{l_{AC}}{l_{AB}} = \frac{E_{AC}}{E_{AB}} = \frac{R_{AC}}{R_{AB}}$$

$$\frac{l_1}{l} = \frac{E_1}{E} = \frac{R_{AC}}{R_{AB}}$$

$$E_1 = \frac{E}{l} \times l_1 \Rightarrow E_1 = \left(\frac{E}{l}\right) \times l_1$$

Becoz

, a
-dewire.
d, silver
-er, Gold
problem.
so
djusted.
ckt
Switch
witch
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lg drop
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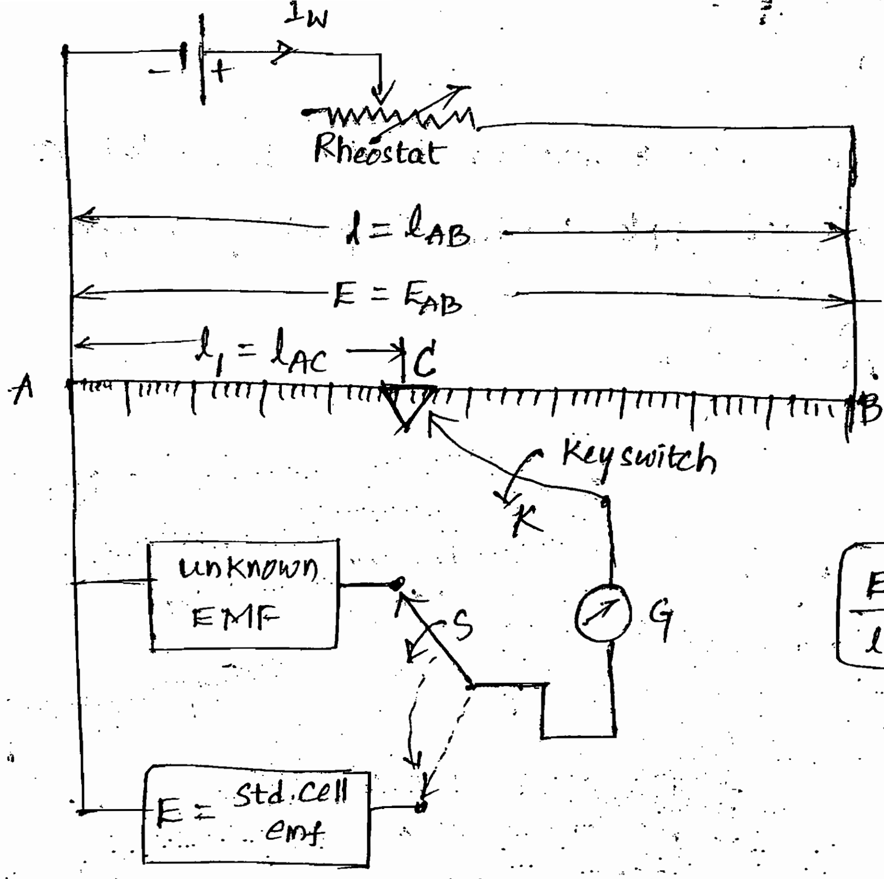


$E = 1.0183V$

$$\boxed{\frac{E'}{l'} = \text{const}}$$

Q3] w.k.T $E_1 = \frac{E'}{l'} \times l_1 \Rightarrow E_1 = \frac{1.18}{600} \times 680 = 1.34V$.

4] $E_1 = \frac{E'}{l'} \times l_1 = \frac{1.45}{50} \times 70 = 2.03V =$ v/g drop a/c unknown

let $S =$ std resistance $= 1.0\Omega$

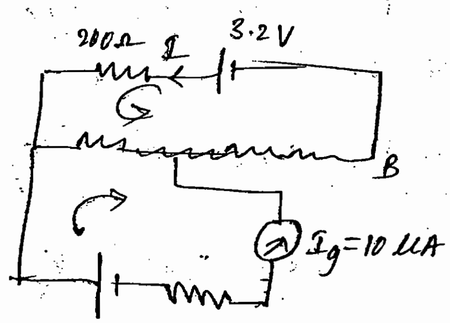
$$I_1 = \frac{E_1}{S} = \frac{2.03}{1.0} = 2.03 \text{ Amp}.$$

7] Apply KVL in loop(1), $200I + 200I + 2800I - 3.2 = 0$

$$3200 I = 3.2 \Rightarrow I = \frac{3.2}{3200} = 1 \text{ mAmp}$$

$$E = 200I = 200 \times 1m = 200mV.$$

Q. In the above problem if the (G) current $= 10\mu A$ then working current = ?

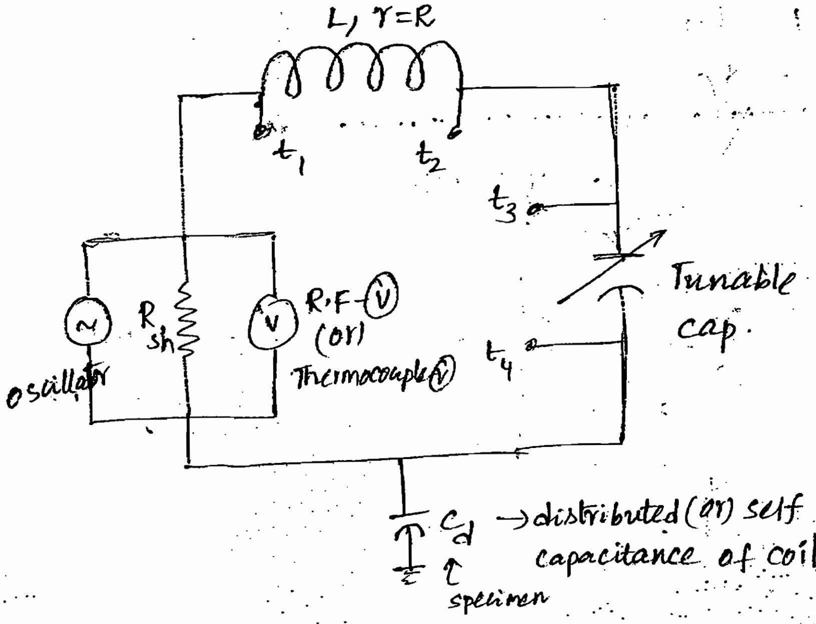


Apply KVL in loop-(1)

$$200I + 200(I + I_g) + 2800I - 3.2 = 0$$

Q-meter

* Q-meter is used to measured the Q-factor of a inductive coil upto Radio frequency range.



$X_C = X_L$

$$\left|\frac{1}{j\omega_0 C}\right| = |j\omega_0 L|$$

$$\therefore \omega_0 = \frac{1}{\sqrt{LC}}$$

$$\boxed{f_0 = \frac{1}{2\pi\sqrt{LC}}}$$

$$f_0' = \frac{1}{2\pi\sqrt{L(C+C_d)}}$$

$$\boxed{\left(\frac{f_{02}}{f_{01}}\right)^2 = \frac{C_1+C_d}{C_2+C_d}}$$

case ①: $f_{02} = n \cdot f_{01}$

$$\left(\frac{n f_{01}}{f_{01}}\right)^2 = \frac{C_1+C_d}{C_2+C_d}$$

$$n^2C_2 + n^2C_d = C_1 + C_d$$

$$\therefore \boxed{C_d = \frac{C_1 - n^2C_2}{n^2-1}}$$

case ②: $f_{02} = 2f_{01}$

$$\boxed{C_d = \frac{C_1 - 4C_2}{3}}$$

Case ③: $f_{02} = \frac{f_{01}}{2}$

$$\boxed{C_d = \frac{C_2 - 4C_1}{3}}$$

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

$$Q = \frac{\omega_0 L}{R} = \frac{1}{\omega_0 RC}$$

case There are two types of errors present in Q-meter reading.

case ①: Error due "C_d" of the coil.

$$Q_{actual} = Q_{True} = \frac{1}{WRC} = Q_T \rightarrow ①$$

$$Q_{measured} = Q_{observed} = \frac{1}{WR(C+C_d)} = Q_M \rightarrow ②$$

EQ

Cas

A1

1

2

3.

$$\frac{Eq(1)}{Eq(2)} \Rightarrow \frac{Q_T}{Q_m} = \frac{C+C_d}{C} = 1+\frac{C_d}{C}$$

$$\therefore \boxed{Q_{actual} = Q_{meas}\left[1+\frac{C_d}{C}\right]}$$ Remember

$$\therefore \boxed{C_d = C\left[\frac{Q_T}{Q_m} - 1\right]}$$

$$\therefore \%\ Error = \frac{Q_m - Q_T}{Q_T} \times 100$$

$$\%\ Error = \left(\frac{C}{C+C_d} - 1\right) \times 100$$

$$\boxed{\%\ Error = \frac{-C_d}{C+C_d} \times 100}$$

$$Error = -ve \Rightarrow Q_m < Q_T$$

Case (2): Error due to R_{sh}

$$Q_{actual} = Q_{True} = \frac{\omega_0 L}{R} = Q_T \rightarrow (1)$$

$$Q_{measured} = Q_{observed} = \frac{\omega_0 L}{R+R_{sh}} = Q_m \rightarrow (2)$$

$$\frac{Eq(1)}{Eq(2)} \Rightarrow \frac{Q_T}{Q_m} = \frac{R+R_{sh}}{R} = 1+\frac{R_{sh}}{R}$$

$$\therefore \boxed{Q_{actual} = Q_{meas}\left[1+\frac{R_{sh}}{R}\right]}$$

$$\therefore \boxed{R_{sh} = R\left(\frac{Q_T}{Q_m} - 1\right)}$$

$$\%\ Error = \frac{Q_m - Q_T}{Q_T} \times 100 = \left(\frac{Q_m}{Q_T} - 1\right) \times 100$$

$$\%\ Error = \left(\frac{R}{R+R_{sh}} - 1\right) \times 100 = \frac{-R_{sh}}{R+R_{sh}} \times 100$$

$$Error = -ve \Rightarrow Q_m < Q_T$$

Applications:

1. Used to measure resonant freq (f_0),
2. " distributed capacitance of coil.
3.

b/w t_3 & t_4 t/m's of a Q-meter ckt.

procedure :- Let C_x be unknown capacitance.

step(1) : $f_{01} = \frac{1}{2\pi\sqrt{L(C_1+C_d)}} \rightarrow (1)$

step(2) : $f_{02} = \frac{1}{2\pi\sqrt{L(C_2+C_x+C_d)}} \rightarrow (2)$

$$\boxed{f_{01} = f_{02}}$$

$$\frac{1}{2\pi\sqrt{L(C_1+C_d)}} = \frac{1}{2\pi\sqrt{L(C_2+C_x+C_d)}} \Rightarrow C_2+C_x+C_d = C_1+C_d$$

$$\therefore \boxed{C_x = C_1 - C_2}$$

Used to measure the inductance of coil $L = \frac{1}{\omega_0^2 C}$

Used to measure the Resistance of coil

$$Q_0 = \frac{\omega_0 L}{R} \Rightarrow \boxed{R = \frac{\omega_0 L}{Q}}$$

Used to measure the B.W of sig.

$$\boxed{B.W = \frac{\omega_0}{Q_0}}$$

$\frac{Q2}{25}$) $C_x = C_1 - C_2 = 300 - 200 = 100\,pf$

$\frac{5}{25}$) $C_d = \frac{C_1 - 4C_2}{3} = \frac{300 - 4\times 60}{3} = 20\,pf$

⇒ Energy meter :

* Energy meter is used to measure the energy consumed by load.

