Measuring Instruments :- (Unit-1)

ⓐ Accuracy :-

The closeness of the measured value to the true value of the physical quantity is known as the accuracy of the measurement.

ⓑ Precision :-

The closeness of two or more measurements to each other is known as the precision.
It shows how close or consistance the readings are a precise reading need not be accurate but an accurate measurement is always precise.

Accuracy without Precision | Precision without Accuracy | Accuracy and Precision | No Accuracy No precision

ⓒ Errors :-

Errors are simply defined as mistake in other words the difference betⁿ true/standard value and observed value is called error.

Error = Standard value - observed value

ⓓ Resolution :-

If the input is slowly increased from some obtained value it will be found that the output does not change at all until a certain increment is exceeded. this increment is known as resolution. In other words it is the smallest change in a measured variable to which an instrument will respond.

Sensitivity:-

It is defined as the ratio of the change in the output of an instrument to a change in the value of the quantity being measured. It denoted the smallest change in the measured variable to which the instrument responds. Deflection factor or inverse sensitivity is the reciprocal of sensitivity

$$\text{Sensitivity } (K) = \frac{\Delta V_o}{\Delta V_i}$$

where, ΔV_o = Change in output

ΔV_i = Change in input

Classification of measuring instrument:-

Measuring Instrument:-

The measuring instrument are defined as instruments & device which is used for the measurement of unknown quantity.

Absolute & Secondary Instruments:-

Absolute Instrument:-

These instruments give the magnitude of quantity under measurement in terms of physical constants of instruments.

Secondary Instrument:-

Gives the magnitude of electrical quantity to be measured directly. Secondary instrument further classified in to 3 parts

(I) Indicating (II) Integrating (III) Recording

(I) Indicating Instruments:- Indicating instruments are those instruments which indicate the magnitude of a quantity being measured. It uses a dial & a pointer for measurement of unknown quantity.

Ex:- voltmeter, Ammeter, wattmeter, power factor meter etc.

(ii) Integrating Instruments:- Measurement the total amount of quantity of electricity or electrical energy supplied over a specified period of time. Ex:- Energy meter, Ampere hour meter etc.

(iii) Recording Instruments:- keep a contineous record of the variation of magnitude of unknown quantity for a perticular period. It used a pen to record the quantity to be measure on sheet of paper fixed or moving.

Analog Instrument:- An analog device is one in which the output or display is a contineous function of time.

Digital Instrument:- The instrument which represent the measured value in the form of the digital number is known as the digital instrument. the digital instruments converts the contineous signal into a countable output signal.

Classification based on process:-

(i) Mechanical Instruments:- In this instruments pointer is deflected due to some mehanical Process. This instruments are used for stable & static conditions.

They are unable to respond rapidly to measurements of dynamic & transient conditions because of having moving parts that are bulky, heavy processing high inertia

(II) Electrical Instrument:- Move of pointer is deflected due to some electrical activity electrical instruments indicating the output of detectors are more rapid than mechanical methods.

(III) Electronic Instruments:- In Electronic instruments pointer is deflected due to movement of electrons. These instrument require use of semiconductor devices. The response time of these instruments are extremely small as a very small interia of electron is only involved the sensitivity of these instruments are also very high. Faster response, lower weight, lower power consumption are some advantage of the electronic instrument.

Deflecting Controlling and Damping arrangement 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.

(I) Deflecting Torque:- This torque is used to move the pointer over the scale it is denoted by Td.

(II) Controlling Torque:- Controling torque is used to neutralise or cancel the deflecting torque. It is denoted by Tc. Tc is propersional to the deflection done by the pointer.

(III) Damping Torque:- This torque is used to absorb the oscillation of the pointer. The above figure shows an indicating type instrumet arrangement.

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

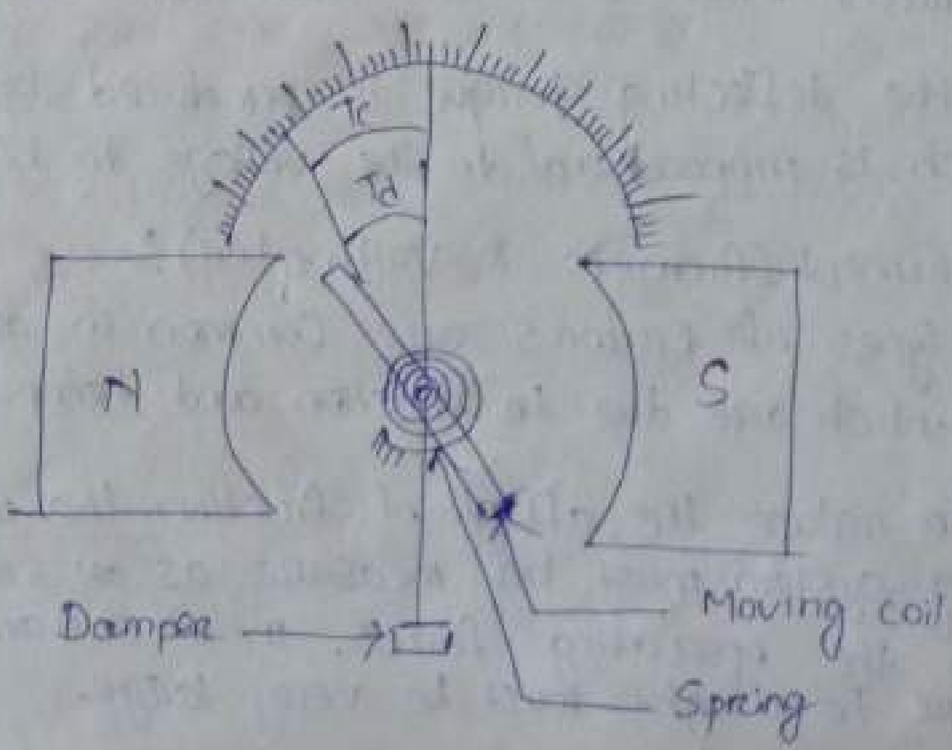
→ when current flows through the moving coil then a magnetic field is developed arround the coil, which acts with the magnetic field of permanent magnet.

→ Due to this interation the coil get deflected by an angle 'θ'. Once pointer is attached to the coil which also get deflected as shows the measured value on the scale.

→ The torque developed or responsible for this deflection is Td. when the current is remove than 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 contrdling torque. one dumper is connected to the pointer which is a cylinder and piston arrangement used to Observe 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 which 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.

