Measuring Instrument

→ It is an instrumental which measured any type of physical quantity. It is
1- Mechanichal Instrument.
2- Electrical Instrument
(a) electrical parameter
(b) electronic parameter

parameters of Measuring Instrument

(1) Accuracy (4) Linearing (7) dead Zone
(2) precession (5) Resolution (8) Error
(3) Sensitivity (6) Dead time (9) Tolerance.

(1) Accuracy:

Accuracy is maybe defined as the degree of closeness of the measured quantity to the true value. It is the ability of the instrument to measure accurate value.

(2) precession:

→ The most repeated or Reproducable value out of the sets of the Recorded is Called precession.

(3) Let's us Consider two Measuring instrument to Measured the value of voltage 2 volt.

M.A. 1.9 1.4 1.6 1.8 1.9 → 1.9 (Accurate & precise can be.

M.B 1.9 1.7 1.7 1.6 1.7 → 1.7 precise but not be Accurate.

→ The Accurate instrument may be precise but precise instrument doesnot indicate accuracy.

(3) Resolution:

The smallest output that we Can indicate detake with clarity is Called Resolution. As Revolution increases clarity will be also increases so that we may not be lose Accuracy.

$$\text{Resolution} = \frac{\text{Full scale value (F.S.V.)}}{\text{Total no. of devision (N.D)}}$$

by increasing total no of division we can achive more accuracy.

(4) Sensitivity:

It is defined as the Ratio of change in output to change in input.

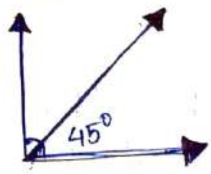
$$S = \frac{\text{change in output}}{\text{change in input}} = \frac{1}{\text{F.S.D}}$$

where F.S.D = Full scale defluction of Current.

→ It denotes are the smallest change in the value of Measured variable to which instrument can response.

(5) Linearity:-

If the output is in linear relationship with input then that instrument is Called linear instrument & the property is Called as linearity instrument.



(6) Dead time:-

→ It is time taken by the instrument to Move the pointer from Null/Zero/initial position.

→ It is also Called as dead time.

(7) Dead Zone:-

→ The minimum input beyond with which the Respond will Comeout is Called as dead Zone.

Dead zone.

(8) Tollerance:-

→ It is defined as the Minimum allow variance in the instrument used to rise in tempreture or heat generated due to Overload.

(9) Error:-

→ It is the estimated difference betn Measured value & true value is Called the Error.

→ Error Can be Measured +ve or -ve. that's why It is writing ± symbole.

Ex:- ± 0.1%, ± 2.5%, ± 40%, ±2%.

Type of error:-

(1) Gross error
(2) Systmatic error → Instrument error / Envirumental error / Observational error
(3) Random error

Gross error:
→ All human negligence error while using the instrument is Called as gross error

Systmatic error:-

Instrumental error:-
This error produced due to the effect of Manufactoring or Calibration effect.
Ex:- Loading error, egging error, gross, Accurate, error etc.

Environmental error:-
These error is produced due to change in physical phenomenon in the environment.
Ex:- Tempreture, humidity, pressure etc.

Observational error:-
This error occure due to observation of human which is using it. This is Called as observational / parallex error, which is line of the vision of vision.

Random error:-
The error which is Caused by no particular reason is Called as random error, it Can be -ve, +ve amplified, Vanishis.

Classification of Measuring Instrument:-

→ Mechanical Instrument
→ electrical Instrument → absolute / Primary Instrument (Indirect) / Secondary Instrument (direct)
→ electronic Instrument.

Secondary Instrument → Analog Instrument → Indicating type Instrumental; Integrating type instrument (energy meter); Recording type instrument (frequency meter)
Secondary Instrument → Digital Instrument

Absolute/primary:-
Ex:- Tangent galvanometer
Secondary:-
Ex:- Ammeter, Voltmeter, wattmeter etc.

Electrical Instrument:-
The Instrument which can measure the electrical quantity like Voltage, Current Resistance, power is Called electrical Measurement.
Ex:- Ammeter, Voltmeter, wattmeter etc.

Absolute Instrument:-
→ The absolute instrument gives the value of measured quantity in terms of physical constant.
(i) The physical Constant may be Angle of deflection, degree or Meter Constant.
(ii) Mathematical eqn is required the find value.
Ex:- Tangent galvanometer

Secondary Instrument:-
The Instrument which can give/shows the measured quantity in terms of deflection of the pointer on a Calibrated scale, is Called Secondary Instrument.
Ex:- Ammeter, Voltmeter, wattmeter etc.

Digital Instrument:-
The digital instrument gives the output in Numeric Form.
→ It is More accurate because no human error occure in the Reading.

Analog Instrument:-

The Instrument whose out put varies continously is known as Analog Instrument.

→ The analog Instrument has a pointer which shows the magnitude of measurable quantity.

It is two types:-

(1) Null type Instrument:-

In this instrument one known and another unknown quantity is used when the both quantity are equal the pointer shows zero deflection.

Ex: pu tentio meter

(2) Deflection type Instrument:-

→ It shows the measuring quantity through the deflecting of the pointer.

→ It is of three type:-

(1) Indecating type:-

The Instrument which indicate the magnitude of measured quantity is known as indicating type instrument.

→ The indicating instrument is dial which moves on the graduated scale.

Ex:- Ammeter, Voltmeter, Multimeter

Integrating type:-

The instrument which measured the total energy supplied particular interval of time is known as integrating type Instrument.

Ex:- energy meter, Ampre, hour meter, watt hour meter

Recording type:-

The instrument which Record the circuit at a particular interval of time is known as Recording type

→ The moving system of the Recording instruments is carries a pen which lightly touch a thin paper. The moving of the coil treated on the paper sheet.

track

Ex:- frequency meter

Essential Factors Required for a Measurement Instrument

According the electrical theory when Current enters to a Circuit it produces Many type of effect,
Magnetic effect, electro magnetic effect, thermal effect, electrostatic effect, induction effect etc.

→ There are basically 3 force or torque produced in the Measuring Instrument · to the above effect.

(1) Deflecting Force / Torque (T_d) :-

This is the Force Required to Move the pointer from the initial Null position to final position on the Calibrated Scale.

→ Due to the deflection torque the pointer will move Continously on the meter irrespective of Magnitude of the quantity which is undesirable for us. So, we Required to the proportional output to the given input by the opposing the deflecting torque. which is Called as Controlling torque.

(2) Controlling Torque / Force (T_c) :-

The torque which is used to the oppose the deflecting Torque for the final output is Called as Controlling torque.

→ When the input is Removed The pointer should back to initial position. This will happen the due to presence of Controlling Torque.

→ When $T_d = T_c$, the pointer will Come to steady state position but before the steady state arrives the pointer will make so many Oscillation which is Undesirable.

(3) Damping Torque / Force :-

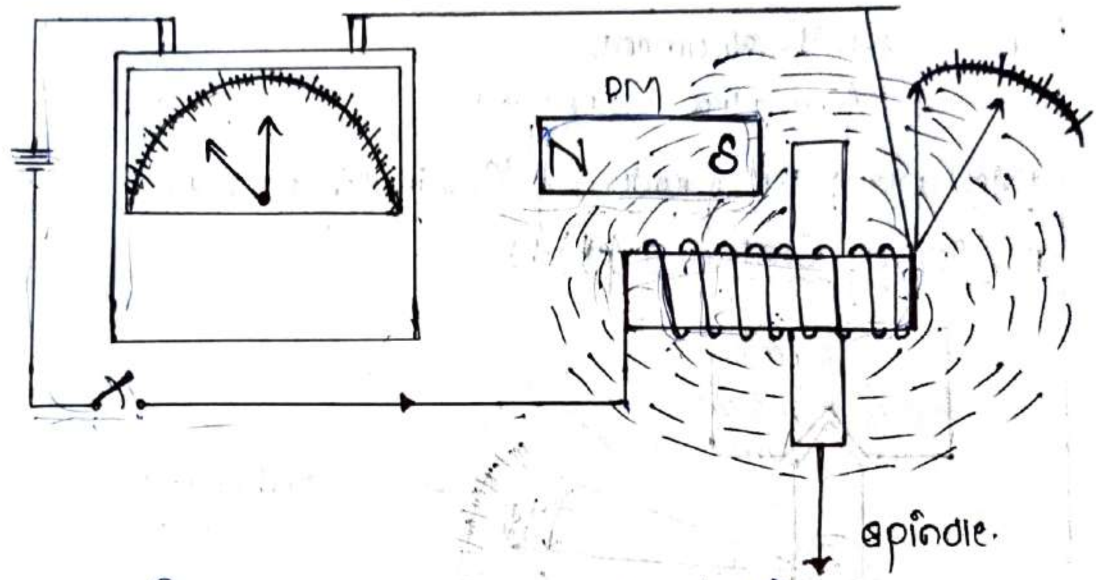
This is Force Required to Reduce the no of oscillation of steady state. That is when $T_c = T_d$.

→ The damping force is of three type,

(1) Air friction damping
(2) fluid friction damping
(3) eddy Current damping

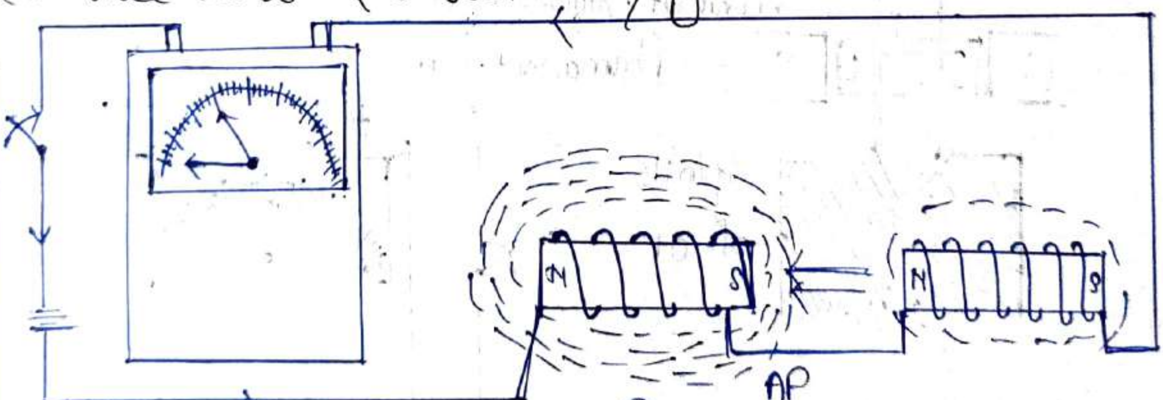
Mechanism of producing Deflecting Torque:-

(a) Force betn permanet Magnet & Current Carrying Coil



Ex: PMMC (Permanent Magnet Moving Coil)

(b) Force betn 2 Current Carrying Coil.



AF = Attraction force.

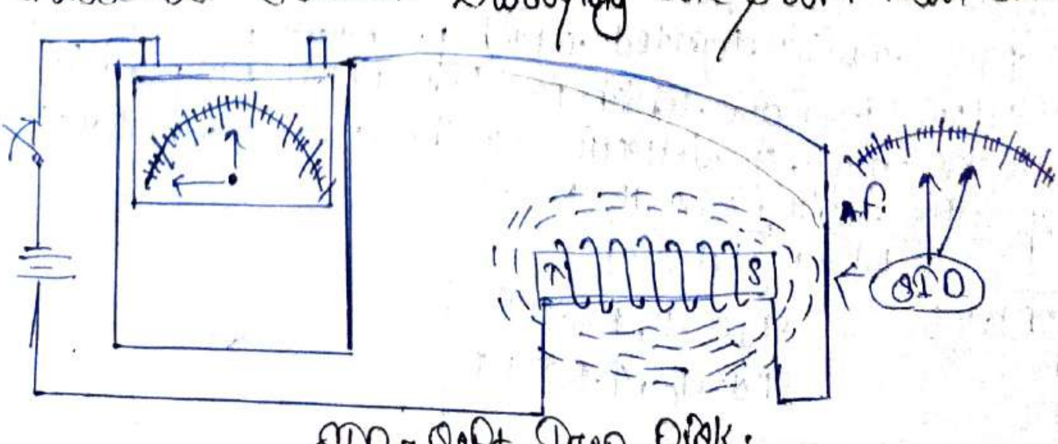
operating

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

L = Length.

Ex- dynamometer, EMMC meter type Instrument.

(c) Force betn Current Carrying Coil & soft Iron disk:



SID - Soft Iron Disk.

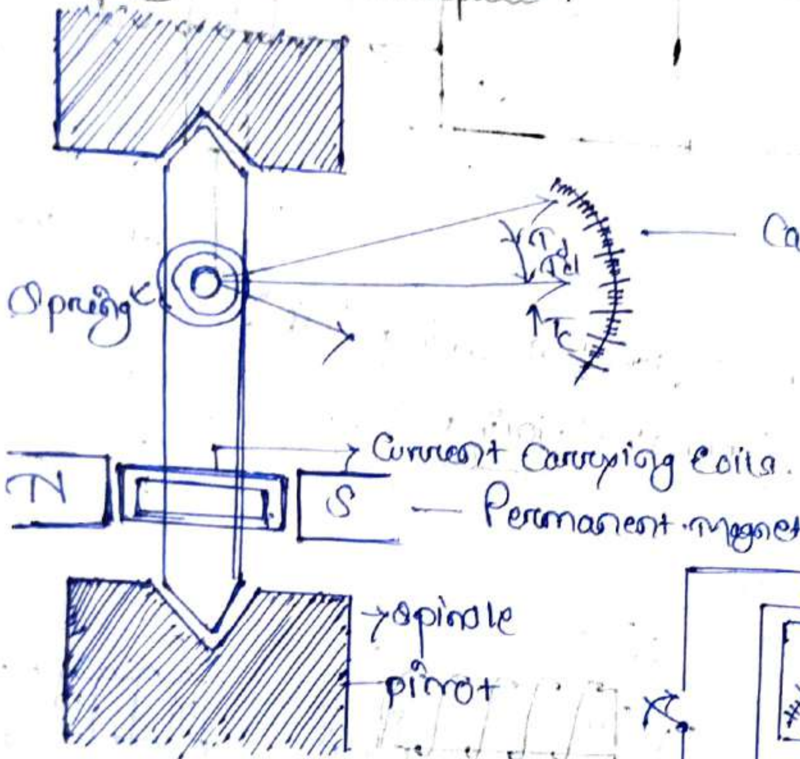
$$T_d = \frac{I^2}{2}\frac{dm}{d\phi}$$

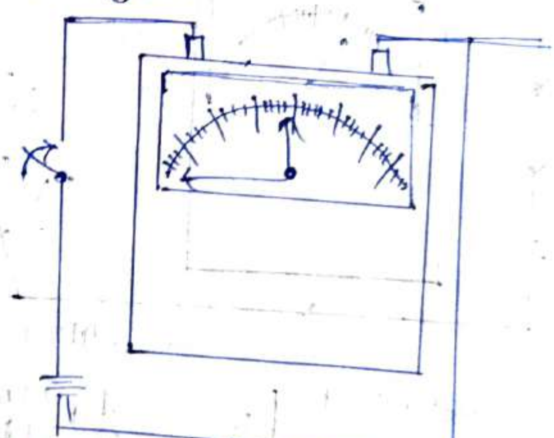
M = mass

Ex: M.I. Instrument.
(Moving Iron Instrument)

Mechanism for producing Controlling torque.

(i) Spring Control Method :-





→ A hair type of spring is made up of phosphorus bronze is attached to the moving path (spindle) of the instrument. With the deflection of the pointer the spring will be tighted which problems produces a Restoring torque which is directional proportional to the angle of deflection of the moving pointer the pointer will come to Rest.

where $T_d = T_c$

Note:- $T_d \propto I$, $T_c \propto \theta$

$T_d = T_c$, $\uparrow \theta \propto I \uparrow$

$T_c = K\theta$, where, K_c = Spring Constant.

| Unit, K_c = N-m/Radian |

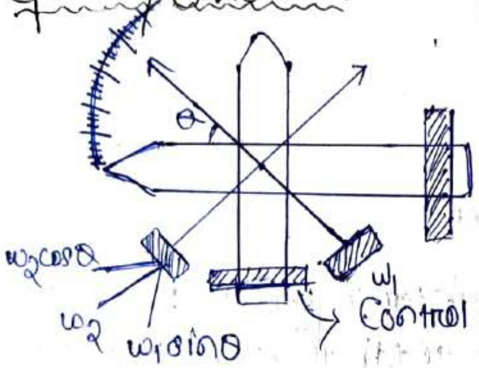
Merities:-

- → Linear Relation ($T_c \propto \theta$)
- → Can be placed in horizontal / Vertical position.

Demeritesf:-

- → ~~ageing~~
- → ageing effect
- → Temprature effect.

Gravity Constant:-



→ In this Method an adjustable ~~weight~~ Control weight) is attached to the spindle.

→ Under the action of deflection Torque(T_d) The pointer Moves from Zero position & Control weight Moves ~~to~~ in the oppositive dirn by the angle of θ.

→ Due to gravity the Control weight try to Come to its original position that is ~~at~~ Vertically downward, therefore it produces A torque / Force which is opposite to the ~~def~~ deflecting Torque.

→ We know $T_d \propto I$. (For gravity Control Method) $T_c \propto \sin\theta$ So, the pointer Comes to steady state ($T_d = T_c$)

| $I \propto \sin\theta$ |

Merits:

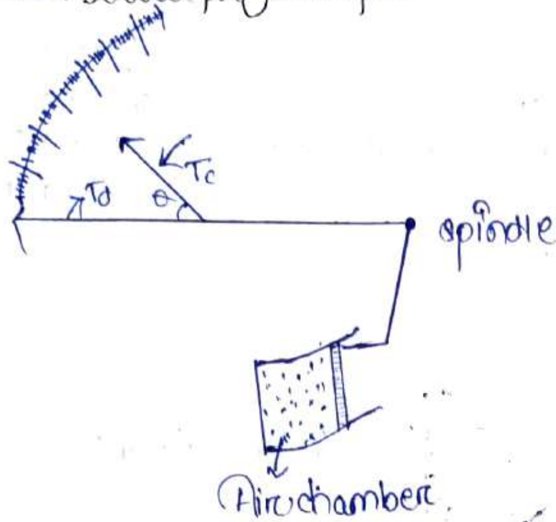
- → Very simple Method
- → no ageing effect
- → no temprature effect

Demerits:-

- → The instrument has to be kept in Vertical position only.
- → no uniform scale.

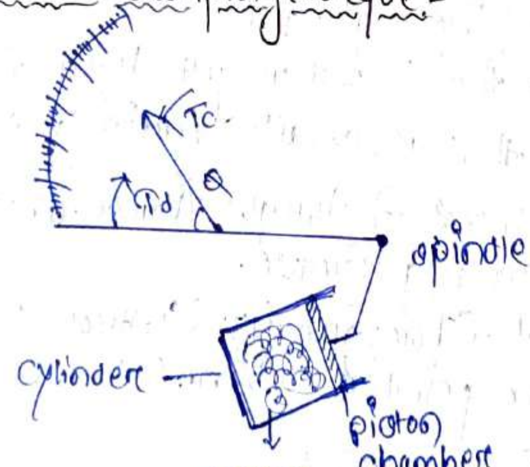
Mechanism for producing damping Torque:-

Air friction damping torque:-



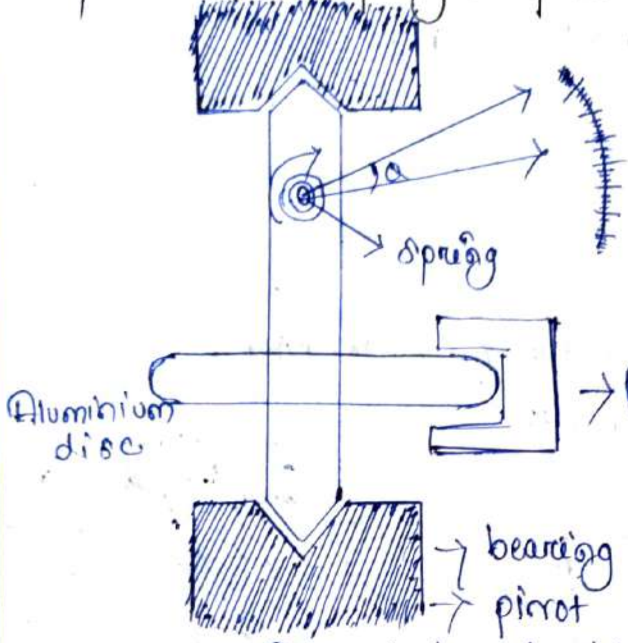
→ In this Method when the pointer Moves upward attain its steady state ($T_d = T_c$), then another link connected to the spindle Moves the piston inward. The air chamber due to air pressure it opposes the inward Movement of the piston. Hence it Reduces the damping/oscillation.

Fluid Friction damping torque:-



→ here A cylinder full of water fluid is connected at the end of the pointer, when $T_c = T_d$. The pointer forces the piston to move inward of the fluid chamber, but the viscosity of the fluid provide the thrust in upward dir^n hence Reducing the damping.

Eddy Current damping Torque:



→ The eddy Current damping is a effective damping but it is not suitable for all the type of instrument. eddy Current damping is used only when only permanent magnet present in the instrument.

→ When the pointer oscillates the disc cut the flux is Causes in the disc by which a Current flowing in the disc which is Called eddy Current.

→ According Lenz's Law, the disc rotates slowly by Creating friction in the pointer so no of oscilation due to Reduced.

Calibration of instrument:

→ Calibration may be defind as the process of Comparision betn a standard value which is to be measured for the determination accuracy of the measuring instrument.

→ In performing Calibration of an instrument following steps are necessary

(1) examing the Construction of instrument following steps are identifying the possible input.

(2) decide as the best provides input will be significant.

(3) For which the instrument will be Calibrated.

(4) by holding some input Constant & varying others Record the output & development desire startic input & output Relationship.