* EM is an integrating type instrument

$$Energy = \int_0^t P.\,dt = \int_0^t V(t).I(t)\,dt = V.I.t$$

Volt amp sec (or) watt-sec (or) Joule

$$Energy = \frac{VI.t^{\rightarrow sec}}{1000} \times KW-sec$$

$$= \frac{V.I.t^{\Rightarrow Hr}}{1000} \times KWH$$

$1sec = \frac{1}{360}\,Hr.$

1 KWH = 1 Unit.

Integrating type inst :

1. Driving Torque
2. Braking Torque
3. Registering mechanism

The torque which is required to revolve the disc or to rotate the disc, Driving torque is obtained by using Electromagnetic induction effect.

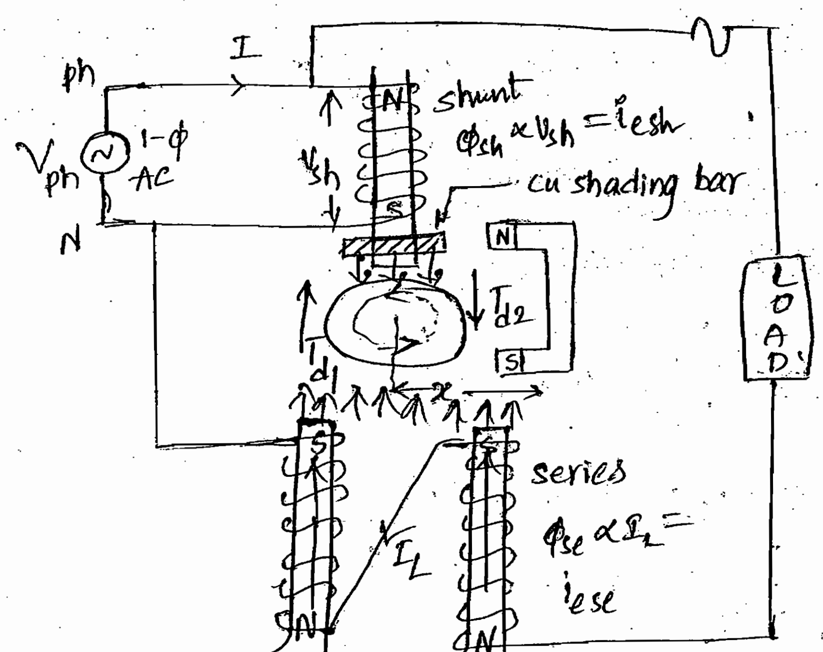
~~Brakin~~ The torque which is required to revolve the disc constant speed. Braking torque is obtained by using permanant magnet placed inside the Energy meter placed near 'Al' disc.

* Energymeter working principle is similar to transformer action.

* EM working principle is similar to 1-ϕ I.M.

* EM works on the principle of theory of Induction inst.

Theory of induction inst :-

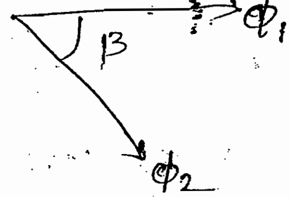


(or)

(or)

let $\phi_1 = \phi_{m_1} \sin(\omega t)$

let $\phi_2 = \phi_{m_2} \sin(\omega t - \beta)$



$$e_1 = -N\frac{d\phi_1}{dt} \Rightarrow e_1 \propto \frac{-d\phi_1}{dt} \propto \frac{-d}{dt}\left[\phi_{m_1}\sin(\omega t)\right]$$

$$\boxed{e_1 \propto -\omega\phi_{m_1}\cos(\omega t) \propto \omega\phi_{m_1}\sin(\omega t - 90^\circ)}$$

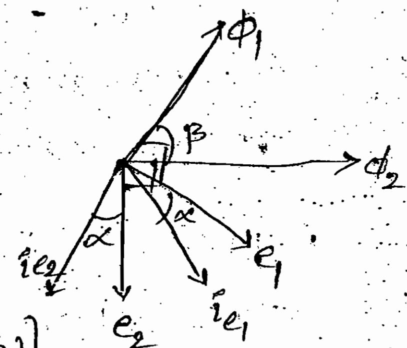
$\boxed{e_1 \text{ lags } \phi_1 \text{ by } 90^\circ}$

let $z_e \to$ Eddy impedance path

$\therefore z_e = r_e + jx_e$, $\alpha = \tan^{-1}\left(\frac{x_e}{r_e}\right)$

let $\alpha \to$ Eddy Impedance Angle

so $i_{e_1} = \frac{emf_1}{z_e} = \frac{e_1}{z_e}$



$\boxed{i_{e_1} \text{ lags } e_1 \text{ by } \text{"}\alpha\text{"}}$

$$\therefore e_2 \propto \frac{-d\phi_2}{dt} \propto \frac{-d}{dt}\left[\phi_{m_2}\sin(\omega t - \beta)\right]$$

$$e_2 \propto -\omega\phi_{m_2}\cos(\omega t - \beta)$$

$$\boxed{e_2 \propto \omega\phi_{m_2}\sin(\omega t - \beta - 90^\circ)}$$

$\boxed{e_2 \text{ lags } \phi_2 \text{ by } 90^\circ}$

$\boxed{i_{e_2} = \frac{e_2}{z_e}}$ $\Rightarrow$ i_{e_2} lags e_2 by "α"

$$T_{d_1} \propto \phi_1 \cdot i_{e_2} \cdot \cos(\angle\phi_1 \;\&\; i_{e_2})$$

$$\boxed{T_{d_1} \propto \phi_1 \cdot i_{e_2} \cdot \cos(90 + \alpha + \beta)}$$

$$T_{d_2} \propto \phi_2\, i_{e_1} \cdot \cos(\angle\phi_2 \;\&\; i_{e_1})$$

$$\boxed{T_{d_2} \propto \phi_2 \cdot i_{e_1} \cdot \cos(90 + \alpha - \beta)}$$

$$T_d = T_{d_1} - T_{d_2}$$

$$T_d \propto \frac{\phi_{m_1}}{\sqrt{2}} \cdot \frac{\phi_{m_2}}{\sqrt{2}} \cdot \cos\alpha \sin\beta$$

Imp

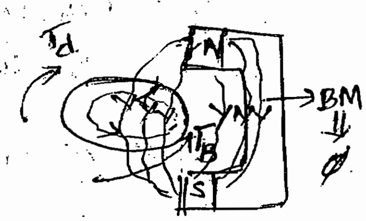
Let Eddy impedance path is pure resistive.

$$\boxed{T_d \propto \phi_1 \cdot \phi_2 \cdot \sin\beta} \Rightarrow \boxed{T_d \propto \phi_{sh}\, \phi_{se} \cdot \sin(\angle \phi_{sh} \,\&\, \phi_{se})}$$

T_B :—

$e \propto n \cdot \phi$

$e = K n \phi$



where $K \rightarrow$ const

$n \rightarrow$ speed of disc.

$\phi \rightarrow$ flux produced by B.M

$r_e \rightarrow$ Eddy resistance path of 'Al' disc.

$$\therefore \boxed{i_e = \frac{emf}{r_e} = \frac{K \cdot n \cdot \phi}{r_e}}$$

$\geq \phi_2$

$$T_B \propto \phi\, i_e \propto \frac{K \cdot n \cdot \phi^2}{r_e}$$

$$\boxed{T_B = \frac{K' K \cdot n \phi^2 x}{r_e}} \Rightarrow \boxed{T_B \propto N}$$

$$\boxed{T_B \propto \text{speed of disc}} \longrightarrow (1)$$

$$\boxed{n\uparrow \propto \frac{r_e\uparrow}{\phi^2 x}}$$

$$r_{e \text{ at } t^\circ C} \uparrow = r_{e_0}[1 + \alpha \Delta t\uparrow]$$

Let 'x' be the distance b/w center of 'Al' disc and braking magnet.

