MEASURING INSTRUMENTS

Measurement:-
It is the process of comparison of a standard quantity with the measured quantity.

Static characteristics:-
It is the condition when the measurement is not varying with respect to time.

a) Accuracy:-
It is defined as the closeness of any instrument reading towards the true value.

→ It is always represented interms of percentage of error.

b) Precision:-
It is defined as the quality of the exact and refers to how close two or more measurements are to each other regardless whether the measurements are accurate or not.

c) Error:-
It is defined as the difference between measured value and the true value of a quantity.

Error = Measured value − True value

d) Resolution:-
It is defined as the least change in input which can be detected by the measuring instrument.

e) Sensitivity:-
Sensitivity of an instrument is defined as the ratio of magnitude of output signal to magnitude of input signal or it can be defined as the ratio between the change in output to the change in input.

5) Tolerance:-

It can be defined as the allowable or permeable limit by which a measurement can carry.

Ex:- If any instrument has tolerance ±0.002 and true value is 10 volt. Then 10.1 volt is not acceptable. The value between 10-0.002 to 10+0.002 are acceptable.

Classification of Instrument:-

The instruments can broadly classified into 2 types.

1. Absolute instrument
2. Secondary instrument

1. Absolute instruments:-

→ These instrument gives the magnitude of a physical constant of the instrument.

→ These are generally not available in market for public used and measurement is very much time consuming. But gives allmost 100% canne of value So there are only used in research laboratory.

2. Secondary instruments:-

→ These instruments are calibrated in comparision with an absolute instrument.

→ These instrument can be used to measure a quantity by absorbing the indicating output.

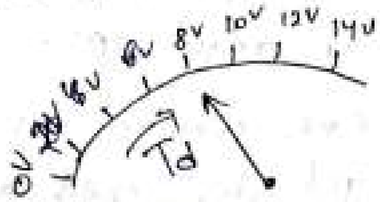
Deflecting, controlling and Damping arrangements in indicating type instrument:-

→ In indicating type instrument a pointer is present which moves over a calibrated scale.

→ In this type of instrument generally 3 types torques are developed.

1. Deflecting torque:-

This torque is used to move the pointer over the scale.



→ It is denoted by Td.

2. Controlling torque:-

→ Controlling torque is used to neutralise or cancel the deflecting torque.

→ It is denoted by Tc.

→ Tc ∝ is proportional to the deflection done by the pointer.

3. Damping Torque:-

This torque is used to absorb the oscillation of the pointer.

→ The above figure shows an indicating type instrument arrangement.

→ In this arrangement a moving coil is present in between the 2 poles of permanent magnet.

→ when current (I) flows through the moving coil there is a magnetic field is developed arround the coil, which interacts with the magnetic field of permanent magnet.

→ Due to this interaction the coil get deflected by an angle 'θ'.

→ One pointer is attached to the coil which also get deflected an shows the measured value on the scale.

→ The torque developed or responsible for this deflection is Td.

→ When the current (T) is removed, then a spring attached to the coil is used to bring it back to it's original position.

→ The torque which is responsible to bring the pointer back is called as controlling torque or (Tc).

→ One damper is connected to the pointer which is a cylinder and piston arrangement used to absorb the oscillation of the pointer. The torque developed by the damper is called damping torque.

Calibration of Instrument:-

→ It is the process of comparision of a particular instrument with known standard instrument.

→ It is done to obtained the accuracy and errors in an instrument.

→ Static characteristics are measured by calibration method.

→ The instrument which is used for measurement must be calibrated against sum reference instrument of higher accuracy.

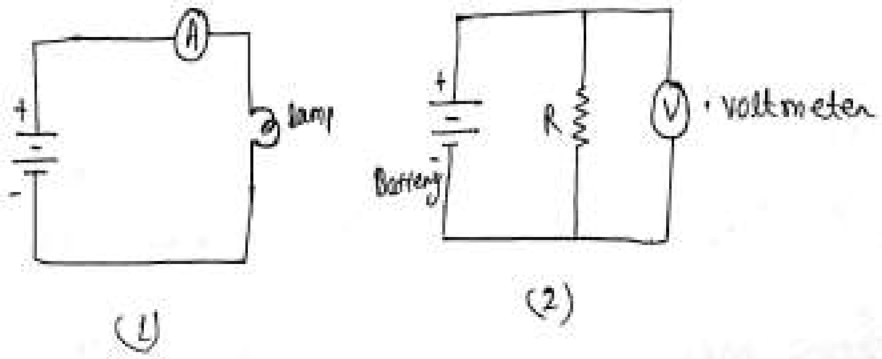
CHAPTER-2

ANALOG AMMETERS & VOLTMETERS

1- PMMC (Permanent magnet moving coil instrument)
2- MI (Moving iron type instrument)
3- Dynamometer type instrument
4- Rectifier type instrument
5- Induction type instrument

→ Ammeter is the instrument which is used to measure current. It is always connected in series in the ckt whose current is to be measured

→ Voltmeter is the instrument which is used to measure the voltage. It is always connected in parallel with the ckt whose voltage is to be measured.



→ Since the resistance offered by a ammeter is very small, it is always connected in series.

→ A voltmeter has a high resistance. So it draws very small current. So it is connected across the points betn which the potential difference is to be measured.

→ The basic working principle of ammeter & voltmeter is same

→ In an ammeter the deflecting torque is produced by the current which is to be measured.

→ In voltmeter the deflecting torque is produced by the current which is proportional to the voltage to be measured.

Comparison of Ammeter & voltmeter:-

Ammeter	Voltmeter
→ It is used to measure current in ampere.	→ It is used to measure voltage in volt.
→ Connected in series with load.	→ Connected in parallel with load.
→ Resistance is low	→ Resistance is high
→ To extend the range low resistance is connected.	→ To extend the range high series resistance is connected.
→ Resistance of an ideal ammeter is zero.	→ Resistance of an ideal voltmeter is infinity.

Errors in instrument (Ammeter & Voltmeter)

Generally 2 types of errors are common in ammeter & voltmeter which are due to friction & temp.

① Friction:-

→ To reduce the effect of friction the weight of of the moving ~~style~~ system must be measure as small as possible with the operating force.

→ In otherwords the ratio of torque to weight must be very large.

(2) Temperature :-

→ It is possible to reduce the error which is caused by the temp. change.

→ The instrument must be mounted in such a ~~pos~~ position that it will be properly ventilated.

→ A swamping resistance of low temp. coefficient material can be connected in series with the coil to reduce the temp. effect on the instrument.

Classification of errors

- Gross errors
- Systematic errors
  - Static error
    - Instrumental error
    - Environmental error
    - Observational error
  - Dynamic errors
- Random errors

① Gross error :-

This is the error due to human mistakes such as careless reading mistakes in recording observation incorrect application of an instrument.

(2) Systematic errors :-

→ A constant uniform deviation of an instrument is known as systematic error.

→ There are 2 types of systematic error.

a) Static errors

b) Dynamic errors

a) Static error:-

The static error of a measuring instrument is the numerical difference betn the true value of a quantity & it's value as obtained by measurement.

b) Dynamic error:-

It is the difference betn measured value & the true value of a parameter or quantity which keeps changing with time.

Types of static error:-

(i) Instrumental errors:-

Occur due to design & constructional features or the mechanical structure of the instruments.

(ii) Environmental errors:-

Occurs due to environmental effects such as temp., pressure, humidity etc

(iii) Observational error:-

Occur due to errors or observation (man made as well as defect in instruments)

③ Random error:-

These errors occur due to unknown causes and reasons which are very difficult to determine.

→ These errors are very small in magnitude & can be treated mathematically.

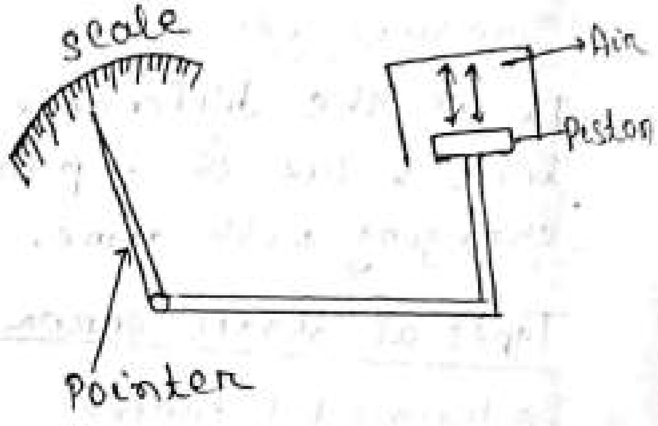
Sources of errors:-

→ Lack of knowledge about measurement process.
→ Operational errors.
→ Poor design & construction.
→ Lack of proper maintenance
→ Change in process parameters & environmental conditions.

Types of Damping:-

(i) **Air Friction Damping:-**

→ Depending on the pointer movement, the air pressure in air chamber changes which reduces the damping produced by the air.

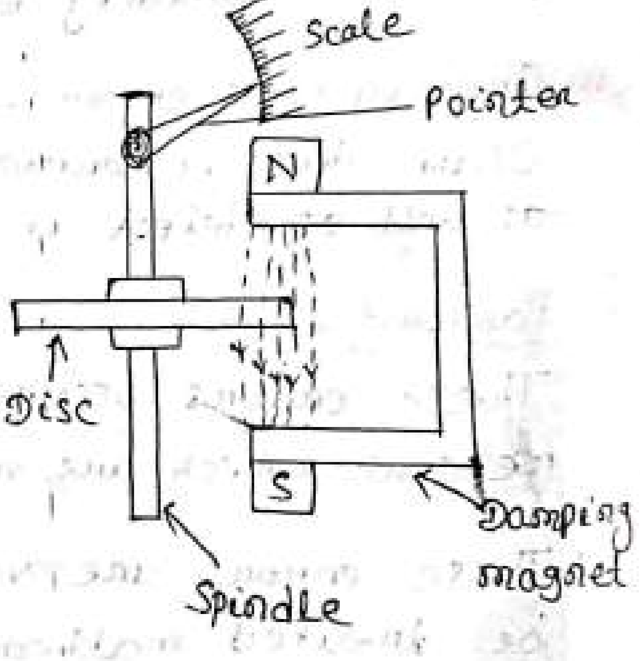


→ Air friction damping is preferred where low value of magnetic field is used.

→ Moving iron and electrodynamometer type instruments

(ii) **Eddy current Damping:-**

→ This method of damping is based on the principle that when a conducting non-magnetic material is moved in a magnetic field an emf is induced in it which causes currents called eddy currents.



→ These eddy currents oppose the damping produced by the pointer.

→ This method is preferred usually where high magnetic field is used.

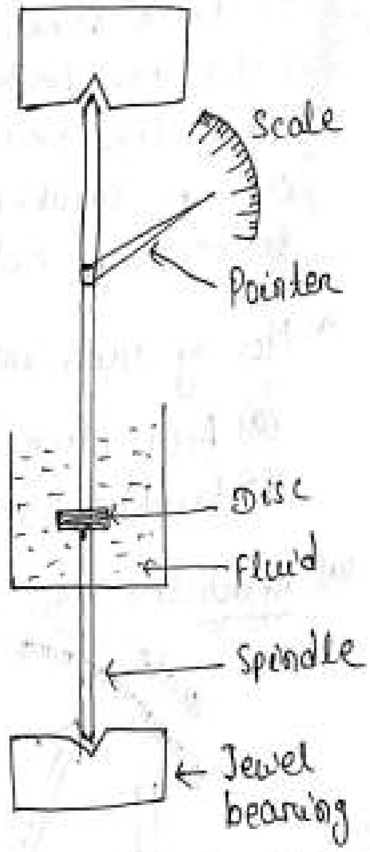
→ Ex- PMMC instruments.

→ In the above fig. copper or aluminium disc is carried by a spindle, can move between the poles of a permanent magnet.

→ If the disc moves in clock wise direction, the emf induced in the disc circulate eddy currents.

→ It follows Lenz's low that these current exerts a force opposing the motion producing there and hence provides damping.

(iii) Fluid Friction damping:-



→ In this method of damping a light disc is attached to the spindle of the moving System and completely Submerge in the damping oil in a pot.

→ The movement of the disc is always opposed by the fluid so that the damping can be required.

→ This method is used in electrostatic voltmeter type instrument.

Moving Iron type instrument (MI)→

→ In this type of instrument a moving iron piece rotates within a current carrying coil. Due to this reason it is called as moving iron type instrument.

→ There are two basic forms of these instruments i.e the attraction type and the repulsion type.