Order of damping Torque: Performance:

eddy Current damping > air > fluid

effectiveness:

eddy > fluid > air

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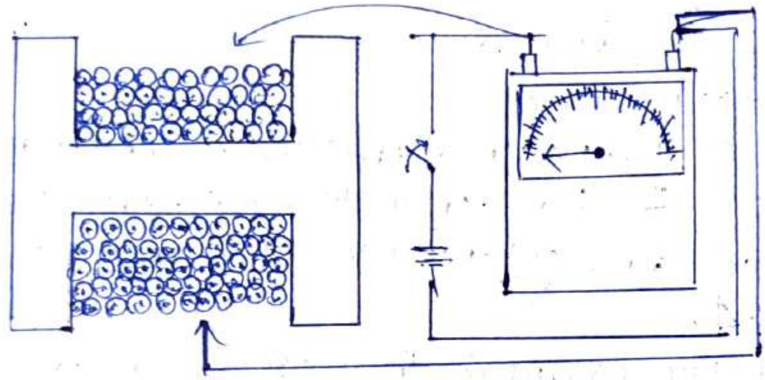
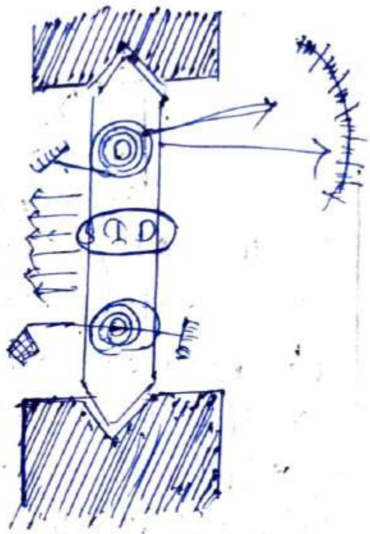
chapter-2 Analog Ammeter & Voltmeter

Moving iron type Instrument:





[Attraction type]

figure change 1 & 2 with opposite place.

→ M.I type Instrument will be measure both DC & AC

principle:

These Instrument are Rest on the principle that when unmagnetised soft iron disc is placed in the magnetic field of the Coil then the soft iron piece is Attached towards the coil. The moving system of the Coil is attached to the soft iron peach. The operating Current is passed through a Coil placed near it. The operating Current setup a magnetic field which attracted to soft iron peach towards it. Therefore, the pointer moves in the Calibrated Scale.

Construction: It Consist of a hollow cylinderical Coil which is shown in the figure. A oval shaped soft iron disc is attached to the spindle in a way that it can move in or out Coil. The pointer is attached to the ~~pointer~~ spindle also that it can deflect with the motion of soft iron disc. here controlling torque is provided by spring method & Air friction damping is used. as there is no permanent Magnet inside it.

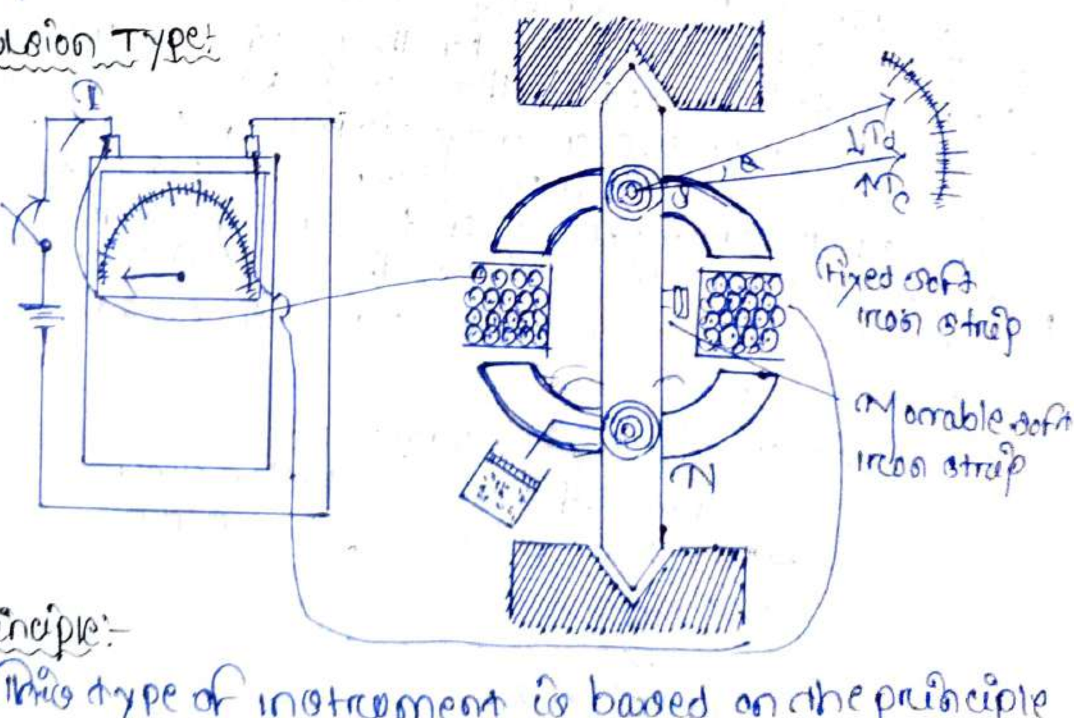
Working:

(1) When the instrument is connected in the circuit the operating current flow through the coil. The current set up a magnetic field in the coil which magnetise the soft iron disc hence a force of attraction moves the soft iron disc towards the coil as the result the pointer is deflected moves over a calibrated scale.

(3) The pointer comes to steady state the deflecting torque is equal to the controlling torque.

(4) If the current in the coil is reverse, the dirn of magnetic field is also reverse. The magnetic field is also reverse. The magnetic field it magnetise a soft iron disc with opposite polarity & force of attraction also exist. hence dirn of deflection remain unchanged show. Such type of instrument are used for both AC & DC instrument.

Repulsion Type:



Principle:-

→ This type of instrument is based on the principle that when 2 soft iron strip is placed in the same magnetic field, they are similarly magnetised & experiences a force of repulsion betn them.

→ which tends to moves the pointer over the Calibrated Scale.

Construction:-

→ It Consist of a hollow cylinder which is wounded with no of turns of coil when Current pass through it a magnetic field is set up inside the cylinder. There are 2 soft iron strip one is fixed & another is Movable

→ The fixed iron is attached to the Coil & moving iron with the spindle under action of deflecting torque, The pointer attached to the moving system moves of the calibrated scale.

→ Spring Control Method is used for the Controlling purpose & Air friction damping Method is used for Reduce the Oscillator.

Working:-

→ when instrument is Connected across the circuit to measure Current, voltage & operating Current flow through the coil & setup a magnetic field.

→ This magnetic field magnetise the two soft iron strip with some polarity.

→ A force of Repulsion exist betn two iron strip due to which the movable strip try to move & hence the pointer moves across the Calibrated scale.

→ The spring are provided for the Required Controlling torque if the Current in the Coil is Reverse unchanged because the Reversion of magnetic field of the coil Reverses of magnetism of both iron strip so, that they Repell each other irrespective of the dirn of Current flowing through the Coil for this Reason such type of instrument are used Repulsion type both AC & DC measurement.

Production of deflecting Torque(T_d):-

$T_d \propto$ Force of Repulsion betn 2 strip

$\propto$ pole strength betn two strip

→ $T_d \propto M \cdot M$

$\propto H \cdot H$

but we know, $H \propto I$

$T_d \propto I \cdot I \propto I^2$

The Controlling torque (T_c) $\propto \theta$

during steady state $T_d = T_c$.

$\theta \propto I^2$

Merits	Demerits

Merits	Demerits
→ It operates for both AC & DC	→ Scale is non-linear
→ The starting torque & weight Ratio is low.	→ It is less accurate since air friction damping is used.
→ It cost is very chip as compair to PMMC.	

Error produced in M.I. type Instrument:-

Frictional error:- Frictional error is more as compair to PMMC type.

Temprature error:- The temprature in the instrument causes the error to rise upto 0.02%.
→ The temprature rises due to excess heat which can be minimized by using swamping Resistance.
Ex:- magnanin, constantine, etc.

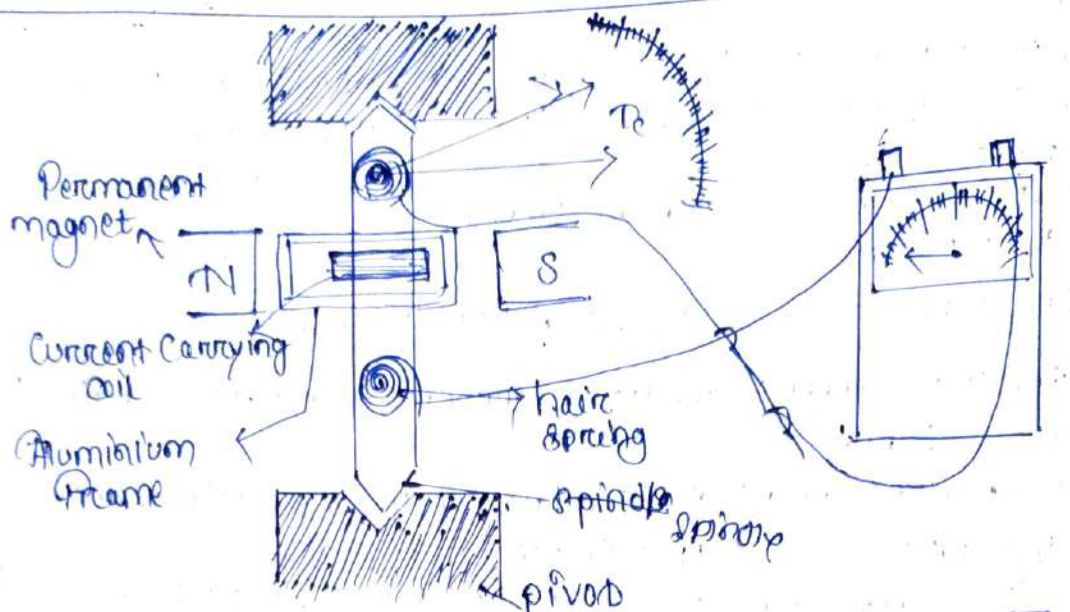
Frequency error:-
The error in the instrument is upto ±5%. This error can also be reduced by swamping Resistance.

Stray magnetic field error:-
This error obtained due to the external effect or magnetic field it can minimised by a covered magnetic field.

hysteresis error:-
This error is produced in the metal core due to magnetisation & demagnetion it can be minimized upto 0.05%. after providing the metal with nickel iron.

* As the error produced are more as compare to PMMC instrument, so, it is less accurate & less sensitity than PMMC.

PMMC TYPE INSTRUMENT:- (1,1,3)



[Constructional digram of pmmc type instrument]

Working principle:-

→ This type of instrument on the ~~best~~ based of the principle that current carrying coil is placed in the magnetic field mechanichal force will act on it.

→ The coil placed in the magnetic field which carryies operating current attached to the moving system, when the coil moves the moving system also moves & hence the pointer also moves from initial position over the calibrated scale.

Construction:-

→ It consist of a U-shape permanent magnet made up off Alnico fitted with 2 iron shaped.

→ A Rectangular coil of many turns made up off copper is wound on aluminium frame.

→ The current is ~~wound on aluminium~~ frame lead in or out of the coil by means of two control hairspring

→ These two springs provide the controlling torque the aluminium frame provide the eddy current damping torque.

→ The hairsprings is made up of nickel, cromina phosporous bronze.

Working:-

→ When the instrument is connected to the circuit for the measurement of currents, voltage the operating current through the coil.

→ Since the Current Carrying Coil is kept inside the magnetic field a mechanical force is experiences by the coil.

→ As a result the moving coil moves on the in or out & the attached pointer moves over the Calibrated scale & indicates necessary measurement.

→ **Why we don't used in A.C. source:**

→ When we applied the PMMC type instrument AC source, In AC source we know that AC source is both +ve, -ve half cycle, for +ve half cycle it will forward dirⁿ but -ve half cycle it will be Reverse dirⁿ.

→ If the Current Carrying coil Reverse the deflecting torque is reverse, The dirⁿ of field is Constant the deflecting torque reverse dirⁿ is, the pointer also moves in reverse dirⁿ. hence these instrument for only DC measurement.

Production of deflecting Torque:-

→ The magnitude of the force is experienced by each coil side is given by,

$$F = BINL \sin\theta$$

Where, F = Force is experienced

B = magnetic flux density

I = Current through it.

L = Length of the Conductor.

θ = angle b/w Φ_0 & Φ_c

T = Torque = Force × ⊥ʳ distance.

= BIL sin θ ×

(Where θ = 90°)

= BIL sin 90° × d × N = BIL d × N

= BIL × d × N = BINA

Where, A - Area of cross section in m².

[∵ A = L × d]

N = no. of turns in the Coil.

∵ It is our responsibility of to make the angle betn the magnetic field & current carrying conduction is 90°.

→ $T_d \propto I$ at constant, B, N, A

$T_c \propto \theta$

at steady state condition, $T_d = T_c$

→ $I \propto \theta$

When, current is directionaly to the angle betn T_d & T_c

So, the scale is also linear. (Proved)

Merits:

→ The scale is uniform as $Q \propto I$.

→ Torque / weight is high

→ hysteresis loss is less because of Aluminium frame

→ highly accurate & high sensitivity instrument as eddy current damping is used.

→ It will be used in DC source.

Demerits:-

→ by using PMMC we can't measure AC source since the force of dirn will be reversed.

→ some errors are set up due to the controlling torque, springs permanent magnet.

→ eging error & temprature error

→ It is costly & measure for DC supply measure

→ By using PMMC we can't measure the high current since, the spring can't be withstand high current.

errors:

(1) Egeing error

(2) Temprature error

Temprature error:-

(1) The temprerture in the instrument causes the error to rise up to 0.02%.

→ The temp. rise due to excess heat which can be minimised by the using swamping resistance.

Ex: Manganin.
: Constantan.

Ageing error:-

→ Due to many used of the instrument with many time in this way which error is produce in called ageing error.

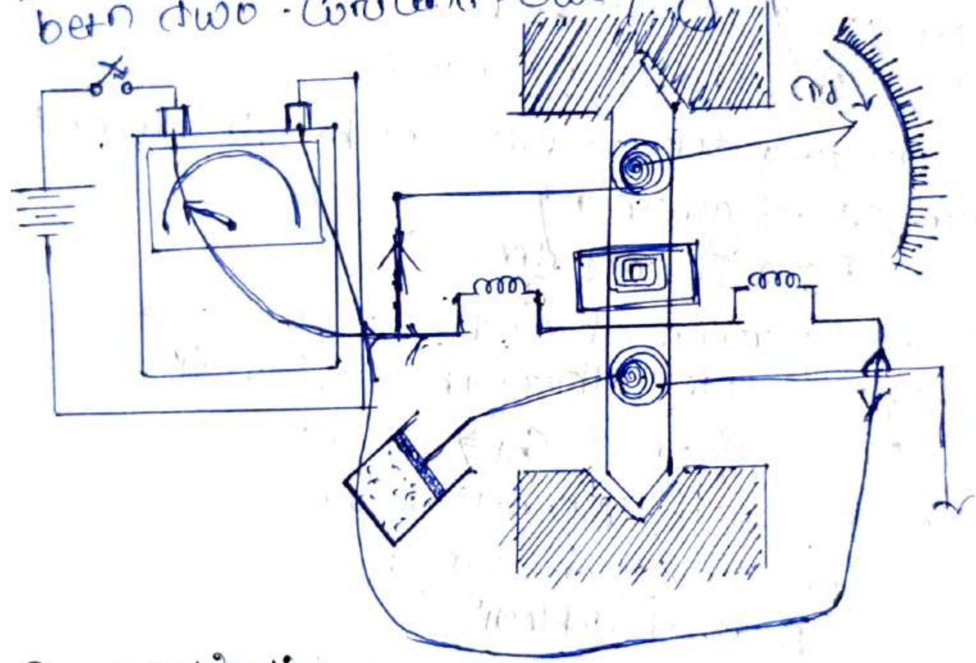
EMMC TYPE INSTRUMENT:-

principle:-

→ These type of instrument are modified certain of PMMC type instrument.

permanent magnet is replaced by electromagnet

It is based on the principle of mutual induction betn two current carrying coil.



Construction:-

→ It has two coils one is fixed coil & moving coil. The fixed coil is attached in betn the fixed coil which is wound on a non-metallic former.

→ The moving coil is mounted on the spindles the pointer is attached to it. The controlling torque is provided by two pairs of hair type spring & the effective damping is provided by air friction damping method.

Working principle:

→ When the instrument is connect to the circuit the operating current flows through the coil due to this a mechanical force exist betn the coil. so it is moving the pointer on the calibrated scale.

→ The pointer comes to steady state when the deflecting torque is equal to the controlling torque by the receiving dirn of deflecting torque remain unchanged.

→ Hence, these type of instrument are used for both ac & all well as DC.

Production of deflecting torque:

→ The deflecting torque produced by the emme type instrument is given by

$$T \propto I_1 I_2 \cos\phi \frac{dM}{d\theta}$$

where I_1 = Current through fixed coil.

I_2 = Current through moving coil.

θ = Angle betn T_d & T_c

$\cos\phi$ = power factor betn 2 coils.

ϕ = phase angle betn I_1 & I_2

θ = Angle of deflection

M = Mutual inductance betn 2 coils.

θ = power factor between I_1 & I_2.

when $I_1 = I_2$

$\phi = 0$

$$T_d \propto I_1^2 \frac{dM}{d\phi}$$

$$T_d \propto I_1^2$$

at steady state condition $T_d = T_c$

then $T_c \propto \theta$

Then $\theta \propto I^2$

∴ Hence the scale is non-linear.

Advantages:-
→ It is used for both AC & DC.
→ There are free from hysteresis & eddy current error because non-metallic frame is used instead of aluminium frame.

Disadvantages:-
→ error produced due to the ageing of spring.
→ Costly.
→ The torque / weight is low.

Errors in EMMC TYPE INSTRUMENT:-

Frictional error:-
→ This errors are more as compair to emmc & MI type instrument since torque / weight ratio is less.

EMMC > MI > PMMC interms of frictional error.

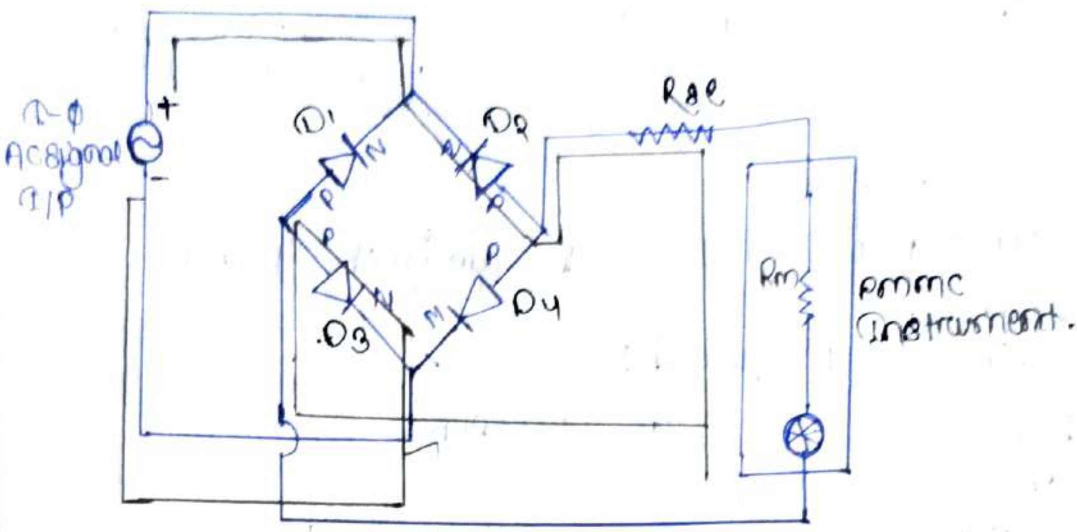
Temprature error:-
→ The temprature occure can be reduced by swamping resistance.
Ex:- Manganin
:- Constatan

Hysteresis error:-
→ This error is almost absent in emmc type instrument as know from, related part in used.

MI > PMMC > EMMC type material.

Stray magnetic field:-
This type of error are more as compare to PMMC & MI instrument since a week magnetic field present inside the meter.

Rectifier type Instrument:-
→ The rectifier type instrument are used for the measurement of AC voltage and current employing the rectifier which converts AC signals into underground DC signals. Then using a responsive type meter for measuring the rectifier DC.



→ This Method is very attractive because PMMC Instrument can be used for this arrangement and it is highly sensitive Then the electro dynamometer can be used for this Arrangment and it is highly sensitive Then the electro-dynamometer Type of mainly iron Type instrument.

→ The Arrangment which employes a full wave Rectifier Circuit having using bridge Rectifiers

→ The sensitivity of the various betn 100 Ω/V to 200Ω/V.

→ The Multiplying resistance Rse is used to the limit value of Current in order to protect The instrument for exceding the Current Rating.

→ The Comparision in with other Type of the AC meters This Rectifiers Type instrument is widely used.

Advantages:-

→ The frequency range is from 20Hz to high audio frequency.

→ This type of instrument have much Lower Current for Measuring voltage.

→ Scale is uniform or Linear.

→ Accuracy is ±5%. under normal Conditions.

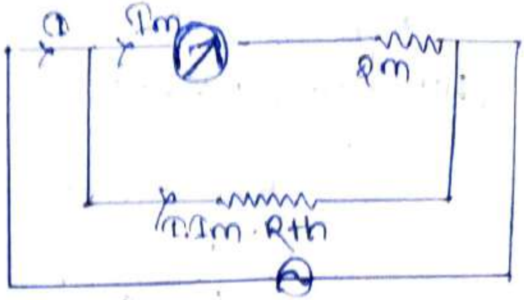
Disadvantages:-

→ It effects the rectifier resistance due to which sensitivity increases.

→ Defect the wave form produce due to rectifier unit.

Extension range:

Ammeter:



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

According to KVL,

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

$\Rightarrow R_{th} = \left(\frac{I_m}{I - I_m}\right) R_m = \frac{R_m}{\frac{I}{I_m} - \frac{I_m}{I_m}} = \frac{R_m}{\frac{I}{I_m} - 1}$

where $m = \frac{I}{I_m}$.