In the analysis of Energy meter, there are two assumptions made :

1) v/g drop across series coil neglected. so that

$V_{ph} = V_{sh} = V_L$ and $\phi_{sh} \propto V_{ph} = V_L$; $\phi_{se} \propto I_L$

Imp 2) flux produced in shunt coil lags the applied v/g

ϕ_{sh} lags $V_{ph} = V_L$ by $90 \Rightarrow$ Ideally

ϕ_{sh} lags $V_{ph} = V_L$ by "Δ" $\Rightarrow$ practically

ϕ_{sh} lags $V_{ph} = V_L$ by "90°" $\Rightarrow$ by using LAG Adjustment

$T_d \propto \phi_{sh} \cdot \phi_{se} \cdot \sin(\angle \phi_{sh} \& \phi_{se})$

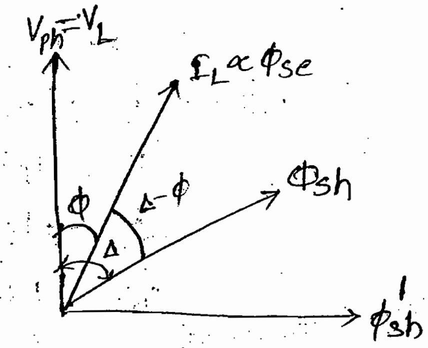
$\Downarrow \quad \Downarrow$

$\boxed{T_d \propto V_L \cdot I_L \cdot \sin(\Delta - \phi)} \Rightarrow P_m$

$\boxed{T_d \propto V_L \cdot I_L \cdot \sin(90 - \phi)} \Rightarrow P_T$

$\boxed{T_d \propto V_L I_L \cdot \cos\phi}$

$\Downarrow \quad \boxed{T_d \propto \text{AC power}} \rightarrow (2)$



Ideally $\Rightarrow \Delta = 90^\circ$

At steady state, $|T_d| = |T_B|$

$$\int_0^t \text{AC power} \propto \int_0^t \text{Speed of disc}$$

Energy consumed $\propto$ No. of revolution

Energy consumed $=$ K·No. of revolutions

where K $\rightarrow$ meter constant $\Rightarrow$ rev/KWH

$$* \boxed{K = \frac{\text{No. of revolutions}}{\text{Energy consumed}}}$$

Static friction: In order to overcome the static friction offered by "Al" disc, a compensating coil is placed inside the Energymeter (in series to V_{sh})

Creeping:

Creeping is the slow rotation of the 'Al' disc under no-load conditions, slightly higher speed under lightly loaded condition and loaded condition.

The main reason for creeping is the over compensation provided in order to overcome the static friction affected by "Al" disc.

Over vlges across shunt magnet

mech. vibrations

Due to excessive rise in temp, so that eddy current resistance path offered by "Al" disc coil —

Remedy : To Reduce the creeping phenamena diagmetrically two opposite holes made on the Al disc.

2. In some cases, small piece of Iron bar is attached to the edge of "Al" disc. so that force of attraction of the braking magnet upon the Iron piece is sufficient to stop the continuous revolutions

21] Case(1): $\phi = 0^\circ \Rightarrow$ upf. Case(2) :— do. try.

$P_M = V_L I_L \sin(\Delta - \phi)$

$= 220 \times 5 \times \sin(85 - 0^\circ)$

$P_M = 1095.8$ watt

$P_T = V_L I_L \sin(90 - \theta)$

$= 220 \times 5 \times \sin(90 - 0^\circ)$

$= 1100$ W

Error $= P_M - P_T = -4.2$ W

27) $V = 230V$, $I = 5A$

1 KWH of Energy → 2400 rev.

Energy consumed $= \dfrac{V \cdot I \cdot t^{\Rightarrow 1 Hr.}}{1000}$ KWH.

1.15 KWH " → ?

$= \dfrac{230 \times 5 \times 1}{1000}$ KWH

$= 2400 \times 1.15$ rev.

$= 1.15$ KWH.

∴ % creep error $= \dfrac{+60}{2400 \times 1.15} \times 100$

N_T

$Error = +ve \Rightarrow N_M > N_T \Rightarrow$ ~~fast~~ $\uparrow$

$Error = -ve \Rightarrow N_M < N_T \Rightarrow$ slow $\downarrow$

$$\%\ \text{creep Error} = \frac{\text{No. of rev/Hr due to creeping}}{\text{No. of rev/Hr due to Energy consumed}} \times 100.$$

Q23

---

22) $V = 230V$; $I = 10A$; $t = 3$ min $= 180$ sec ; $N_M = 90$ rev.

$$\text{Energy consumed} = \frac{V \cdot i_{attraction} \times t}{1000 \times 3600} \text{ KWH}.$$

$$= \frac{230 \times \frac{10}{2} \times 180}{1000 \times 3600} \text{ KWH}.$$

$= 0.0575$ KWH

1 KWH of energy $\longrightarrow$ 1800 rev.

0.0575 KWH " $\longrightarrow$?

$= 0.0575 \times 1800$

$N_T = 103.5$

$$\%\ Error = \frac{N_M - N_T}{N_T} \times 100 = \frac{90 - 103.5}{103.5} \times 100 = -13.04\%$$

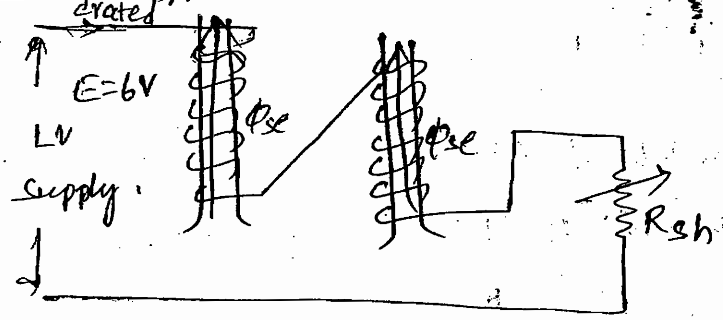
$= -ve \Rightarrow$ slow.

24)

⇒ phantom loading :-

During testing of Energymeter in order to avoid unnecessary power loss a separate arrangement is used known as phantom loading.

In phantom loading arrangement, shunt coil is energised by normal v/g but series coil is energised by a separate source having low v/g but supplying rated current so that the power loss in the calibration work is minimum.



w/o phantom loading:

$$P_{loss\ P.C} = \frac{V_{ph}^2}{R_{sh}} = \frac{(220)^2}{8800} = 5.5W$$

$$P_{loss\ C.C} = V_{ph} \times I_{rated} = 220 \times 5 = 1100$$

$$P_{loss\ Total} = 1105.5W$$

w/o phantom loading:

$$P_{loss\ C.C} = E \times I_{rated} = 6 \times 5 = 30W$$

$$P_{loss\ P.C} = 5.5W$$

$$P_{Total\ Loss} = 35.5W$$

24) $V = 250V$.

given meter constant, $K' = 14.4 \ \frac{\text{Amp-sec}}{\text{rev}}$.

Actual meter constant $\Rightarrow K = \frac{1}{K'}$

$$K = \frac{1000}{14.4 \times 250 \times KV\text{-}Amp\text{-}sec} = \frac{1000}{14.4 \times 250\,KW \times \frac{H}{360}} \ \text{rev.}$$

$$= 1000 \ \text{rev}/KWH.$$

CRO

* CRO mainly consist of CRT.
* The main components of CRT:
  1. Electron Gun
  2. Deflecting plates
  3. Screen of CRO
* The main components of Electron Gun:
  1. Heating element
  2. Cathode
  3. Control Grid
  4. Pre & post accelerating anode
  5. focusing Anode

1. Heating element:

It is used to heat up the cathode, the required v/g around 6.3 volts, required current 600mA.

2. cathode:

It is in cylindrical shape, at the end of which a layer of bariumoxide (BaO) or stronsiumoxide is deposited in order to have high emission of electron.

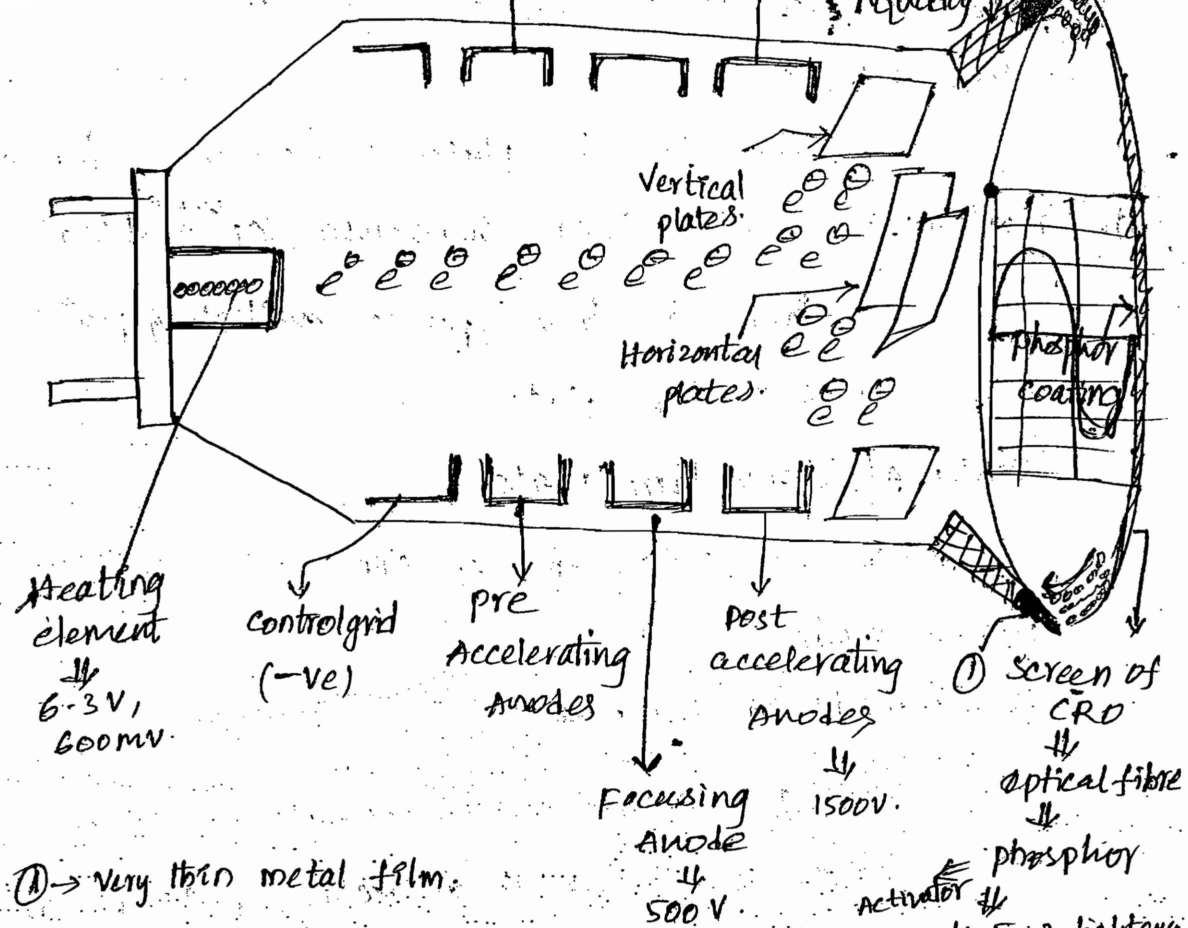
3. Control Grid:

The control grid which is in cylindrical in shape given to -ve potential in order to control the intensity of electron beam which is prepared by Nickel material.