(Unit-2)

Analog Ammeters and Voltmeters:-

→ 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.

→ The basic working principle of ammete and 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 mesured

Erros in Instrument (Ammets & Voltmeter):-
Generally 2 types of Errors are Common in ammeter & voltmeter which are due to friction and temperature.

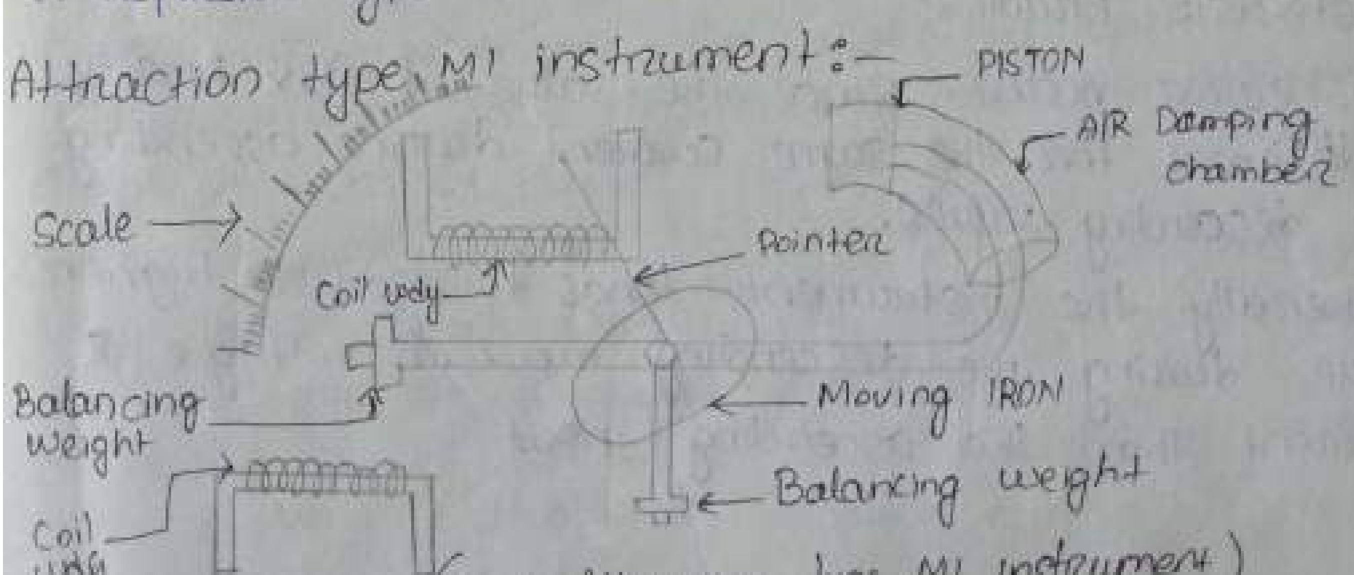
Friction:- To reduce the affect of friction the weight of the moving system must be measure as small as possible with the operating force. In other words the ratio of torque to weight must be very large.

Temperature:- It is possible to reduce the error which is cause by the temperature change. The instrument must be mounted in such a position that it will be properly ventilated.
A swamping resistance of low temperature coefficient material can be connected in series with the coil to reduce the temperature effect on the instrument.

*Moving iron type Instrument:-
In this type of instrument a moving iron piece rotates within a current carrying coil for this reason it is called as moving iron type instrument.

Working Principle:-
A plate or vane of soft iron is used to make moving element of the system. This iron vane is situated in such a way that it can move in a magnetic field produced by in the coil.
→ The coil is excited by the current or voltage to be measured. when the coil excited it becomes an electromagnet and iron vane moves in such a way that it also moves the pointer over the graduated scale associated through it.
→ Moving iron instrument are of 2 type
(I) Attraction type MI instrument
(II) Repulsion type MI Instrument

Attraction type MI instrument:-



(Fig:- Attraction type MI instrument)

→ The above figure shows an attraction type MI instrument. Here MI is a flat disc, which is mounted within the magnetic field of the coil.
→ when the current flow through the coil a magnetic field is produced which attracts the moving iron piece and rotates it.
→ The pointer which is connected the MI also get deflected due to the movement of moving iron. The controlling torque is provided by gravity control by using balancing weights if the instruments are vertically mounted.
→ Damping is provided by air friction with the help of a light alluminium piston which moves inside a fixed chamber.

Repulsion type MI instrument:-
→ In repulsion type MI instrument 2 iron vanes are present inside the coil wave one is fixed and the other one is movable.
→ When the current flows through the current that it's made magnetised and a force of repulsion acts betn two iron vanes which result the momentum movable iron vane.

Errors in MI instrument:-
Errors with both DC & AC measurement:-
(i) Hysterisis Error:-
→ This error occurs since the value of flux density is different for the same current during ascending and descending values.
→ Generally the instrument tends to read higher value during the descending input of voltage & current than the ascending input

(II) Temperature error:-

-> The effect of temperature changes on MI type instrument is very high due to the shell. fitting of coil and series resistances and high temperature coefficient spring material.

-> Arround 0.02% of variation occurs per °C temperature changes.

(III) Stray Magnetic field:-

-> This error occurs due to the magnetic field other than the instrument magnetic field which is present in it's environment.

-> Due to the stray magnetic field the instrument operating magnetic field get distorted.

Errors in AC Measurement:-

I) Frequency Error:- Charges in frequency of AC quantities generally change in the reactance of instrument coil, so it's effect of magnetic field strength of the coil.

II) Eddy Current Error:- These errors are caused by eddy currents induced in the iron parts of the instrument.

Advantages:-

-> These instruments can be used for both AC & DC measurement. These instrument are very cheap and simple in construction.

-> Accuracy of is very high. MI type instrument has very large scale length. The degree of deflection is arround 240° in Circular scale.

-> It has very high operating torque so torque to weight ratio is very high which reduces the friction of the instrument.

Disadvantages:-

→ Power consumption is higher for low voltages range measurements. Stiffness of the spring reduce with increaing in temperature.