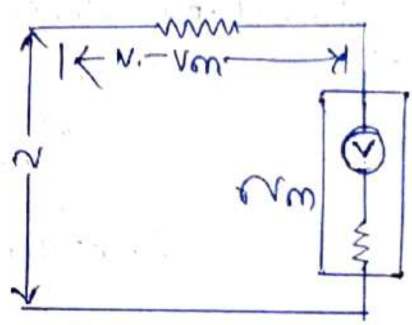
Where, m = multiplier

Rm = Internal resistance.

Rsh = shunt resistance

According to KCL,

Voltmeter:



$\rightarrow \frac{V - V_m}{R_{se}} = \frac{V_m}{R_m}$

$V_m \rightarrow R_{se} = \left(\frac{V - V_m}{V_m}\right) R_m.$

$= \left(\frac{V}{V_m} - 1\right) R_m$

$= (m-1) R_m.$

where, m = Multiplier

Rm = Internal resistance.

Rse = Series resistance

→ where 'm' is the multiplying factor Rse & Rsh is the series and shunt element respectively.

(1) An instrument with range 0-1mA with an internal resistance of 100Ω is to be converted into 0-10mA. Find out the shunting resistance.

→ Given data, $I = (10-0)\,mA = 10\,mA$

$I_m = (1-0)\,mA = 1\,mA$

$R_m = 100\,\Omega$

For Ammeter,

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

where, $m = \frac{I}{I_m} = \frac{10}{1} = 10$

$R_{sh} = \frac{100}{10} = 11.11\Omega$ (Ans)

Alternating Method,

$$I = \frac{V}{R_{eq}} = \frac{V}{R_m \| R_{sh}} = \frac{I_m R_m}{R_m \| R_{sh}}$$

$$\Rightarrow 10 = \frac{100(R_m R_m)}{R_m + R_{sh}} = 10 = \frac{R_m \times R_{sh}}{R_m + R_{sh}}$$

$$\Rightarrow \frac{100 R_{sh}}{100 + R_{sh}} = 10$$

$$\Rightarrow 100 R_{sh} = 1000 + 10 R_{sh}$$

$$\Rightarrow 90 R_{sh} = 1000$$

$$\Rightarrow R_{sh} = \frac{1000}{90} = 11.11\Omega$$

Q2. A 1 Instrument with an internal resistance of 100Ω is to be converted into 0-10Vm. What should be the external resistance connected with the meter?

→ Given data,

$$V = (10-1)V = 10V$$

$$R_m = 100\Omega$$

$$R_{se} = ?$$

$$V_m = I_m R_m = (1-0)mA \times 100\Omega$$

$$= 10^2 \times 10^{-3} V$$

$$= 10^{-1} V = 0.1V.$$

$$R_{se} = (m-1)R_m$$

where, $m = \frac{V}{V_m} = \frac{10}{0.1} = 100V$

$$R_{se} = (100-1) \times 100 = 99 \times 100$$

$$= 9900\Omega = 9.9k\Omega \quad \text{(Ans)}.$$

If the new instrument is of 0-100V then find out the external resistance.

→ Given data, $I_m = (1-0)mA = 1mA$

$$R_m = 100\Omega$$

$$V = (100-0) = 100V$$

$$V_m = I_m \times R_m = 100 \times 1mA$$

$$= 0.1V$$

$$m = \frac{V}{V_m} = \frac{100}{0.1} = 1000$$

$$R_{se} = (m-1)R_m = (1000-1) \times 100 = 99.9k\Omega$$

$$= 99900\Omega \quad \text{(Ans)}$$

Induction Type Instrument:-

→ We used the induction type Instrument for AC Measurement only because the induction phenomenon only occures in AC.

→ We can used this type of instrument as ammeter, voltmeter, wattmeter, energy meter.

Working principle:-

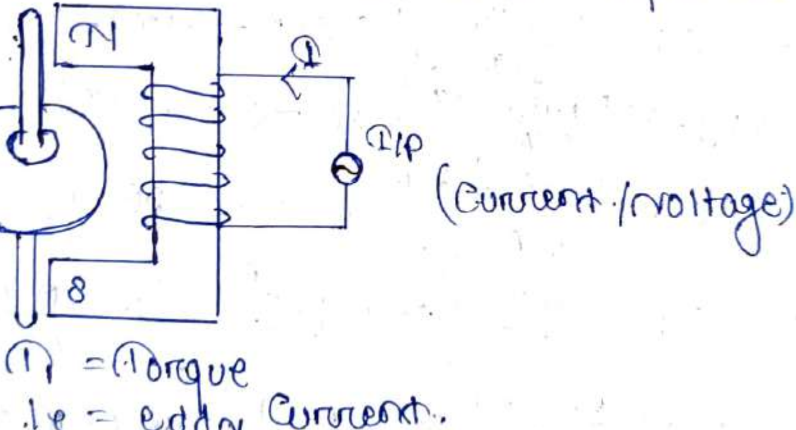
→ Induction type instrument have a electromagnet to produce they are required magnetic field.

→ Alternating Current (AC) in the electromagnet produces changing flux betn it's pole.

→ Here we place one Aluminium disc drum in the magnetic field hence the changing flux links with the aluminium disc.

→ As a result we the flux includes an eddy Current on the disc. This eddy Current oppose the flux which has induced it. hence there will be a mechanichal force acting on the disc.

→ Due to this Mechanichal torque the moving system of the instrument rotates is deflect the pointer



Where T = Torque
i_e = eddy Current.
ϕ = flux.

Production of Torque:-

→ The torque depends on two factor.
(a) The strength of magnetic flux.
(b). Eddy current in the aluminium.

⇒ That means $T \propto \phi \times i_e$
We know that,
⇒ $\phi \propto I$
⇒ $i_e \propto \phi$
⇒ $T \propto i_e$

$\Rightarrow T_i \propto I \cdot \propto I \propto \phi$ i.e,

$\Rightarrow T_i \propto I^2$

$\Rightarrow$ The deflecting torque is directly proportional to the torque of measuring current. The scale will be non-linear.

<u>Derivation</u>

$\phi = \phi_m \sin\theta$

$i = i_m \sin(\theta - \alpha)$

At any time flux produced is given by,

$\phi_m \sin\theta$

Q. The phase angle betn the flux & the induced eddy current is α Hence.

The equation of eddy current,

$i = i_m \sin(\theta - \alpha)$ where, T_d = Mechanical Force,

We know that,

$T_d \propto \phi i$ i.e

$\Rightarrow T_d \propto \phi_m \sin\theta \times i_m \sin(\theta - \alpha)$

$\Rightarrow T_d \propto \frac{1}{\pi} \int_0^\pi \phi_m \cdot i_m \sin\theta \cdot \sin(\theta - \alpha)$

$\Rightarrow T_d \propto \frac{\phi_m i_m}{2\pi} \int_0^\pi \cos(\theta - \theta + \alpha) - \cos(\theta + \theta - \alpha)$

$\Rightarrow T_d \propto \frac{\phi_m i_m}{2\pi} \int_0^\pi \cos\alpha - \cos(2\theta - \alpha)$

$\Rightarrow T_d \propto \frac{\phi_m i_m}{2\pi} \int_0^\pi \cos\alpha - \cos(2\theta - \alpha)$

$\Rightarrow T_d \propto \frac{\phi_m i_m}{2\pi} \left[\cos\alpha [\theta]_0^\pi - \left[\frac{\sin(2\theta - \alpha)}{2} \right]_0^\pi \right]$

$\Rightarrow T_d \propto \frac{\phi_m i_m}{2\pi} \left[\pi \cos\theta - \frac{1}{2} \cdot \left[\sin(2\pi - \alpha) - \sin(\alpha) \right] \right]$

$\Rightarrow T_d \propto \phi_{rms} \times I_{rms} \times \frac{1}{\pi} \left[\pi \cos\alpha - \frac{\sin(2\pi - \alpha) - \sin\alpha}{2} \right]$

$\Rightarrow T_d \propto \frac{\phi_{rms} I_{rms}}{\pi} \left[\pi \cos\alpha + \frac{\sin\alpha - \sin\alpha}{2} \right]$

$= T_d \propto \phi_{rms} \cdot I_{rms} \cdot \cos\alpha$,

α is the phase angle betn the flux & eddy current

So there must be some

Mean in the induction type instrument. Now that it will be present, the phase angle from being 90° (α ≠ 90°).

Ferrari type Instrument:

Here, we split the winding of electromagnet into two half. then we provide inductance in one soft half & the resistance will be another half. Due to the presence of the inductance. Resistance there is a phase difference betn. 2 flux. but this difference cut by 90° Then these 2 fluxes is produced eddy current with the same phase difference.

→ The interaction of one flux with eddy current with another flux linked produce the torque.

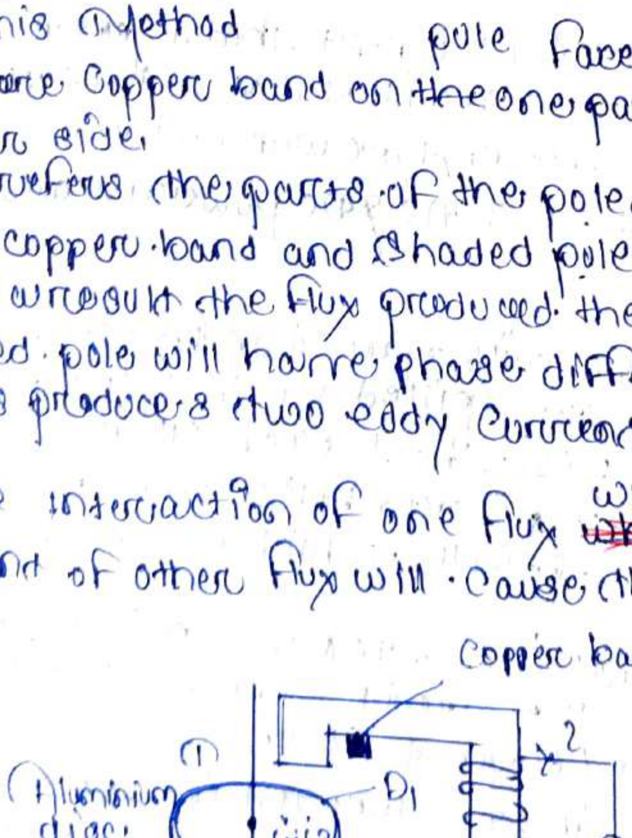
Shaded pole Type Instrument:

→ In this Method pole face into 2 parts we Put, are copper band on the one part of the pole face or either side.

→ We refers the parts of the poles provided is the copper band and shaded pole.

→ As a result the flux produced the shades some shaded pole will have phase difference. There two fluxes produces two eddy current on the aluminium disc

→ The interaction of one flux ~~which~~ with the eddy current of other flux will cause the deflecting torque.



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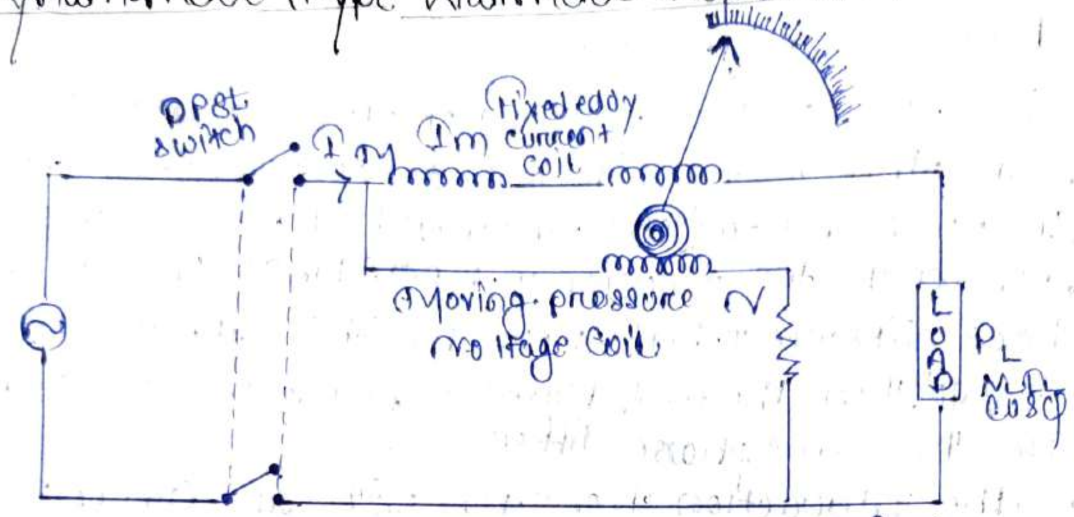
WATTMETER AND MEASURMENT OF POWER

Dynamometer type Wattmeter Instrument:-



DPST – Double pole single throw switch.

→ This Method is volt-amm Method voltage in parallel series to Load.

→ Wattmeter is an Instrument that Measure electrical power in a Circuit it is of two types,

(i) Dynamometer type wattmeter Instrument (both AC & DC power measure)

Construction:-

→ It consist of Two coils named as fixed & moving coils, The fixed coil is spilted in to two equal parts which are placed close to each other.

→ The moving coil pivots being fixed with & Mounted on the spindle, which is attached to the pointer.

→ The fixed coil is connected in series with the load & carryies the circuit current that's why It is called fixed / current coil.

→ The moving coil is Connected in across the load & carries the current proportional to the voltage Therefore It is called as pressure / voltage coil.

→ Generally, high value of resistance is Connected in series with the pot potential / Pressure coil to Limit the Current through it. voltage.

→ For Controlling Torque The Spring Control Method is used & the Air Friction damping is employed In this type Instrument.

Working:-

→ It is Based upon the principle that the Mechanichal Force exist. betⁿ two Current Carrying. Conductor. When the Instrument is Connected in Circuit For Measuring the power the Current coil is Connected with the Load. While Voltage coil is Connected across the load. due to the Current in both the Coil Magnetic Field is produced the Mechanichal Force exists betⁿ it.

→ As a result Coil Rotates the pointer moves over Calibrated Scale. The pointer Comes to Steady state the Controlling Torque is equal to deflecting Torque.

→ By reversing The dirⁿ of Current the dirⁿ of magnetic Field also reverse, so the dirⁿ of deflecting Torque Remains unchanges, Therefore This type of instrument is used For both AC & DC.

<u>production of ~~both AC &~~ DC deflecting Torque & Measurement of power:-</u>

$T_d = I_1 I_2 \cos\phi$

I_1 = Current through Fixed coil

I_2 = Current through moving coil

ϕ_2 = Angle of deflection.

ϕ = phase angle betⁿ I_1 & I_2

m = Mutual induction.

where $I_1 = I_m = I_m$, $I_2 = I_P$

$$I_P = \frac{V_P}{R_P} \times I_L (\cos\phi) \cdot \frac{dm}{d\phi}$$

$$= I_L \times \frac{V_L}{R_P} (\cos\phi) \frac{dm}{d\phi}$$

$$= \frac{I_L V_L}{R_P} (\cos\phi) \frac{dm}{d\phi}$$

where, $T_d \propto V_L I_L \cos\phi$ (Average power)

here, The Measurement of power we have to Take some assumptions.

(1) There is no voltage drop across The Current coil. That means, Supplied voltage = Load voltage V_L.

(2) The moving coil is purely resistive & of ϕ value, So, that I_P in phase with V_L, $\cos\phi = 1$ $(\phi = 0)$.

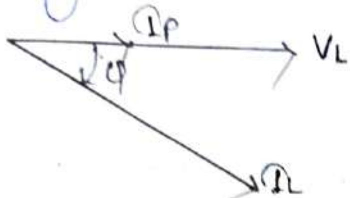
For PEMMC Type Instrument we get that,

$$T_d = \frac{V_P}{R_P} \times I_L \cos\phi \frac{dm}{d\theta}$$

$$= \frac{I_L V_L}{R_P} \cos\phi \frac{dm}{d\theta}$$

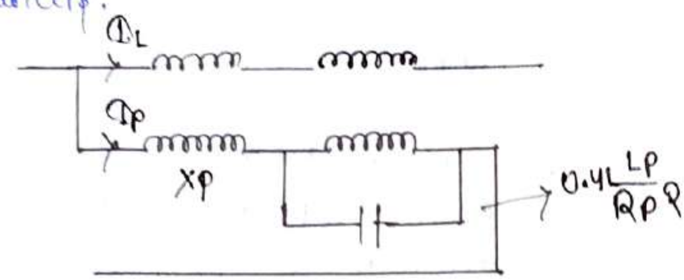
$\Rightarrow$ True AC power

phasor diagram:-



Error due to pressure Coil Inductance:

As we assume that previously that the pressure coil is purely resistive but in real practice there are no-purely Resistive coil. It is Combination Resistance R_P & reactance (X_P) So that we will get of error in Measurement which is Called as the error due to pressure coil inductance.



$$T_d = I_1 I_2 \cos\phi \frac{dm}{d\phi}$$

$$= I_L I_P \cos(\phi - \beta) \frac{dm}{d\theta}$$

$$\Rightarrow I_L \frac{V_P}{Z_P} \cos(\phi - \beta) \frac{dm}{d\phi}$$

$$= I_L \frac{V_L}{Z_P} \cos(\phi - \beta) \frac{dm}{d\phi}$$

$$= \frac{R_P}{Z_P} = \cos\beta$$

$$\Rightarrow Z_P = \frac{R_P}{\cos\beta}$$

$$\Rightarrow I_L \cdot \frac{V_P \cos\beta}{R_P} \cos(\phi - \beta) \frac{dm}{d\phi}$$

$$\Rightarrow P_T = \frac{I_L V_L}{R_P} \cos\phi \frac{dm}{d\phi} \quad [P_m > P_C]$$

$\Rightarrow Q_m \times C.F = P_i$

$\Rightarrow CF = \frac{P_i}{P_m}$

$= \frac{I_L V_L}{R_P} \cos\phi \frac{dm}{d\phi}$ | $\frac{I_L V_L}{Z_P} \cos\beta \cos(\phi - \beta) \cdot \frac{dm}{d\phi}$

$$\Rightarrow C.F = \frac{\cos\phi}{\cos\beta \cdot \cos(\phi - \beta)}$$

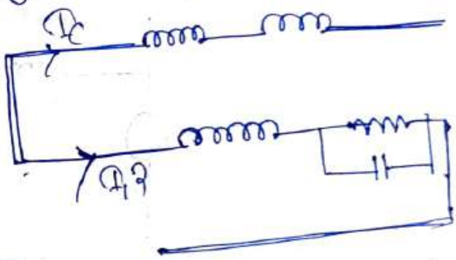
→ The error due to the pressure coil inductance can be reduced by connecting a capacitance across C_P. In such way that the capacitive reactance will cancle out the inductive reactance,

$$C_P = 0.41 \frac{L_P}{R_P^2}$$

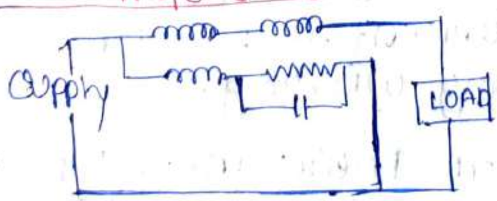
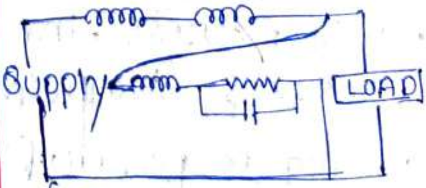
L_P = inductive reactance pressure.
C_P = capacitive reactance pressure
R_P = Resistive pressure

→ Now the pressure coil will act as purely resistive & the value of capacitance is given by,

$$C_P' = 0.41 \frac{L_P}{R_P^2}$$



→ The best on the connection of pressure & current coil, there are two types of wattmeter.
(1) MC short
(2) LC short

MC Short	LC Short
 (Volt-Ammeter Method)	 (Ammeter-Voltage Method)
→ When the current coil is connected near the load circuit it is called as MC short type.	→ When the voltage coil is connected to near the load circuit it is called as LC short type. → It is similar to Ammeter Voltmeter Method.

→ It is similar to the Volt-meter + Ammeter Method.

→ $P_m = I_1 I_2 \cos\phi \frac{dm}{d\phi}$

$= I_L I_p \cos\phi \frac{dm}{d\phi}$

$= P_t \cos\phi +$

$= P_t + I^2 R$

→ $P_m > P_t$.

→ where P_t = True value of power

P_m = Measure value of power

→ error due to current coil. $P_t + I^2 R$

→ It is similar to the Ammeter Voltmeter Method.

→ $P_m = I_1 I_2 \cos\phi \frac{dm}{d\phi}$

$= (I_L + I_p) I_p \cos\phi \frac{dm}{d\phi}$

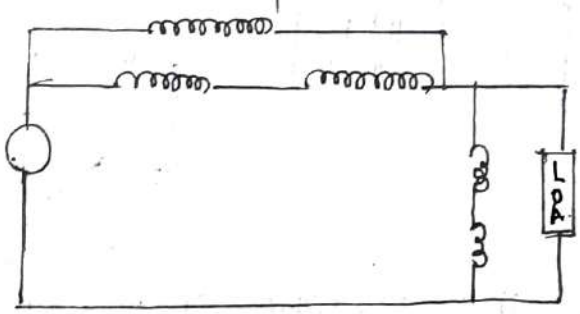
→ $P_m = P_t = V^2/R$

→ $P_m > P_t$.

→ where P_t = True value of power

P_m = Measured value of power.

→ Overloading of pressure coil current.



Mo most suitable for measure power measurement because in LO short wattmeter over reading of overreading will be happend. To rectify these these type of LC wattmeter will be connect to a loop winding across the current coil which is called Loss Compensating winding.

According to power factor their are 2 type of wattmeter

LPF wattmeter	UPF wattmeter
→ Low power factor	→ High power factor
→ $T_d = I_L \times \frac{V_L}{R_p} \cos\phi \frac{dm}{d\phi}$	→ $T_d = I_L \times \frac{V_L}{R_p} \cos\phi \frac{dm}{d\phi}$
→ As low power factor is given to the instrument the pointer will not move and we can get the actual reading. In order to deflect the pointer we have to decrease the value of Rp.	→ As we give high power factor the pointer will move more than the actual reading so we have to increase the value of Rp.
→ Rp is less in LPF wattmeter.	→ Rp is greater in UPF wattmeter.