4. Pre & post accelerating Anodes:

These are the anodes responsible for ~~get the mo~~ inject or imparting acceleration to the electron beam. For that these anodes are held at 1500V.

In case of high freq CRO post accelerating



$$\uparrow K.E \downarrow = \frac{1}{2} \uparrow m v_e^2 \downarrow \; , \quad W = V_a Q = e V_a$$

$$K.E = W$$

$$\frac{1}{2} m v_e^2 = V_a e$$

$$\therefore \boxed{v_e = \sqrt{\frac{2 e V_a}{m}}}$$

$$\boxed{\uparrow v_e \propto \sqrt{V_a} \uparrow}$$

Anode is used to increase the brightness of the trace when the sig freq greater than 10MHz.

Focusing anode:

This anode is responsible for electrostatic focusing s/m, the CRT of CRO uses electrostatic focusing s/m where as the CRT of TV picture tube use electro magnetic focusing s/m

The CRO which uses electrostatic focusing s/m

Deflecting plates :

These are the plates responsible for get the motion of electron beam horizontal ~~or~~ well as vertical

There are two types of deflecting plates.

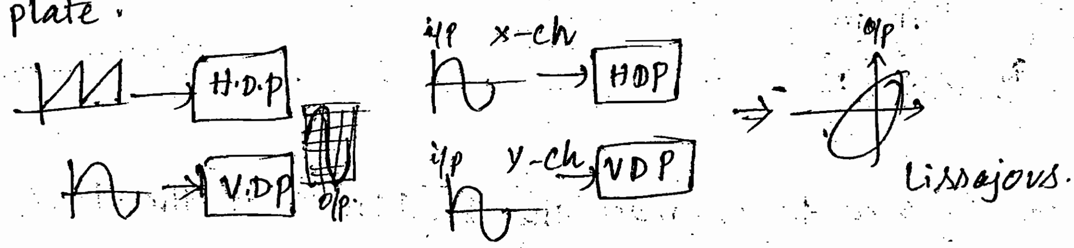
1. Horizontal deflecting plate.
2. Vertical deflecting plate.

There are two modes of CRO :

1. Normal mode
2. Dual mode or x-y mode.

In the normal mode, o/p of sweep wave (G) is connected to Horizontal deflecting plate where as i/p sig is given to vertical deflecting plate.

In Dual mode, o/p of sweep wave (G) is disconnected from Horizontal deflecting plates and x-i/p channel is ~~connected~~ given to Horizontal deflecting plate and Y-channel sig is " " Vertical " plate.



⇒ Dual trace oscilloscope :-

In a dual trace CRO, the o/p of sweep wave (G) is given to Horizontal deflecting plates. There are two i/p sigs given to vertical deflecting plates with the help of multiplexer ckt. The i/p sig freq is selected as exactly equal and half of the wave (4) so that the electron beam shifts alternatively to the two waveforms with very high switching rate. The two o/p sigs are displayed on the screen of CRO but which is not possible in case of Normal CRO.

Screen of CRO :—

It is made up of optical fibres, inside the screen, inside phosphor coating is deposited. The f^n of phosphor is to convert the K.E of electron beam into light energy.

Some of the activators is added to the coating of phosphor, in order i) to increase the illuminance intensity. ii) spectral emission.
iii) To increase the persistance of phosphor.

On the non-viewing side of screen of CRO, a very thin metal is prepared by 'Al' is deposited.
i) the metal acts as heat sink.
ii) It provides connecting path for secondary emitted $\bar{e}$ screen to acquadog.
iii) It reflects the light scattered from phosphor back towards the screen.

Acquadog is an acqueous solution of graphite, which is used to collect the scdry emitted $\bar{e}$.

Expression for Electrostatic De

let l_d be the length of Deflecting plate
d be the separation distance b/w the deflecting plates.
L distance b/w screen of CRO & center

V_d – potential difference b/w the deflecting plates

V_a – accelerating potential

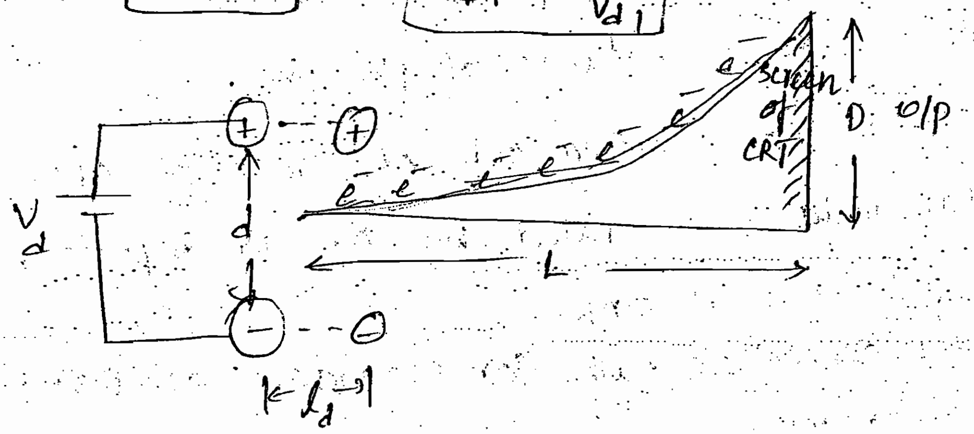
D – be the electrostatic deflection.

$$\boxed{D = \frac{V_d \cdot L \cdot l_d}{2V_a \cdot d}}$$

$$\boxed{S = \frac{\Delta o/p}{\Delta i/p} = \frac{D}{V_d} = \frac{L \cdot l_d}{2V_a \cdot d}} \quad \frac{mm}{volt}$$

* Deflecting Factor (or) Scaling factor $= \frac{1}{S} = \frac{\Delta I/p}{\Delta o/p} = \frac{V_d}{D} = \frac{2V_a \cdot d}{L \cdot l_d}$ $\frac{volt}{mm}$

* $\boxed{D \propto V_d} \Rightarrow \boxed{\frac{D_2}{D_1} = \frac{V_{d2}}{V_{d1}}}$

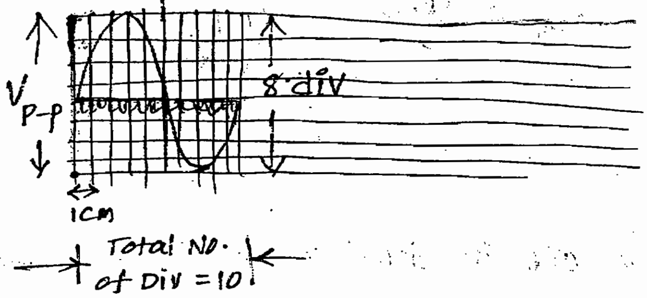


⇒ Measurements by using CRO :– $\boxed{V, I, \phi, f, T}$

By using CRO we can measure v/g, current phase angle, frequency, time period but power measurement is not possible.

1) V/g measurement :–

CRO always measures peak to peak v/g.



$V_{RMS} = \frac{V_M}{\sqrt{2}} \Rightarrow V_M = \sqrt{2}\, V_{RMS}$

$V_{p-p} = 2V_p = 2V_M = 2\sqrt{2}\, V_{RMS}$

$$\boxed{V_{RMS} = \frac{V_{p-p}}{2\sqrt{2}}} \;**$$

x-div $\Rightarrow 0.5 \frac{msec}{cm}$

$\boxed{\text{Total Time on } x\text{-axis} = (x\text{-div}) \times \text{Total no. of divi. on } x\text{-axis}}$

$t = \frac{0.5\,msec}{cm} \times 10\,cm.$

$t = 5\,msec.$

Volt/mm

y-div $\Rightarrow 100\,mV/cm$

$\boxed{\text{Amplitude} = (y\text{-Div}) \times \text{Total no. of DIV on } y\text{-axis}}$

$= \frac{100\,mV}{cm} \times 8\,cm$

Amplitude $= 800\,mV$

$$\boxed{\text{No. of cycles displayed} = \frac{\text{Total time on } x\text{-axis}}{\text{Time period displayed signal}} = \frac{t}{T}}$$

$= \frac{5\,msec}{5\,msec} = 1$ cycle. given sig $\Rightarrow f = 200$

$T = \frac{1}{f} = \frac{1}{200}$

$= 5\,msec.$

current

$V_{RMS} = 300\,mV$

$V_{p-p} = 2\sqrt{2}\, V_{RMS} = 2\sqrt{2} \times 300$

$V_{p-p} = 848.5\,mV.$

$\Rightarrow$ Measurement of current:

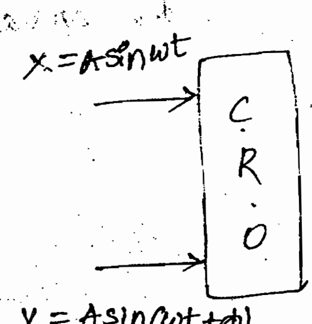
CRO can't measure the current directly. It measures the current indirectly by passing through std. resistance observe the vlg waveform on the screen of CRO across that resistor

$I_{RMS} = \frac{V_{RMS}}{S} = \frac{V_{p-p}}{2\sqrt{2} \times S}$

C.R.O

⇒ Measurement of phase :—

By operating CRO in dual mode or x-y mode, by giving two sinusoidal sigs x and y channels of CRO having equal Amplitude but having some phase difference so that Li... pattern is obtained on the screen of CRO.