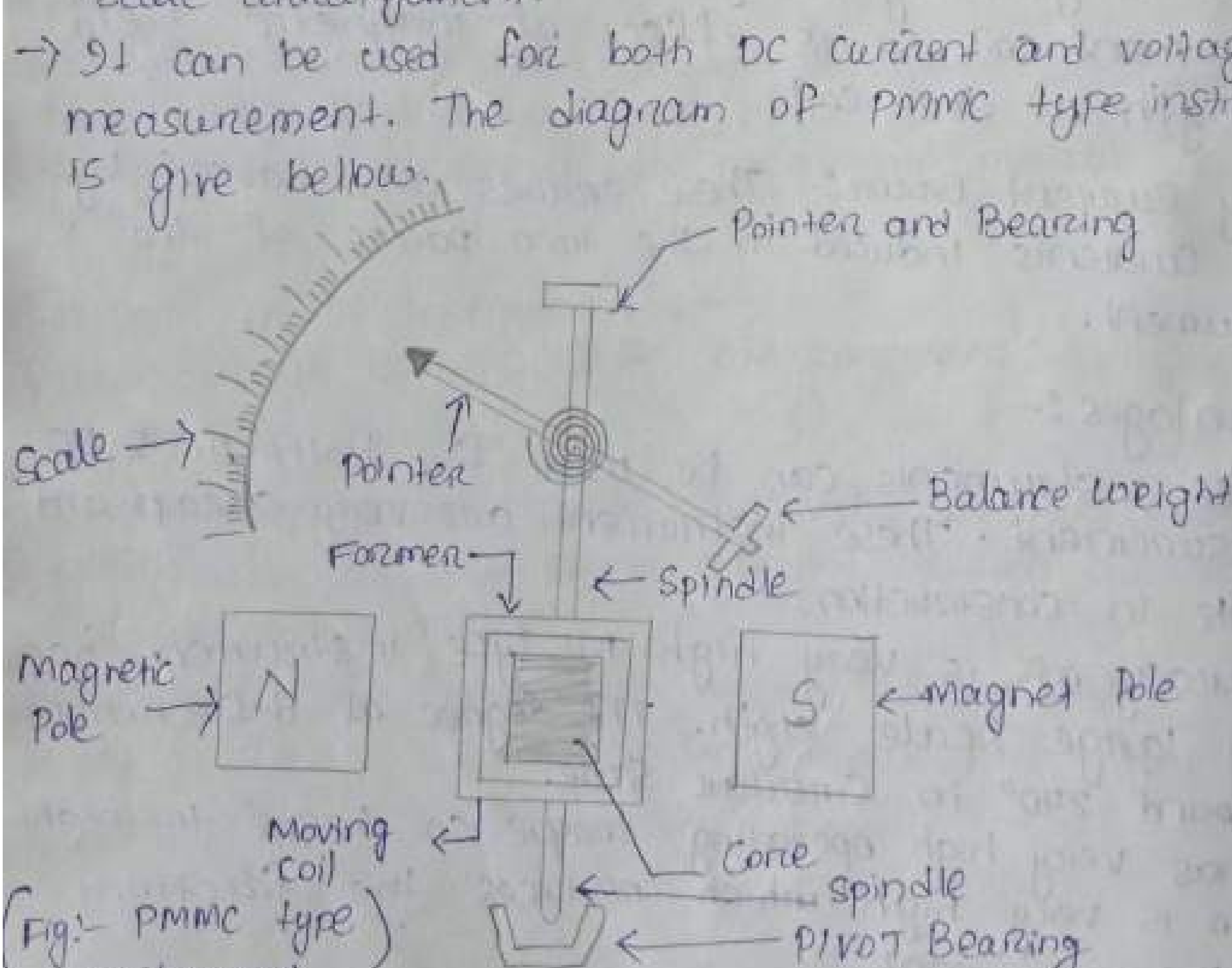
→ Frequency change can cause error in AC measurement.

→ Stray magnetic field effects of MI type instrument. Histerisis error is also present in this type of instrument.

* Permanent Magnet Moving coil type Instruments (PMMC Instrument):-

→ The permanent magnet moving coil instrument consists of a moving coil, permanent magnet system controlling and damping arrangement and a pointer scale arrangement.

→ It can be used for both DC current and voltage measurement. The diagram of PMMC type instrument is give bellow.



(Fig:- PMMC type instrument)

Moving Coil:-

→ The moving coil is wound with many terns of silk covered copper wire on a rectangular alluminium former.

→ The coil moves freely in the field of permanent magnet.

Magnet System:-

→ The coil which is describe above is present within a magnetic field which can achiaved by placing permanent magnet.

→ The angle of rotation of the coil may vary the arrangement of magnetic poles.

→ For example of U-shaped magnets provides maximum 90° rotation. By using concantric magnetic poles the angle of rotation can be extended up to 250° or more.

Control:-

Here coils are attached by bronze springs which provides the controlling torque. This springs in few cases also carries the current in an out of the coil.

Damping:-

The damping torque is produced by the movement of alluminium former which abserbes the oscillation.

Pointer Scale:-

The pointer is connected to the spindle which moves over the graduated scale.

The pointer is of very light weight and the arrangement is done in such as way that it reduces the parallel error.

Working Principle :-

→ When a current is to be measured that current is allows to pass through the moving coil. Due to the flowing of current a magnetic field is developed arround the coil former.

→ This generator magnetic field interacts the permanent magnetic field and a deflecting torque is produced in the coil.

$$T_d = NBldI$$

where,

N = No. of turns in the coil
B = Magnetic flux intensity in wb/m^2
l = langth of the coil } Dimension of the coil
d = diameter of the coil }
I = Current flowing throught the coil in 'A'

Since,
N, B, l, & d are constant for a particular coil & magnet arrangement, so $T_d \propto I$.

→ So the deflecting torque is produced in the coil proporsional to the current flowing through it.

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

→ If Tc is the controlling torque then.

$$T_c = T_d$$

→ The dumpers are connected to the pointer or damping arrangement is made in the coil to absorb the oscillation of the pointer.

Ammeter shunt :-

→ The coil winding of a ammeter is very small and light which can carry very small amount of current.

. When heavy are to be measured then if all the current will flow through the coil, the coil get damaged.

→ To avoid this situation the major part of the current is bypassed through a low resistance called shunt.