Error due to Eddy Current:-

→ The eddy current are ~~in actual~~ induced in solid metal parts which will have its own magnetic field and alter due to the magnitude and direction of the phase of current coil which coil will cause the error.

Stray magnetic field error:-

→ The electro dynamometer type wattmeter has a relatively large operating field so that it is particularly affected by stray magnetic field. resulting series error.

→ Hence these errors are eliminated by shielding the cause.

Temprature error:-

→ As the temprature changes the resistance of the pressure coil also changes accordingly which coil will cause error in instrument. The temprature also produces error by decreasing stiffness of spring control.

→ This can be eliminated by using manganin or constantine.

Error Caused by Vibration of Moving System:-

→ This type of error is found occasionally when AC Current is used. Here the torque varies cyclically with the frequency, which will vibrate, often with considerable amplitude.

→ This causes error in the instrument.

Advantages:-

→ It can be used for both AC & DC power measurement.

→ It is very accurate.

→ The scale is uniform because the deflecting torque proportional to average power

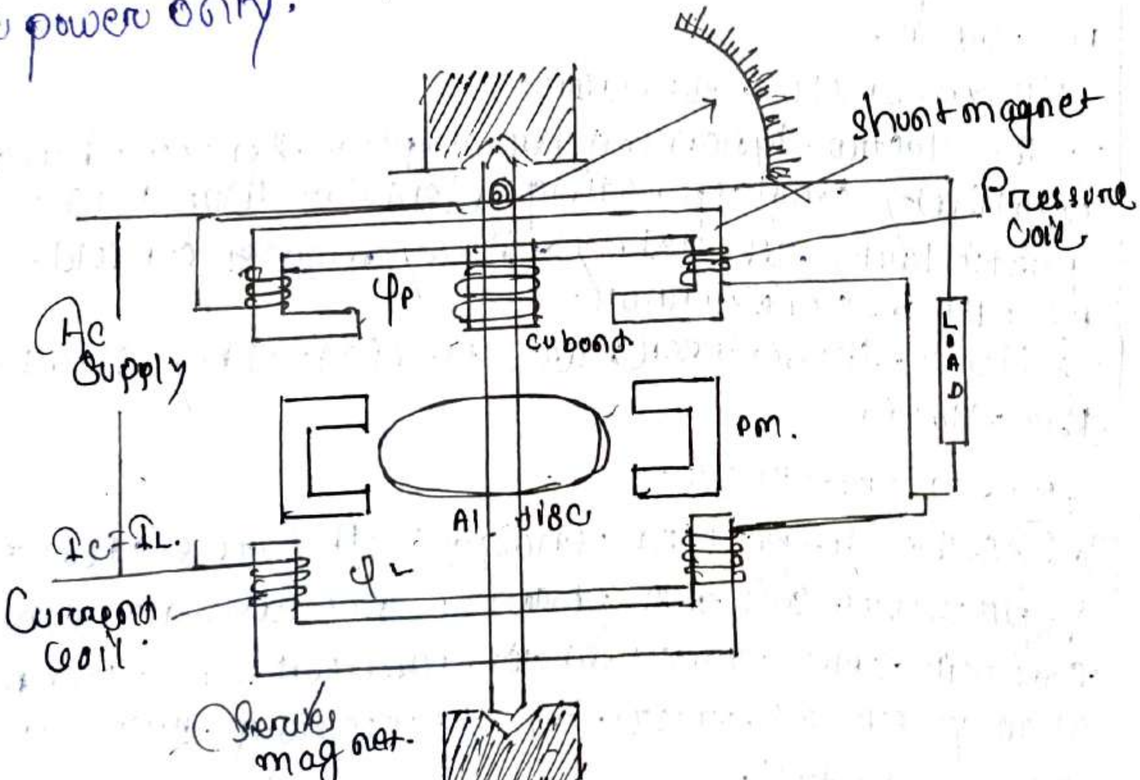
Disadvantages:-

→ It is very costly.

→ At lower power factor, the inductance of pressure coil causes serious error.

Induction Type Instrument:-

→ The induction type wattmeter is used to measure ac power only.



Principle of Induction type Instrument:-

The principle of operation of an induction wattmeter is same as that of induction ammeters and voltmeters i.e. Induction principle. However, it differs from induction ammeter or voltmeter in so far that separate two coil are used to produced the rotating flux in phase place of one coil with phase split arrangement.

Construction of Induction type Instrument:-

The principle parts ~~from~~ of an induction wattmeter is as shown in the figure below. It consists of two laminated electromagnets. one electromagnet called shunt magnet is connected across supply and carries current proportional ~~after~~ to the voltage. The coil of this magnet is connected in series with supply and carries the load current. The coil of this magnet is made highly non-inductive. so the angle of lag or lead is ~~demi~~ determined fully by the load.

- Althin Aldisc mounted on the spindle is placed ~~in the~~ between the two magnets. The controlling torque is provided by spiral springs.
- The damping is electromagnet and is usually provided by a permanent magnet embracing the aluminium disc.
- Two or more closed copper rings, called shading rings are provided on the ~~load~~ central ~~lim~~ limb of the shunt magnet.
- By adjusting the position of these rings, the shunt magnet flux can be made to lag behind the supply voltage by 90°.

Working:

→ When the wattmeter is connected in the circuit to the measure ac power, the shunt magnetic carries current proportional to the supply voltage and current.

→ The two fluxes produced by the magnets induce eddy current in the aluminium (Al) disc.

→ The interaction between the fluxes and eddy current on the disc, causing the pointer connected to the moving system to move over the scale.

Deflecting torque of induction type ~~instrument~~: Wattmeter:

Let v = applied voltage

i_L = load current carried by the series magnet.

i_v = current carries by the shunt magnet

$\cos\phi$ = lagging power factor of the load.

→ The vector diagram of the this wattmeter is shown in figure below the current I_v in the shunt magnet lags the applied voltage v by 90°, and also does the flux ϕ_v produced by it.

→ The current i_c in the series magnet is the load current and hence the lags behind the applied voltage by ϕ.

→ The flux ϕ_c produced by this current I_c is in phase with it.

→ Therefore the two currents I_c in the current coil and I_v in the voltage coil and also corresponding fluxes ϕ_v and ϕ_c are $90°-\phi$, a part.

→ Similarly, flux ϕ_c induced eddy current I_{ec}, which again lags behind flux ϕ_c by 90°.

→ Mean deflecting torque, T_d proportional to $I_c \sin(90-\theta)$

$T_d \propto VI\cos\phi$

$T_d \propto$ ac power

→ Since control is by spring, therefore T_c is directly proportional deflection.

→ For steady deflected position, $T_d = T_c$.

∴ Deflection proportional to power

→ Hence, such instrument have uniform scale.

chapter-4

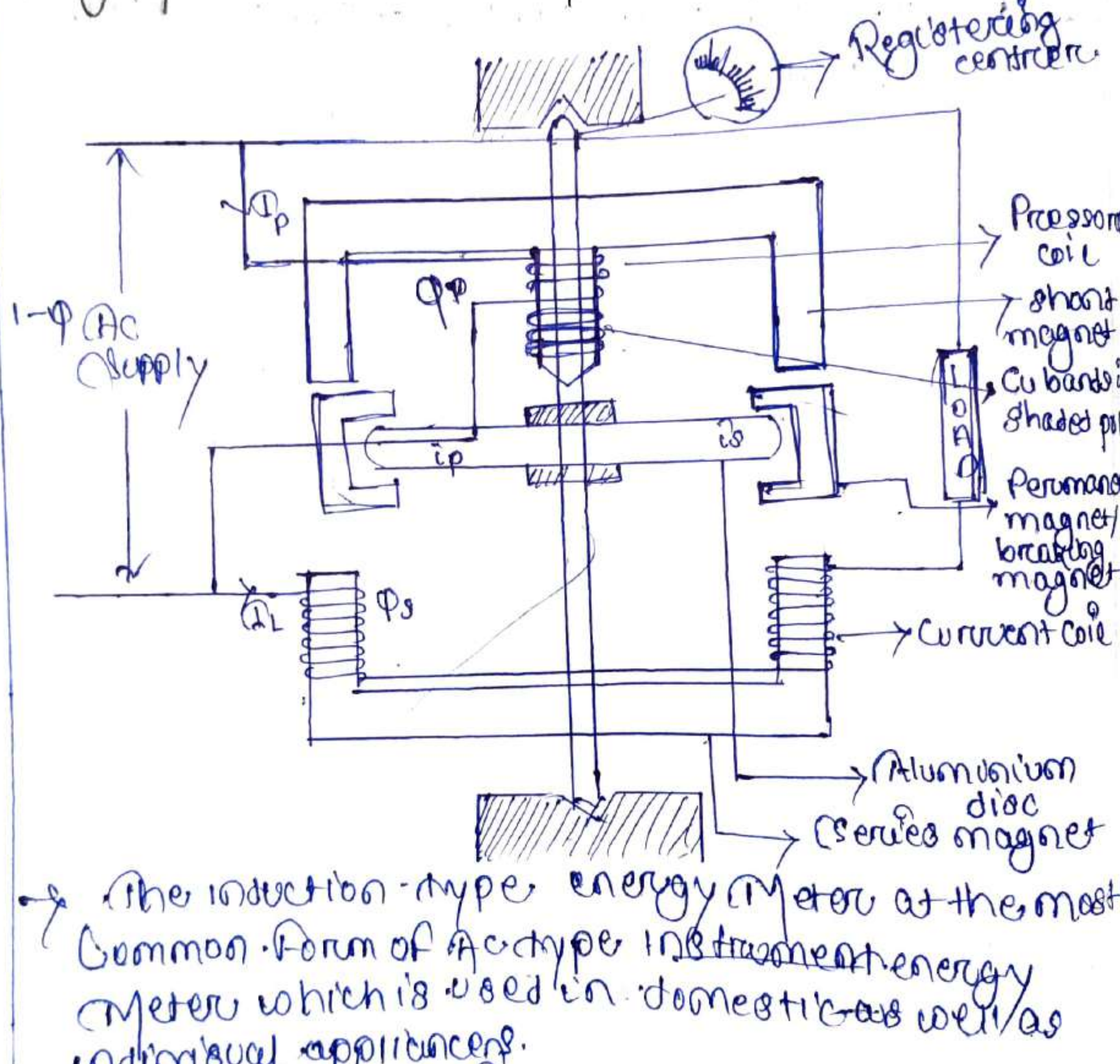
Energy Meter and Measurement of Energy.

Introduction:-

→ The energy meter is an integrating type of instrument which is used to measure the electrical energy supplied to a circuit in the given time.

→ This instrument measures electrical energy in the form of kW/hour.

Single phase Induction type Energy Meter:-



→ The induction type energy meter is the most common form of AC type instrument energy meter which is used in domestic as well as individual appliances.

→ It causes lower friction & high torque.

→ The principle of this type of instrument is very much similar to induction type wattmeter except that control spring is replaced by pointer type counters.

and two number of breaking magnets.

Construction:-

→ It consists of two electromagnets m_1 and m_2.

→ m_1 is excited by the wire current which is called Load current. Which is called as series magnet.

→ The coil which is wounded over series magnet is called current coil.

→ The other electromagnet m_2 is connected across the load. therefore, it carries a current which is proportional to applied voltage or load voltage which is called shunt magnet and the coil wounded on it is called the ~~coil wounded~~ pressure coil or voltage coil.

→ Aluminium disc is fitted in the airgap upto electromagnet.

→ permanent magnets or breaking magnets fitted on the both side of aluminium disc. The number of revolution can be registered by pointer type counter.

→ The energy meter has 4 main parts:-

① Driving system:- AC supply, Electromagnet current coil.

② Moving system:- Spindle, Al disc

③ Breaking system → permanent magnet.

④ Registering system → Registering counter.

→ The phase displacement can be achieved by adjusting ~~zro~~ a number of copper (Cu) shading bands.

→ The pressure coil purely inductive so that the flux produced by the pressure coil lag the supply voltage 90° and the current coil is non-inductive so that, the phase difference between supply voltage and highest depends upon the nature of load.

Working:-

→ When ac supply is given to the system the two magnets m_1 and m_2 produces flux ϕ_p and ϕ_s.

→ ϕ_p and ϕ_s further induces two circulating eddy current i_p and i_s respectively.

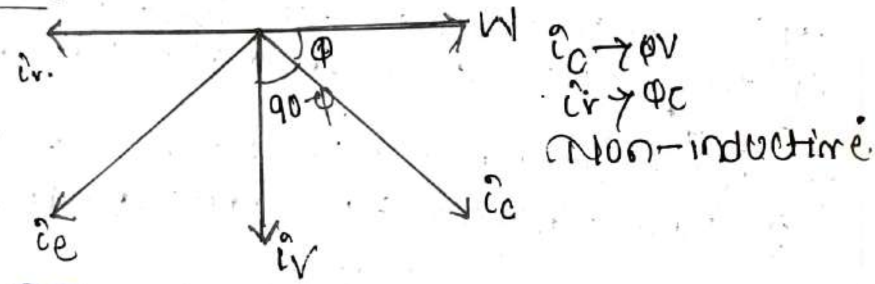
→ The interaction between ($\phi_p \leftrightarrow i_s$) and ($\phi_s \leftrightarrow i_p$) produces two torque which difference driving torque. T_d.

→ This mechanichal force rotates the aluminium disc.

→ For controlling the speed of aluminium disc two breaking magnets are there which produces breaking torque.

→ The pointer mechanism is that either pointer type or cyclometer type.

phase diagram:-



Production of Torque:-

Mathematical,

$$T_d \propto V_L I_L \cos\phi$$

At steady state condition,

$$T_d \propto T_b \text{ (breaking torque)}$$

$$= T_B \propto V_L I_L \cos\phi$$

$$V_L I_L \cos\phi \propto N$$

$\Rightarrow$ AC power $\propto N$

As it is integrating type of instrument on integrating both side, wrt.

$$\int V_L I_L \cos\phi \cdot d\theta \propto \int N d\theta$$

$$= \frac{\int AC \text{ Power } dt \propto \int N dt}{\text{Electric } \propto \text{ total no. of revolution.}}$$

→ Hence, in the given time, the total energy consumed is directly proportional to total number of revolution.

Meter constant:-

→ Meter Constant = $\frac{\text{No of revolution}}{\text{Killowatt hours}}$

→ The number of disc revolution should be made by the disc in the order to indicate sumption is called an meter constant.

Error in its Comparision:-

	Error	Cause	Effect	Remedy
(1)	Phase angle error	It is produced because of resistance of coil and also due to the iron loss in the coil.	The energy meter resists energy even through the actual energy is zero but torque is non-zero.	This type of errors due to can be eliminated by adjusting the copper shading band provided in the control limit of the shunt magnet.
(2)	Speed error	This is due to improper position of breaking magnets	The al disc either more faster or slower depending up on the position of breaking magnet.	For eliminating the fast speed the browny may be more towards the control of the disc.
(3)	Creeping	The slow but continous rotation of disc even through no load is on the instrument.	The energy still records with needs even in the no load condition	Two no of poles are drilled diametrically on the opposite side of spindle of the same distance.
(4)	Temprature	It is due to various conditional is usually very small but can be magnified as compare to the other type of error.		
(5)	Friction	This error is due to the wire and tear of moving system of the instrument.		

Problem:-

(1) A meter constant of 230V, 10 amp watt hour meter 1800 revolution per killowatt hour. meter 1800 The meter is tested as half load condition and rated voltage of unity power factor. revolution 13 sec. Determine the error as half load condition.

Solution:-

Given data,

$V = 230V$

$I = 10 Amp$

$M_c = 1800$ rev/Kwh

in 1/2 load condition:-

number of revolution = 80

total time = 138 sec.

$\cos\phi = 1$

error = Pt - Pm.

Theoritical Formula,

Pt = total energy consumed.

$\Rightarrow E_c = VI\cos\phi t$.

$= 230 \times 10 \times 1 \times \frac{138}{3600}$

= 88.16 wattmeter

Energy consume at 1/2 load,

$= \frac{88.16}{2} = 44.08$ watt hour

= 0.04408 kwh

$M_c = \frac{\text{revolution}}{\text{Kwh}}$

$\text{Kwh} = \frac{\text{revolution}}{M_c}$

$= \frac{80}{1800} = 0.044$ Kwh.

Percentage error $= \frac{E_t - E_m}{E_m} \times 100$

$= \frac{0.04408 - 0.044}{0.044} \times 100$

= 0.1814.

Testing of energy Meter :-

→ To ensure the accuracy and reliability of energy Meters it has to go through sum standard test as per IEC standard.

→ The standard scale are divided into 3 segments :-

(i) **Mechanical Stress :-**
To test the various mechanical components inside the meter.

(ii) **Climatic Condition Test :-**
It includes through limit which influence the Meter performance wise externally.
Ex :- temperature limit, humidity limit

(iii) **Electrical Circulating test :-**
under this segment the energy is tested
for (a). Heating effect
(b) proper insulation
(c) Supply of Voltage
(d) production of each point.
(e) Electromagnetic capacity.

Electromagnetic Capacity :-

→ An EMC test is the most important test which finally ensured that the meter is accurate or not. It has two parts :-
(a) Emission test.
(b) Immunity test.

→ The energy meter is used ~~in the~~ an emit electromagnet energy which can affect its own circulating or the meter near by it.

→ The electromagnetic energy can travel through two ways :-
(1) Radiation :- Travelling through free space.
(2) Conduction :- Travel through wire or conductor.

Emission Test:-

→ The meter has different chokes circuit layout switching element etc. which produces EMI.

→ This test ensure that the energy meter does not affect the performance of nearby instrument.

→ In other words it ensures that it doesn't conduct or radiated beyond a definite limit.

Immunity Test:-

→ This test ensure that the meter do not work as a reacepter and properly function in pressure of (EMI)

→ It is up two types based on
 (1) Radiation
 (2) Conduction.

Conducted immunity Test:-

→ This test ensured the function of meter if it is in contact through other power or datalines etc.

Radiated immunity Test:-

→ During this test the meter function is Monitor and checked if it gets affected by EMI personal in the secondary surrounding area.

→ This is otherwise known as electromagnetic frequency test.

chapter 6 Dt:- 04/05/2022

Measurement of Inductance, Resistance, Capacitance.

(1) Measurement of Resistance:-

Classification of Resistance:

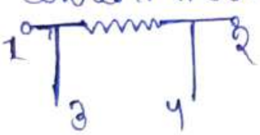
All type of Resistance are devided into 3 parts.

1. low resistance
2. Medium resistance.
3. High resistance.

Low resistance

$R < 1\Omega$

Current Terminal



1,2 → current Terminal

3,4 → voltage Terminal

1,2 → are connected to Ammeter

3,4 → are connected to the voltmeter

~~Ex:- Armature winding,~~

The ratio betn voltmeter & Ammeter Reading to give low Resistance.

Ex:- Armature winding, series winding.

Medium resistance

$1\Omega < R < 100K\Omega$

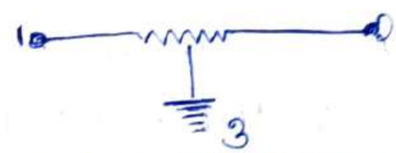
1,2 → Connecting Terminal

1,2 → Terminals are directly connected to the instrument

Ex:- Shunt field winding

High resistance.

$R > 100K\Omega$



→ 1,2 → Connecting Terminal

→ 3 → grounded.

→ 1,2 → Terminals are connected to the instrument & 3 terminal are grounded to supply the higher leakage current.

Ex:- Insulation resistance, diode Reverse bias Resistance, OP-AMP input resistance.

Methods of Measurement of Resistance:

Low Resistance:

(1) Kelvin's double bridge Method.

(2) potentiometer Method.

Medium Resistance:

(1) Wheatstone bridge Method.

(2) A-V to V-A Method.

(3) Substitution Method.

(4) ohm-meter Method.

High Resistance:

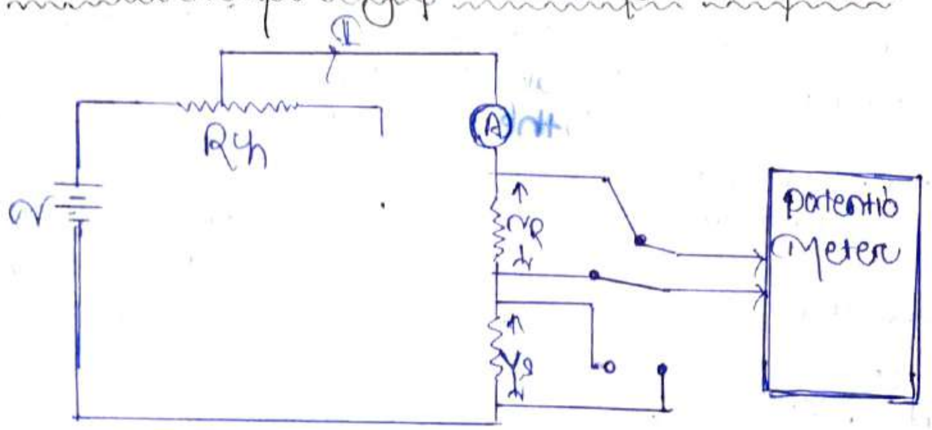
(1) Megger Method

(2) loss of charge Method

(3) direct deflection Method.

(4) Mega-ohm meter Method.

Low resistance by using potentiometer Method:-



potentiometer → It is the device. It is across a resistance will be present. It will be convert the voltage in Meter.

where V is the supply battery voltage & R is the unknown Resistance, standard know Resistance R_n = Rheostat, A = Ammeter

Calculation:

Voltage across unknown Resistance (R)

$= I \times R = V_R$

$\Rightarrow I = \frac{V_R}{R}$ ——— (i)

Similarly, voltage across known Resistance (S)

$$\Rightarrow I \times S = V_S$$
$$\Rightarrow I = \frac{V_S}{S} \quad \text{———— (ii)}$$

Current is equal in both the resistance & their is Series Connection hence from eq (i) & (ii) we get that,

$$\Rightarrow \frac{V_R}{R} = \frac{V_S}{S}$$
$$\Rightarrow \boxed{R = \frac{V_R}{V_S} \times S}$$

Construction:-

→ It is an instrument which measure the unknown low resistance by comparing the voltage across unknown & known / standard Resistance.