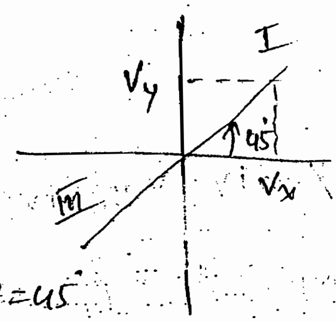
<u>case ①</u> : $\phi = 0^\circ$

$x = A\sin\omega t$

$y = A\sin(\omega t + \phi)$

$y = x = 1 \cdot x$

Slope $= \tan(\theta) = 1 \Rightarrow \theta = 45^\circ$



$$\boxed{\begin{array}{l} \text{slope} = +ve \\ \theta = \tan^{-1}\frac{V_y}{V_x} \end{array}}$$

<u>case ②</u> : $\phi = 90^\circ$ (or) 270°

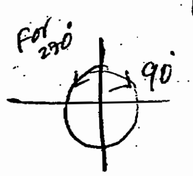
$x = A\sin\omega t$

$y = A\sin(\omega t + 90^\circ)$

$y = A\cos\omega t$

$$\boxed{x^2 + y^2 = A^2}$$

↳ circle



<u>case ③</u> : Let $\phi = 30^\circ$

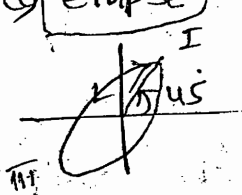
$0^\circ < \phi < 90^\circ$ (or) $270^\circ < \phi < 360^\circ$

$x = A\sin\omega t$

$y = A\sin(\omega t + 30^\circ)$

$y = A\sin(\omega t)\cos 30^\circ + A\cos\omega t \sin 30^\circ$

↳ Ellipse.



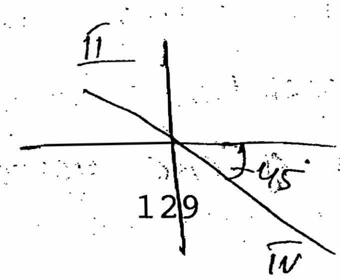
<u>case ④</u> : $\phi = 180^\circ$

$x = A\sin\omega t$

$y = A\sin(\omega t + 180^\circ)$

$y = -A\sin(\omega t)$

$y = -x = (-1) \cdot x$



slope $= -ve \Rightarrow \theta = -45^\circ$

③ : $90 < \phi < 180$. (or) $180 < \phi < 270$

$\phi = 120°$

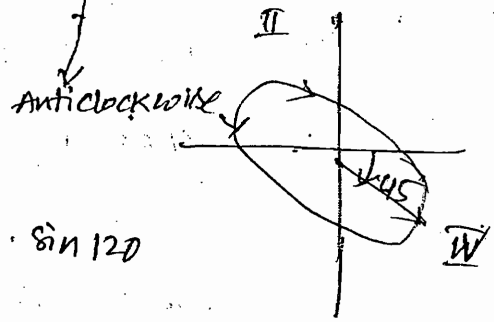
$x = A \sin \omega t$

$y = A \sin(\omega t + 120°)$

$y = A \sin(\omega t)\cos(120°) + A\cos\omega t \cdot \sin 120$

↳ slope = −ve

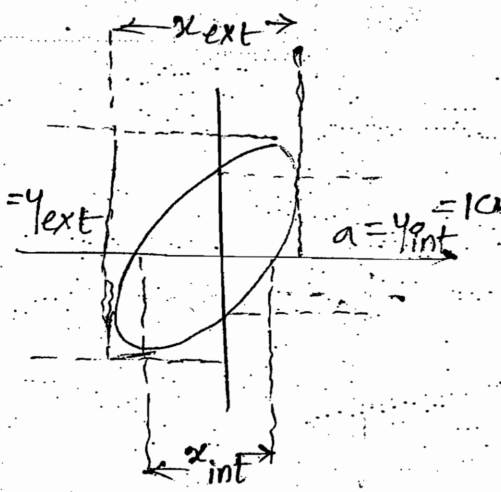
↳ Ellipse



Note:

When the phase angle is lying in b/w 0 to 180°, the direction of pattern is clockwise. Whereas in b/w 180 to 360 the direction of pattern is in the Anticlockwise.

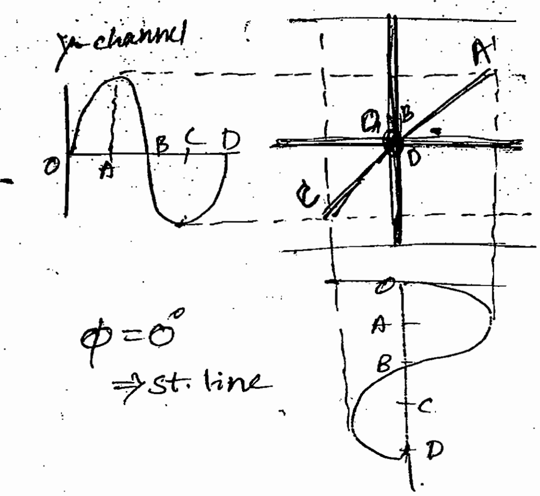
Measurement of phase angle:



$\phi = \sin^{-1}\left(\frac{1}{2}\right) = 30 \Leftarrow \phi = \sin^{-1}\left(\frac{y_{int}}{y_{ext}}\right)$

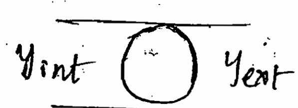
$\phi = \sin^{-1}\left(\frac{x_{int}}{x_{ext}}\right)$

Q:



$\phi = 0°$

⇒ st. line



$\phi = \sin^{-1}(1)$

$\boxed{\phi = 90°}$

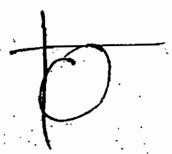
Measurement of frequency:

By operating CRO in x-y mode, for x-ch known sig is given and for y-ch unknown sig is given, so that we can obtain Li[ssajous] pattern can measure the unknown sig freq.

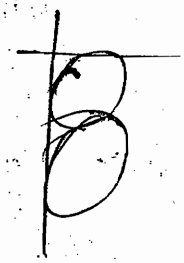
$$\boxed{\frac{f_y}{f_x} = \frac{\text{max. no. of horizontal tangents drawn to L.P}}{\text{max. no. of vertical tangents drawn to L.P.}}}$$

(or)

$$\boxed{\frac{f_y}{f_x} = \frac{\text{max. no. of horizontal intersections drawn to LP}}{\text{max. no. of vertical intersections drawn to LP}}}$$

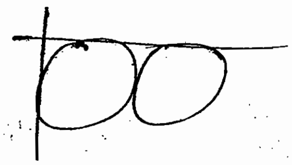


$\frac{f_y}{f_x} = \frac{1}{1} \Rightarrow \boxed{f_y = f_x}$



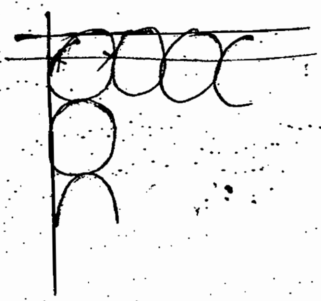
$\frac{f_y}{f_x} = \frac{1}{2}$

$\boxed{f_y = \frac{f_x}{2}}$

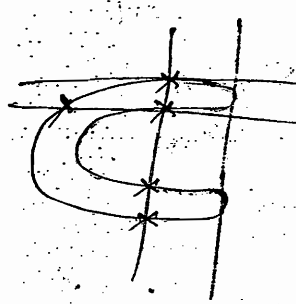


$\frac{f_y}{f_x} = \frac{2}{1}$

$\boxed{f_y = 2 f_x}$

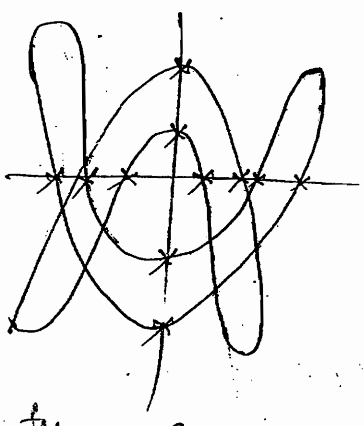


$\frac{f_y}{f_x} = \frac{3+\frac{1}{2}}{2+\frac{1}{2}} = \frac{\frac{7}{\cancel{2}}}{\frac{5}{\cancel{2}}} = \frac{7}{5}$



$\frac{f_y}{f_x} = \frac{1}{2}$

$\frac{f_y}{f_x} = \frac{\cancel{2}}{\cancel{4}} = \frac{1}{2}$



$\frac{f_y}{f_x} = \frac{8}{4}$

z-axis modulation :-

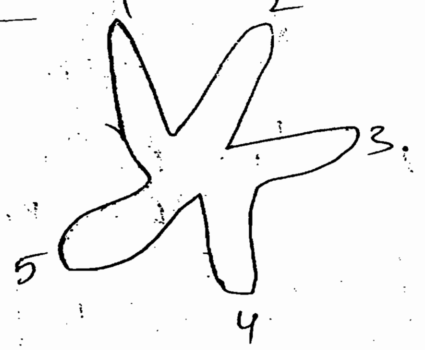
$\frac{f_m}{f_p} = \frac{\text{No. of gaps in circle}}{1}$

where $f_M \rightarrow$ modulated freq

$f_p \rightarrow$ Defl. plate freq

$\boxed{\frac{f_M}{f_p} = \frac{3}{1}}$

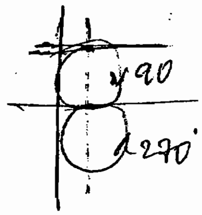
uas to
·P
on to
L.P.