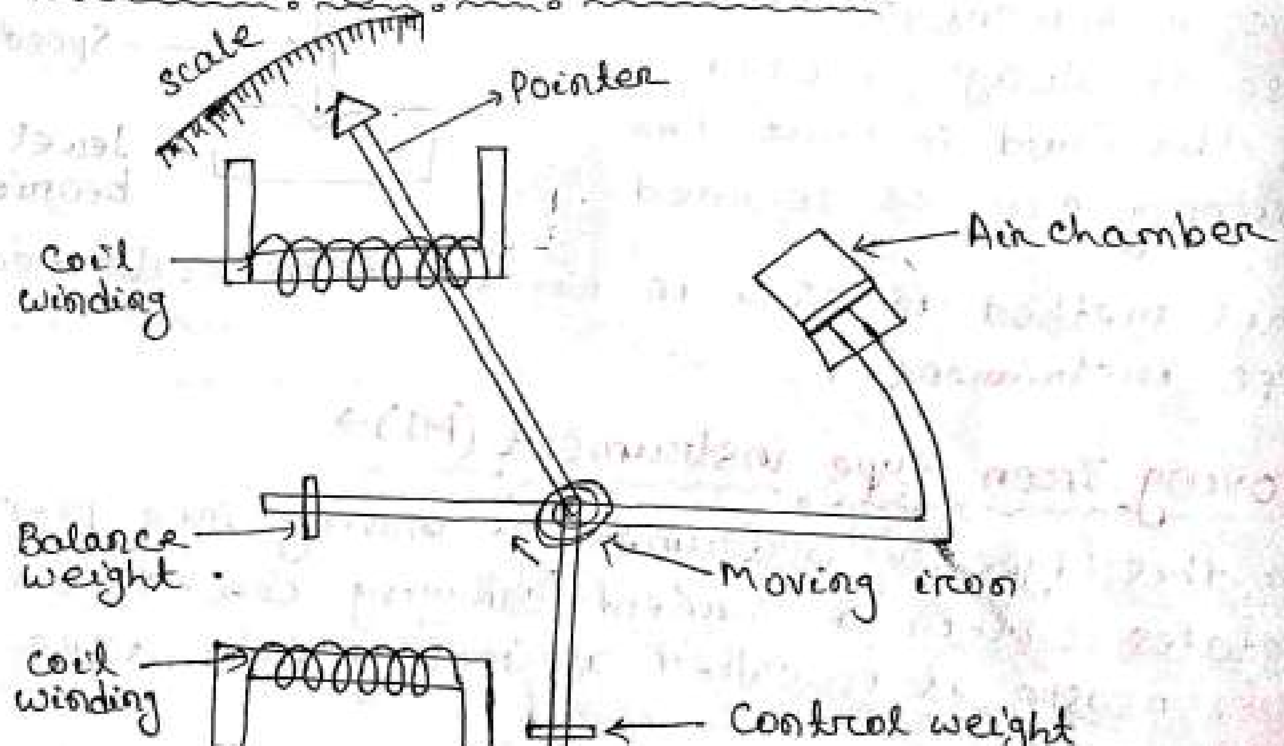
→ The operation of the attraction type depends on the attraction of a single piece of soft iron into a magnetic field and that of repulsion type depends on the repulsion of two adjacent pieces of iron magnetized by the same magnetic field.

→ In ~~the~~ case the instrument is to be used as an ammeter, the coil has comparatively reverse turns of thick wire so that the ammeter has low resistance because it is connected in parallel with the circuit. As the current through the coil is small, it has large no. of turns in order to produce sufficient ampere turns.

→ Moving iron instruments are of 2 types.

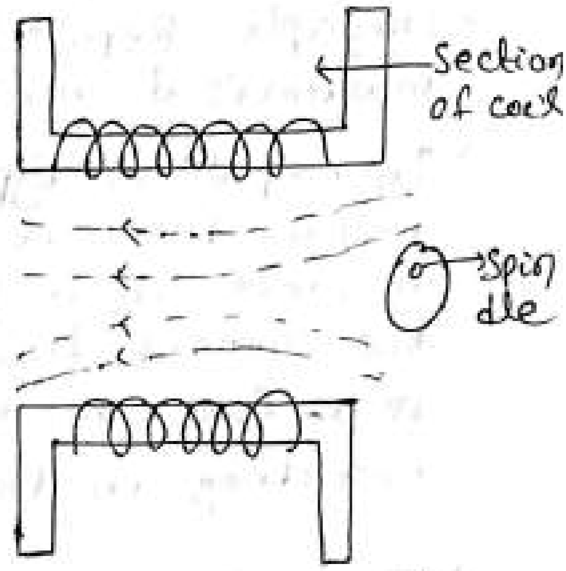
(a) Attraction type M.I instruments
(b) Repulsion type M.I instruments

(a) Attraction type M.I instruments:-



Working principle →

When a soft iron piece is placed in a magnetic field of current carrying coil, it is attracted towards the centre of coil.



→ When instrument is connected to the circuit the, operating current flows through the Stationary.

→ A magnetic field is setup and soft iron piece is magnetised which is attracted towards the centre of coil.

→ Thus, the pointer attached to the spindle is deflected over the calibrated scale.

→ Deflecting torque (T_d) depends on force acting on Iron piece.

As we know, $F \propto MH$

M = pole strength

H = Field strength, produced by coil

$m \propto H$

$F \propto H^2$

$H \propto I$

$F \propto I^2$

$T_d \propto I^2$

$T_c \propto \theta$ (θ = Angle of deflection)

$T_d = T_c$

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

(b) Repulsion type M.I instrument :-

→ Principle :- Repulsive force act when two similar magnetised iron pieces are placed together.

→ In repulsion type M.I, there are two vanes inside the coil. One is fixed and the other is movable. These are similarly magnetized when the current flows through the coil and there is a force of repulsion between the two vanes resulting in the movement of the moving vane.

→ Two different designs for moving iron instruments commonly used are as follows:
(i) Radial vane types
(ii) Coaxial vane types

Working :-

→ When the instrument is connected to the circuit, the operating current flows through the coil.

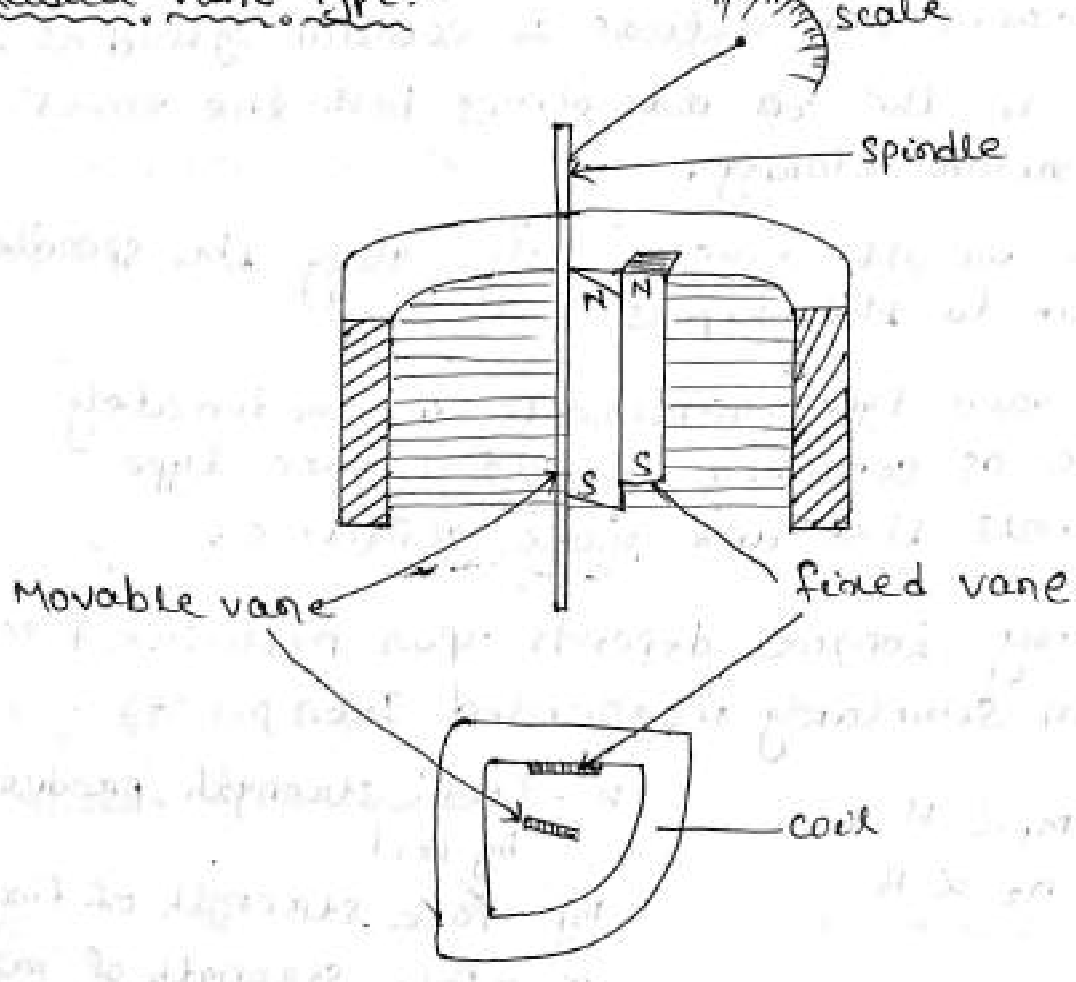
→ A magnetic field is set up along the axis of the coil.

→ The field magnetises both the iron pieces similarly (same polarities)

→ A force of repulsion act betn the two, therefore movable piece / vane move away from the fixed piece.

→ Thus the pointer attached to the spindle deflects over the calibrated scale.

(i) Radial Vane Type:-

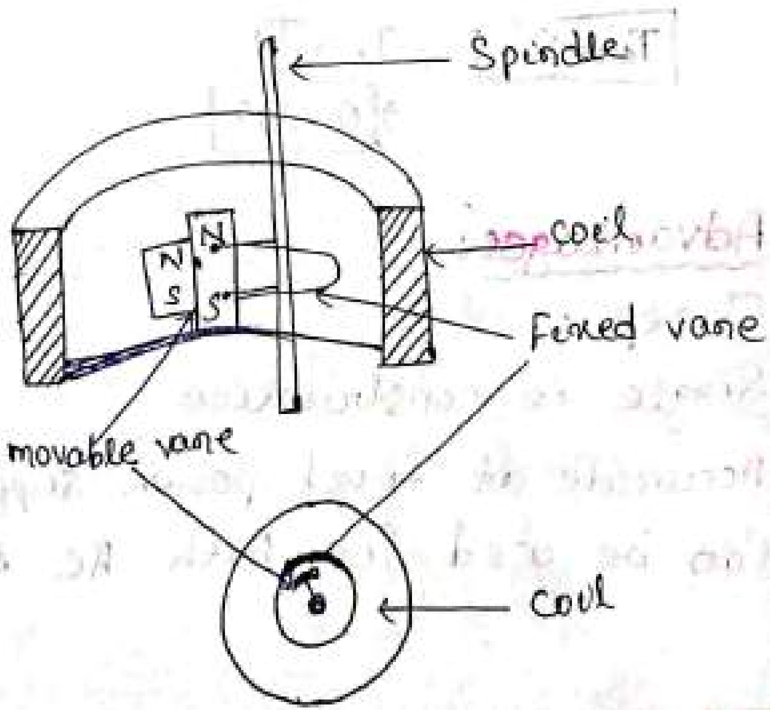


→ In this type the vanes are radial strips of iron.

→ The fixed vane is attached to the coil and the movable one to the spindle of the instrument.

→ The instrument pointer is attached to the moving vane spindle.

(ii) Co-axial Vane Type:-



→ In these types of instruments, the fixed and moving vanes are sections of coaxial cylinders.

→ Current in the coil magnetizes both the vanes with similar polarity.

→ Thus the movable vane rotates along the spindle axis due to this repulsive force.

→ Coaxial vane type instruments are moderately sensitive as compared to radial vane type instruments that are more sensitive.

→ Deflecting torque depends upon repulsive forces between similarly magnetised Iron pieces.

$m_1 \propto H$

$m_2 \propto H$

H - Field strength produced by coil

m_1 - Pole strength of fixed iron

m_2 - Pole strength of moving iron

$F \propto m_1 m_2$

$\therefore F \propto H^2$

$H \propto I \Rightarrow F \propto I^2$

$\therefore T_d \propto I^2$

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

$\Rightarrow \theta \propto I^2$

Advantages :-

→ Cheep

→ Single in construction

→ Accurate at fixed power supply and frequency.

→ Can be used for both AC & DC.

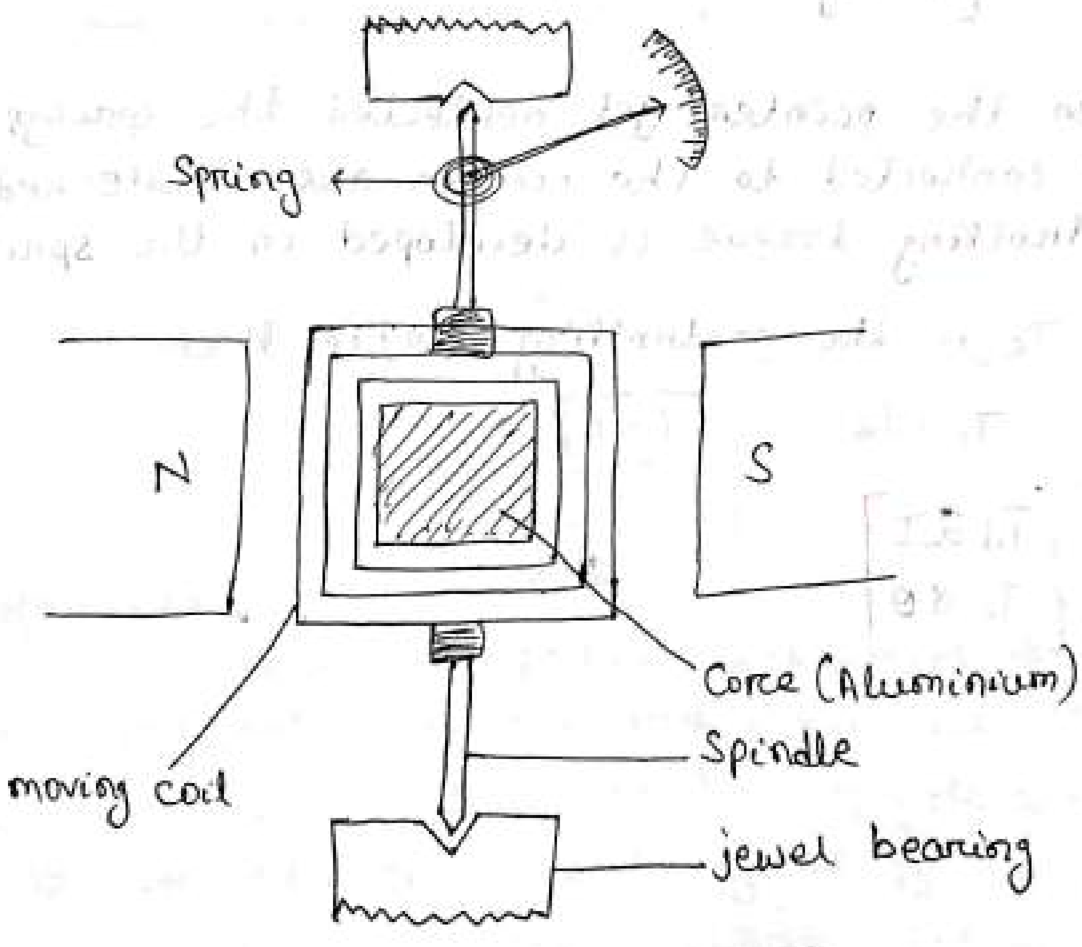
Disadvantages:-

- Can not be calibrated with a high degree of precision with dc on accural of effect of hysteresis in iron rods.
- Not very sensitive
- Power consumption is high

Applications of moving Iron Instruments:-

(i) Heavy current moving iron Ammeters.
(ii) Moving iron voltmeters.
(iii) Moving iron power factor meters
(iv) Moving iron synchroscopes.