→ The circuit of measurement of low resistance by potentiometer method is shown in above figure.

→ here the unknown Resistance (R) is connected in Series with known / standard Resistance (S) The current through the circuit by controlling by the.

→ A DPDT (Double pole double throw) is used for switching betn two Resistance.

→ when the switch is at S end connected to the unknown Resistance to the potentiometer. for measuring voltage across it.

→ Suppose the Reading of potentiometer is V_R,

$$V_R = IR \quad \text{———— (i)}, \quad \left(I = \frac{V_R}{R}\right)$$

Now the switch is thrown to 2-2' position across the standard Resistance, Connected to potentiometer is V_S, $V_S = IS$ ———— (ii) $= I\frac{V_S}{S}$

(from eq (i) & (ii))

$$R = \frac{V_R}{V_S} \times S$$

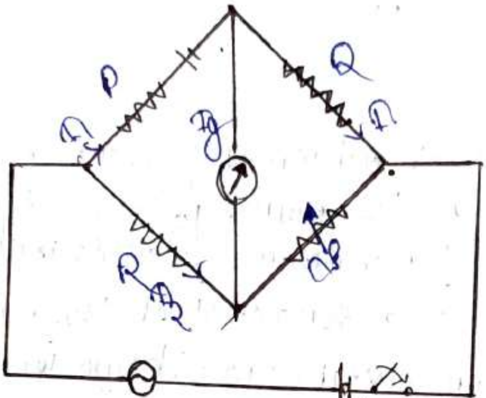
→ Since the value of standard Resistance (S) is Accurately known so, that the unknown Resistance will be Accurately

. Calculated.

→ The Accuracy of these Method also depends upon the observe that there is no change in value of [illegible] instrument when 2 different Measurement are taken.

→ Therefore, a steady dc supply absoulted by necessary.

Medium Resistance by using wheatstone bridge:-



(ckt diagram for Medium resistance by wheatstone bridge Method)

→ A very Important finding the value of Medium resistance by using wheatstone bridge Method, shown in the fig above figure.

→ The wheatstone bridge Method the Measurement are taken by using null identification technic or principle, this Means the identification is independent of calibration of the null indicating.

→ A very high degree of accuracy is obtained by using wheatstone bridge Method.

→ It consist of 4 resistance (arm) connected together with a source of battery voltage V. with a null deflector that is a galvanometer G.

→ when the bridge is at balanced condition then there is no current flow through the galvanometer.

→ This condition will be achieved when the voltage across ABD is equal to DCA.

→ Under the balanced condition.

voltage drop across AB = voltage drop across AC.

$I_1 P = I_2 R$

$\Rightarrow \frac{I_1}{I_2} = \frac{R}{P}$

→ Again voltage drop across BD = voltage drop across CD.

$I_3 Q = I_4 S$

$\Rightarrow \frac{I_3}{I_4} = \frac{S}{Q}$

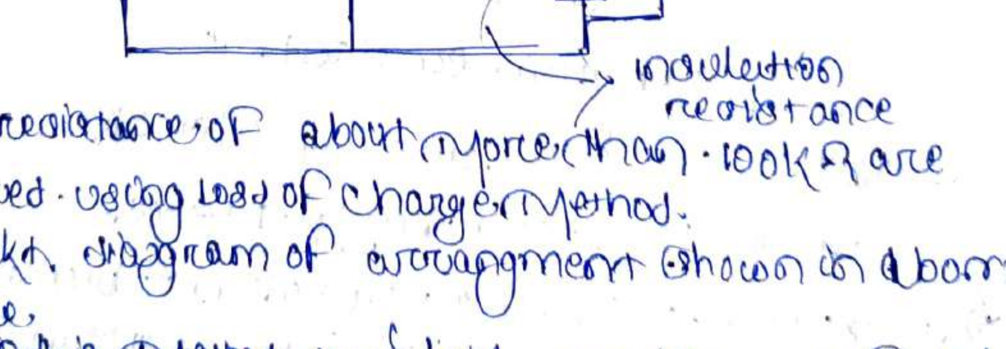
But when the bridge is balanced $I_1 = I_3$ & $I_2 = I_4$

that means $\frac{R}{P} = \frac{S}{Q}$

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

where the value of P, Q, R & S known voltage values R is the unknown value of medium resistance.

Measurement of high resistance Loss of charge Method:-



→ The resistance of about more than 100kΩ are measured using loss of charge method.

→ The ckt. diagram of arrangement shown in above figure.

→ In this method the high resistance is to be connected in parallel with a capacitor and an ~~electric~~ electrostatic voltmeter connected across the unknown resistance R.

→ The Capacitor is first charged by putting the switch S_1 in the on position and after that it is being discharged by making the switch S_2 closed.

→ During the 1st case (S_1 on and S_2 off) the capacitor is charged to max^m value.

→ In second case (S_2 on and S_1 off) the current flow through the unknown high resistance than the fully changed capacitor and the voltage across measured by electrostatic capacitor voltmeter.

→ The loss of charge method is suitable for the measurement of insulation resistance of cables.

→ The discharge voltage across the capacitor is given by: $v = V e^{(-t/RC)}$

$$\Rightarrow \ln(V/v) = \frac{t}{RC}$$

$$\Rightarrow \boxed{R = \frac{0.434\, t}{C \log(V/v)}}$$

Where, t = the time for which capacitor is charged.

V = supply voltage

v = voltage across capacitor

C = the value of resistance.

t = time constant.

It can be done by following methods.

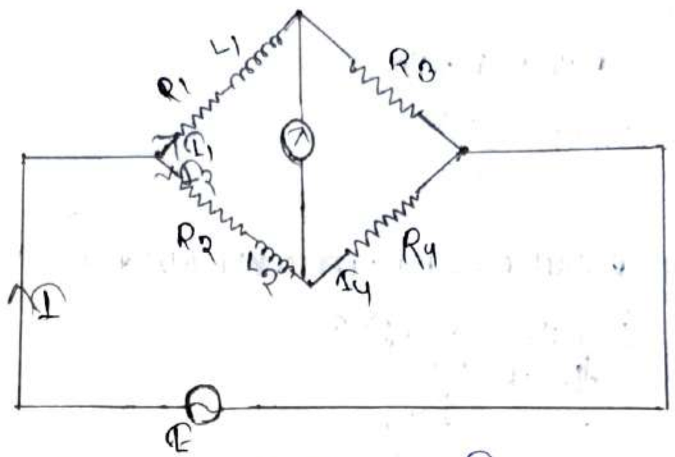
(i) Maxwell's inductance bridge method.

(ii) Maxwell's inductance capacitance bridge method.

(iii) Anderson's bridge method (Low resistance)

(iv) Hay's bridge method. (High inductance)

(v) Owen's bridge method.



let, us Consider 4 arms Consist of.

$R_1 L_1$ – unknown resistance and inductance.

R_2, L_2 – known resistance and, inductance.

$R_3, R_4 \rightarrow$ Non inductive, standard resistance.

In this method the unknown ~~resistance~~ inductance is compared with a variable known inductance.

→ A deflection galvanometer is Connected betn the point 'b' and 'd'.

→ Supply is given to the Circuit betn point a & c.

→ Under balanced condition the potential difference betn the point b & d is zero that means the potential drop across a, b is equal to potential drop across ac.

$E_1 = E_2 = E$

$\Rightarrow I_1 Z_1 = I_2 Z_2$ —— (1)

→ Also under balanced condition $I_1 = I_3 = \frac{E}{Z_1 + Z_3}$ —— (2)

$I_2 = I_4 = \frac{E}{Z_2 + Z_4}$ —— (3)

using the value of eq (2) & (3) in eq (1) we get,

$\Rightarrow \frac{E}{Z_1 + Z_3} \times Z_1 = \frac{E}{Z_2 + Z_4} \times Z_2$

$\Rightarrow Z_1 Z_2 + Z_1 Z_4 = Z_1 Z_2 + Z_2 Z_3$

$\Rightarrow Z_1 Z_4 = Z_2 Z_3$

$\Rightarrow (R_1 + j\omega L_1) R_4 = (R_2 + j\omega L_2) R_3$

$\Rightarrow R_1 R_4 + j\omega L_1 R_4 = R_2 R_3 + j\omega L_2 R_3$

~~$Z_1 Z_4 = Z_2 Z_3$~~

By equating Real and imaginary parts for L.H.S & R.H.S we get,

$$R_1R_4 = R_2R_3$$

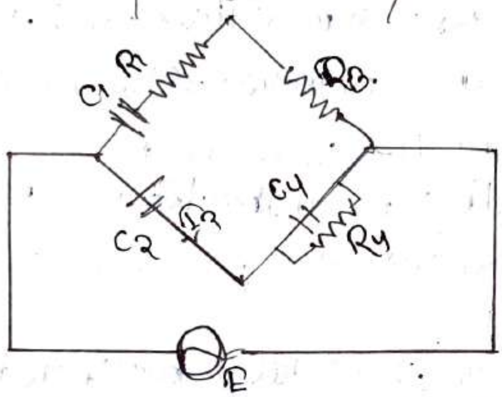
$$\Rightarrow \boxed{R_1 = \frac{R_2R_3}{R_4}}$$

Similarly equating the imaginary part we get,

$$j\omega L_1R_4 = j\omega L_2R_3$$

$$\Rightarrow \boxed{L_1 = L_2\frac{R_3}{R_4}}$$

Measurement of Capacitance by Schering bridge Method:-



→ Let us consider that the ckt of Schering bridge is as given Figure.

→ Here C1 is the unknown capacitance to which a series resistance R_1 is connected. C_2 is the standard capacitance, then R_3 it is a pure resistor i.e. a non-inductive Resistance. R_4 is connected in parallel.

→ under balanced condition that the potential diff. betn the point bond should be equal to zero.

→ Hence the galvanometer will not have any type of deflection for balanced condition

$$Z_1 \times Z_4 = Z_2Z_3$$

where $Z_1 = R_1 + \frac{1}{j\omega C_1}$

$Z_2 = \frac{1}{j\omega C_2}$

$Z_3 = R_3$,

$$Z_4 = \frac{R_4}{R_4 + 1/j\omega C_4}$$

Now using the value of Z_1, Z_2, Z_3 and Z_4 we get,

$$Z_1 Z_4 = Z_2 Z_3$$

$$\Rightarrow \left(R_1 + \frac{1}{j\omega C_1}\right)\left(\frac{R_4}{1 + j\omega C_4 R_4}\right) = \frac{R_3}{j\omega C_2}$$

$$\Rightarrow \left(\frac{j\omega C_1 R_1 + 1}{j\omega C_1}\right)\left(\frac{R_4}{1 + j\omega C_4 R_4}\right) = \frac{R_3}{j\omega C_2}$$

$$\Rightarrow (1 + j\omega \cdot C_1 R_1) R_4 j\omega C_2 = R_3 (1 + j\omega C_4 R_4) j\omega C_1$$

$$\Rightarrow j\omega C_2 R_4 (1 + j\omega C_1 R_1) = j\omega C_1 R_3 (1 + j\omega \cdot C_4 R_4)$$

$$\Rightarrow j\omega C_2 R_4 + j^2\omega^2 C_2 C_1 R_1 R_4 = j\omega C_1 R_3 + j^2\omega^2 C_1 C_4 R_3 R_4$$

$$\Rightarrow j\omega (C_2 R_4 + j\omega C_2 C_1 R_1 R_4) = j\omega (C_1 R_3 + j\omega C_1 C_4 R_3 R_4)$$

$$\Rightarrow C_2 R_4 + j\omega C_1 C_2 R_1 R_4 = C_1 R_3 + j\omega C_1 C_4 R_3 R_4$$

$$\Rightarrow (C_2 R_4 - C_1 R_3) + j\omega C_1 C_2 R_1 R_4 - (j\omega C_1 C_4 R_3 R_4) = 0$$

$$\Rightarrow (C_2 R_4 - C_1 R_3) + (j\omega C_1 C_2 R_1 R_4 - j\omega C_1 C_4 R_3 R_4) = 0$$

$$\Rightarrow C_2 R_4 - C_1 R_3 + j\omega \cdot C_1 C_2 R_1 R_4 - C_1 C_4 R_3 R_4 = 0.$$

Solving from real parts:-

$$C_2 R_4 = C_1 R_3.$$

$$\Rightarrow \boxed{C_1 = \frac{C_2 R_4}{R_3}}$$

Solving from imaginary part,

$$C_1 C_2 R_1 R_4 = C_1 C_4 R_3 R_4$$

$$\Rightarrow C_2 R_1 = C_4 R_3$$

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

Megger:-

Construction:-

→ The megger is the instrument which is used for measuring the resistance of the ~~instrument~~ insulation,

→ It works on the principle of comparison that is the insulation resistance is compared with the known value of resistance.

→ The accuracy of megger is very high as compared to other insulation.

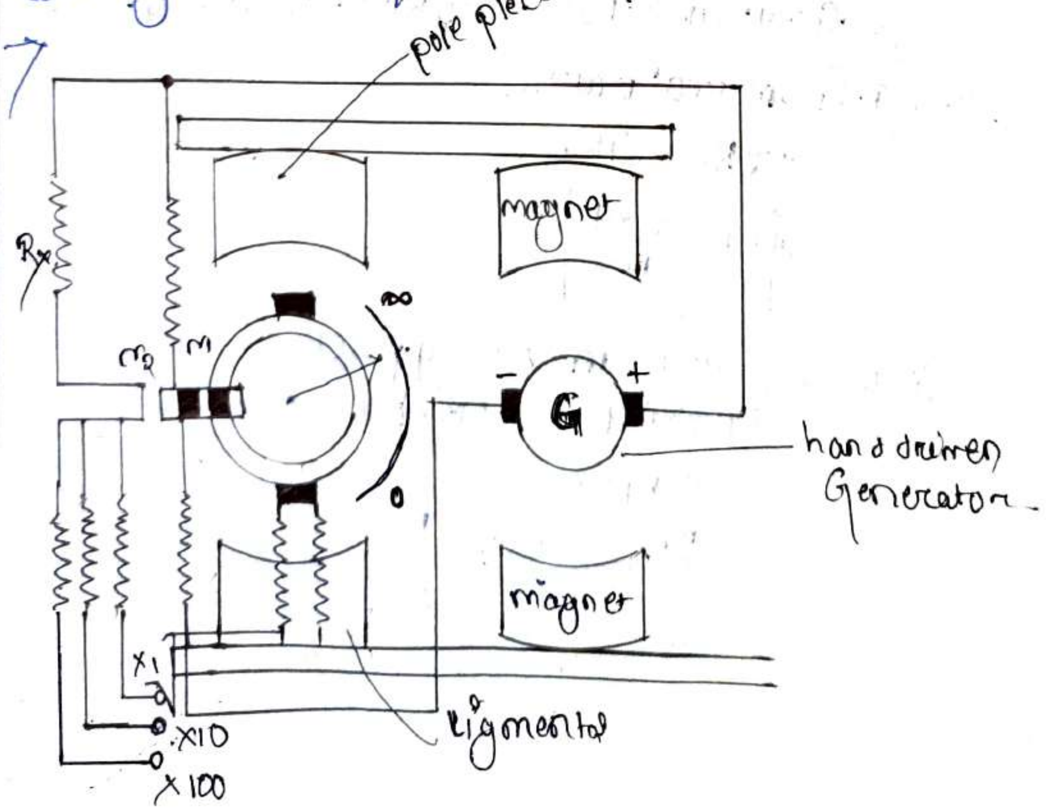
Construction:-

→ The megger has 1 current coil and 2 voltage coil (V_1 & V_2).

→ The voltage coil V_1 & V_2 passed over the magnet connected to the generator

→ when the pointer PMMC instant deflect to infinity it means that the voltage coil wound remain is weak magnetic field & hence experienced a very little torque.

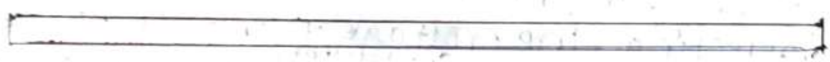
→



→ The torque experienced by the coil increase when it moves in-side the strong magnetic field.
→ The coil experienced maximum torque under the poles faces and the pointer set at the zero end of resistance scale.
→ From improving the torque the voltage coil r_2 is used.
→ The coil r_2 is shows allocated that when the pointer deflects from ∞ to 0 the coil moves into a stronger magnetic field.
→ In megger the combined action of r_1 & r_2 are considered, the spring of variables steadiness is attached to the voltage coil. It's steady near the zero end and becomes very weak near the infinity end.
→ The instant has the voltage selected switch which is used for selecting the voltage range of the instant.
→ The voltage range is controlled by selecting the varying resistance are connecting the series the current coil.
→ The voltage is generated by hand driven generator then working of megger. The testing voltage is generally 500V, 1000V, 2500V which is generated by hand driven generator.
→ The constant voltage is used for testing the insulation having the low resistance. The pressure coil rotates the moving coil in the circuit, the pointer of the moving coil becomes stable.
→ The pressure coil and the current coil balances the pointer and set it in the middle on the coil.
→ The deflection of the pointer is directly proportional to the applied voltage to the external circuit.
→ When the testing circuit is applied across the megger and if there is no shorting through out insulation there is the pointer deflection towards infinity.
→ Which is source that the resistance has high insulation.

Earth tester:

→



- The instrument used for measuring the resistance of the earth is known as earth tester.
- All the equipment of the power system is connected to the earth enough the earth electrode.
- The earth protects the equipments of the power system is connected to the earth enough the earth electrode.
- The earth protects the equipment and personal from the fault current.
- The resistance of the earth is very low.
- The fault current through the earth electrode passes to the earth, thus protect the system from damage.
- The earth electrodes control the high potential of the equipment which is caused by the high rating surges and voltage spikes.

→ The neutral of the three phase circuit is also connected to the earth electrodes for their protection.
→ Before providing the earthing to the equipment it is essential to determine the resistance of that particular area from where it is the earthening pit can be dig.
→ The earth should have low resistance so that the fault current easily passes to the earth.
→ The resistances of the earth is determined by the help of earth tester instrument.

Construction:-

→ The earth tester uses the hand driven generator.
→ The rotational current reverser and rectifier are two main parts of the earth tester.
→ The current reverser and the rectifier are mounted on the shaft of the DC generator.
→ The earth tester works only the DC because of the rectifier.

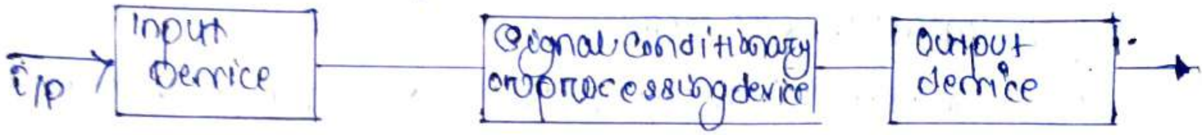
Working:-

→ The tester has two commutators place along with the current reverser and rectifier.
→ The each commutator is a device used for converting the direction of flows of current.
→ It is connected in series with the armature of the generator and the brushes are used for transferring the power from the stationary parts to the moving parts of the device.
→ The arrangment of brushes can be done in such a way that they are alternately connected with one of the commutator.
→ The brushes and the commutators are always connected to each other.
→ The power of the pressure coil and the current coil are placed across the permanent magnet.

→ The one coil of current and pressure coil is short-circuited and it is connected to the auxiliary electrodes.
→ The one end terminals of the pressure coil is connected to the earth electrode.
→ Similarly, the current coil is connected to the rectifier and earth electrode.
→ The each tester consist the potential coil which is directly connected to the DC-generator.
→ The potential coil is placed between the permanent magnet.
→ The coil is connected to the pointer and the pointer is fixed on the calibrated scale.

Transducer

A generalized Measurement system consists of three Major Components.



input device – receives the measurand i.e. the quantity which is to be measured and delivers a proportional analog electrical signal e.g. voltage, Current to the Signal conditioning device.

output device:-

Signal conditioning device:-

Here the signal is applied, attenuated, Filtered, Modulated & converted to a format acceptable to the output device.

output device:-

→ It gives the output in user understandable form.

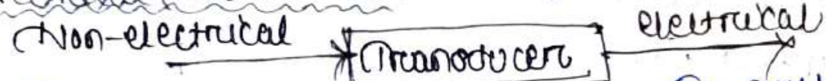
→ The i/p quantity is in most instrument system is a non-electrical Quantity. in order to use electrical Methods we have to convert it into electrical signals.

Transducer:-

Transducer is a device which transforms energy from one to another.

→ It converts any non-electrical quantity to electrical quantity

Electrical transducer:-



Eg. Heat, Temprature, Flow rate, liquid level

Eg- voltage, Frequency, Current, resistance, Capacitances

→ Transducer is of two types:-
1. electrical Transducer
2. Mechanical transducers.

Electrical transducer:-

→ Non-electrical quantities can not be measured directly.
Ex:- temperature, pressure, displacement, speed flow rate.

→ Electrical quantities can be measured ~~Quantity~~ directly ex:- voltage, current, resistance, inductance, capacitance etc.

→ For measurement of non-electrical quantities these are to be ~~measured~~ converted into electrical quantities and thus ~~the~~ function of conversion is done by a ~~der~~ device, called as electrical transducer.

Advantages:-

(i) Electrical o/p from the transducer can be ~~applied~~ amplified to any desired level of voltage & current.
(ii) very small power ~~is~~ is required to control electrical & electronic system.
(iii) Effect of friction is minimised.
(iv) electrical o/p can be used transmitted & processed very easily.
(v) o/p can be measured at a distance from the ~~sens~~ sensing element through wired or wireless system.

Disadvantages:-

(i) costly.
(ii) Low reliability in comparison to mechanical transducer.
(iii) ~~Ag~~

→ Transducer is a combination of two closely related parts.

Transducer	
Sensing/detecting element	Transduction element

→ It senses / responds to a change in physical quantity phenomenon

→ It transform the o/p of a sensing element to an electrical o/p.

* Sensor or detecting element:-

→ It senses and response to a change in physical phenomenon.

* Transduction element:-

→ It transforms the output of a sensing element to an electrical o/p quantity.