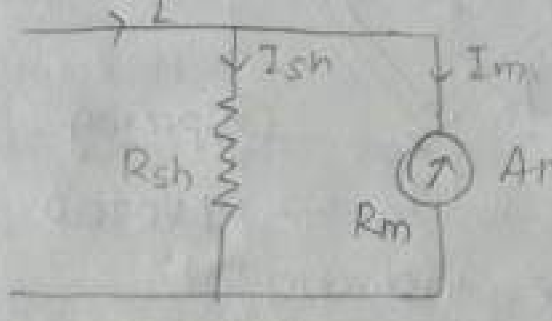


Fig Basic Ammeter

Advantages :-

→ The scale is uniform

→ It consumes less power as 25 uw to 200 uw

→ The torque to weight ratio is very high so the instrument accuracy is very high.

→ The single instrument can be used for different current and voltage range measurements.

Disadvantages :-

→ It can only be used for DC measurements.

→ Cost of these instrument are comparitively higher than moving iron instrument.

* Dynamometer type instruments :-

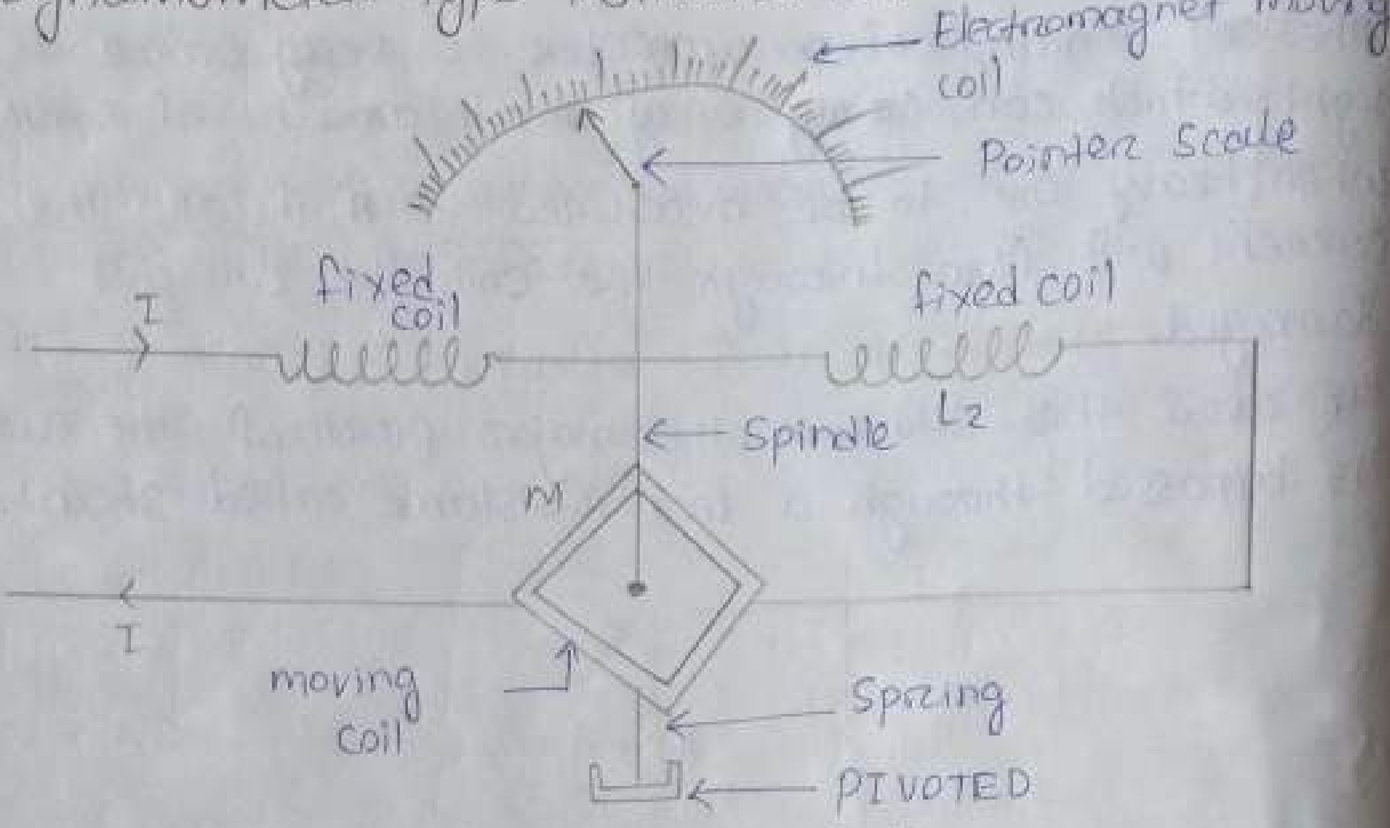


Fig:- Dynamometer type instrument

Construction:-

→ The instrument consists of two fix coil l_1 & l_2 and one moving coil 'M' the moving coil is placed on a 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 fix coil made of up few tons of copper wire and knows as current coil. the current need to be measured is passed through the fixed coil at the starting.

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

→ when a magnetic field is developed in the fixed coil and moving coil due to the passage of current.

→ Then a deflecting torque is produce in the moving coil. The provide deflecting torque is proportional to product of current passing through the fixed and moving coil.

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

Advantages:-

→ It can measure both AC & DC parameter.

→ It is free from hysterisis error.

→ Magnetic field strength can be varied & there is no change of magnetic field loss like incase of permanet magneto moving coil type instrument.

Disadvantages:-

→ It has low sensitivity.

→ More frictional loss due to heavy moving parts.

→ Scale is non-uniform.

* Rectifier type Instrument:-

→ Rectifier type instrument are used for measurement of AC current and voltage.

→ In this type of instrument a rectifier is used which converts AC to DC and a permanent magnet moving coil type Instrument is used to indicate the measure value.

→ Both half wave & fullwave rectifier can be used for AC to DC converction.