Permanent Magnet Moving coil instrument:-(PMMC)



Principle:-

Works on electromagnetic effects of current when a current carrying conductor is placed in a magnetic field. it is acted upon by a force which tends to move it one side & out of the

→ Torque developed in the coil can be written as, $T_d \Rightarrow NBdIl$

where, N = No. of turns in the coil

B = Magnetic flux intensity in wb/m^2

l = length of the coil.

d = diameter of the coil

I = Current flowing through the coil in 'A'.

Here we can write

$$T_d = NBAI$$

$[A = ld]$

→ When the pointer get deflected the springs which are connected to the pointer are stratched and controlling torque is developed in the springs

→ If T_c is the controlling torque then.

$T_c = T_d$ $\boxed{I \propto \theta}$

$$\begin{bmatrix} T_d \propto I \\ T_c \propto \theta \end{bmatrix}$$

Advantages:-

→ Low power consumption

→ Passes high torque/weight Ratio

→ No hysteresis loss

→ Effective & efficient eddy current damping.

Disadvantages:-

→ Can not be used for AC measurement

→ Costlier then moving iron instrument

→ Friction & temperate might introduce same error.

→ Ageing.

Electrodynamometer type moving coil Instrument:- (EMMC)

Construction:-

→ The construction part of this instrument consists of two fixed coil L_1, i_2 and are moving coil 'm'.

→ The moving coil is placed on the spindle which is pivoted for producing controlling torque.

→ Spring is attached to the spindle.

→ Pointer is connected in the spindle which moves over the graduated scale.

Working:-

→ The fixed coil is made up of few turns of copper wire & also known as current coil.

→ The current that to be measured is passed through the fixed coil at the starting.

→ The moving coil is made up of large number of turns of copper wire and is called as pressure coil.

→ Fixed coil → Used to produce operating field

(i) Split into 2 parts to have uniform distribution of flux around moving coil

→ Moving coil → Produce deflecting torque (T_d)

→ When a magnetic field is developed in the fixed coil and moving coil due to the flow of current then a deflecting torque is produce in the moving coil.

→ The produced torque i.e deflecting torque is directly proportional to product of current passing through the fixed and moving coil

$$\theta \propto I_1 I_2$$

→ The controlling torque is provided by spring control mechanism and damping torque is provided by a current damping.

Advantages:-

(i) It can measure both AC & DC parameter

(ii) It is free from hysteresis error.

(iii) Magnetic field strength can be varied & there is no change in magnetic field loss.

Disadvantages:-

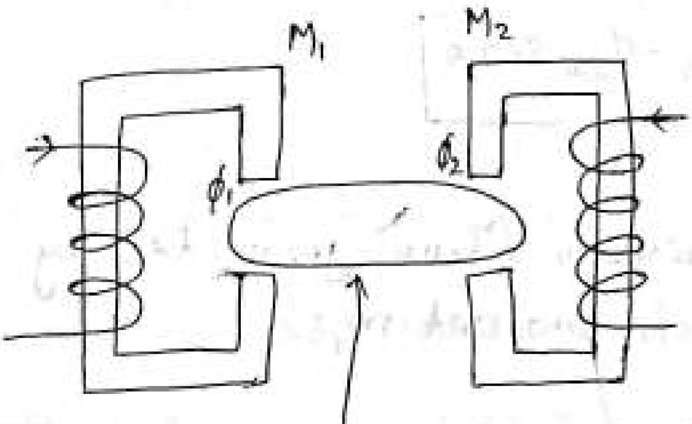
(i) It has low sensitivity

(ii) Move frictional loss due to heavy moving.

(iii) Scale is non-uniform.

Induction type instrument:-

Principle:- This type of instrument works on the principle of electromagnetic induction. When the conducting material is placed in an alternating magnetic field, it induces eddy current in the material. The interaction between the magnetic field and eddy current produces deflecting torque on the disc and makes it rotate.



→ The above figure shows the induction type instrument which can be used only for the measurement of AC quantities.

→ It can be used as ammeter, voltmeter, wattmeter or energy meter.

Construction:-

→ Two electromagnets and a metal disc are the main parts of this type of instruments.

→ Generally the metal disc is made up of Aluminium

→ The metal disc is placed in betⁿ the two electromagnets.

→ Working:-

→ The electromagnets m_1 and m_2 produces flux ϕ_1 & ϕ_2 respectively.

→ Both the fluxes ϕ_1 & ϕ_2 are induced into the metal disc.

→ Due to the phase difference betⁿ the fluxes a deflecting torque is produced on the disc.

→ The torque acting on the disc is

$$\boxed{T_d \propto \phi_{1m} \cdot \phi_{2m} \sin\theta}$$

where,

ϕ_{1m} = Maximum flux generated by electromagnet m_1

ϕ_{2m} = Maximum flux generated by electromagnet m_2

θ = phase difference betⁿ the two fluxes

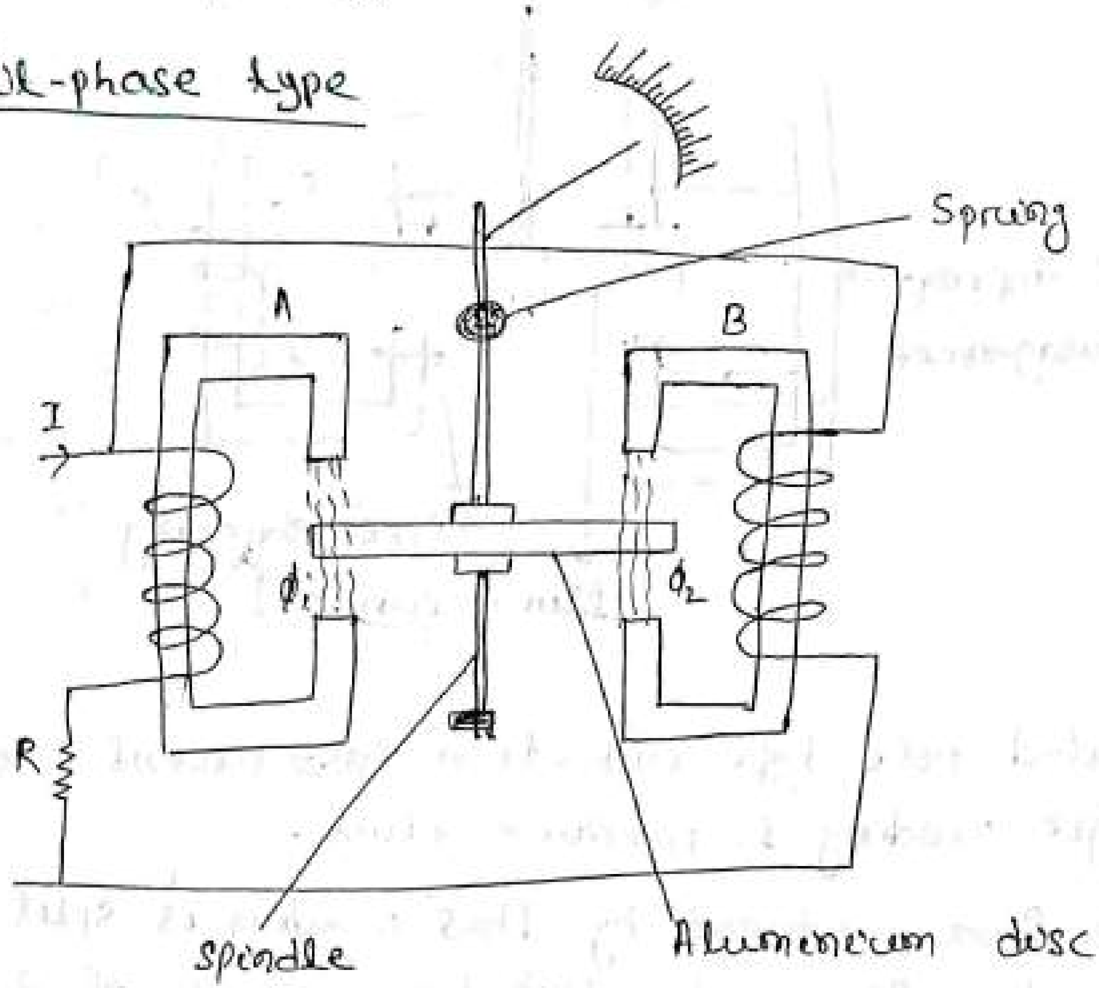
→ The maximum amount of deflection is produced when the phase difference is 90°.

→ The induction type instruments are of 2 types

(1) Split-phase type

(2) Shaded-pole type

(1) Split-phase type



→ In this type of instruments two electromagnets are present to generate two fluxes ϕ_1 & ϕ_2.

→ An aluminium disc is placed betⁿ the magnets.

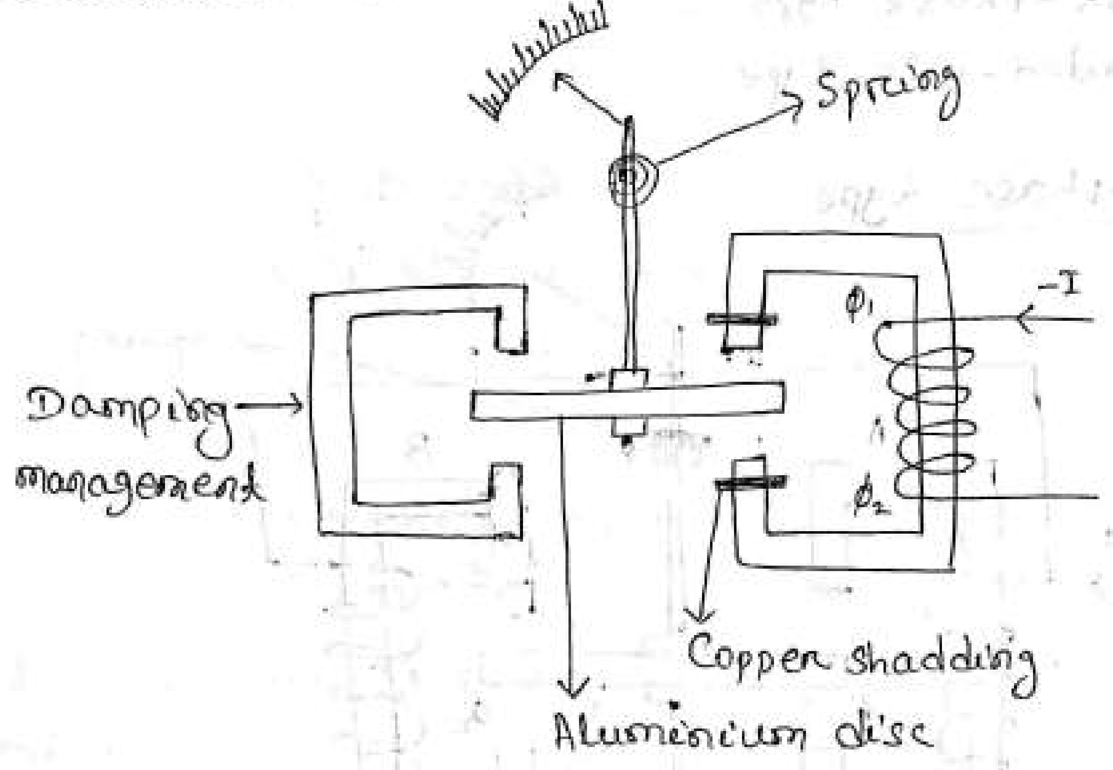
→ A highly resistive resistance is connected in series with the coil of magnet A.

→ The current in B winding lags with respect to the total line current.

→ This helps to develop the necessary phase angle (θ) betⁿ the two fluxes.

→ Eddy current damping is used in this type of instruments.

(2) Shaded-pole type:-



→ Shaded pole type induction instrument uses a single winding to produce flux.

→ The flux produced by this winding is split up into two fluxes by this, having phase ~~of~~ difference with respect to each other.

→ One damping magnet is present to absorb the oscillation of the disc.

→ The ends of the electromagnet are covered with copper shading, so that it will generate flux of different phase differences.

→ Hence damping is provided by a damping magnet placed at the opposite side of the electromagnet. So that the disc can be used for production of both deflecting and damping torque.

Advantages:-

(i) High torque to weight ratio.
(ii) Effective and efficient damping.
(iii) For wide load range this type of instruments are very accurate.
(iv) The scale can be extended over 300.
(v) Less maintenance required.

Disadvantages:-

→ Introduction type instruments consumes very high power.
→ It is expensive.
→ Scale is non-uniform.
→ Only applicable for AC management.