Classifications of Transducer:-

On the basis of the method of application:-

Primary	Secondary
1) Input is sensed by a transducer and the physical quantity into electrical quantity. Ex:- Thermistor (2) senses the temperature directly and cause a change in resistance according to the changing temperature.	① Input first sensed by a sensor, output of the sensor which is an non-electrical quantity converted into electrical quantity. Ex:- Pressure is to be measure. (2) Pressure → displacement. voltage → Bourdon tubes.

→ On the basis of energy conversion:-

Active transducer	Passive transducer.
① It doesnot required any external power source for its operation. → It can generate an electrical signal directly in response to the physical quantity to be measured.	① It require auxiliary power source for its operation. → In this transducer resistance, inductance and capacitance change in respone to any physical quantity

→ Ex:- ~~Thermal power~~, tacho generator, photovoltaic cells.	require power source. Ex:- Resistive, inductive, Capacitive.
→ It is called self generating type transducer	→ It is called externally power transducer.

→ <u>On the basis of Nature of output</u>

Analog	Digital
→ It convert input to output signal which is continuous function of time. Ex:- Strain gauge, Thermocouple.	→ Output is in discrete form which is p. → Ex:- used in digital measuring.

→ <u>On the basis of Mode of operation:</u>

Transducer	Inverse transducer.
→ It convert physical quantity to electrical quantity.	→ It convert electrical quantity to physical quantity.

→ <u>Resistive transducer:-</u>

In resistive transducer resistance changes due to change in physical phenomenon.

physical quantity → Resistance → voltage/current.

As we know resistance of a metal conductor is given by $R = \frac{\rho L}{A}$.

where ρ = resistivity / specific resistance.

L = Length of the wire(m)

A = area of the cross sectional of the wire (m^2).

→ ρ, L, a all quantities depend upon the nature of the material; so if any parameter changes the resistance will change.
→ It is the most preferred because both AC and DC voltage or current can be handle or suitable for resistance measurement.
Ex:- potentiometer, strain gauge, thermistor etc

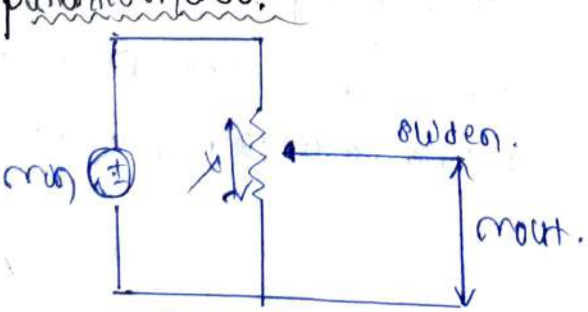
potentiometer:-
Length varies so change in resistances.

Strain gauge:-
When gauge is strain there is a change in cross-sectional area so change in Resistance.

Temperature Measurement:-
Temperature change so resistivity changed. Hence voltage change in resistance.

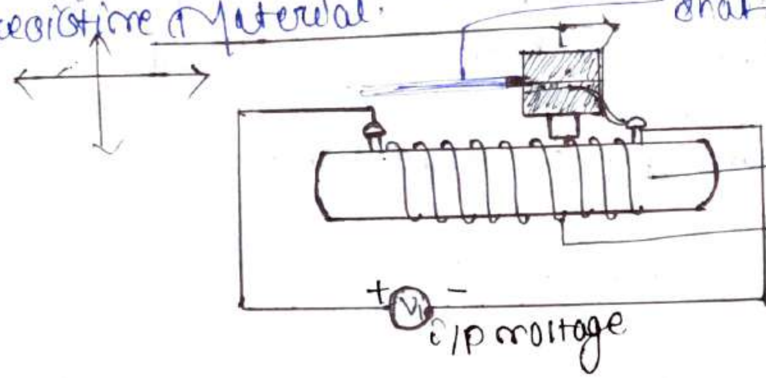
potentiometer:-
Here change in displacement causes change in voltage.
→ It is a passive transducer, Hence it required external power source for it's operation.
→ It is very cheap and very widely used.
→ Displacement can be change
→ Tran. → linear → potentiometer.
(linear pot)
→ Rotational → Rotary pot
→ Helical pot.

Linear potentiometer:-



$I = \frac{V_{in}}{Rx}$ $V_{out} = Iy$
$\Rightarrow \frac{V_{in}}{x} y$
$\Rightarrow V_{out} = y/x \, V_{in}$

→ where x is the total length of the resistive Material.
→ y is the relative position of the slider on the resistive Material.

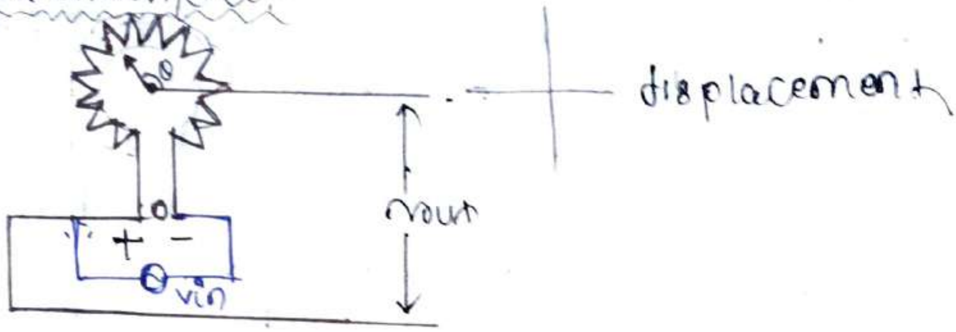


→ This is used for Measurement of displacement.
→ It is simple and cheap.
→ It is output voltage is a function of linear displacement.

Construction:-

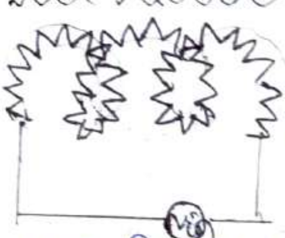
→ It is consist of resistive element provided with a sliding contact.
→ A sliding contact is the known as wiper.
→ The resistive body of the potentiometer is wire wound and the wire is made up of nickel and platinum alloy.
→ Displacement of the slider determines the change in voltage drop related to position of the slider.
→ It is Mostly used in Laboratory but not suitable for industrial purpose.
→ The transl resistive element are straight device and have a strok 2mm to 0.5m.

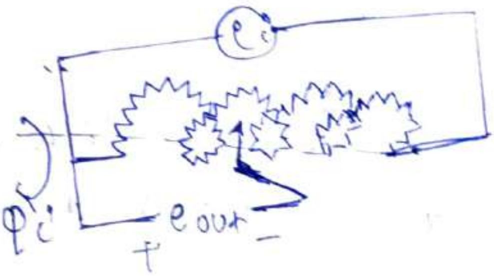
Rotary potentiometer:-



→ Here the resistance element connected in a linear circular manner.
→ The principle of operation is same as that of linear pot.
→ This kind of potentiometer have rotary moment and so it is useful for measurement of angular displacement.
→ The angular displacement measured between 0° to 357°.

Helical potentiometer:-





→ Some pots is the combination of two motion i.e. translational as well as Rotational.
→ Here is resistive element is in the form of a helix.
→ Hel pot can be measure upto 3500 of rotation.

Advantages:-
→ It can measure Large displacement.
→ It has high electrical efficiency.
→ It is easy in construction.
→ It is cheap and easy to operate.

Disadvantages:-
→ Sliding contact may be wear out and get contaminated (junk) and generate noise
→ They required larger force to move the slider.

Strain gauge:-

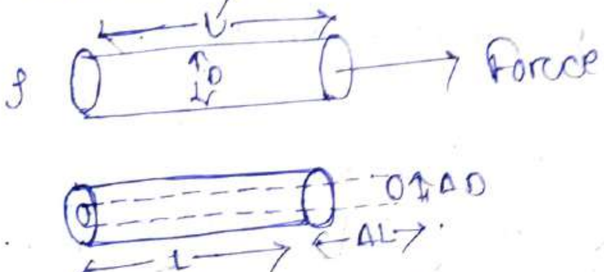
→ The transducer which is used for Measurement of strain is called Strain gauge.

→ When a Metal conductor is stretched or Compressed then its resistance changes due to change in length & diameter of the Conductor.

→ Load carrying capability is characterised by stress.

Stress = Force per unit area = Pressure.

→ When the wear is subjected to be a stress the parameter going to be affected are length, area and resistivity.



→ When L is the original length and ΔL is the change in length and D is the original diameter and ΔD change in original diameter. A is the original area & ΔA is the change in area.

→ R is the resistance of the wire and ΔR is the change in resistance of the wire

→ Stress can not be Measure directly, so we will Measure strain gauge element.

$$\text{Strain} = \frac{\Delta L}{L}$$

→ The relation between stress & strain
Young's Modulus (E)

$$(E) = S/\epsilon$$

Bounded wire strain gauge:-

→ It is used for both stress analysis and for constructing transducer.

→ A resistive wire strain gauge consists of grid of fine resistance wire of about 0.025 mm in diameter or

→ The grid is cemented to carrier (base) which be thin sheet of paper of bakelite or teflon.

→ The wire is covered on the top with the thin sheet of material so as to prevent it for any type of mechanical damage.

→ The spreading of the wire permits and uniform distribution of stress over the grid.

→ The base bounded with an adhesive material to the specimen under study.

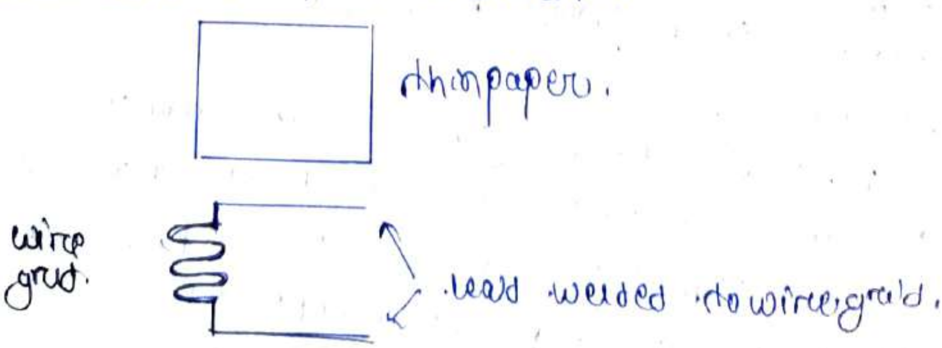
→ The wires can not buckle as there embeded in in a mat of cement and hence pole of tensile and compressive force of a specimen.

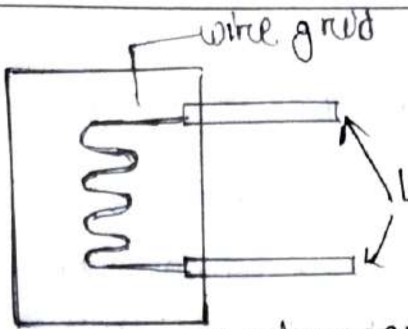
→ The wire made of Cu-Ni; Cr-Ni; Ni-Fe alloys.

(i) High value of gauge factor.

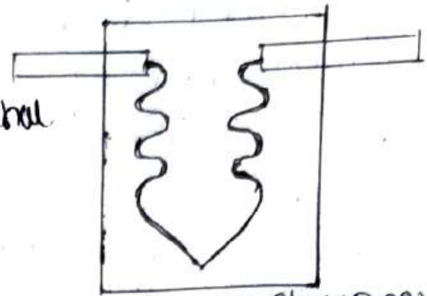
GF↑ ⇒ sensitivity ↑

(ii) Resistance of a strain gauge must a high value as it minimizes the effect of undesirable variable of the resistances in the circuit.

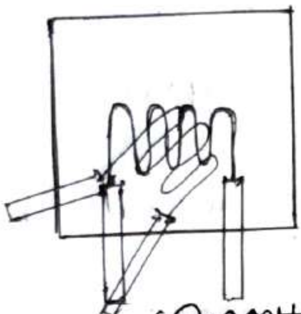




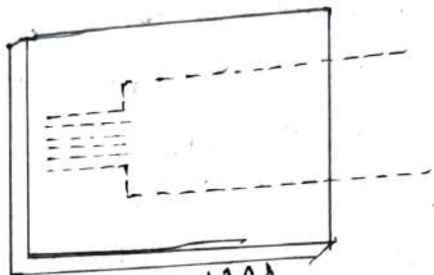
(Linear strain gauge)



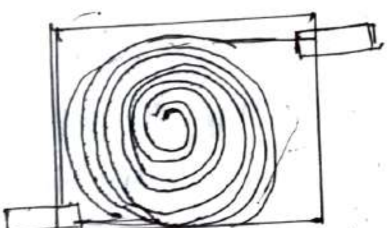
Torque strain gauge.



(Rossette)



Assembled Gauge.



(Helical gauge)

Platinum Resistance Thermometer:

→ The resistance of a conductor changes when its temperature is changed. This property is utilised for measurement of temperature.

→ The requirements of a metal used in resistance to be

i) The change in resistance of material per unit change in temp. should be as large as possible (sensitivity)

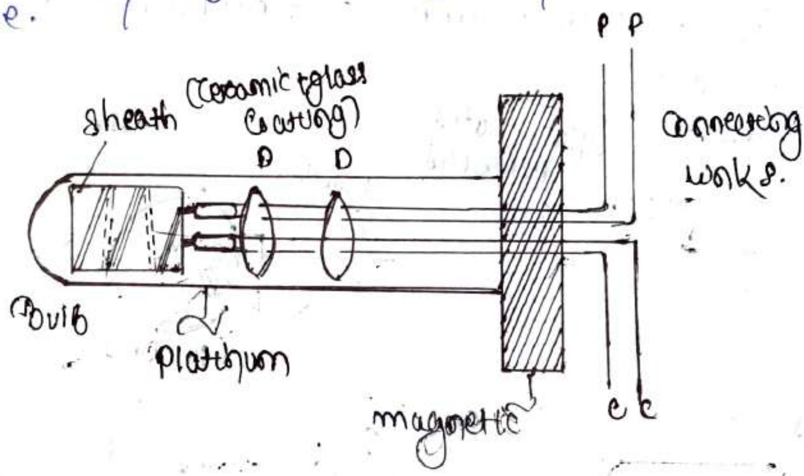
i) The material should be of high value of resistivity so that minimum value of material is used.

ii) The resistance of material should have continuous & stable relationship with temperature.

→ The resistance of materials should have continuous & stable relationship with temperature.

→ The resistance type thermometer bulbs are sensing element & in the form of the wires.

→ The Filums deposited on insulating surface are also used for Temprature sensing.
→ In the wire type the arrangment are Commonly a helical coil wound as a double wire to avoid inductive effect.
→ The laboratory type Resistance thermometer have the temprature sensing element wound on a Cross mica. Former & enclosed in pyrex tube.
→ In the industrial type of thermometer, the former is not of grooved ceramics. The wire is being protected by a glass coating or by a stainless steel tube.



→ The element is normally enclosed in glass when used for Temprature upto 150°C. Ceramic for use of 850°C.
→ Resistive elements are also made up of thin grids of Metal wire similar in shape of a type Strain gauge.
→ They are Constructed of platinum & may be bounded to plastics backing for attachment to Surface.
→ platinum is preferred because of can withstand high temprature with maintaining stability & It avoids Contamination.

* Thermistor :- (Thermal Resistor)

→ Thermistor is generally composed of Semiconductor Material.
→ Most of the thermistor have -ve temprature co-efficients.
i.e- decreases with Resistance with increase in Temprature.

→ This allows the thermistor ckt detect small changes in temperature which not be obtained with RTD or thermocouple. (Resistance thermal detector)

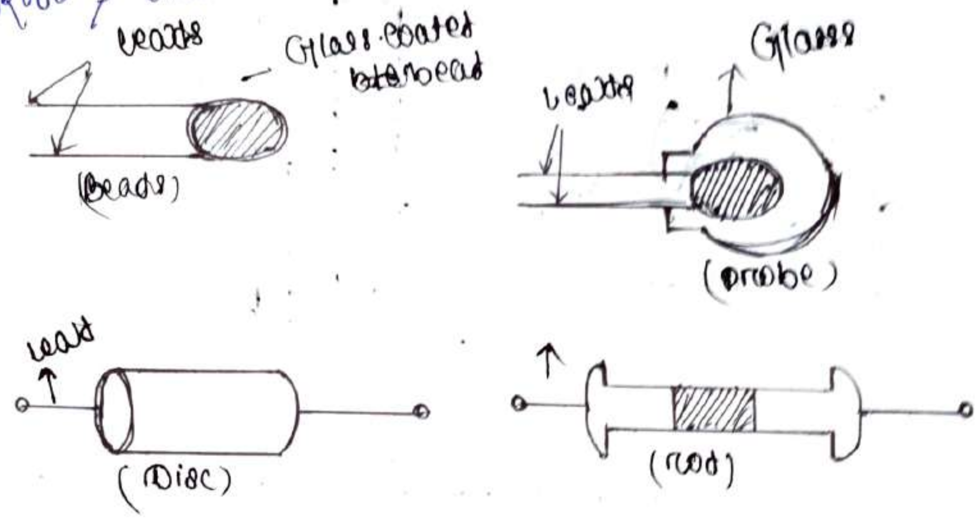
→ The Resistance of thermistor Range from 0.5Ω to 0.75Ω & temperature Range from -60°C to 15°C.

* **Construction:-**

→ These are composed of Mixture of ceramic oxides such as magnanese, nickel, cobalt, copper, iron & uranium.

→ They are available in varieties of shape & size.

→ The thermistor may be in the form of bead, Rods & discs.



* **Resistance Vs. Temperature characteristics of Thermistors:-**

This is given by :- Steinhart – equation

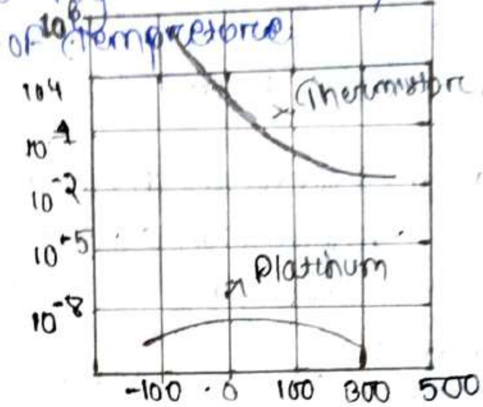
$$R_T = R_{T_0} * \exp\left(B\left(\frac{1}{T_1} - \frac{1}{T_0}\right)\right)$$

where, R_T = Resistance of thermistor of absolute temperature.

B = a constant depending upon the materials of thermistor.

→ Thermistor have very high -ve temp co-efficient of Resistance making it an ideal temperature transducer.

→ Between -100°C to 400°C thermistor changes its Resistivity making it an ideal form 10^4 to 10^{-7} Ωm, which explains high sensitivity of thermistor & for Measurement of temperature.



Inductive Transducer:-

→ The most widely used inductive transducer is linear variable.

Differential transducer:-

→ LVDT is used for translating the linear Motion (Motion or displacement into electrical signal (inductance)

→ It is a passive transducer as it's Require for it's operation process.

Construction of LVDT:-

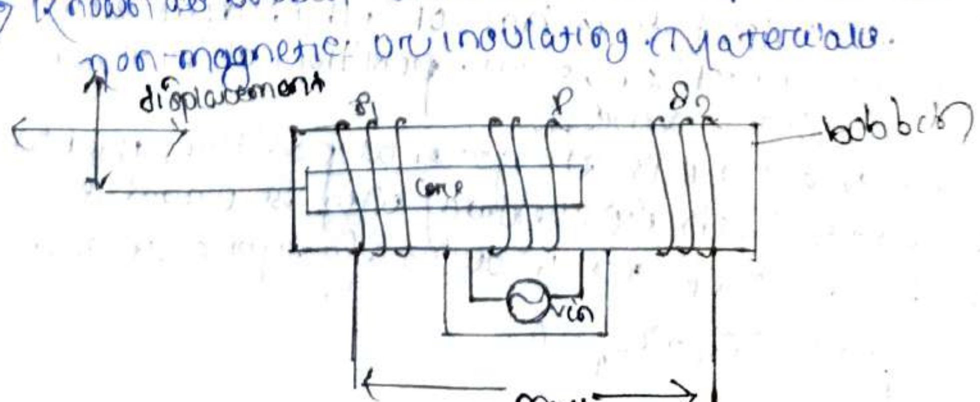
→ LVDT consists of two windings.

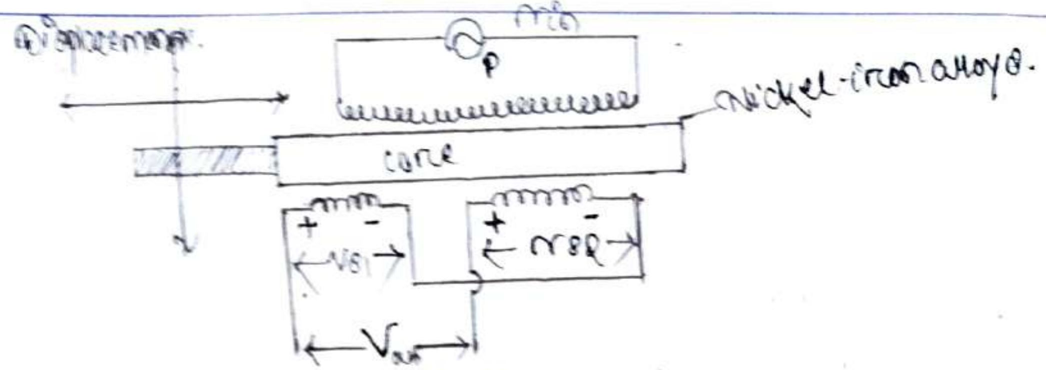
(a) Primary winding (P)

(b) Secondary winding (S_1 & S_2)

→ These two windings are wound on hollow cylindrical former.

→ Known as bobbin which is made up of either non-magnetic or insulating Materials.





→ Both the secondary winding (S_1 & S_2) have equal no of turns & are placed on both side of primary winding.

→ primary winding connect to AC source voltage.

→ A movable cylinderical soft iron core is attached to the sensing element of transducer. The core is made up of nickel-iron alloys, to reduces to eddy current loss.

→ The core slides freely within the hollow portion of bobbin.

→ The displacement is measure & is attached to the soft iron core.

→ In order to get a displacement output voltage the two single voltage signal V_{S1} & V_{S2} from the secondary winding S_1 & S_2 are connected in series phase opposition.