$\frac{f_y}{f_x} = \frac{1}{5}$

on to LP
uon to CP

10)



$\frac{f_y}{f_x} = \frac{1}{2} \Rightarrow f_y = \frac{f_x}{2} \Rightarrow \omega_2 = \frac{\omega_1}{2}$

$P(\omega_1, t) = A \sin(\omega_1 t)$

$q(\omega_2, t) = A \cos(\omega_2 t), \; \omega_2 = \frac{\omega_2}{2}$

17) $x(t) = P \sin(4t + 30°)$

$\Downarrow$

$\omega_x = 4$

$\omega_y = \frac{\omega_x}{2} = \frac{4}{2} = 2$

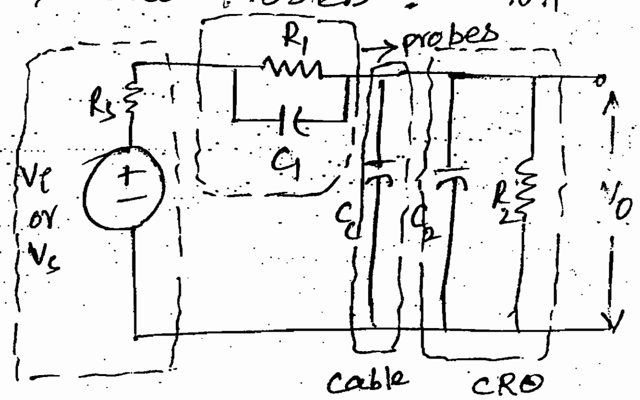
$y(t) = Q \sin(2t + 120°)$

15) $R = X_c = \frac{1}{2\pi f C}$

$\boxed{R = 5k\Omega}$

$\Rightarrow$ CRO Probes :— $M\Omega \rightarrow$ high impedance

10:1



Let $R_1 \rightarrow$ Resistance of probe

$C_1 \rightarrow$ Csh connected a/c pro

$R_2 \rightarrow$ i/p resistance of CRO

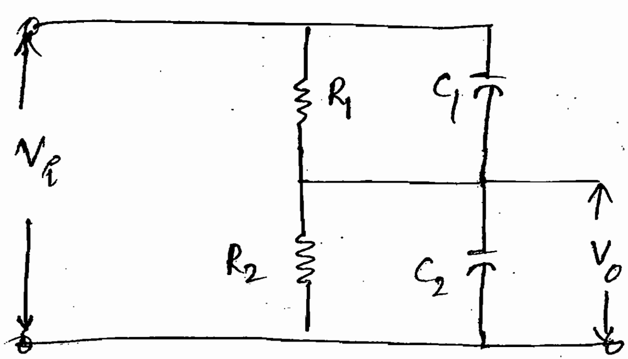
$C_2 \rightarrow$ i/p capacitance of CRO

$C_c \rightarrow$ cable capacitance

R_s & C_c are neglected $\Downarrow$

:—

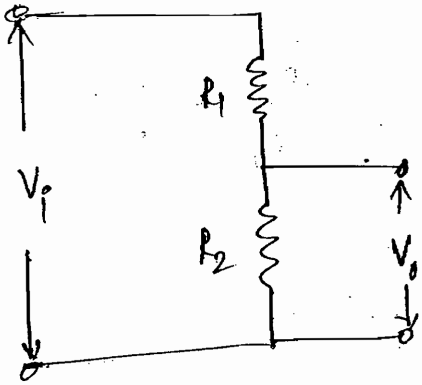
f gaps in circle



dulated freq

plate freq

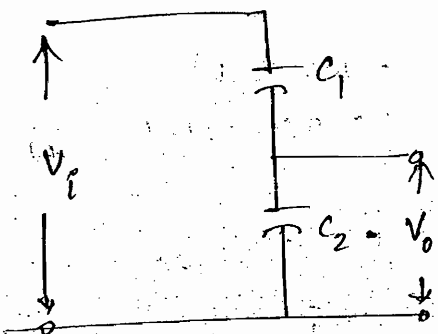
$K =$ V/g divider ratio (or) Attenuator factor $= \frac{V_i}{V_o} = \frac{10}{1} = 10:1$



$$V_o = V_i \times \frac{R_2}{R_1+R_2}$$

$$K = \frac{V_i}{V_o} = \frac{R_1+R_2}{R_2} = 1+\frac{R_1}{R_2}$$

$$\therefore \boxed{R_1 = R_2\left[K-1\right]}$$



$$V_o = V_i \times \frac{C_1}{C_1+C_2}$$

$$K = \frac{V_i}{V_o} = \frac{C_1+C_2}{C_1} = 1+\frac{C_2}{C_1}$$

$$\therefore \boxed{C_1 = \frac{C_2}{K-1}}$$

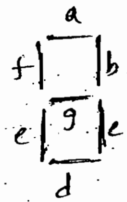
Q9] $R_1 = R_2(K-1) = 2M\left[10-1\right] = 18M\Omega$

$$C_1 = \frac{50\,pF}{10-1} = 5.55\,pf.$$

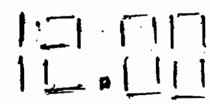
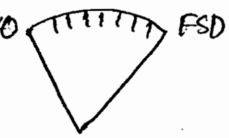
Q.8] $B.W = \dfrac{0.35}{t_r} \Rightarrow t_r = \dfrac{0.35}{10\times10^6} = 35\,nsec$

DIGITAL VOLTMETER [DVM]

R_1 / R_2 The basic measurable point of DVM is low vlg DC supply (0-1V) or (0-10V) or (0-100V). Most commonly preferred digital display is BCD-7 segment. Digital display have very high Resolution.

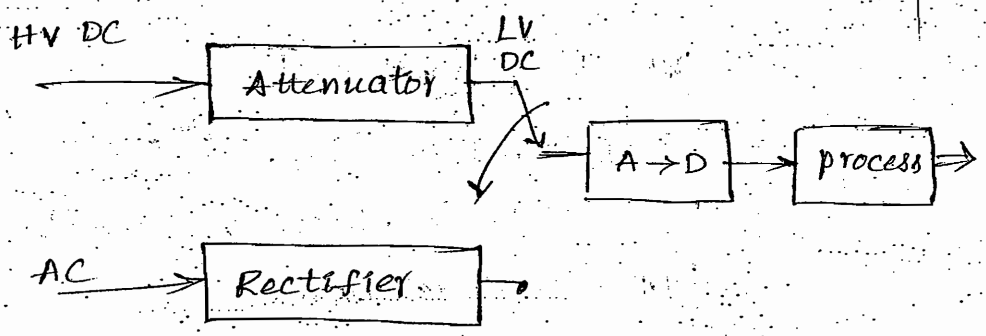


	a	b	c	d	e	f	g
1 →	0	1	1	0	0	0	0

DVM	Analog inst
* 	*0 
* superior Resolution	* Inferior Resolution
* More durability.	* less durability
* High sensitivity	low Sensitivity

BCD-7 segment : $N = 7$; (0-10V) ↳ V_{FSD}

2 / 1 $$\boxed{\text{Resolution} = \frac{V_{FSD}}{10^N}} = \frac{10}{10^7} = 10^{-6}$$



$$\boxed{\text{Sensitivity of DVM} \uparrow = \text{Resolution} \uparrow \times \text{lowest FSD}}$$

DVM

* capacity to read RMS values.
* Calibration can be done independent of measuring ckt
* No parallax error
* I/p. range 1.000000 to 1000.000
* Easy to process
* Easy to store digital data
* No external effects
* I/p. impedance High

Disadv :
* We must require A → D converter in all DVM's. ~~Basical~~

1. Parallel (or) FLASH (or) comparator type
2. Dual slope integrator
3. SAR
4. Ramp (or) counter (or) single slope integrating

1) Basic Ramp type (Does not use DAC)

2) staircase Ramp type ← Use as DAC

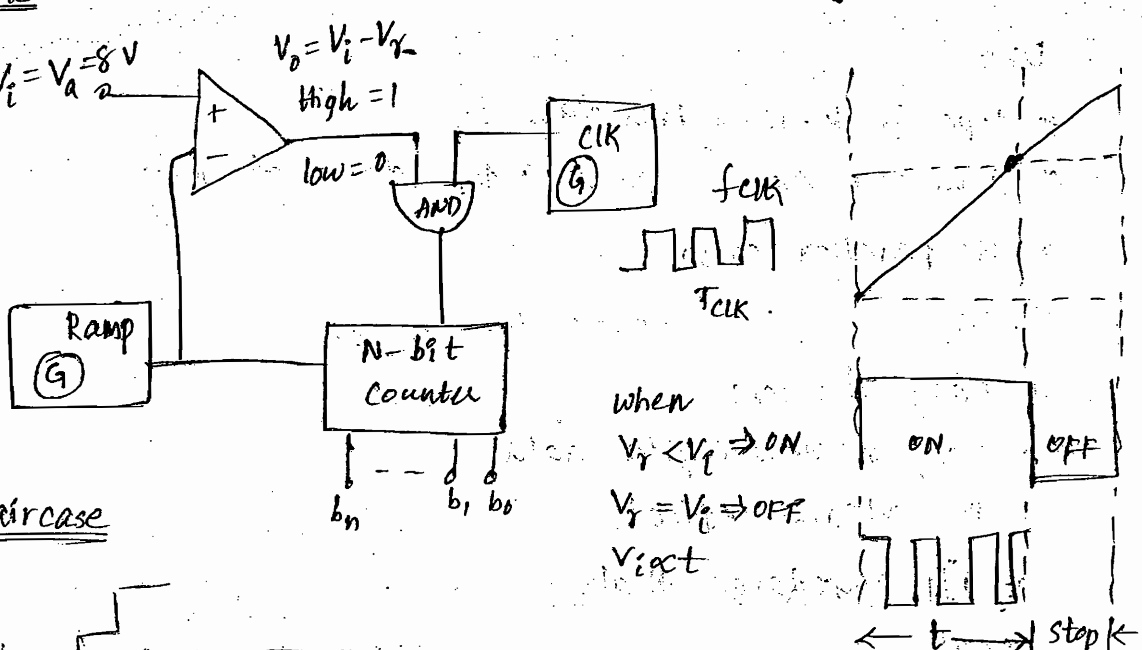
Flash type ⇒
- ⇒ less accurate becoz Resistive n/w.
- ⇒ Fastest & costiest
- ⇒ No. of comparators $= 2^n - 1$
- ⇒ Conversion time, $T_{clk} = 1$ cycle.

SAR Type ⇒ 2^{nd} fastest & moderate cost
⇒ Conversion time, $T_{clk} = n$ · cycles.