* Extension of the Range of Ammeters & Voltmeters

Shunt →

→ It is use for extension range of ammeter.

→ Shunt is very small resistance connected in parallel with ammeters.

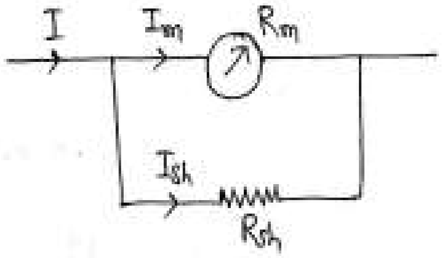
→ Combination is connected in series with the ckt whose current is to be measured.

Multiplier:-

→ It is use for extension of range of voltmeters.

→ Multipliers are high resistances connected in series with the instrument whose range is to be extended.

Extension of Ammeter Range :-



I = Current to be measured

Im = Full scale deflection of meter

Ish = Shunt resistance current

Rm = Resistance of meter

Rsh = Shunt resistance

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

$$\boxed{R_{sh} = \frac{I_m R_m}{I_{sh}}} \quad \text{—— (i)}$$

Applying KCL

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

$$\boxed{I_{sh} = I - I_m} \quad \text{—— (ii)}$$

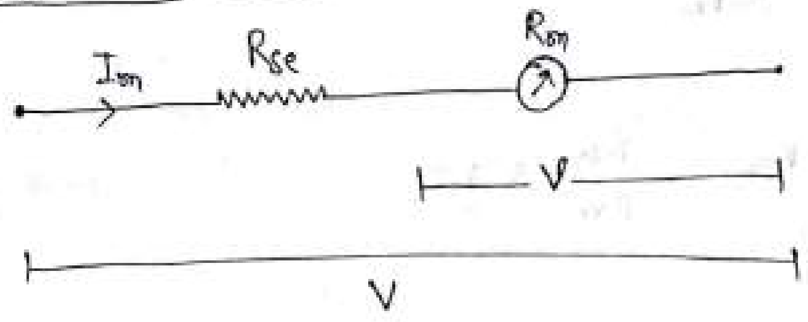
Putting eq^n (ii) in (i)

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

$\Rightarrow m \Rightarrow \frac{I}{I_m}$ multiplying factor

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

Extension of Voltmeters Range:-



V = voltage to be measured

v = voltage across meter

Im = Full scale deflection current of meter

Rse = Series resistance

Rm = Resistance of meter

$$\boxed{I_m = \frac{v}{R_m}} \text{ ——— (i)}$$

$$V = I_m R_{se} + I_m R_m \text{ ——— (ii)}$$

$$\Rightarrow I_m R_{se} = V - I_m R_m$$

$$\Rightarrow R_{se} = \frac{V - I_m R_m}{I_m}$$

$$\Rightarrow \boxed{R_{se} = \frac{V}{I_m} - R_m}$$

or $V = I_m R_{se} + v$

$\Rightarrow I_m R_{se} = V - v$

$$\Rightarrow \boxed{R_{se} = \frac{V - v}{I_m}}$$

From eq^n (i) $v = I_m R_m$

" " (ii) $V = I_m (R_{se} + R_m)$

$\frac{V}{v} = m \rightarrow$ Multiplying factor

$$m = \frac{I_m (R_{se} + R_m)}{I_m R_m}$$

$$\Rightarrow m = \frac{R_{se} + R_m}{R_m} = \frac{R_{se}}{R_m} + 1$$

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

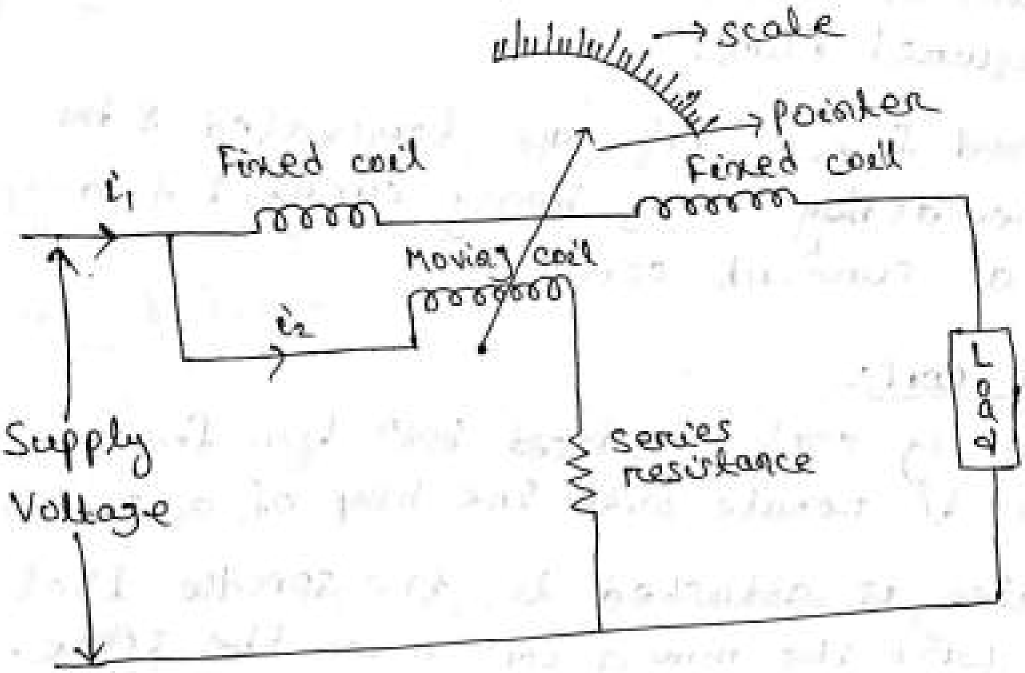
$$\Rightarrow \boxed{R_{se} = R_m (m - 1)}$$

CHEPT-3

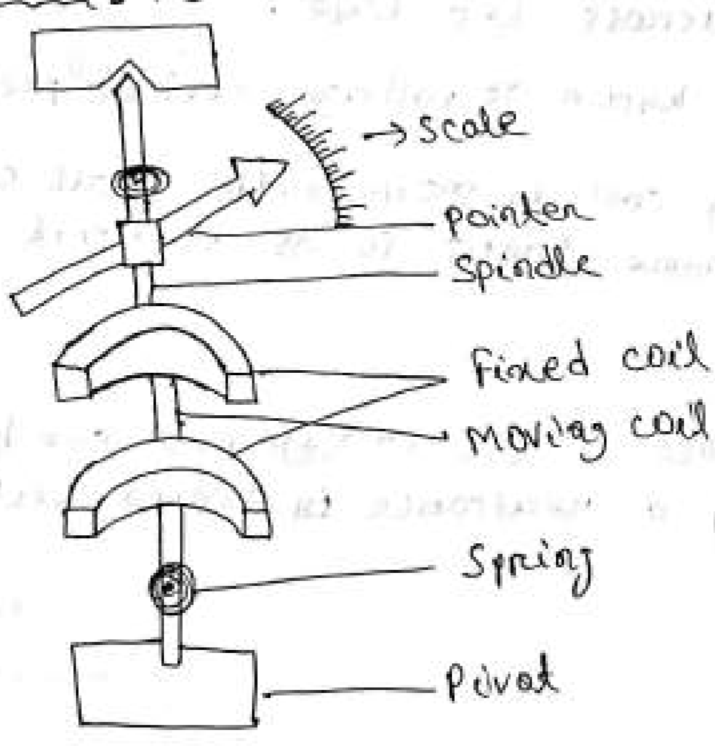
Wattmeters & Measurement of Power :-

Electrodynamometer type wattmeter :-

Electrodynamometer type wattmeter is an machine whose function is related to the rea^n bet^n the magnetic field of a fixed coil and a moving coil. It is used for both AC circuit & DC circuit.



Construction of electrodynamometer



1. Fixed coil

→ It is basically an air cored coil with the large no. of crossection & fewer turns.

→ The fixed coil are divided into 2 sections & a moving coil is placed betⁿ them.

→ These two coils are connected in series with the line and hence carry the full line current.

→ The main funⁿ of the fixed coil is to produce the required flux.

→ The ~~fixed~~ fixed coil are laminated & to varnished as they carry heavy current & also known as current coil.

2. Moving coil:-

→ The moving coil is placed betⁿ two fixed coils & made to rotate with the help of a spindle.

→ A pointer is attached to the spindle that moves with the moving coil over the scale.

→ The coil is wounded on a metalic former and connected across the line.

→ It is also known as voltage coil or pressure coil.

→ The moving coil is made with small crossectional area and more turns so as to limit the current through it.

→ The resistance of the voltage coil can be increase by connecting a resistance in series with it.

3. Control:-

→ It provides controlling torque on the instrument.

→ Gravity control & spring control are two types of control mechanism but here only spring control system is use as it aids in the motion of the pointer.

4. Damping:-

→ This type of instrument is provided with air friction damping to damp out oscillations by providing necessary damping torque.

→ The moving coils carry a pair of aluminium vanes which move in sector shaped chamber at the bottom of the instrument.

5 Scale & Pointer:-

→ A linear scale is used in this device.

→ The device uses a knife edge pointer to eliminate parallax error caused by oversights

Working of electrodynamometer type wattmeter:-

→ The fixed coil connected in series acts as a current coil & the moving coil connected across the supplied terminals acts as a voltage coil.

→ The fixed coil is proportional to the load current & the moving coil is proportional to the voltage.

→ When the current passes through these coils the fixed coil as well as the moving coil creates a magnetic field due to which the deflecting torque is developed ~~(TD)~~ (T_D) which is proportional to the power.

→ Thus the power can be measured by using the electrodynamometer type wattmeter.

Expression for torque:-

i_1 = instantaneous current in fixed coil

i_2 = instantaneous current in moving coil

M = mutual inductance b/w fixed & moving coil

T = Time period

T_I = Instantaneous torque

T_D = Deflecting torque

The deflecting torque can be given by,

$$T_D = \frac{1}{T}\int_0^T T_I \, dt \quad \text{---} \ (1)$$

but $T_I = i_1 i_2 \frac{dM}{d\theta}$ --- (2)

Substituting eqn (2) in (1),

$$\boxed{T_D = \frac{1}{T}\frac{dM}{d\theta}\int_0^T i_1 i_2 \, dt} \quad \text{---} \ (3)$$

Let,

$i_1 = I_{m_1} \sin \omega t$

$i_2 = I_{m_2} \sin(\omega t - \phi)$

Substituting the value of i_1 & i_2 in eqn (3)

$$T_D = \frac{1}{T}\frac{dM}{d\theta}\int_0^T I_{m_1} I_{m_2} \sin \omega t \sin(\omega t - \phi) \, d\omega t \quad \text{---} \ (4)$$

Or

On solving eq^n (4)

$$T_D = \frac{I_{m_1} I_{m_2}}{2} \cos\phi \frac{dm}{d\phi}$$

→ In DC operation of dynamometer type wattmeter the deflection produced in the torque is given by,

$$\theta_{DC} = \frac{I_1 I_2}{K} \times \frac{dy}{d\theta}$$

where

$I_1 I_2$ = Currents in fixed and moving coils respectively.

$\frac{dm}{d\theta}$ = Rate of change of mutual inductance

K = Spring constant

* In ac operation of a dynamometer type wattmeter the deflection produced in the torque is given by.

$$\theta_{AC} = \frac{I_1 I_2}{K} \cdot \cos\phi \frac{dy}{d\theta}$$

where,

$I_1 I_2$ = Rms values of currents in fixed and moving coils respectively.

$\cos\phi$ = Power factor

→ Hence, the deflection is proportional to the product of RMS values of the currents in both coils, power factor and rate of change of ~~motor~~ mutual inductance.

→ Therefore, for a dynamometer type wattmeter, the scale is calibrated with the square root of the current that is squared, which is nothing but the RMS value of the ac quantity.

→ Hence, in this way, both ac and dc can be measured using dynamometer type wattmeter and indicates power, whether it is connected in ac or dc circuit.

Errors in Electrodynamometer type instrument:-

→ There are different types of errors introduced in the dynamometer type wattmeter, while measuring power they are.

→ Errors due to mutual inductance
→ Errors due to connections
→ Eddy current errors.
→ Errors due to stray magnetic fields.
→ Errors due to vibration of the moving system.
→ Temperature error.
→ Errors caused due to pressure coil inductance.
→ Errors caused due to pressure coil capacitance.

1) Error due to mutual inductance:-

→ Errors may occurred due to the mutual inductance between the current and pressure coil of the wattmeter.

→ The errors are quite low at power frequency. But they increased with, increase in frequency,

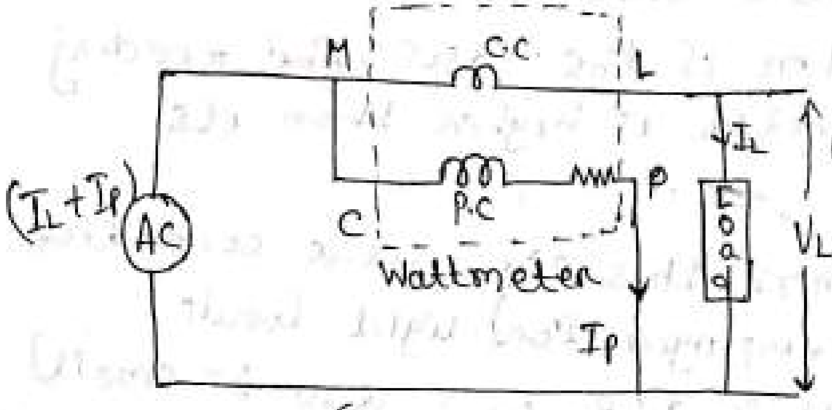
→ The effect of mutual inductance can be avoid by arranging the coil system in ~~which~~ such a way that they have no mutual inductance.