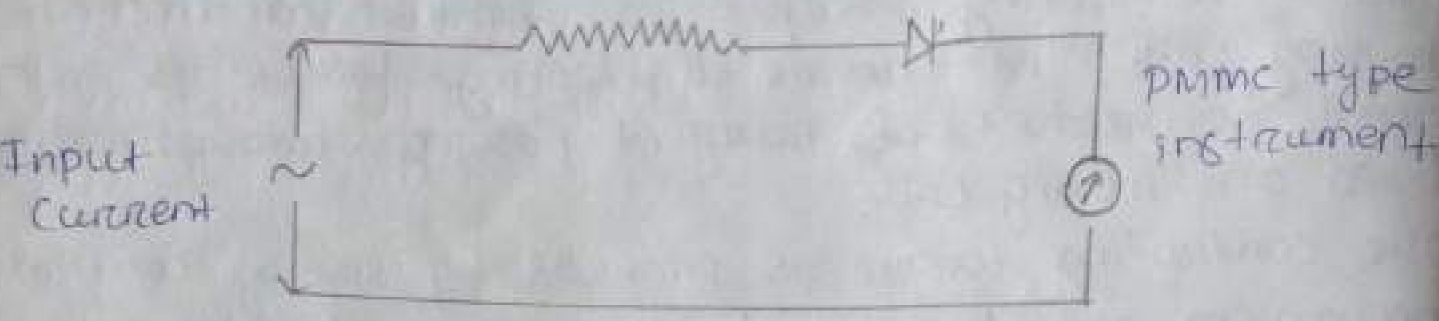


Fig:- Rectifier (Half wave) type instrument

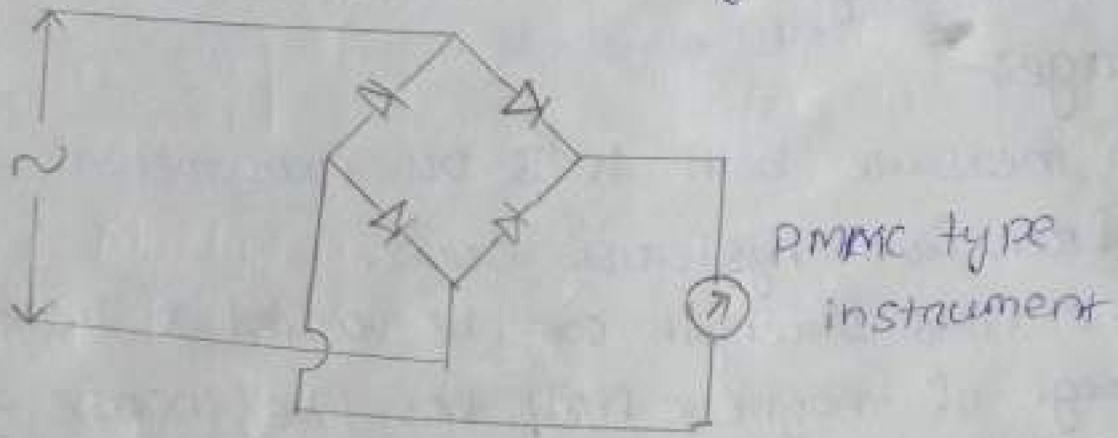


Fig-Rectifier (fullwave bridge) type instrument

→ PMMC type instrument are the most sensitive instrument than others but it can only measure DC quantity.

→ By connecting rectifiers to PMMC type instrument it can be used for AC quantity measurements.

Ammeter shunt:-

Extension of Range of Ammeter:-

→ Current range of a DC ammeter may be varied by connecting different values of shunt resistance this type of DC ammeter where multiple Rsh is present is known as multirange ammeter.

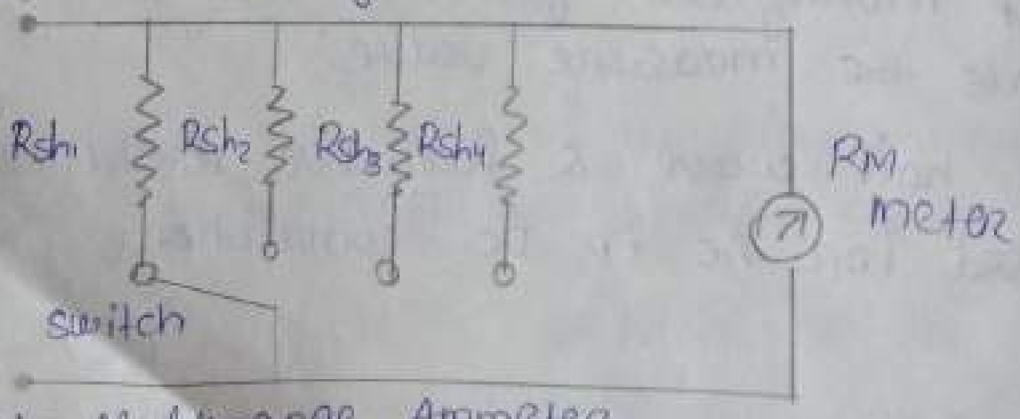


fig:- Multirange Ammeter

→ In the above circuit 4 shunt resistances Rsh1, Rsh2, Rsh3, & Rsh4 are connected in parallel with the meter, which can provide 4 different current range I_1, I_2, I_3 & I_4 respectively.

→ Let M_1, M_2, M_3 & M_4 are the shunt multiplaying power for current I_1, I_2, I_3, & I_4 respectively.

$M_1 = I_1 / I_m$ $\quad m_3 = I_3 / I_m$

$m_2 = I_2 / I_m$ $\quad m_4 = I_4 / I_m$

where,

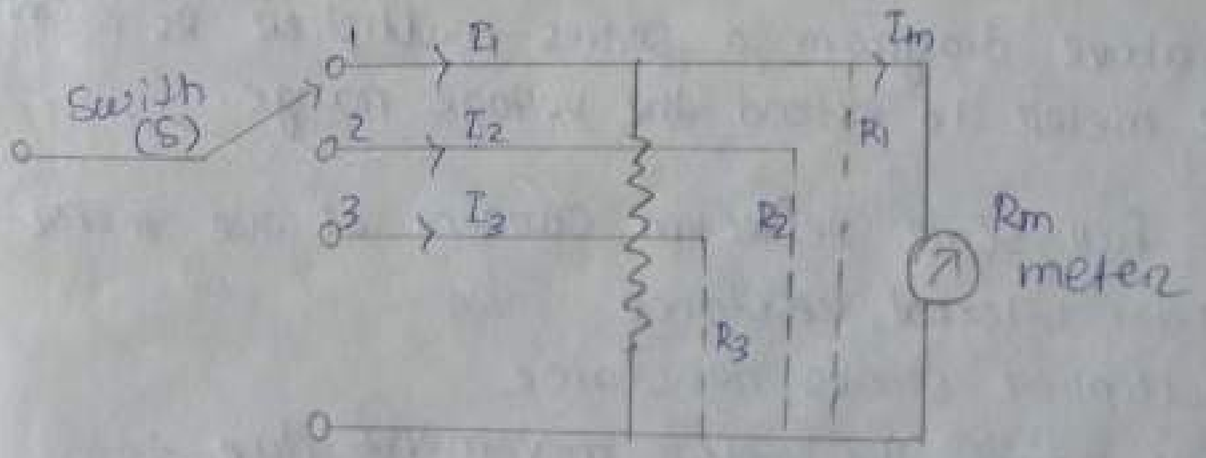
I_m = full scale deflection current.