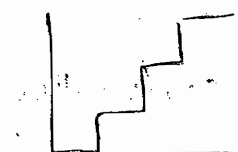
DUAL SLOPE ⇒ slowest & lesser cost
⇒ Conversion time, $T_{clk} = 2^N$ · cycles.
⇒ most accurate ; becoz less sensitive temp & noise variation.

Ramp type ADC :-

1) Basic



2) staircase

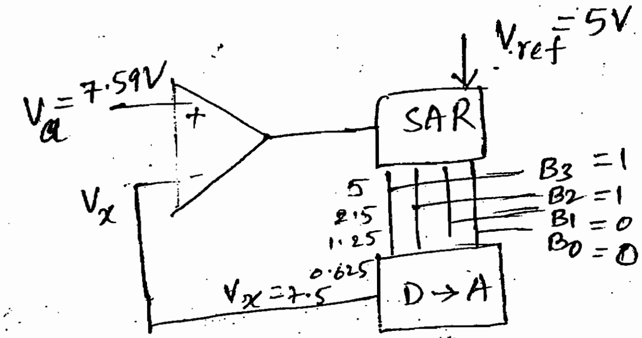


$$\boxed{\text{No. of pulses} = \frac{t}{T_{clk}} = t \times f_{clk}}$$

$$\boxed{\frac{V_{i_2}}{V_{i_1}} = \frac{t_2}{t_1}}$$

In SAR type always set MSB to 1.

consider 4-bit converter.



case① : If $V_a > V_{ref}$

set $B_3 = 1 \Rightarrow B_3 = \frac{V_{ref}}{2^0}$

$= V_{ref}$

B_3	B_2	B_1	B_0
$\frac{V_{ref}}{2^0}$	$\frac{V_{ref}}{2^1}$	$\frac{V_{ref}}{2^2}$	$\frac{V_{ref}}{2^3}$

$V_{ref} = 5V \Rightarrow$

	$\frac{5}{2^0}$	$\frac{5}{2^1}$	$\frac{5}{2^2}$	$\frac{5}{2^3}$
	5	2.5	1.25	0.625
$V_a = 7.59 \Rightarrow$	1	1	0	0
$V_a = 3.79 \Rightarrow$	0	0	0	0

case②: If $V_a < V_{ref}$ set $B_3 = 1 \Rightarrow B_3 = \frac{V_{ref}}{2^1}$

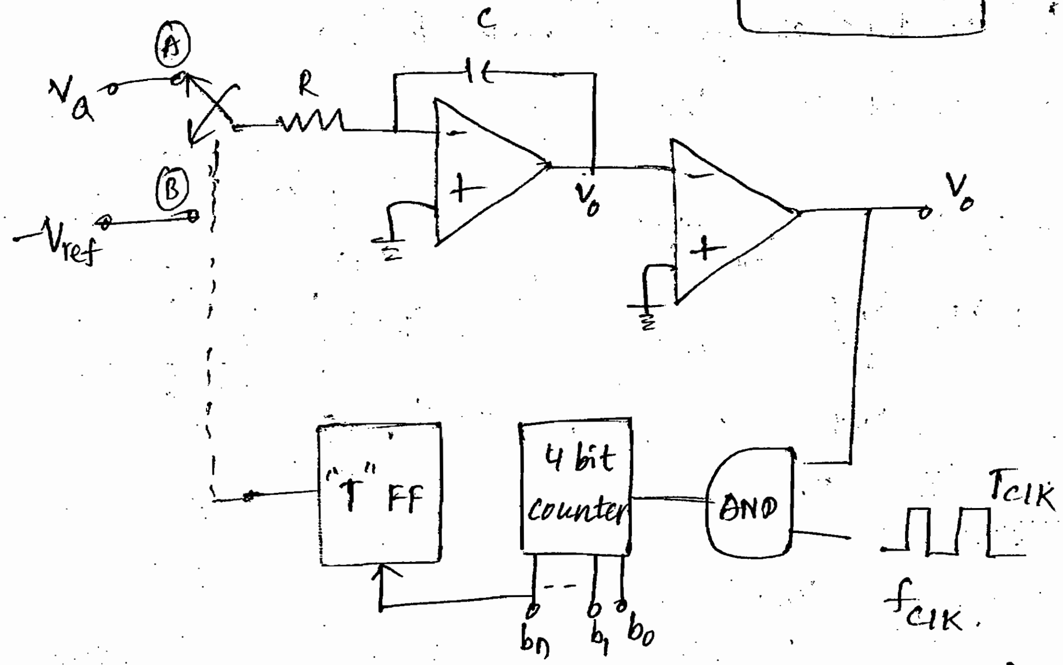
B_3	B_2	B_1	B_0
$\frac{V_{ref}}{2^1}$	$\frac{V_{ref}}{2^2}$	$\frac{V_{ref}}{2^3}$	$\frac{V_{ref}}{2^4}$

$V_{ref} = 5V \Rightarrow$	2.5	1.25	0.625	0.3125
	⇓	⇓	⇓	⇓
$V_G = 3.79V \Rightarrow$	1	1	0	0
$V_G = 8.217 \Rightarrow$	1	1	0	1

⇒ Dual slope integrator :-

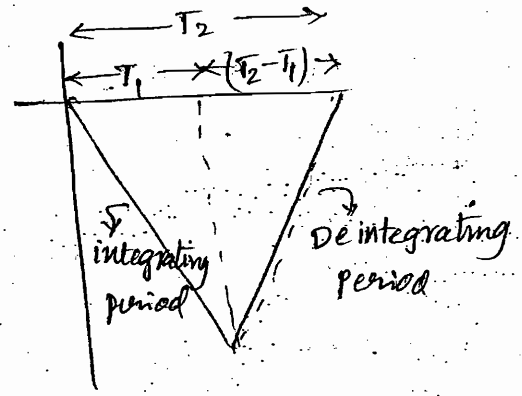
In this technique analog sig and ref sig are sequencially connected with the help of switch arrangement.

$\boxed{T = 2^N T_{clk}}$



<u>Case ①</u>:

$0 < t < T_1$



$$V_o = \frac{-1}{RC}\int_0^{T_1} (V_a)\, dt$$

$$= \frac{-V_a}{RC} \times |t|_0^{T_1}$$

$$\boxed{V_o = \frac{-V_a}{RC} \times T_1}$$

$$\boxed{V_o = -\frac{V_a}{RC} \times 2^N \times T_{clk}}$$

<u>Case ②</u>: $T_1 < t < T_2$

$$V_o = \frac{-V_a}{RC} \times T_1 + \left[\frac{-1}{RC}\int_{T_1}^{t} (-V_{ref})\, dt\right]$$

$$\boxed{V_o = \frac{-V_a}{RC} \times T_1 + \frac{V_{ref}}{RC}\left[t - T_1\right]}$$

At $t = T_2 \Rightarrow V_o = 0$.

$$0 = \frac{-V_a}{RC} \times T_1 + \frac{V_{ref}}{RC}\left[T_2 - T_1\right]$$

$$\boxed{V_a = \frac{V_{ref}\left[T_2 - T_1\right]}{T_1}}$$

Q2) $V_a = 100mV \dfrac{(370.2)}{300}$

$V_a = 123.4$ msec.

Q3) $f_{max} = \dfrac{1}{T_1} = \dfrac{1}{2^N T_{clk}}$

$= \dfrac{f_{clk}}{2^N}$

$= \dfrac{10^6}{2^{10}}$

$= 1$ KHZ

ating

* Instrument t/F's are used for extension range of current as well as voltages.
* For extension range of (A) currents t/F is used.
* For extension range of (V) potential t/F is used.
* Both C.T & P.T's are basically step down t/F's.
* C.T can reduce the current level & PT can reduce the v/g level.

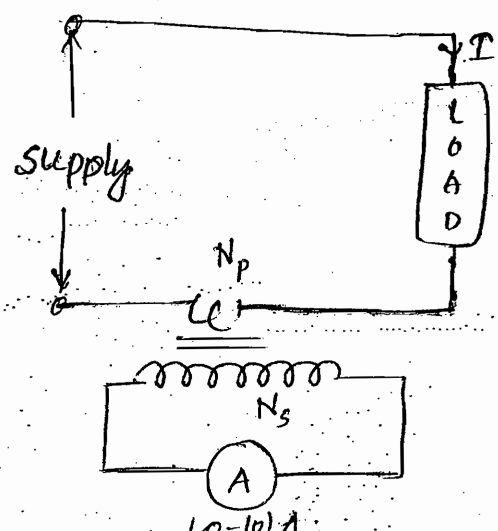
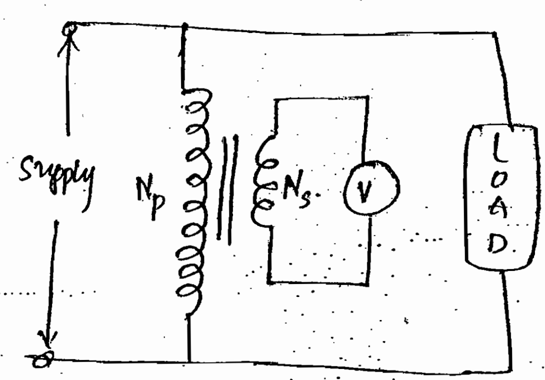


Fig: C.T



$N_p > N_s$

Fig: P.T

In the analysis of C.T following terms are involved:

1. Burden: $I^2 Z_e$ is known as burden. The load which is connected on C.T sedry side known as burden which includes the meter impedance.

$$Z_e = r_e + jx_e \; ; \; |Z_e| = \sqrt{r_e^2 + x_e^2}$$

$$\Delta = \tan^{-1}\left(\frac{x_e}{R_e}\right)$$
↳ Burden angle

if Burden is pure resistance $\Delta = 0$ $(\because x_e = 0 \Rightarrow Z_e = R_e)$

C.T equivalent ckt:

Let ϕ be the core flux (or) working flux of the t/F.

$I_0 \rightarrow$ No load current

$\alpha \rightarrow$ angle b/w I_0 & core flux

$E_p \rightarrow$ induced pry vlg.