Working:-

→ Any physical displacement of the core causes the voltage of one secondary winding to increase while simultaneous reducing the voltage in the other.

→ The difference of the two voltages appear across the output terminal of the transducer & gives measure of physical position of the core & hence the displacement.

→ When the core is at normal position the flux linking with both secondary wdg is equal & hence equal emf are induced so net output i.e

$V_0 = V_{S1} - V_{S2} = 0$.

→ If the core is moved to the left of the normal position more flux gets linked with S_1 & less with S_2. So $V_{S1} > V_{S2}$. Hence we get a +ve output voltage.

→ Similarly when core is moved to the right of null position then flux linked with S_2 is more than S_1, so $V_{S1} < V_{S2}$.

→ The difference of o/p voltage of secondary winding gives the amount of displacement.

Advantages of LVDT:-

→ It's output is very high so no need of amplification.

→ The device consumes less power.

→ It is very simple, light weight & easy to maintain.

→ It can tolerate high degree of shock & vibration.

Disadvantages:-

→ This devices are very sensitive to stray magnetic field.

Capacitive Transducers:-

→ It is a device in which the capacitance is varied by the nonelectrical quantities being measured.

→ The principle of operation of capacitive transducer is based upon the principle of parallel plate capacitor.

→ Capacitance $C = \frac{\epsilon A}{D} = \frac{\epsilon_0 \epsilon_r A}{D}$

Where, ϵ = permittivity of medium (F/m)

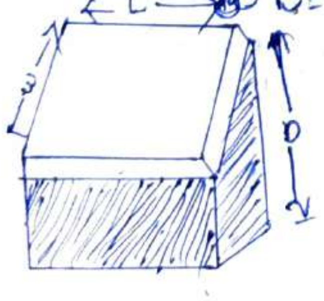
ϵ_r = relative permittivity of medium

ϵ_0 = permittivity of free space

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

A = overlapping area of the plates (m²)

D = Distance between two plates.



→ Capacitive transducer work on the principle of change in capacitance, caused by.

(i) change in overlapping area (A)

(ii) change in distance betn the plates (D).

(iii) change in dielectric constant (ε)

→ These changes are caused by the physical variables like displacement, force, & pressure, which causes the change in capacitance and hence the change in non-electrical quantity change in to electrical quantity.

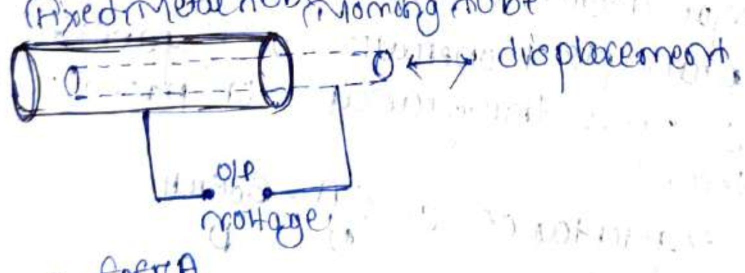
(i) Transducers using change in area of plates:-

→ Capacitance of a material is directly proportional to the area thus the capacitance changes linearly with the change in area of plates.

For cylinderical tube:-

→ The moving tube is inside a fixed tube.

→ The movement in the moving tube causes change in overlapping area (A) due to which capacitance changes & hence there is a change in output voltage.

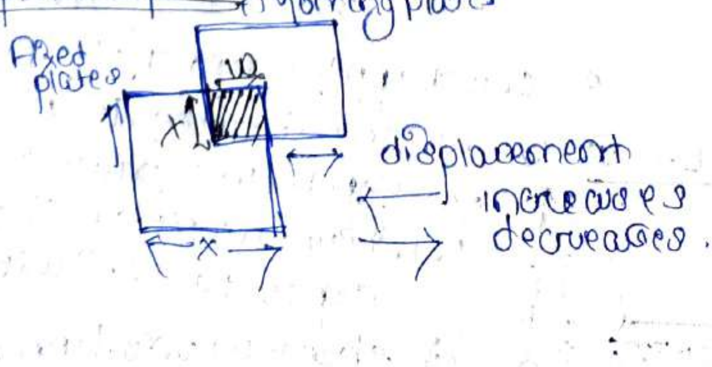


$C = \frac{\epsilon_0 \epsilon_r A}{D}$

$\rightarrow C \propto A$, $C \propto \frac{1}{D}$

Capacitance ← increases → decreases.

For parallel plate,



In this diagram, the Capacitance changes due to the change in the overlapping area.

→ The overlapping area changes due to displacement of Moving plate.

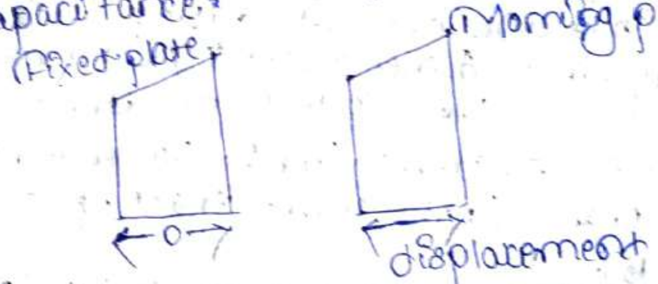
→ Currently the overlapping area $A = w \times x$. Thus

$$C = \frac{\epsilon_0 \epsilon_r (w \times x)}{D}$$

→ Hence when there is changes in w or x, then there is a change in the Capacitance due to change in overlapping area.

(ii) Transducer using changes in distance bet^n plates:-

→ In this Mechanism, if there is a change in the distance bet^n the two plates then there is a change in Capacitance.



as $C = \frac{\epsilon_0 \epsilon_r A}{D}$, $C \propto \frac{A}{D}$

→ If distance increases the Capacitance decreases and vice-versa.

Applications:-

→ Capacitance transducers are used for Measurement of small displacements.

→ These are used for linear displacement, force, pressure.

Advantages:-

→ Very small force is required to operate the system.

→ It is highly sensitive.

Disadvantages:-

→ Capacitive transducers are very sensitive to vibrations & temperature.

→ Metallic parts of capacitor must be insulated from each others.

→ Performance is attached by humidity, dirt & other contaminations.

Piezoelectric Materials:-

→ A piezoelectric material is one in which an electric potential appears across certain surfaces of a crystal if the dimensions of the crystals are changed by the application of mechanical force.

→ The potential is produced by the application of charges. This effect is reversible i.e if we will vary the potential which is applied to the proper axis of crystal, it will change the dimensions by deforming it. This effect is called piezoelectric effect.

→ ex:- Rochelle salt, ammonium hydrogen phosphate, Lithium sulphate, dipotassium nitrate, quartz, Ceramics (A & B).

→ Except quartz & ceramic (A, B) all are man made crystals grown from aqueous solution under controlled conditions.

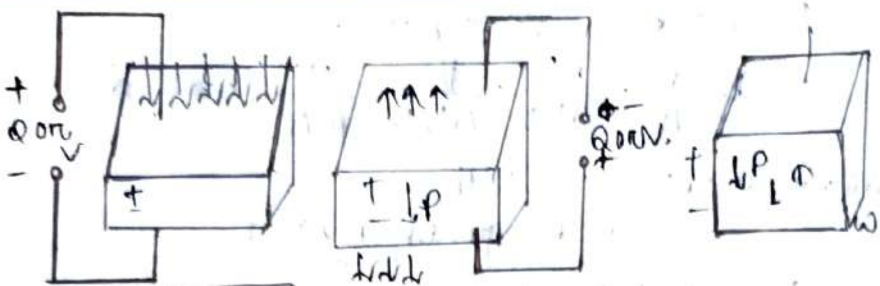
→ The materials that exibit a significant & useful piezo electric effect are divided into 2 catagories

(i) Natural group - ~~Rochelle salt~~, quartz, ceramic A & B

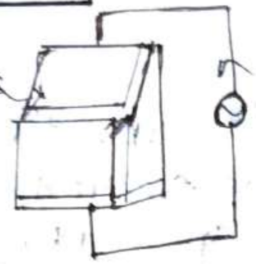
(ii) Synthetic group - Lithium sulphate, Ethylene.

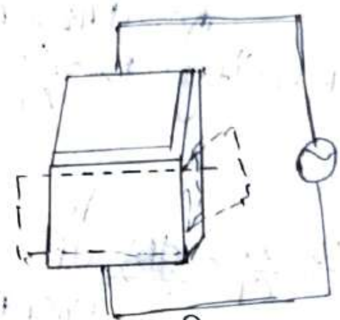
→ The piezo electric effect can be made to respond to the mechanical determinations of the material.

→ It is used for converting mechanical motion to electrical signal which can be throught like generators & a capacitors.



piezo electric Motor

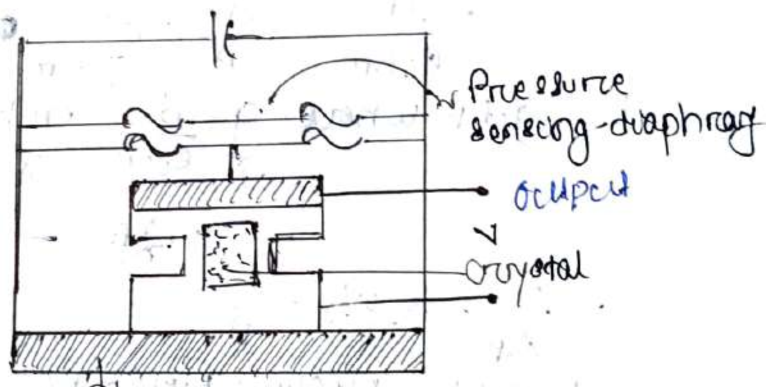




Electric Conversion.

$F = AE \frac{\Delta t}{t}$

$E = \frac{stress}{strain}$



→ Mechanical de formation generates a charge & this charge appears across the electrodes.

$voltage\ E = Q/C$ Q = charge, C = Capacitance,

→ This tensile force produces a voltage of one polarity while a compressive force produces a voltage of opposite polarity.

→ Charge $Q = d \times F$ ——— (1)

where d = charge sensitivity of the crystal (C/N)

F = applied force (N)

Force F causes a change in thickness of the crystal

$F = \frac{AE}{t} \Delta t$ (Newton) ——— (2)

where E = Young's Modulous (N/m²) = $\frac{stress}{strain}$

A = Area of crystal (m²)

t = thickness of crystal (m)

$$E = \frac{F}{A} = \frac{P}{\Delta t/t} = \frac{P}{\Delta t/t} = \frac{Ft}{A\,\Delta t} \; N/m^2$$

(A) Also $A = W \times L$ W = width
L = length of crystal

From eqn (1) & (2)

$$Q = dAE\,(\Delta t/t)$$

O/p voltage $E_0 = \frac{Q}{C_p}$. where C_p is capacitance between electrodes
& also $C_p = \epsilon_0 \epsilon_r A/t$

$$E_0 = \frac{Q}{C_p} = \frac{dF}{\epsilon_0 \epsilon_r A/t}$$

$$= \frac{dF}{\epsilon_0 \epsilon_r} \times \frac{t}{A} = \frac{dt}{\epsilon_0 \epsilon_r} \cdot P \qquad \boxed{P = F/A}$$

$E_0 = g \cdot t \cdot P$. where $g = \frac{d}{\epsilon_0 \epsilon_r}$ voltage sensitivity of the crystal
= Vm/N —— (3)

$$g = \frac{E}{tP} = \frac{E_0/t}{P} = \frac{\epsilon}{P}$$

where E = electric field = $\frac{E}{P}$ / stress

→ Crystal voltage sensitivity g can be defined as the ratio of electric field in density to pressure or stress.

→ Unit of g is volt·m/newton.

→ From eq (3) $d = g\epsilon_0\epsilon_r$ = change sensitivity uses of potential piezoelectric variations & variation in humidity, so quartz is used for stabilizing electronic oscillator.

→ This transducer is used in accelerometres, vibrations pick ups under water detection system i.e. SONAR etc.

Dt:-02/06/2022

Cathode Ray Tube CCR

→ The CRO is an instrument for display, measurement, and analysis of waveforms & other phenomenon. In electrical & electronic circuits.

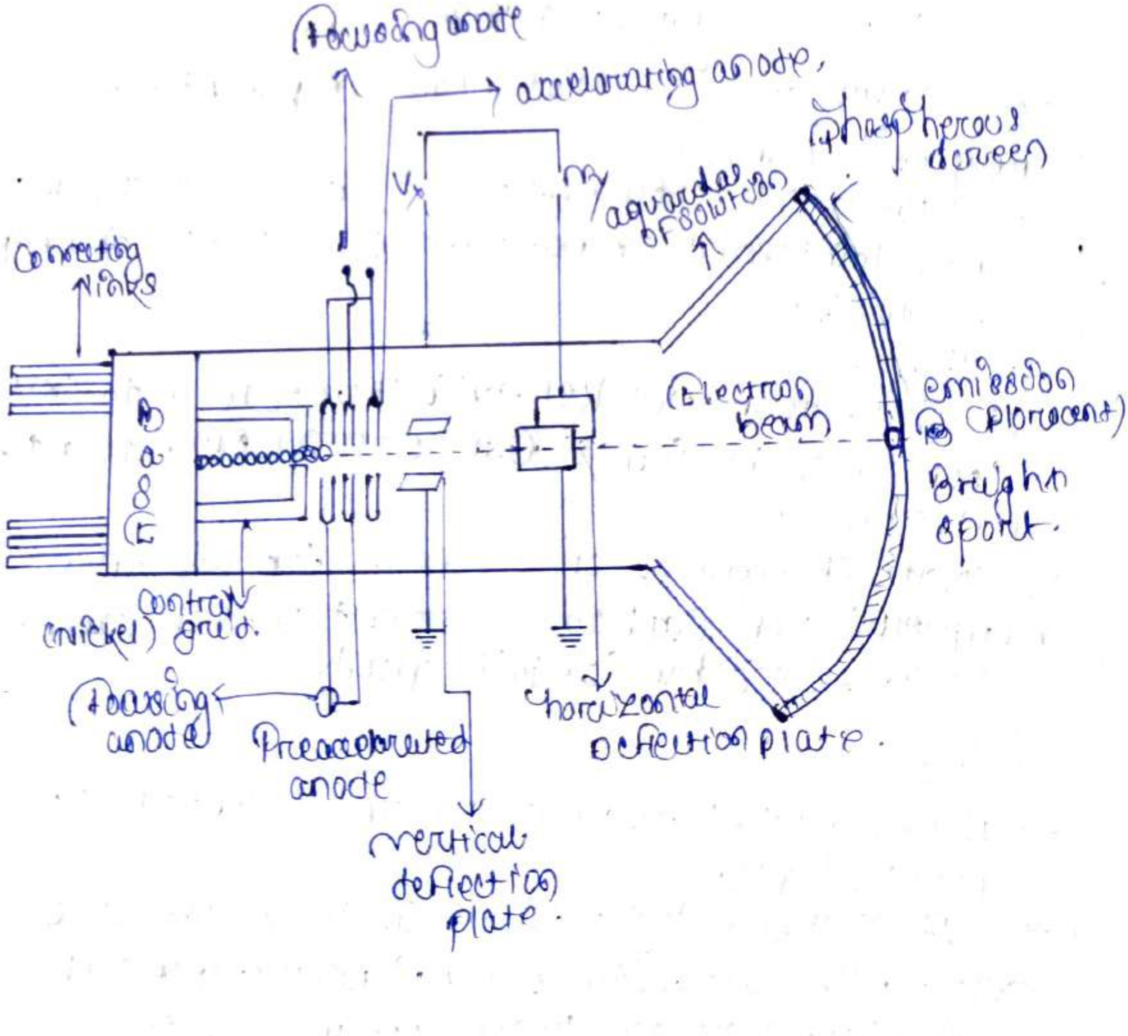
→ CROs are very fast x-y. plotter, displaying input verses another signal (generally time).

Principle of operation of Cathode Ray tube:-

→ A CRT is a main part of Cathode Ray. oscilloscope with additional circuitary to operate the circuit.

→ Its main parts are:-

(1) Electron Gun assembly
(2) Deflection plate assembly
(3) Fluorescent screen
(4) Glass envalope
(5) Base for making the connection



→ CRT is a vaccum tube & Convert an electrical signal into visible one.
→ Cathode Ray tube makes available plenty of electrons. The electrons are accelarated to high velocity & are focused on a Fluroscent Screen.
→ The electron beam produces a spot of light whenever it strikes.
→ The electron beam is deflected on its journey in response to electrical signal under steady. Hence the electrical signal is displayed.

(i) Electron Gun Acce Assembly :-
→ The Source of focused & accelarated electron beam is the electron gun.
→ It consists of
(a) an indirectly heated Cathode
(b) A control grid Surrounding the Cathode
(c) a Focusing anode
(d) An accelarating anode.
→ control grid is held at negative potential with respect to anode.
→ Two anodes (Focusing anode & accelarating anode are maintained at positive potential with respect to Cathode.

Cathode:-
→ It Consists of a nickel cylinder coated with oxide Coating of barium & Strontium emit plenty of electrons.
→ Rate of emission of electrons depends upon magnitude of cathode Current which can be Controlled by Control grid.

Cathode grid:-
→ It is a nickel cylinder with a centrally located hole.
→ It encloses the cathode and Consist of a Metal cylinder with tiny Circular opening to keep the electron beam small in size.

→ These plates are responsible for the movement of electron beams in the horizontal left and right on the fluorescent screen.

Fluorescent Screen:-

↳ The end wall or inside face of the tube coated with some fluorescent material like phosphor, zinc oxide, zinc orthosilicate etc. fluorescent screen.

↳ When high velocity of electron beam strikes the screen a spot of light is produced at the point.

→ It absorbs the kinetic energy of the electron and convert into light.

Glass envelope:-

↳ It is highly evacuated glass housing in the which volume is maintained inside

↳ Inner wall of CRT between neck and the screen are usually coated with conducting material called aquadag

↳ This coating electrically connected to the accelerated anode so that electron which accidentally strike the wall return to the anode.

↳ This prevents the wall from charging to a high -ve potential

→ This aquadag ~~the wall from charging to a high~~ -ve coating prevents the formation of -ve charge on the screen.

Principle of operation of oscilloscope:-

→ CRO is the most useful laboratory instruments for studying wave shapes of ~~alte~~ alternating current, voltage, power, frequency having amplitudes waveform.

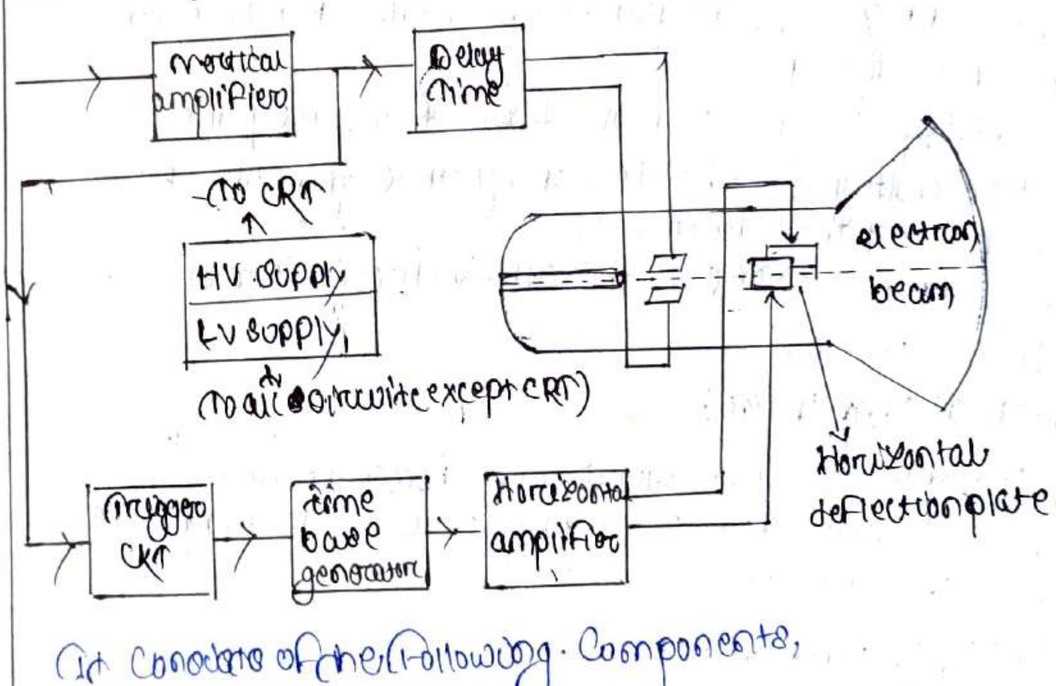
→ It allows the users to the amplitude electrical signal as a function of time on the screen.

→ With CRO wave shapes of signal can be studies and can be used for measuring.

(i) Voltage
(ii) Frequency
(iii) phase shift

Application of CRO

(i) Tracing the actual waveform of current and
(ii) Determination of amplitude of a variable quantity.
(iii) Comparison of phase and frequency.
(iv) can be used any kind of electronic component on electronic circuits.
(v) For finding B-H curve of hysteresis loop.
(vi) Tracing characteristics of any electronic component like diode, transistors.
(vii) In CRT television
(viii) In RADAR



It consists of the following components,

- CRT
- power supply block.
- vertical amplifier
- Horizontal Generator
- Trigger circuit.

Cathode Ray tube:
→ It is the heart of the oscilloscope.
→ It generates sharply focused electron beam & accelerate the beam to a high velocity and deflect

to create image.

→ It contains the phosphor screen, where the electron beam become visible.

→ While travelling from the electron gun to screen the electron beam passes between two sets of deflection plates, vertical and horizontal deflecting plates.

↳ Voltage applied to the vertical deflection plate to move the beam in the vertical plane & CRT moves up and down.

↳ Voltage applied to the horizontal plates to move the beam in the horizontal directly.

power supply block:-

↳ It provides the voltage required by the CRT to generate & accelarate the electron beam as well as to supply the required operation for the other ckt of oscilloscope.

↳ Voltage in the range of ~~kV of~~ KV are required by CRT.

↳ Low voltage for heater of electron gun of CRT which emit the electrons.