$$R_{sh1} = \frac{R_m}{(m_1 - 1)} \qquad R_{sh3} = \frac{R_m}{(m_3 - 1)}$$

$$R_{sh2} = \frac{R_m}{(m_2 - 1)} \qquad R_{sh4} = \frac{R_m}{(m_4 - 1)}$$

→ This ammeter uses a multiposition make before break switch (S) to select different shunt resistance this switch is a special switch which is required during the current range changing.

Universal shunt :-



$I_m R_m = (I_1 - I_m) R_1$

$\Rightarrow I_m R_m = I_1 R_1 - I_m R_1$

$\Rightarrow I_m R_m + I_m R_1 = I_1 R_1$

$\Rightarrow I_m (R_1 + R_m) = I_1 R_1$

$\Rightarrow \frac{I_1}{I_m} = \frac{R_1 + R_m}{R_1}$

$\Rightarrow \boxed{m = 1 + \frac{R_m}{R_1}}$

$\Rightarrow \frac{R_m}{R_1} = m_1 - 1$

$\Rightarrow R_1 = \frac{R_m}{m_1 - 1}$

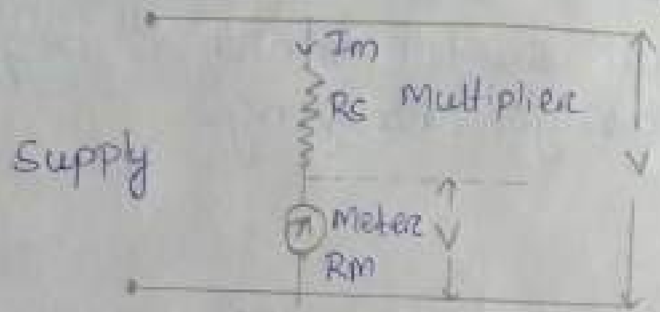
similarly we can derive $R_2 = \frac{R_m}{(m_2 - 1)}$

$R_3 = \frac{R_m}{(m_3 - 1)}$

Voltmeter Multiplier :-

→ To convert a basic meter movement into voltmeter a series resistance is connected with it. This series resistance is known as multiplier.

→ The multiplier limits the current through the meter so that it does not exists the value of full scale deflection current and prevents it from getting damage.



In the above diagram a series multiplier Rs is connected with the meter to extend the voltage range.

Let,

I_m = full scale deflection current of the meter

R_m = Meter internal resistance

R_s = Multiplier series resistance

v = voltage acros the meter movement due to current (I_m)

V = Full range voltage of the instrument after connecting Rs.

$u = I_m R_m$

$V = I_m (R_S + R_m)$

$\Rightarrow \frac{V}{I_m} - R_m = R_S$

$\Rightarrow R_S = \frac{V}{I_m} - R_m$

The multiplying factor for the multiplier

$\boxed{m = \frac{V}{u}}$

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

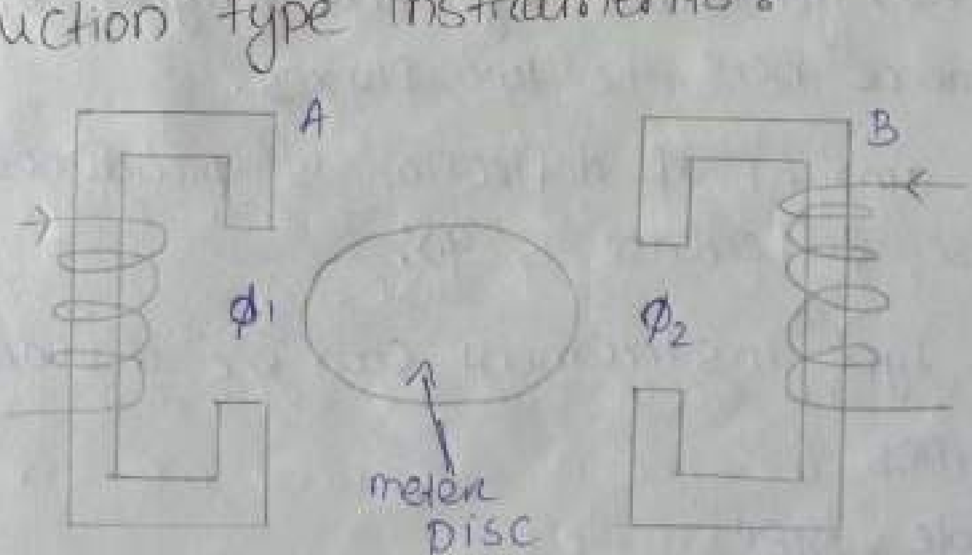
$\Rightarrow m = \frac{R_S + R_m}{R_m}$

$\Rightarrow m = \frac{R_S}{R_m} + 1$

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

- The multiplier resistance should not change with time and should have small temperature coefficient.

* Induction type Instruments :-



The above figure show an 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 instrument generally the metal disc is made up of Aluminium.

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

Working:-

→ The electro magnet A & B Produces flux ϕ_1 & ϕ_2 respectively.

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

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

→ The deflecting torque $(T_1) \propto \phi_{1m} \phi_{2m} \sin\theta$

where

ϕ_{1m} = maximum flux generated by electromagnet A

ϕ_{2m} = Maximum flux generated by electromagnet B.

θ = Phase difference betn the two fluxes.