$\delta \rightarrow$ angle b/w I_s & E_s $\Rightarrow \delta = \tan^{-1}\left[\dfrac{X_s + X_e}{R_s + R_e}\right]$

$\rightarrow$ I_s lags E_s by 'δ' & δ is the angle b/w $\angle I_s$ vs V_s

There are two types of errors are present in C.T

1) Ratio error (or) magnitude error.

2) phase angle error.

$\rightarrow$ Ideally $|I_p| = |I_s|$ & $\angle I_p$ & I_s $= 180^\circ$ but practically, $|I_p| \neq |I_s|$ and $\angle I_p$ & I_s $= 180 - \theta$.

$\rightarrow$ Causes of errors in C.T are :

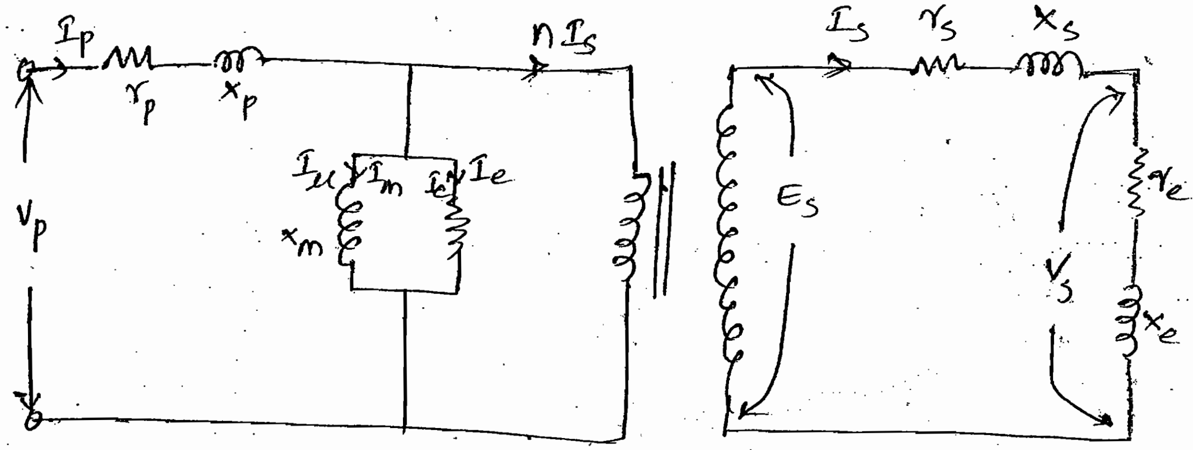
1) The mag. flux density (B) is not linear function of magnetising force.

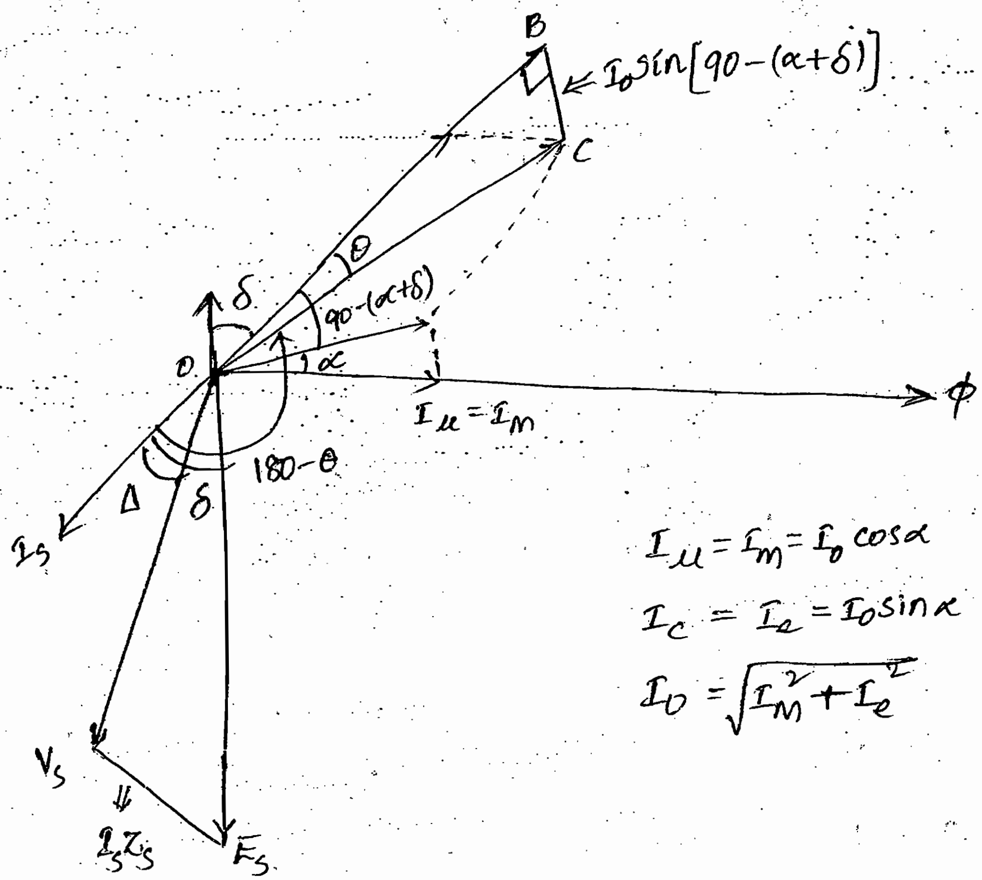
$\rightarrow$ Due to magnetic leakage losses in the wdgs of the t/F losses in the core of the t/F.

Reduction of Error's in C.T :-

To reduce the errors in C.T a low reluctan high permeability core is used for that the materials usa are C.R.G.O, hot rolled silicon steel stampings. We can also use strip wound core. To reduce the magnetic leakage distance b/w pry and scdry wdg is reduced. By using Ferrite core we can reduce both ratio and phase angl error. Ferrite core is a combination of mumental, hipernic, ~~& phase angle error remains same. i.e it doesn't have any effect on the phase angle error~~

By reducing either 1 or 2 turn we can reduce only Ratio error. But the phase angle error remains same. i.e it does not have any effect on the phase angle error.





$I_\mu = I_m = I_0 \cos\alpha$

$I_c = I_e = I_0 \sin\alpha$

$I_0 = \sqrt{I_M^2 + I_e^2}$

From $\triangle^{le}$ OBC $\Rightarrow$ $OC^2 = OB^2 + BC^2 = (OA+AB)^2 + BC^2$

$$I_p^2 = [nI_s + I_0 \sin(\alpha+\delta)]^2 + [I_0 \cos(\alpha+\delta)]^2$$

$$\boxed{I_p = \sqrt{[nI_s + I_0 \sin(\alpha+\delta)]^2 + [I_0 \cos(\alpha+\delta)]^2}} \Rightarrow \text{Exact eq}^n$$

$\Downarrow$

$nI_s + I_0 \sin(\alpha+\delta) >> (I_0 \cos(\alpha+\delta)) \Rightarrow$ neglect

$\boxed{I_p \ldots n I_s + I_0 \sin(\alpha+\delta)]}$ ⇒ Approx eq

case ①: If core loss component is neglected

$$I_c = I_0 \sin\alpha = 0 \Rightarrow \boxed{I_c = 0} \;\&\; \boxed{\alpha = 0} \;\&\; I_0 = I_m$$

$$\boxed{I_m = \frac{MMF}{N_p}}$$

$$I_p = \sqrt{[nI_s + I_0 \sin(0+\delta)]^2 + [I_0 \cos(0+\delta)]^2}$$

$$\therefore \text{If } \delta = 0 \Rightarrow I_p = \sqrt{(nI_s)^2 + I_0^2}$$

$$\boxed{I_p = \sqrt{(nI_s)^2 + I_m^2}}$$

The following techniques are involved in analysis of inst. t/F.

(i) Transformation ratio :- It is defined as the ratio of actual pry phasor to the actual scdry phasor may be either current (or) v/g.

$$R = \frac{I_{p\,(actual)}}{I_{s\,(actual)}} \quad \text{For C.T}$$

$$R = \frac{V_{p\,(actual)}}{V_{s\,(actual)}} \quad \text{For P.T}$$

(ii) Nominal ratio :-

It is defined as the ratio of rated pr phasor to the rated scdry phasor, phasor may be either current (or) v/g.

$$K_n = \frac{I_{p\,rated}}{I_{s\,rated}} \quad \text{for C.T} \qquad K_n = \frac{V_{p\,rated}}{V_{s\,rated}} \quad \text{for P.T}$$

$$\%\text{ ratio error} = \frac{K_n - R}{R} \times 100 = \left(\frac{K_n}{R} - 1\right) \times 100 = \left(\frac{1}{RCF} - 1\right) \times 100$$

Ratio correction factor: $\boxed{RCF = \frac{R}{K_n}}$

$$\boxed{R = n + \frac{I_e}{I_s}} \Rightarrow n = \frac{I_p}{I_s} \Rightarrow I_s = \frac{I_p}{n} \text{ and}$$

$$\boxed{R = n\left[1 + \frac{I_e}{I_p}\right]}$$

Case③ : In Δ^{le} OBC $\Rightarrow Tan(\theta) = \frac{BC}{OB} = \frac{BC}{OA+AB}$

for very small values of 'θ' $\Rightarrow$ $\boxed{\tan\theta = \theta = \frac{I_0 \cos(\alpha+\delta)}{nI_s + I_0 \sin(\alpha+\delta)}}$

$\Downarrow$ Exact eq^n. neglect

$nI_s >> I_0 \sin(\alpha+\delta) \Rightarrow$ neglect

$\therefore$ $\boxed{\theta = \frac{I_0 \cos(\alpha+\delta)}{nI_s}}$ $\Rightarrow$ Approx eq^n.

If $\delta = 0 \Rightarrow$ $\boxed{\theta = \frac{I_0 \cos\alpha}{nI_s} = \frac{I_m}{nI_s}}$ rad.

$\Rightarrow$ $\boxed{\theta = \frac{I_m}{nI_s} \times \frac{180^\circ}{\pi}}$ $\Rightarrow$ phase angle error.