→ So we can eliminate the errors due to mutual inductance.

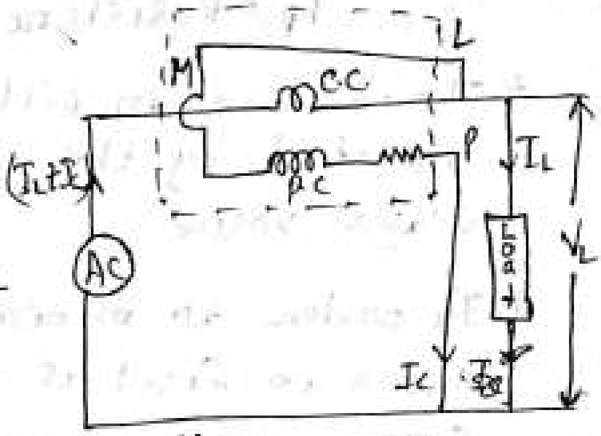
→ The drysdale Torsion head wattmeter is an example for such type.

(2) Errors due to connections:-

→ There are two methods to connect a wattmeter in the circuit whose power consumption is to be measured.



(Figure -1)



(Figure - 2)

→ When the voltage coil is connected across the supply as shown in fig-1, it measures the voltage drop across the series combination current coil and load.

→ Hence the wattmeter reading P_R will be the sum of power consumed by the load P_L and the power loss in the current coil P_C.

i.e $P_R = P_L + P_C$

$= P_L + I_L^2 R_C$

Where,

R_C = Resistance of current coil.

Similarly, when the voltage coil is connected across the load, the current measured by the current coil is the sum of the currents through the load and voltage coil.

→ Hence the wattmeter reading P_R will be the sum of power loss in the voltage coil P_P.

i.e $P_R = P_L + P_P$

$= P_L + I_P^2 R_P$

Where,

R_P = Resistance of current coil

→ There fore, in either of the cases, the reading indicated by the meter is higher than it's actual value.

→ In order to minimize this error, the connection shown in fig-1 is employed for light loads (as I_L will be small so, $I_L^2 R_C$ will also be small) and for heavy loads, the connection shown in fig-2 is employed ($\because I_P << I_L$ so, $I_P^2 R_P$ will be negligible)

(3) Errors due to stray magnetic fields:-

→ The electrodynamometer type wattmeter, has a weak ~~elect~~ operating field and therefore it effected by stray magnetic fields (i.e external magnetic fields)

→ So, if the external field aids the main field then, the meter reads high and if it opposes the main field then the meter reads low.

→ In order to reduce these errors, proper shielding is to be provided.

(4) Eddy current errors:-

→ The alternating flux produced by the current coil when links with the conductors and metal parts of the meter an emf is induced on them.

This results in the circulation of eddy currents in those parts.

→ This eddy currents produces a magnetic flux which aids the main field flux for leading power factor loads and opposes the main field flux for lagging power factor loads.

→ Since the deflection torque is directly proportional to the main field flux meter reads high for leading loads and low for lagging loads.

→ Also the resultant flux is displaced from the phase angle of the current coil (or main field) flux.

→ For leading power factor loads, the phase angle between resultant flux and the voltage coil flux is decreased and for lagging power factor loads it is increased.

→ Since the deflecting torque is directly proportional to the cosine of angular phase displacement betn the two fluxes, the meter reads high for leading loads and low for lagging loads.

→ Hence the effect is similar to the effect caused due to the change in magnitude of the main field flux.

→ In order to reduce this error laminated metalic parts and standard conductor are employed.

5) <u>Error due to vibration of moving system:-</u>

→ As the supply is an alternating one, the torque produced in the moving system pulsates at double the frequency of supply f.

→ If any parts of the moving system like pointers, spindle, spring etc has it's natural frequency of pulsating torque 2f, it comes under resonance and starts vibrating with that frequency.

→ These vibrations in the moving system cause the pointer to deflect at some other position thus introducing error.

→ Also it is not quite easy to read the position since the frequency vibration is double that of supply.

→ In order to avoid this error, the natural frequency of various parts of the moving system is kept far away from 2f.

(6) Temperature error:-

→ An increase in temperature causes an increase in the resistance of the voltage coil and current coil.

→ This reduces the current through the coils and hence the operating field.

→ Thus the deflection or torque is reduced. Also due to an increase in temperature, the stiffness of the spring increases thereby, the control torque reduces.

→ Thus, the variations in deflecting and controlling torques cancel eachother's effect and so, the effect of variations in temperature are almost negligible.

→ Hence to reduce the temperature error, the voltage coil circuit resistance should be made up proper composition of the alloy, so as to have a low temperature efficient.

(7) Errors due to pressure coil inductance:-

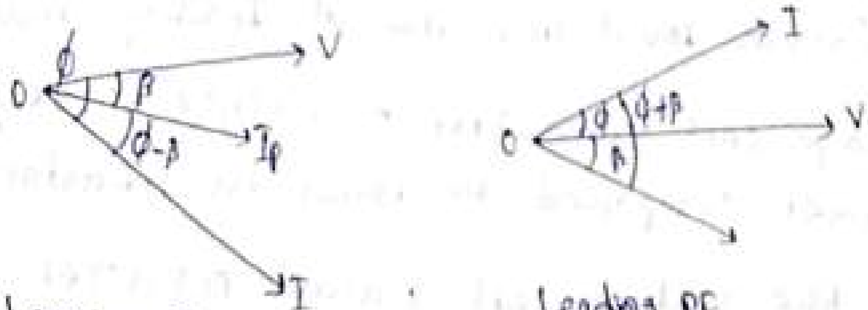
→ The inductance of voltage coil makes the voltage coil current I_p to lag the applied voltage by a small angle β and β is given by

$$\beta = \tan^{-1}(\omega L / R_p)$$

Where

L = Inductance of voltage coil

R_p = Total resistance of voltage coil.



Lagging PF   Leading PF

→ As lagging power factor loads, due to the effect of inductance, the voltage coil current I_p will be come nearly equal in phase with load current.

→ The correction factors to be multiplied by the wattmeter reading to obtain the actual power consumption is $\dfrac{\cos\phi}{\cos\beta \, \cos(\phi-\beta)}$

→ As Leading power factor loads, as the phase angle between the load current I and voltage coil current I_p is more, the driving or deflecting torque reduces and makes the meter read low.

→ Hence a correction factor to be multiplied with the reading in order to obtain the actual power consumption is $= \frac{\cos\phi}{\cos\beta \cos(\phi+\beta)}$

(8) Errors due to pressure coil capacitance:-

→ Apart from inductance, the voltage coil also possesses the effect of capacitance which is due to the inter-turn capacitance of the series resistance.

→ So, the wattmeter reads high at lagging power factor loads and low at leading loads.

→ The voltage coil capacitive reactance is very small when compared to inductive reactance.

→ Hence, the voltage coil circuit possesses net inductive reactance. So, the wattmeter reads high on lagging powerfactor loads and low on leading power factor loads.

Induction type Wattmeter:-

CHEPTER-6

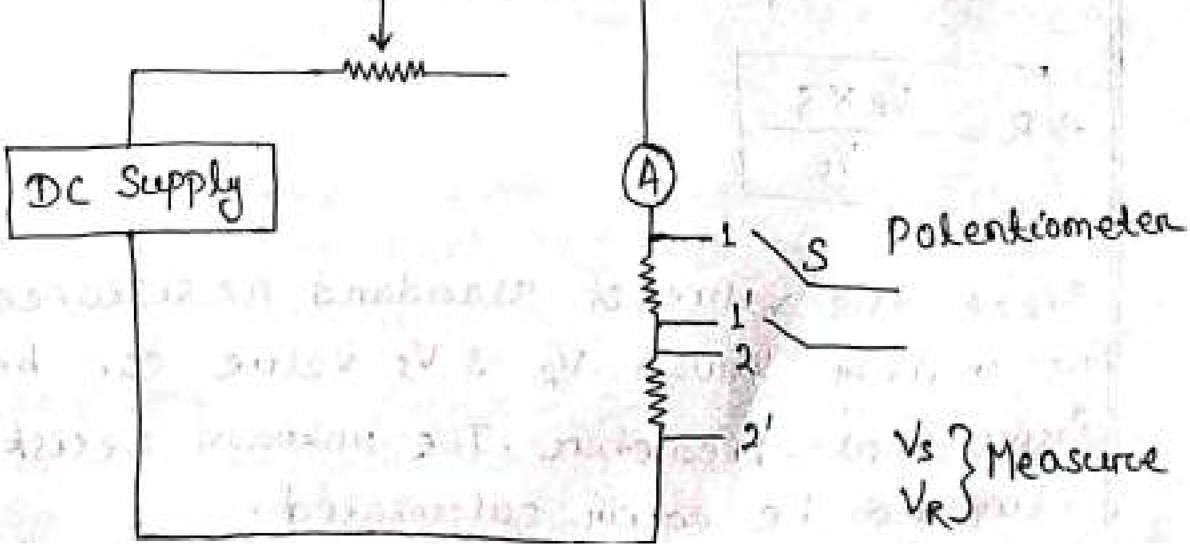
Measurement of Resistance, Inductance and capacitance:-

Classification of Resistance:-

Low Resistance	Medium Resistance	High Resistance
→ Resistance Less than or equal to 1Ω (≤ 1Ω)	→ Resistance 1Ω to 100 kΩ	→ Resistance > 100kΩ
→ Ex - Ammeter, internal resistance, All motors, gener, ator and trans-former winding. resistances. Earthing resist-ances, all Semiconductor devices forward biase.	→ Ex:- DC machine shunt field winding resistance, All heater coil resistances, human body resistance, volt meter resistance (100 Ω)	→ Ex:- Cable insulation resistance, All motors, generators, trans-former winding insulation resistance, All semiconductor when reverse biase.

Low resistance measurement by potentiometer method:-

Potentiometer is a device which can detect variable unknown variable unknown voltages.



→ The above circuit is use to measure the unknown resistance which is with the help of a potentiometer.

→ The above circuit R is the unknown resistance whose value is to be measure and S is the known standard resistor. The circuit current is control with the help of a rheostat. A double throw switch is use to connected 1-1' to 2-2' terminals.

→ The double to switch is connected to a potentiometer to measure the voltage drop of unknown resistor R (V_R) when the switch is connected 1-1' terminals then voltage drop $V_R = IR$

$$V_R = IR$$

$$\Rightarrow I = \frac{V_R}{R} \quad \text{——— (1)}$$

When the switch is connected 2-2' terminals then voltage drop

$$V_S = IS$$

$$I = \frac{V_S}{S} \quad \text{——— (2)}$$

From eq^n (1) & (2) we get

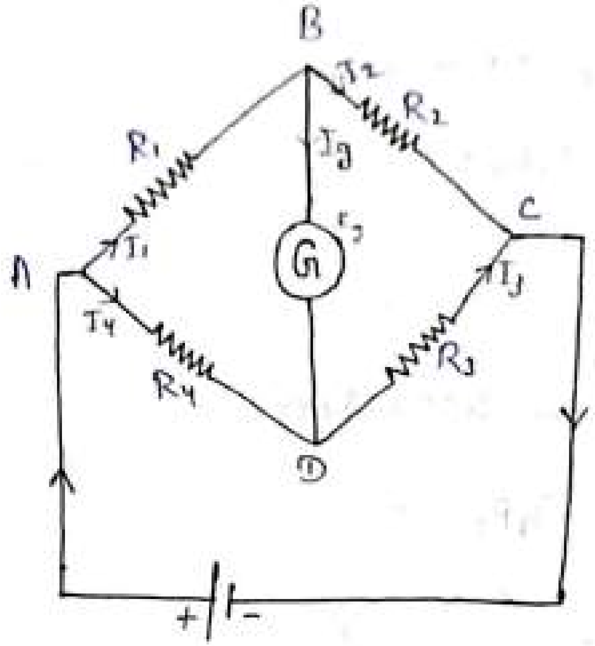
$$\frac{V_S}{S} = \frac{V_R}{R}$$

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

Since the value of standard resistance S is accurately known V_R & V_S value can be detected from potentiometer. The unknown resistance R value can be easily calculated.

Medium Resistance Measurement by wheatstone bridge Method:-

Wheatstone is an electrical circuit which have 4 no. of resistor are connected in a bridge structure out of this 4 resistances 3 resistances are known and 1 resistance is unknown.



→ Consider the 4 resistance R_1, R_2, R_3 & R_4 connected in a wheatstone bridge.

Let R_1, R_2 & R_3 are known resistance and R_4 is unknown resistance.

Let I_1, I_2, I_3 and I_4 are the current flowing through the resistances.

→ A null type carbon ammeter is connected between B & D junction. I_g is the current coil through the galvanometer.

Consider R_1 is the variable resistor whose value is show adjust that the galvanometer show null deflection. At this condition $I_g = 0$

At balancing cond^n

R_g = Internal resistance of the galvanometer

At junction B

$I_1 = I_2 + I_g^{\,0}$

$I_1 = I_2$ ——— ①

At junction D

$I_4 + I_g^{\to 0} = I_3$

$\Rightarrow I_4 = I_3$ ——— ②

Applying KVL in ABD loop.