↳ Supply voltage for the other circuit is not more than few 10V.

vertical amplifier:-

It amplifies the signal waveform to be view. This is a wide band amplifier used to amplifies signal in the vertical section.

Horizontal amplifier:

It is fed with saw tooth voltage. It amplified saw tooth voltage before it is applied to horizontal deflection plates.

Time base Generator:-

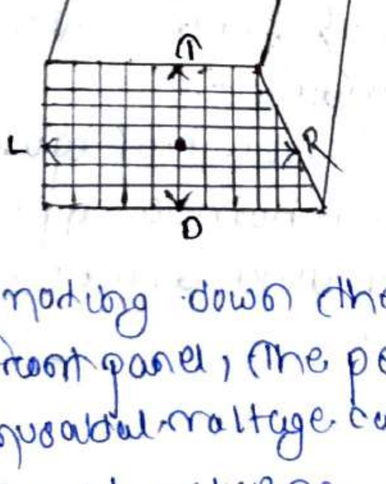
→ It develops saw tooth voltage waveform required to deflect the beam in the horizontal section.

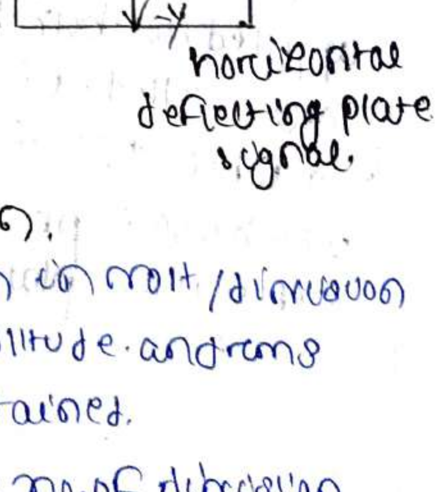
Trigger Circuit:
The trigger circuit is used to convert the incoming signal into trigger pulses so that frequency can be synchronous.

Delay line:
It is inserted b/w o/p of vertical amplifier by an amount of time equal to time consumed in the horizontal section to produce the signal.

CRO Measurement:
Various parameters can be measured by CRO are
1. voltage 2. current 3. time period.
4. frequency 5. phase angle 6. Amplitude.
7. peak to peak value.

* voltage measurement:
↳ voltage to be measured is applied to the vertical deflection plates through vertical amplifier.
↳ The horizontal plate is excited by time base generator.





selection.

→ After noting down the ~~section~~ in volt/division from front panel, the peak amplitude and rms value sinusoidal voltage can be obtained.

(i) Peak to peak value $V_{p-p} = \frac{volt}{div} \times$ no. of division

(ii) Amplitude $V_m = \frac{V_{p-p}}{2}$

(iii) Rms value $V_{rms} = \frac{V_{p-p}}{2\sqrt{2}} = \frac{V_m}{\sqrt{2}}$

→ volt/ division = $\frac{1}{\text{deflection sensitivity}}$

⇒ deflection sensitivity = $\frac{\text{division}}{\text{volt}}$

*Current Measurement:-

→ CRO has high input impedance and can't be for direct measurement. However the current can be measured in terms of voltage drop across a standard resistance $I = V/R$.

* Time period Measurement:-

↳ ~~CRO has high input impedance and can't be for direct measurement.~~ "

↳ From the screen, after noting down the time the time period of the wave form can be obtained as time period T = Time/division × no. of division.

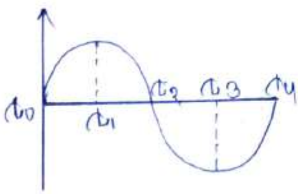
$$\text{Frequency } (F) = \frac{1}{T}$$

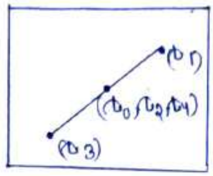
Frequency Measurement:-

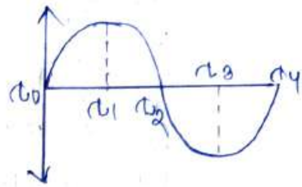
↳ The patterns that appear on the screen of CRO when sinusoidal voltage are simultaneously applied to both horizontal & vertical plates. are called Lissajous patterns.

↳ when two sinusoidal voltage of equal frequency which are in phase with each other applied to the deflection plates, the pattern will be a straight line.

t	v_x	v_y
t_0	0	0
t_1	$+2V_m$	V_{max}
t_2	0	0
t_3	$-V_{max}$	$-V_{max}$
t_4	0	0







→ For Measurement of accurate Frequency, Lissajous patterns are used.

↳ This Signal whose Frequency is to be Measured is applied to Y-phase plates.

↳ A standard variable Frequency source used to supply to the X-axis plates.

↳ When the Lissajous pattern appears, two lines are drawn one horizontal and the other vertical so that they don't pass through any intersection of different parts of the curve.

↳ Then no of cuts by the horizontal line, vertical line is calculated.

Now

Ex-1.

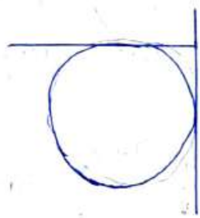
$f_x = 1$

$f_y = 1$

Given $f_x = 1000\,Hz$

Then $\frac{f_y}{f_x} = \frac{1}{1}$

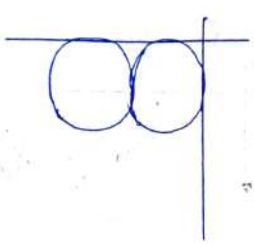
$\Rightarrow f_y = f_x = 1000\,Hz$



Ex-2

$\frac{f_y}{f_x} = \frac{2}{1}$

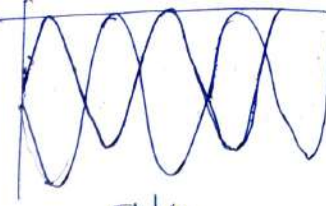
$\Rightarrow f_y = 2 \times f_x = 2000\,Hz$



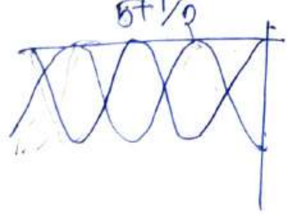
Ex-3

$$\frac{f_y}{f_x} = \frac{5}{1}$$

$\Rightarrow f_y = 5 \times f_x = 5000\,Hz$



Ex-4



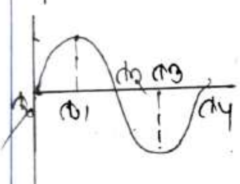
$$\frac{f_y}{f_x} = \frac{3+1/2}{1}$$

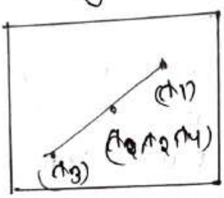
$\Rightarrow f_y = \frac{7}{2} \times f_x$

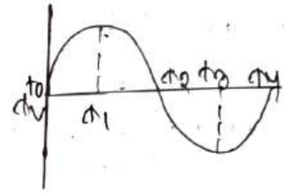
$\Rightarrow f_y = 7/2 \times 1000$

$\Rightarrow f_y = 3500\,Hz.$

→ If the phase difference is 0 i.e., two signal here, ~~therefore~~ same magnitude and frequency, then pattern will be a straight line.



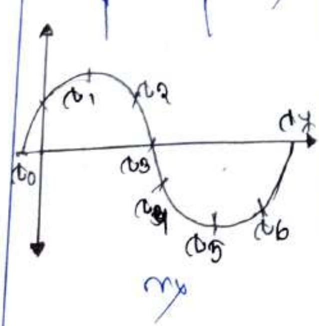


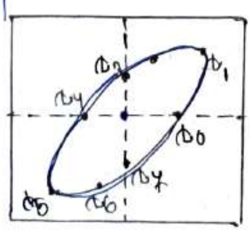


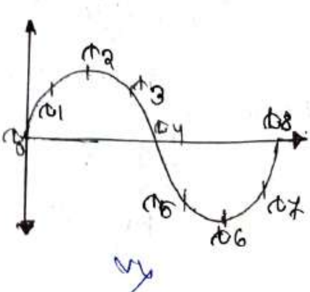
→ If the phase difference is 45°, then.

t	v_x	v_y
t_0	+ve	0
t_1	+vmax	+ve
t_2	+ve	vmax
t_3	0	+ve
t_4	-ve	0
t_5	-vmax	-ve
t_6	-ve	-vmax

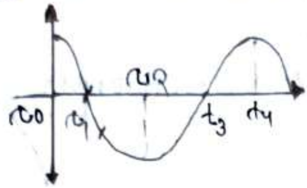
	v_x		v_y
t_7 →	0	→	-ve
t_8 →	+ve	→	0



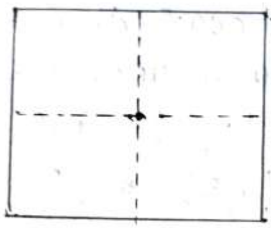


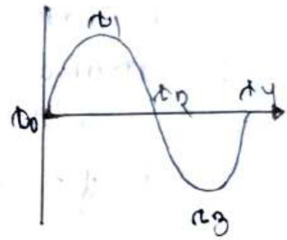


↳ If the phase angle is 90°, then it will be.



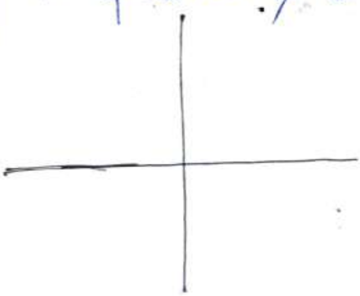
t	x	y

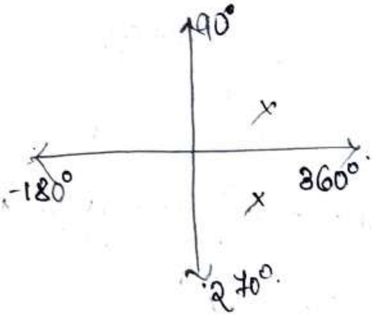




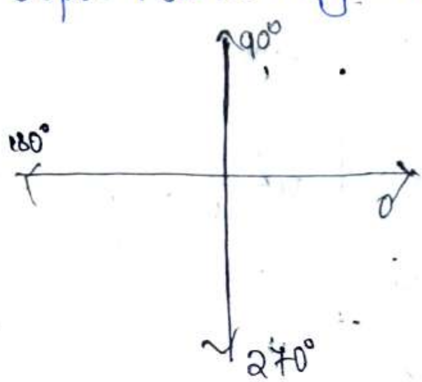
↳ The magnitudes of two waveforms must be same.

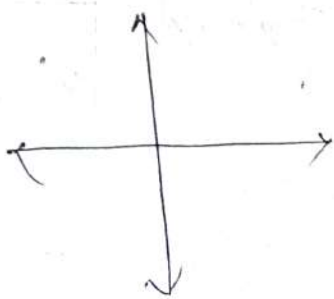
↳ If the phase angle between (0–90°) or (270–360°) then the ellipse has its major axis in the 1st quadrant & 3rd quadrant.





↳ If the phase distance is betn 90° and then the ellipse has it's major axis in the 2nd & 4th Quadrant.

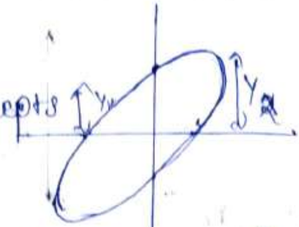




↳ value of ϕ is given by,

$\sin\theta = Y_1/Y_2$

where Y_1 and Y_2 are intercepts



(i) When ϕ is between 0 and 90°, then major axis will be in 1st and 3rd quadrant. (270 to 360°)

$\therefore \sin\theta = \frac{1}{\sqrt{2}}/\frac{1}{\sqrt{2}} = \frac{1}{2} = 0.5$

$So\ \phi = \sin^{-1}(0.5) = 30°.$

(ii) When ϕ was between 90° & 180° or 180° to 270°, then the major axis will be in 2nd & 4th quadrant.

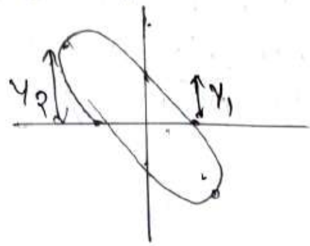
$\phi = \sin^{-1}(\frac{1}{\sqrt{2}}/\frac{1}{\sqrt{2}}) + 180°$

$= \sin^{-1}(\frac{1}{2}) + 180°$

$= 180° + 30°$

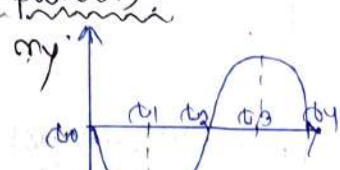
$= 210°$

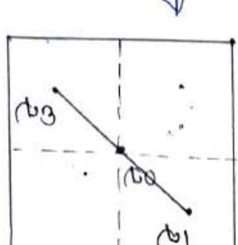
or $180 - 30° = 150°$

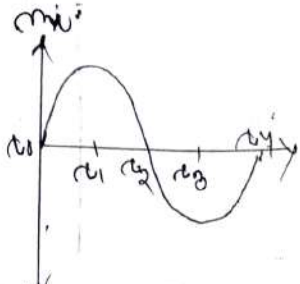


(For $\phi = 180°$ (Lissajous pattern):

t	Vx	Vy
t0	0	0
t1	+Vmax	-Vmax
t2	0	0
t3	-Vmax	+Vmax
t4	0	0



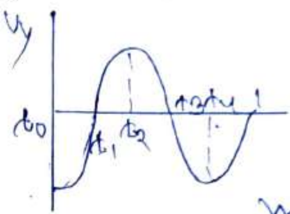


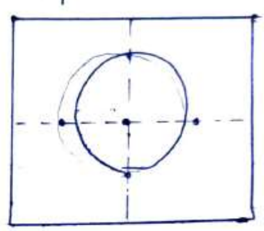


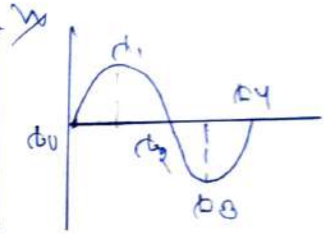
→ (D) iagonal making 135° with x-axis:

$\phi = 270^0$

t	v_x	v_y
t_0	0	V_{max}
t_1	V_{max}	0
t_2	0	V_{max}
t_3	$-V_{max}$	0
t_4	0	$-V_{max}$







↳ If we see our figure for ϕ is known $[0° < \phi < 90°]$ then

(i) LF $[180 - \phi]$ is mirror angle image of LF $[\phi]$

(ii) LF $[180 + \phi]$ is mirror image of LF $[\phi]$

(iii) LF $[360 - \phi]$ is same as LF $[\phi]$.

Multimeter

↳ As the name when a single device is used to Measure Multiple Quantities, the device is called Multimeter.

↳ There are two types of Multimeters:-

- Analog Multimeter
- Digital Multimeter

Analog Multimeter:

↳ An analog Multimeter is a permanent magnet Moving coil (PMMC) Meter type Measuring instrument.

↳ It works on the principle of ~~Arp~~ d'Arsonval galvanometer.

↳ The analog Multimeter has an analog display that uses the deflection ~~has an~~ of a pointer on the scale to the indicate the level of Measurement being Made.

Working of the Analog Multimeter:-

↳ Since, the analog Multimeter is a PMMC type instrument, so when a Current is passed through its coil, the Coil Moves in a Magnetic Field produced by the permanent magnet. A pointer is attached with the coil when the Current flows in a Coil, a deflecting torque acts on the Coils that will rotate it by an angle, so the pointer Moves over a scale.

A pair of hairsprings is attached to the spindle to provide the Controlling torque.

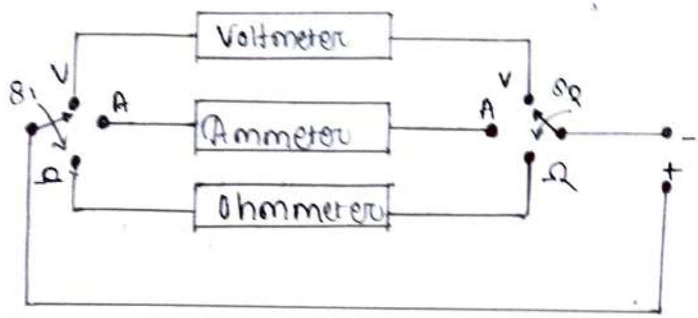
* Analog Multimeter Measuring Quantities:-

A typical analog Multimeter can Measure following electrical quantities:-

- DC Voltage
- AC Voltage
- DC Current
- Resistance

* Block Diagram of Analog Multimeter:-

↳ Here two switches S_1 and S_2 are used to select the desired Meter. It also has a rotary range-selector switch to choose a particular range of Current, Voltage and Resistance.



* Advantages of Analog Multimeter:

↳ It gives Continous reading, thus a sudden change in signal can be detected which is not possible with digital Multimeter.

↳ Analog Multimeter are very cheap.

↳ All Measurement can be Made using a single Meter only.

* Disadvantages of Analog Multimeter:

↳ They are bulky and larger sized.

↳ Multiple scales, these can cause Confusion.

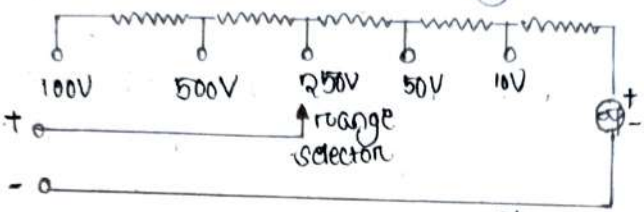
↳ Low input resistance.

↳ Less accurate than a digital Multimeter.

↳ Analog Multimeters do not have autopolarity function. Therefore, it is neccessary to connect probes ~~corre~~ correctly.

• Voltage Measurement by Multimeter

Generally, a galvanometer has a current sensitivity of the order of 0.1mA and a small internal resistance of about 500 ohms. As such, it cannot measure high voltages. To measure high voltages, it's range extended by connecting a high resistance in series with the galvanometer.



DC Voltage Measurement.

↳ If the galvanometer resistance is denoted by G and I_g is the full scale deflection current and the voltage to be measured is V volts, then the value of series resistance R_s is determined as under.

$$V = I_g R_s + I_g G$$

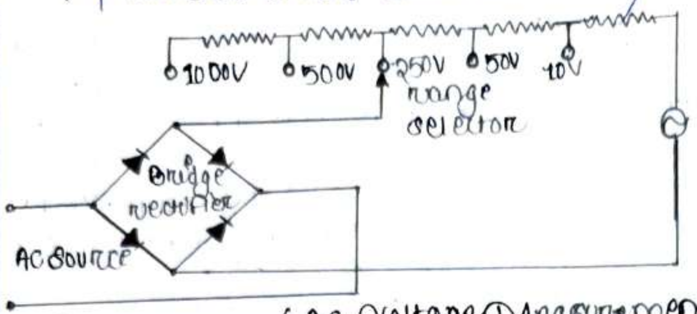
$$\text{or } R_s = (V - I_g G)/I_g$$

↳ This series resistance is also called the Multiplier. The voltage range can be increased by increasing the number or value of multipliers. Either a selector switch is provided to select different range or some sockets indicating the voltage range are provided in a multimeter.

↳ While Making Measurement AC. For this purpose, a full-wave rectifier is incorporated in the multimeter. The rectifier converts AC in DC for application to the galvanometer.

↳ The selected desired AC voltage range is selected by the selector switch or sockets. When AC voltage is to be measured, the switch should be thrown to AC or test lead should be inserted in the AC socket. The range of multiplier

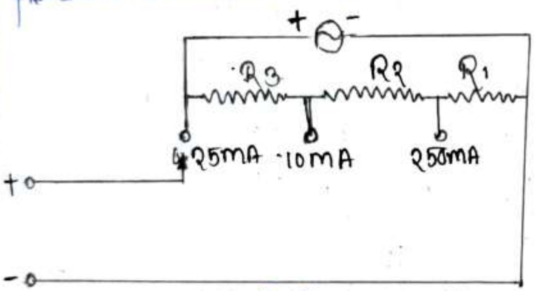
Multimeter should also be suitably selected.



(AC Voltage Measurement)

• **Current Measurement by Multimeter**

↳ The same galvanometer can be used for measuring current when it is converted into an ammeter by connecting a small resistance R_{sh} in parallel with the meter, as shown in the figure.



(DC Current Measurement by Multimeter)

↳ If G is the internal resistance of meter, I_g its full scale deflection current and I is the total current to be measured, then the value of shunt resistance R_{sh} required can be found as under.

$$(I - I_g) R_{sh} = I_g G$$

$$\text{or } R_{sh} = I_g G / I - I_g$$

↳ The range of ammeter can be extended to any value within limits by reducing the value of shunt resistance. Some low resistance are connected in parallel with the meter through a selector switch, as shown in the figure.

The desired range can be selected by moving the selector switch to a particular position.

↳ If the total current to be measured, I is very high, the value of shunt resistance required R_{sh} becomes very low, which is sometimes practically not possible. In this case, connections are so arrangement that as we move from low range to higher range, the meter resistance is also increased in the value of shunt resistance.

Resistance Measurement by Multimeter:-

↳ The same basic instrument can be used as an ohmmeter to measure resistance. In this circuit, an internal battery is connected in series with the meter through an adjustable resistance R and the fixed resistance.

↳ The fixed resistances limit the current within the desired range, and the variable resistance is used for zero adjustments.

↳ The resistance to be measured (test resistance) is connected between test leads. The current flowing through the circuit depends upon the resistance of the test piece. The deflection of the needle indicates current, but the scale is calibrated in ohms to give the value of resistance directly. The ohmmeter is generally made multi-range instrument by using different values of fixed resistances.

↳ To measure resistance by the multimeter, a suitable range is selected. Then the meter leads are shorted, the variable resistance is adjusted to give full-scale deflection.

↳ Under this condition, the resistance between test leads is zero, therefore, the scale of ohmmeter indicates zero on the extreme right end. Then the resistance under measurement is connected between terminals test leads.

Digital Multimeter:

A digital Multimeter (DMM) is a measuring instrument used to measure various electrical quantities. The standard measurements that are performed by a (DMM) are current, voltage, and resistance. Apart from these, a digital multimeter can also measure temperature, frequency, capacitance, continuity, transistor gains etc.