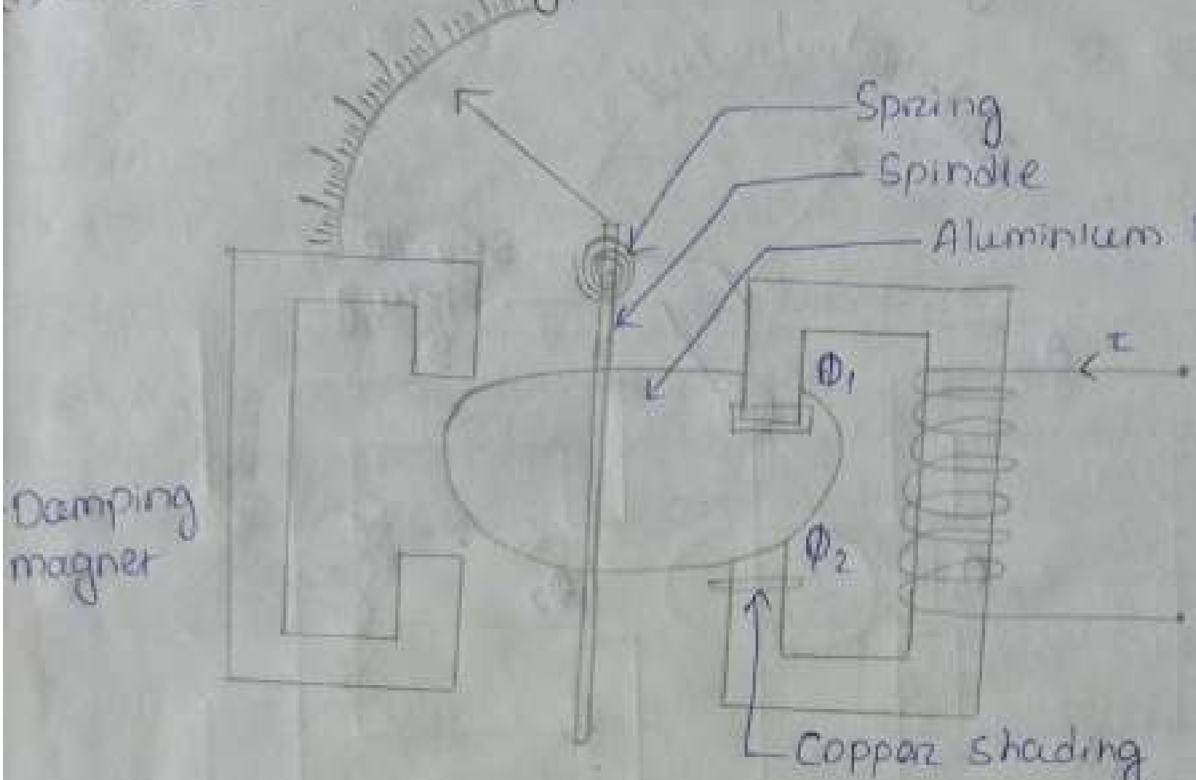
The maximum amount of deflection is produced when the phase difference is 90°.

The induction type instrument can be divided into two types

(i) Shaded pole type

(ii) Split phase type

(ii) Shaded Pole Type:-



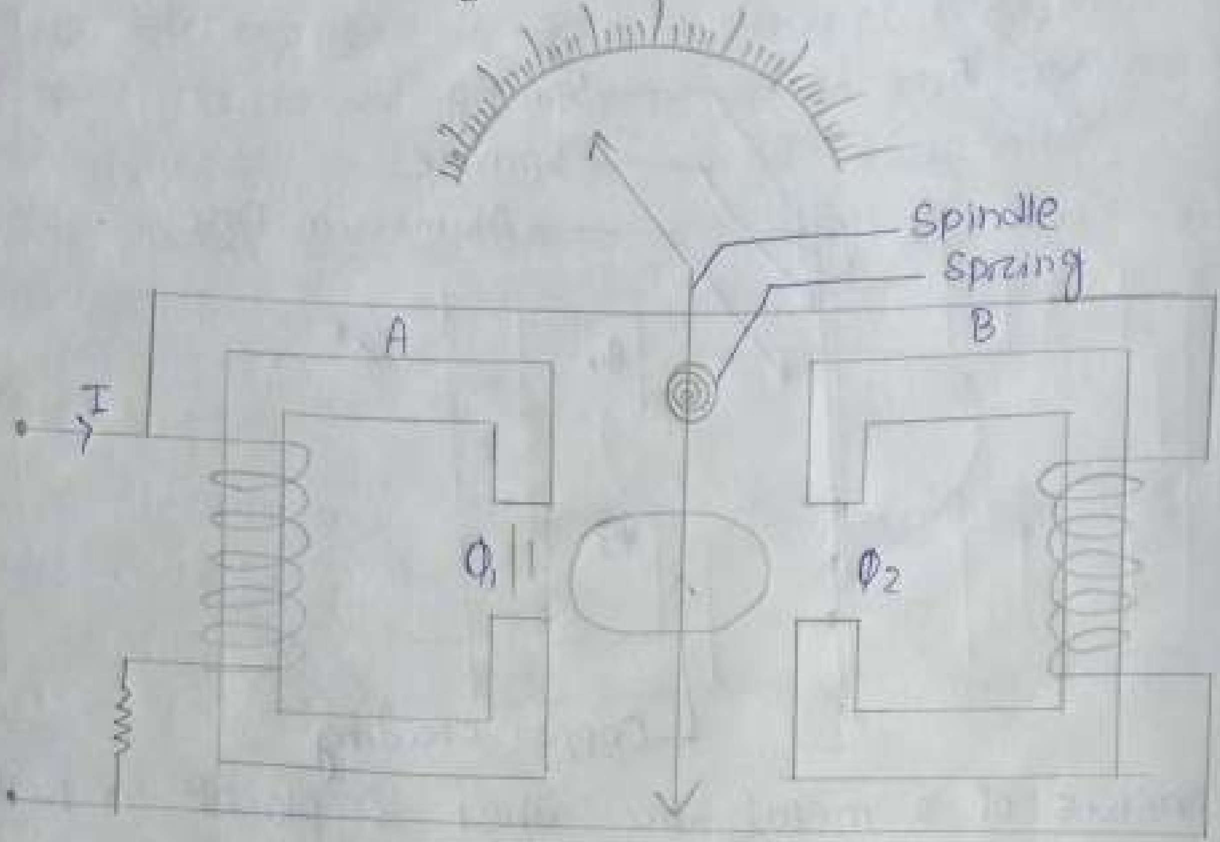
→ It is consists of a metal disc which is placed in betn the poles of an electromagnet. One damping magnet is present to absorb the oscillation of the disc.

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

→ When the electro-magnet winding is excited than two flux as ϕ_1 & ϕ_2 are induced on the metal disc & deflecting torque is produced.