$I_1 R_1 + I_g R_g^{\to 0} - I_4 R_4 = 0$

$\Rightarrow I_1 R_1 = I_4 R_4$ ——— ③

Applying KVL in BCD loop

$I_g R_g^{\to 0} + I_3 R_3 - I_2 R_2 = 0$

$\Rightarrow I_3 R_3 = I_2 R_2$ ——— ④

Diving eqⁿ ③ with eqⁿ ④ we get

$$\frac{I_1 R_1}{I_2 R_2} = \frac{I_4 R_4}{I_3 R_3}$$

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

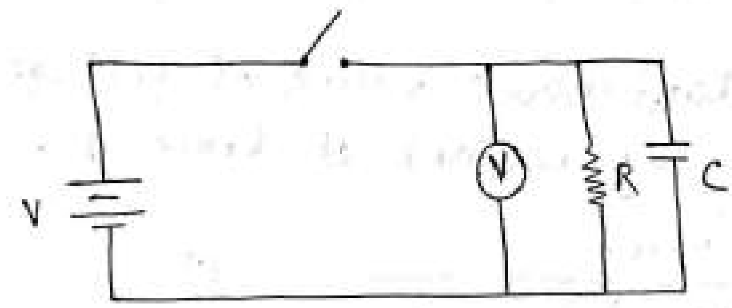
$$\Rightarrow R_4 = R_3 \times \frac{R_1}{R_2}$$

From the above expression the value of unknown resistance R_4 can be calculated.

There are 2 types of wheatstone bridge

1. Null balance type
2. Deflection type.

High resistance measurement by loss of charge method :-



→ The high resistance is also known as insulation resistance.

→ In this method the insulation resistance are whose value is to be measure is connected in parallel with the capacitor c and a voltmeter.

Working:-
Capacitor is charged to a suitable voltage by using a battery after that the capacitor is allow to discharge. During the dischary the terminal voltage across the capacitor or at any instant of time 't' can be given by

$$V_c = V e^{-t/CR}$$

$$\Rightarrow \ln \frac{V_c}{V} = \ln e^{-t/CR}$$

$$\boxed{\ln C = 2.30 \log x}$$

$$\Rightarrow \ln \frac{V_c}{V} = -\frac{t}{CR}$$

$$\Rightarrow \ln \left(\frac{V}{V_c}\right) = \frac{t}{CR}$$

$$\Rightarrow \boxed{R = \frac{t}{C \ln\left(\frac{V}{V_c}\right)}}$$

$$R = \frac{t}{C\, 2.3 \log\left(\frac{V}{V_c}\right)}$$

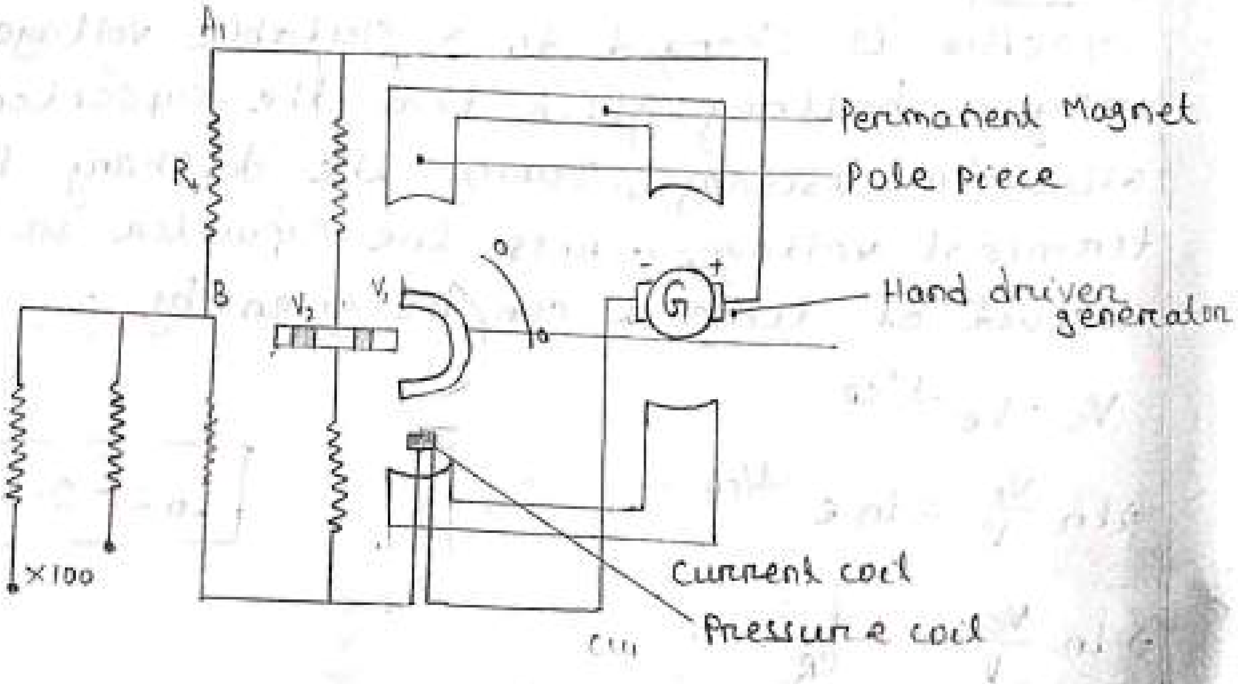
$$= \frac{0.434t}{C\log\left(\frac{V}{V_C}\right)}$$

V is the intantaneous value of voltage across a capacitor at any instant of time 't'.

$$R = \frac{0.434t}{C\log\left(\frac{V}{V_C}\right)} \quad \text{——— (1)}$$

Megger:-

→ Megger is an instrument which is used to measure insulation resistance and very high resistance. It is also known as insulation tester.



→ It is a modified PMMC type instrument.

→ This instrument contains 1 current coil and 2 pressure coils.

→ The pressure coils are V_1 and V_2, this 2 coils are so located that when the magnetic field gradually become stronger the pointer moves from ∞ to 0.

→ The current coil also controls the pointer movement by it's magnetic field.

→ When the current in the current coil is the large, than the pointer indicates '0', which means Rx is very small. (Rx = test resistance)

→ Similarly when the current in current coil is low, it indicates '∞' over than scale, which means Rx value is very large.

→ The voltage range of the instrument can be controlled by using variable resistor switch, which is connected in series with current coil.

→ The generator is use to generate the testing voltage while measuring the unknown resistance.

→ The unknown resistance Rx can vary the current flowing through 'PC' coil & 'CC' coil. So the movement of pointer can be affected by the unknown resistance 'Rx'.

→ When A & B ends are upon circuited than the pointer indicate's '∞'.

→ When A & B end short circuited than the pointer indicates '0'.

→ The pointer movement can be calibrated in terms of resistance to measure the 'Rx' value.

→ A centrifugal clutch in incorporated in the generator to drive it, at a constant speed while generate in the voltage.

Earth tester:-

→ Earth tester is an instrument which is used to measure earth resistance.

→ While earthing the earth electrode should be present in a low resistance coil, so that it can carry the excess current to the earth without any distoration.

→ The earth soil resistance is affacted by the moisture contain of the soil. So periodic testing of earth resistance is required to make the earthing system more affective.

Construction:-

The earth tester is a special type of megger with some additional features.

(i) Current reversal

(ii) Rectifier.

→ This instrument consists of commutators made up of 1-shaped segments.

→ This segments are mounted on the shaft of the generator.

→ Is commutator has four brushes, this brushes are position that one pair contact alternately with one segment, while the second pair fixedly contact to the same point, when the commutator rotates.

→ The earth tester has four terminal P_1, P_2, C_1 & C_2.

→ Two terminal P_1 & C_1 are shorted are connected to earth electrode.

→ The other two terminal P_2 & C_2 are connected to auxiliary electrodes 'P' & 'C'.

→ The indication of earth tester instrument depend upon the ratio of voltage across the pressure coil and the current flowing through it.

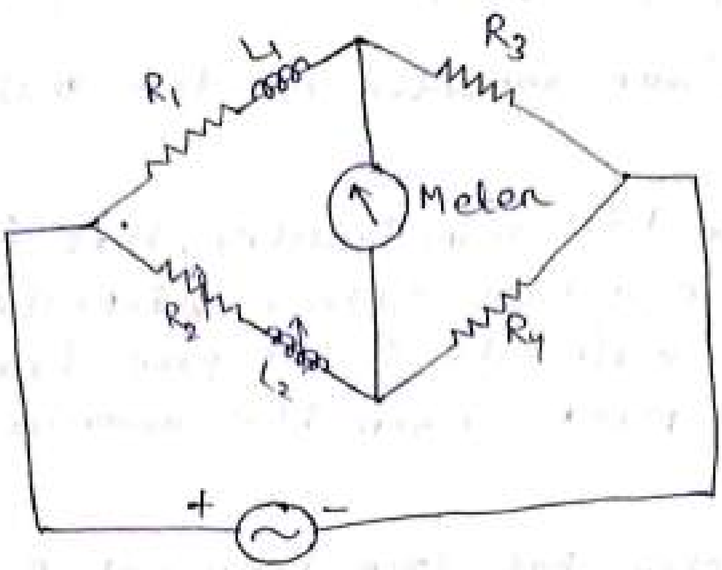
→ The deflection of instrument pointer indicates the earth resistance directly.

Note:-

→ When DC current is supplied to the earth for measurement of resistance, than the back emf is generated in the soil, due to electrolyte effect.

→ To avoid this condition AC current supply through the soil for the measurement of earth resistance

Maxwell bridge for inductor Measurement :-



→ The maxwell bridge measures inductance by comparing with a variable standard inductance.

→ In the above circuit L_1 = unknown inductance
L_2 = Variable inductance
R_1, R_3, R_4 = known resistance
R_2 = Variable resistance

→ The balancing condition of the bridge can be given by,

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

$\Rightarrow Z_1 Z_4 = Z_2 Z_3$

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

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

→ Equating the imaginary part of the above eqn we get,

$\Rightarrow j\omega L_1 R_4 = j\omega L_2 R_3$

$\Rightarrow L_1 R_4 = L_2 R_3$

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

→ In the above eqⁿ the value of L_2, R_3, R_4 are known, so the unknown inductance L_1 can be calculated.

→ By equating the real parts $R_1R_4 = R_2R_3$ this condition also has to be satisfy.

Measurement of capacitance by schering bridge:-

Scharing bridge is used for the measurement of unknown capacitance.

C_1 = Capacitor whose capacitance is to be measured.

r_1 = A series resistance representing loss in capacitor.

C_2 = Standard capacitor

C_4 = Variable capacitor

R_4 = Variable Resistor in parallel with C_4

R_3 = Standard resistance.

The balancing condition of the bridge can be given by,

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

$$\Rightarrow Z_1 Z_4 = Z_2 Z_3$$

$$\Rightarrow \left(r_1 + \frac{1}{jwC_1}\right)\left(\frac{R_4}{1+jwC_4R_4}\right) = \frac{1}{jwC_2} \times R_3$$

$$\Rightarrow r_1 - j\frac{1}{wC_1} = \frac{R_3 + jwC_4R_3R_4}{jwC_2R_4}$$

$$= \frac{R_3}{jwC_2R_4} + \frac{jwC_4R_3R_4}{jwC_2R_4}$$

$$= -j \times \frac{R_3}{wC_2R_4} + \frac{C_4R_3}{C_2}$$

$$\Rightarrow r_1 - j\frac{1}{\omega C_1} = \frac{C_4 R_3}{C_2} - j\frac{R_3}{\omega C_2 R_4}$$

Comparing the real part from the above eq^n we get, $r_1 = \frac{C_4 R_3}{C_2}$ ——— (I)

Comparing the imaginary part from the above eq^n we get $\frac{1}{\omega C_1} = \frac{R_3}{\omega C_2 R_4}$

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

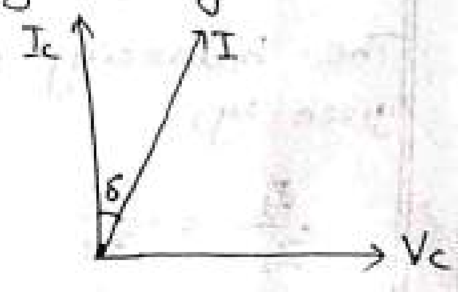
$$\Rightarrow C_1 = \frac{C_2 R_4}{R_3} \quad \text{——— (II)}$$

So, the unknown resistance C_1 can be determine from eq^n (II). C_2, R_4 & R_3 values are known. So 'C_1' can be calculated.

This dissipation factor can be given by

$$\tan\delta = \omega C_1 r_1$$

$$= \omega C_1 \times \frac{C_4 R_3}{C_2}$$



Multimeter:-

- This is a measuring instrument which is used for measurement of multiple quantities like voltage, current, resistance etc.

- There are 2 types of multimeter available
  - a. Analog multimeter
  - b. Digital multimeter

(a) Analog Multimeter:-

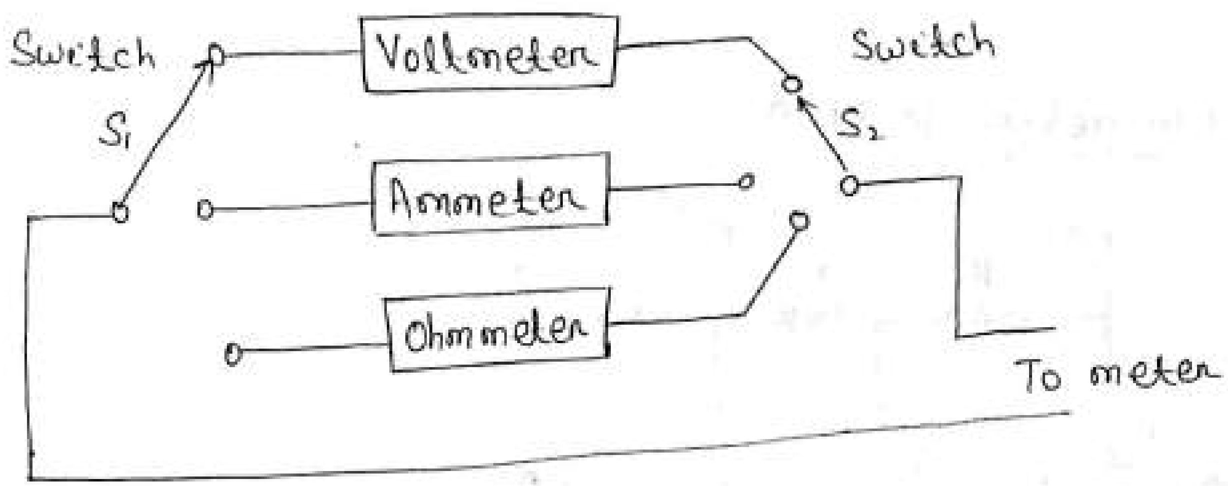
→ An analog multimeter is an PMMC type meter which works on 'd' arsonval movement principle.

→ It consists of a needle or pointer to indicate the measured valve over a graduated scale.

→ The PMMC type meter acts as ammeter when shunt resistors are connected.

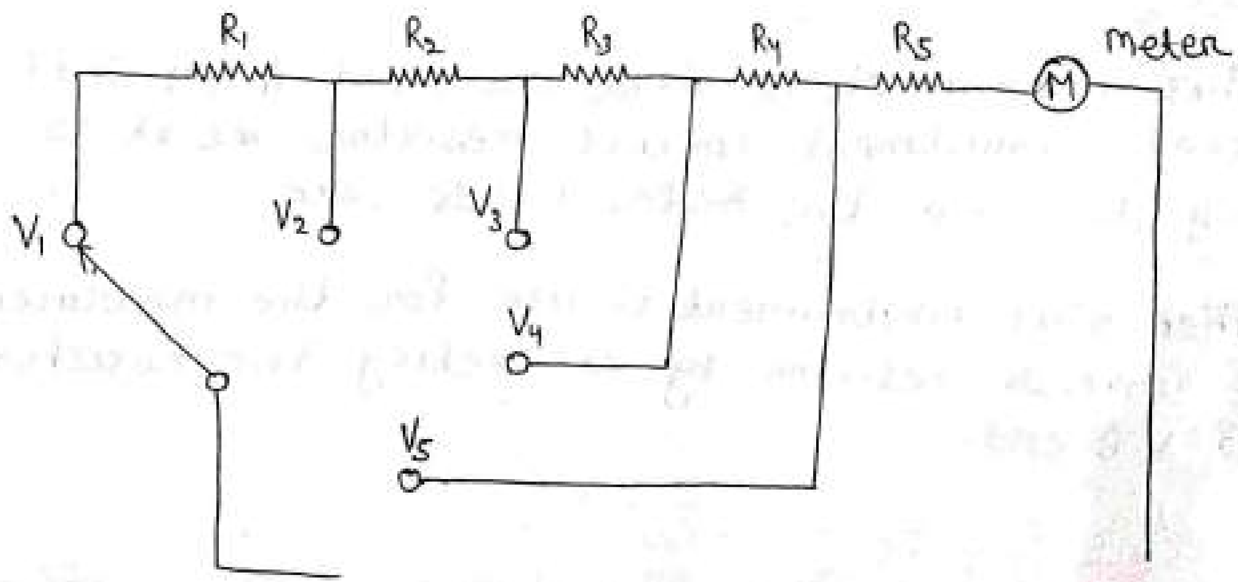
→ The meter acts as voltmeter when multiplier resistors are connected.

→ It acts as ohmmeter when a battery and a resistance network is connected.



(Block diagram of multimeter)

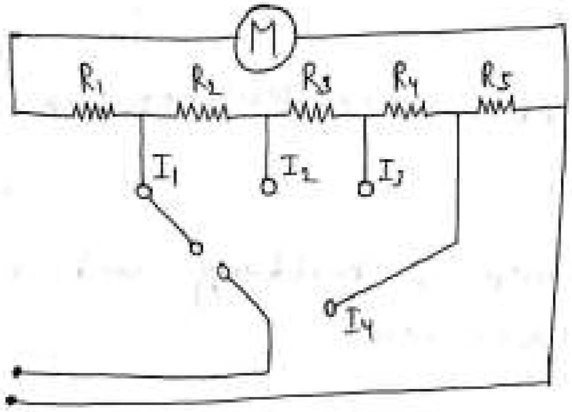
Voltmeter Section:-



→ Multipliers are connected in series with the PMMC type wattmeter.

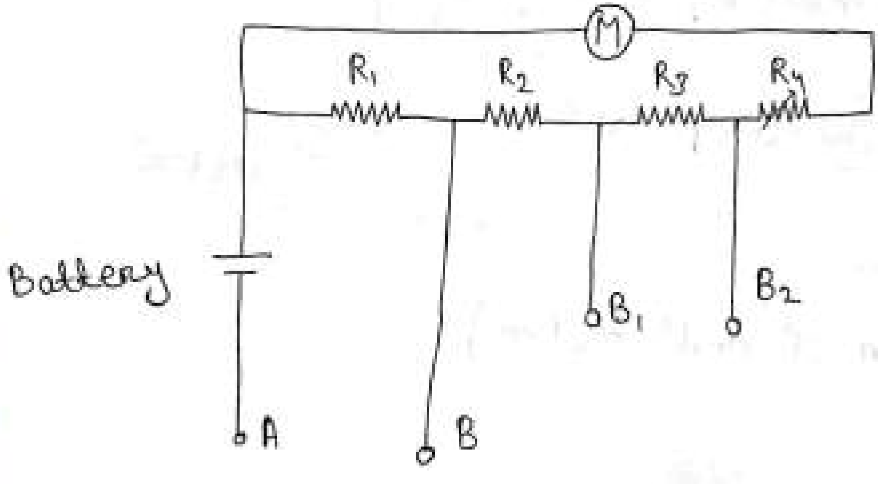
→ In the above figure V_1, V_2, V_3, V_4 and V_5 are the different voltage ranges for measurement.

Ammeter section:-



→ Shunt resistors are connected parallely with the meter. In the above fig. I_1, I_2 I_3 & I_4 are different current ranges for measurement.

Ohm meter section:-



→ This instrument is short circuited A & B ends & the '0' adjustment control resistor are it so adjusted that the meter reads zero.

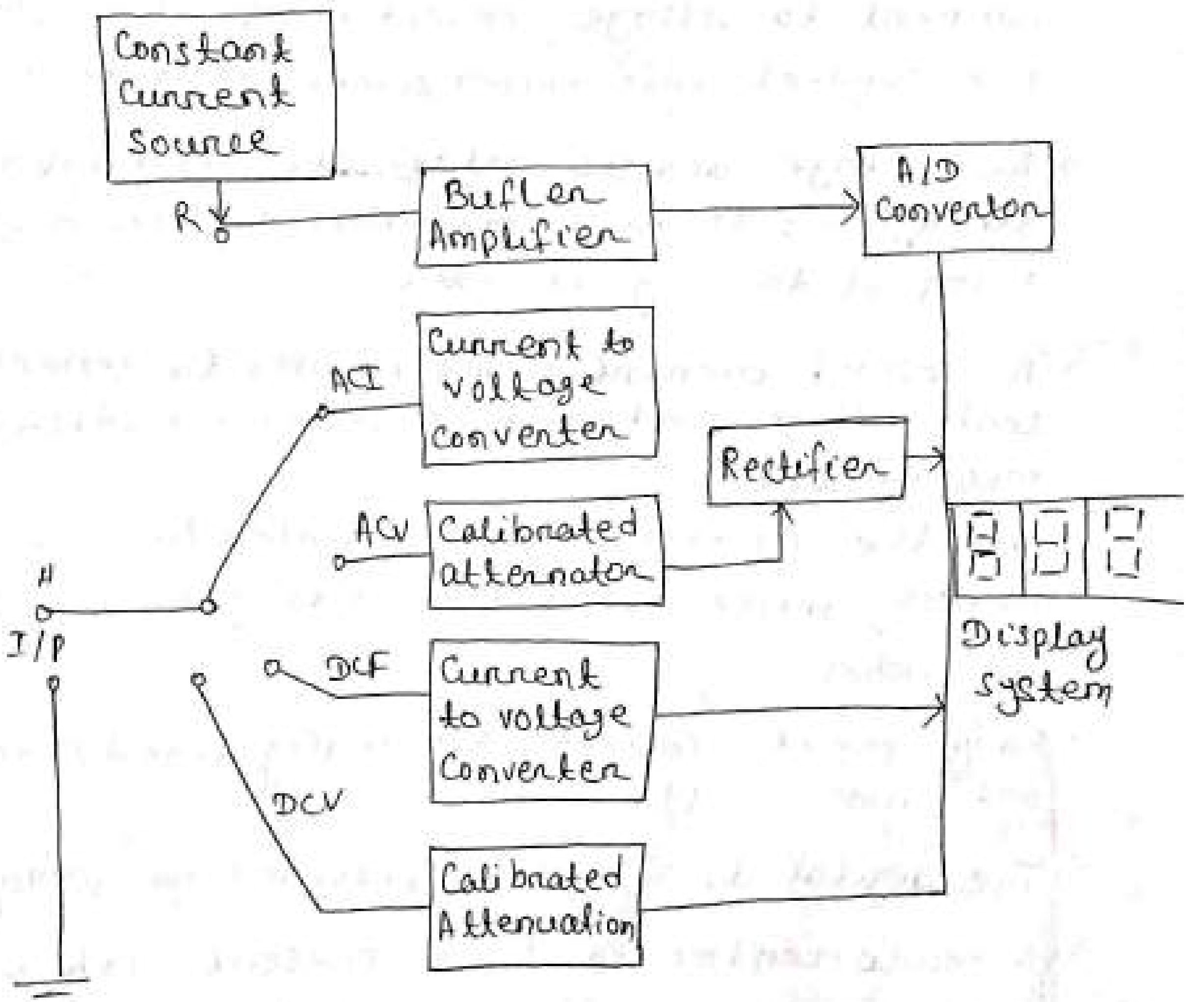
→ Then this instrument is use for the measurements of unknown resistor by connecting the resistor to A.B end.

→ The range of the measurement can be varied by varing the position of B end. In the above figure B, B_1 & B_2 can be used to acheived different resistance ranges from measurement.

→ A switch can be used to select AC/DC quantity for measurement. If DC quantity is selected by the switch than the input is direct fed to the PMMC meter for indication.

→ If AC quantity is selected than the input is passed through a rectifier ckt, which converts AC quantity to DC and the fed to PMMC meter for indication.

Digital Multimeter:



→ Digital multimeter is the instrument which is used to measure multiple quantity like:- voltage, current, resistance etc & display the measure quantity interms of digits.

→ In digital multimeter the +ve input probe is connected to a rotary switch through which different measurements can be selected like:- resistance, AC current, DC current, AC voltage and DC voltage.

→ The AC quantities after converting to perticular voltage range is passed through a rectifier ckt for AC to DC conversion.

→ AC current and DC current are passed through current to voltage converter at which converts the current into proporsional to voltage.

→ AC voltage and DC voltage are attenuated (decrease strength) with in a perticular voltage range before giving it to eddy convertor.

→ A constant current source is used to generate equivalent voltage w.r.t. unknown resistance which resistance measurement.

→ All the quantities are converted to DC voltage from by using proper ckts & then it is given to eddy convertor.

→ Eddy convertor converts the analog signal into digital and forms (0 to 1)

→ The digital data is than provided to display system.

→ A micro-controller chip is present with in the display system, which control the digit display on segment LEDS.

Chapter-7

SENSOR & TRANSDUCERS:

Transducer is a device which can convert or transduce one form of energy into another form.

→ Sensors are special type of transducers which are used to sence or detect physical parameters and provides output generally used electrical form.

Ex- Speaker, potentiometer, turbine etc.

Classification of transducers:-

It based upon the output produce by transducers elements, transducers are of two types.

(1) Mechanical transducers:-

This transducers produced output interms of mechanical energy, i.e displacement speed.

Ex- Turbine, Bourden tube

(2) Electrical Transducers:-

→ This transducers produced output interms of electrical energy.

Ex- LVDT, transducers, strain, gauge, piezoelectric sensor etc.

Active transducers:-

The transducers which can generate electrical output interms of voltage or current without any external power supply are known as active transducers.

Ex- Thermocouple.

Passive transducers:-

The transducers which requires external power supply to generate output interms of voltage and current are known as passive transducers.

Ex- LVDT, Strain gauge, potentiometer.

→ The passive transducers produces output in terms of resistance, inductance and capacitance w.r.t input parameter. According to this the passive transducer are categorised into 3 types.

(1) Resistive transducer:-
The output resistance of this transducers changes w.r.t input parameters.
Ex- Potentiometer, thermistor, Resistance thermometer, Straingauge

(2) Inductive transducers:-
~~The~~ The output inductance of this tranducer changes w.r.t input parameter.
Ex- LVDT

(3) Capacitive transducers:-
The output capacitance of this transducers changes w.r.t input parameter.
Ex- Variable area type capacitive transducers
variable airgap type capacitive transducers

Note:-
The tranducer which is directly connected to the physical parameter ring measured is known as primary transducers and the transducer which are connected to the primary transducer is known as secondary tranducers.

Resistive transducers:-
The resistance of this transducers, changes w.r.t change in input parameter.

→ These are passive transducer i.e external supply is required to generate voltage and connect as output.

a) Potentiometer :- (POT)

→ It is a type of displacement sensor.

→ POT meter consist of uniform ~~resistive~~ resistive element and a ~~so~~ sliding contact. The sliding contact is known as slider or wiear.

→ The motion of the sliding contact may be translattering or rotational.

→ Depending open the movement of the slider the potentiometer are classify into 2 catagory.

(i) Linear potentiometer

(ii) Angular potentiometer

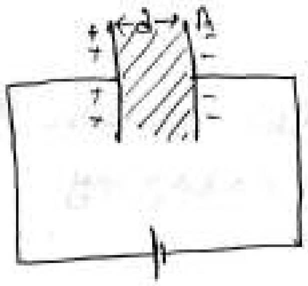
Note:-

A 3rd type POT is also available where the slider can move in both translational and rotational direction. This POT is known as helipot.

Capacitive transducers:- 19/05/22

The transducer which capacitance changes w.r.t changes in input parameter is known as capacitive transducers.

C



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

$$\varepsilon = \varepsilon_0 \varepsilon_r$$

$$\varepsilon_r = \frac{\varepsilon}{\varepsilon_0}$$

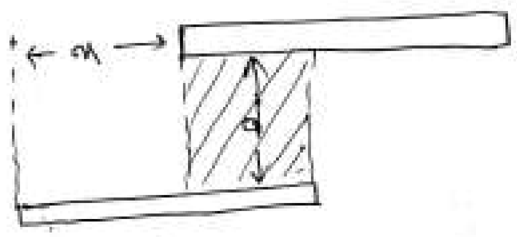
A = Overlaping area betⁿ two plates

C = Capacitance

ε_r = relative permitivity

d = distance betⁿ 2 plates

Variable area capacitive transducers:-

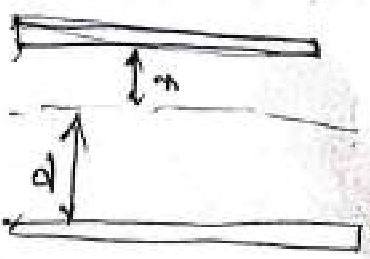


$$C = \frac{\varepsilon (A - Wx)}{d}$$

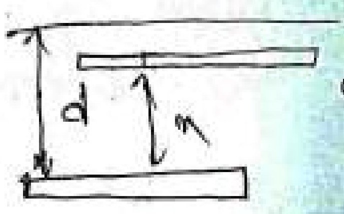
W = Width of the plate

$A = Wl - Wx$

Variable Distance betⁿ two plate capacitive Transducer-



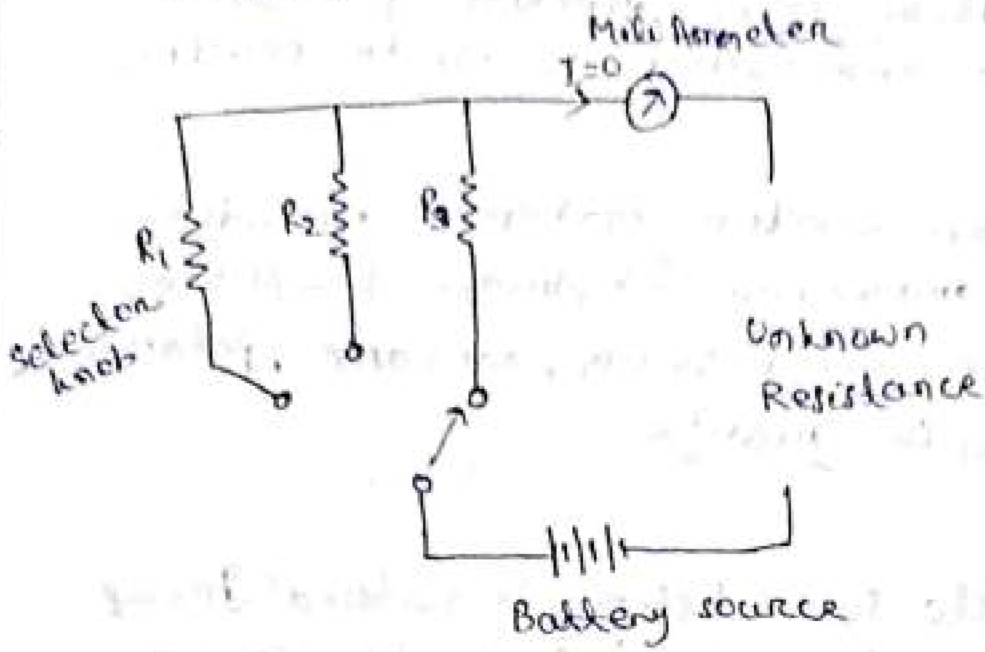
$$C = \frac{\varepsilon A}{d + x}$$



$$C = \frac{\varepsilon A}{d - x}$$

23/05/22

$X_C = \frac{1}{2\pi f C}$



26/05/22

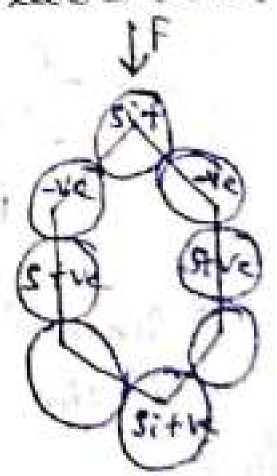
Active transducers:-

Transducers which do not require any external power supply for the generation of electrical output (voltag & current) is known as active transducers.

Piezo-electric Transducers:-

A piezo-electric material is one in which at electric potential appears across shenten surfaces of a crystal in the dimension of the crystal are change by the application of mechanical force.

→ The potential is produce by the displacement of charges.



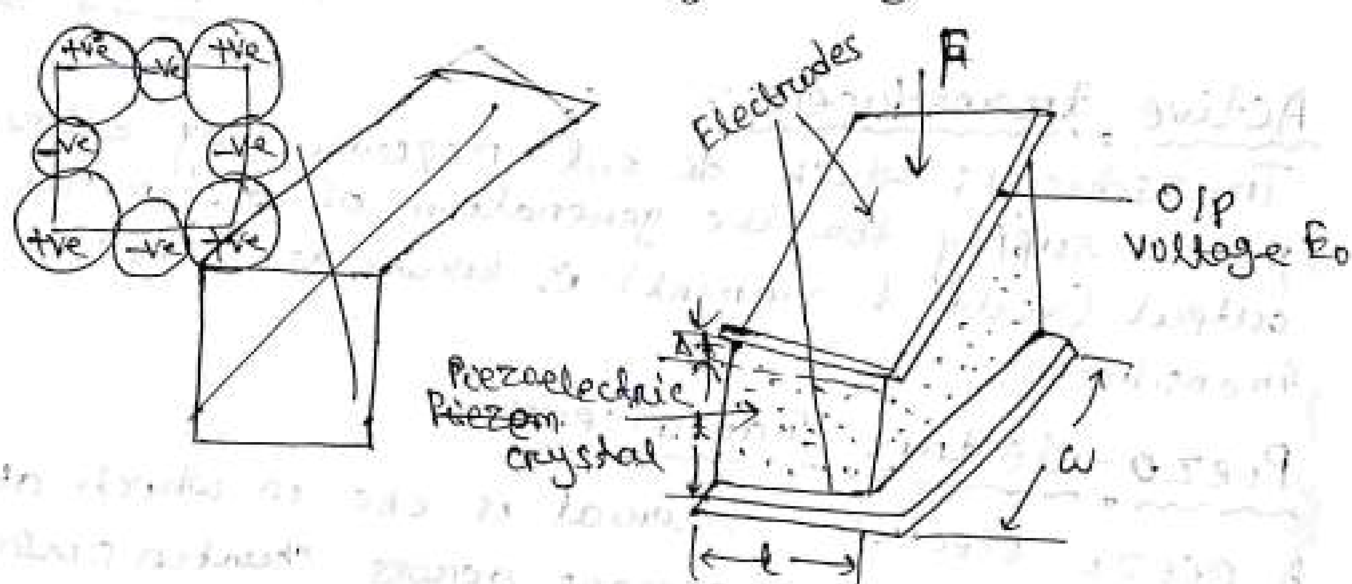
→ Conversly if varied potential is applied to the proper axis of the crystal it will change the dimension of the crystal (Deformation happen)

→ This effect is known as piezo-electric effect.

→ Elements exhibiting piezo-electric qualities are some time are called as electro resistive elements.

→ Eg- Common piezo-electric material includes, Rochelle salts, ammonium dihydrogen phosphate, lithium sulphate, dipotassium, eartarie, potassium dihydrogen phosphate, quartz,

→ Quartz & Rochelle salts belong to natural group. While others are belongs to synthetic group.



Charge $Q = dF$

where

d = Charge sensitivity of the crystal

↓ unit

$\frac{Q}{F}$ $\frac{\text{Coulum}}{\text{Newton}}$

F = Applied forced

→ The force F causes a change in thickness of the crystal.

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

where
A = area of crystal
t = thickness of crystal
E = Young's modulus (N/m^2)

Young's modulus $E = \frac{\text{stress}}{\text{strain}} = \frac{Ft}{A\Delta t}$ N/m^2

$A = w \times l$

where w = width of ~~distance~~ crystal
l = length of crystal

$$Q = d\frac{AE}{t}\Delta t$$

The charge at the electrodes gives rise to an output voltage E_o.
where
C_p = capacitance betn electrodes

$$C_p = \frac{\varepsilon_r \varepsilon_0 A}{t}$$

$$Q = d\frac{AE}{t}\Delta t$$

$$E_o = \frac{Q}{C_p} \text{ volts} \quad \text{--- (1)}$$

$$= \frac{dF}{\frac{\varepsilon_r \varepsilon_0 A}{t}} = \frac{dFt}{\varepsilon_r \varepsilon_0 A}$$

$$C_p = \frac{\varepsilon_r \varepsilon_0 A}{t}$$

$$E_o = \frac{dt}{\varepsilon_r \varepsilon_0}\frac{F}{A}$$

$$= \frac{d}{\varepsilon_r \varepsilon_0} tP$$

$$= g\,tP$$

where $g = \frac{d}{\varepsilon_r \varepsilon_0}$ (Voltage sensitivity of the crystal)

$$g = \frac{E_o}{tP}$$

$= \frac{E_0/t}{P}$ (Electric field upon stress)

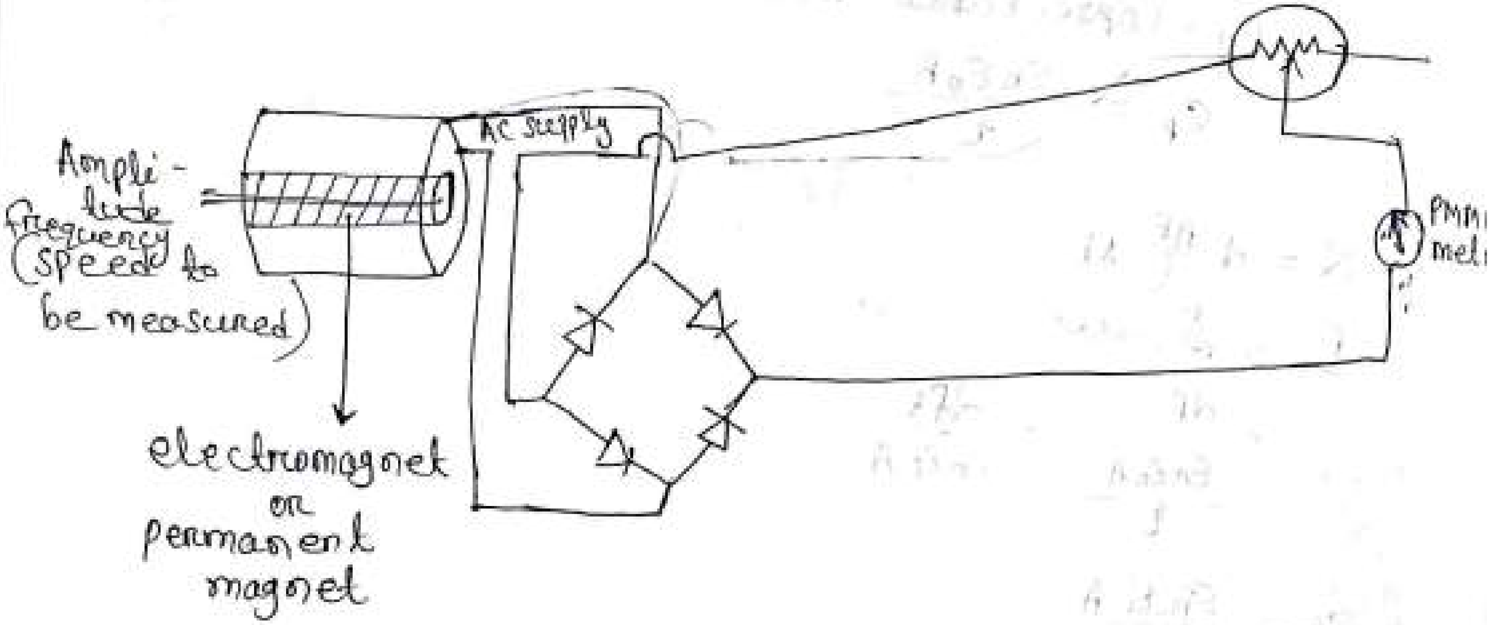
quartz :- $\epsilon = 40.6 \times 10^{-12}$ F/m. $\quad C = \frac{\epsilon A}{d}$ F/m

$2PC/N = 40.6 \times 10^{-12} \times 50 \times 10^{-3}$

10/6/22

AC Tachogenerator:-

The AC tachometer generator contain rotating magnet which can be either permanet magnet & an electromagnet. The tachometer generator generally generate AC voltage w.r.t the major speed.



This AC tachometer generator generates O/P AC voltage which can be converted to equivalent DC voltage with the help of rectifier ckt. PMMC line meter can be used to indicate this generated voltage which can be calibrated w.r.t measure speed.

→ The speed can also be measured w.r.t the frequency of the AC voltage. So we can easily identify the dirⁿ of speed using dc tachometer.

Disadvan

→ DC tachometer required regular maintainance as the carbon brushes easily get damaged.

→ AC tachometer generator required very less maintainance as compare to DC tachometer generator.

→ Frequency meter:-

It is a device which is used to measure the frequency of supplied input signal.

There are two types of frequency meter

(a) Mechanical resonance type frequency meter

(b) Electrical resonance type frequency meter