→ A spindle is attached to the metal disc which get deflected w.r.t the aluminium disc.

(II) Split phase type :-



→ In this type of induction type instrument two electromagnets are present to generate two flux ϕs ϕ_1 & ϕ_2

→ The aluminium disc is placed in betn the two electromagnets where the flux ϕ_1 & ϕ_2 are pla

→ The deflecting torque is produced on the metal disc due to the phase difference in ϕ_1 & ϕ_2

→ The spindle attached to the metal plate g deflected w.r.t the metal disc.

Advantages :- The scale can be extended over 300°. Less maintainance is required as the instrument is very simple.

Disadvantages :- It is only used for AC quantiti measurement and can not used DC quantity. It has non-uniform scale deflection.

CHAPTER - 3

Wattmeters and Measurement of Power:-

Wattmeter is an instrument which is used to measure the power developed in a circuit across a load.

Electrodynamometer type Wattmeter:-

Electrodynamometer type wattmeter design is similar to the electrodynamometer instrument which is used for the measurement of current and voltage.

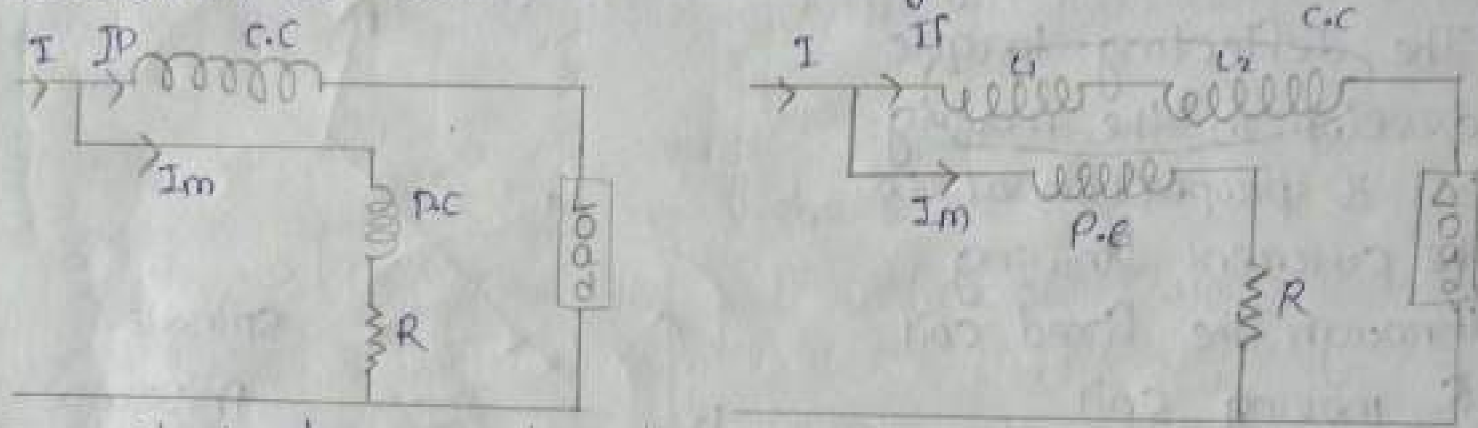


Fig :- Electrodynamometer type wattmeter

The electrodynamometer type wattmeter which is use for measurement of power, consists of 2 coil which are :-

1- Fixed coil (current coil)
2- Moving Coil (Pressure coil)

Fixed Coil:-

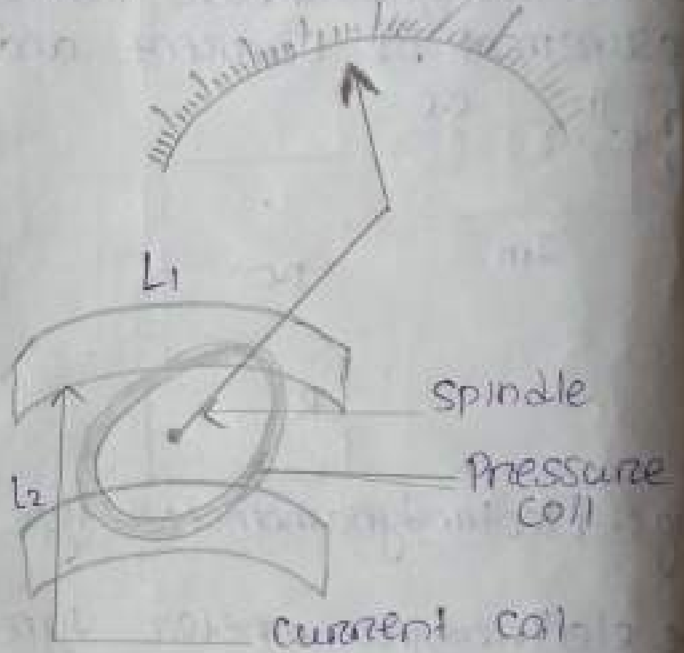
- The fixed coil is connected in series with the load and carry the current in the circuit. Therefore it is called as current coil or current coil of wattmeter.
- This fixed coil is divided into two halfs.
- The wires present in this coil are laminated & are very heavy wires which can carry a large amount of current.

Moving Coil :-

→ The moving coil is connected across the load, So that the Current proporsional to the voltage drop can flow through the coil. Since the current proporsional to the voltage is flowing through it. It is also called voltage coil or pressure coil

→ The moving coil is mounted on a spindle. So that it can move frealy.

→ The deflecting torque develop in the moving coil is proporsional to the current flowing through the fixed coil & moving coil



$T_d \propto I_p \cdot I_m$

$T_d \propto I_f \frac{V}{R_m}$

$T_d \propto$ power

→ If 'ϕ' is the angle betn the voltage & current in the current coil show we can say that current lags the voltage by an angle 'ϕ'.

→ If 'M' mutual inductance betn the coils then we write.

$$\boxed{T_d = \frac{V I_f}{R_m} \cos\phi \cdot \frac{dm}{d\phi}}$$

Erros in Dynamometer type instrument :-

The deflection of the pointer is dependent on the power factor of the load so the pointer deflection many varie produce an error wild measuring low power factor loads.

So another type of arrangement is made to measure this type of load powers which is known as LPF wattmeter.

Working:-

→ When the current passes through the fixed coil & moving coil than due to the interaction of generated magnetic field the moving coil turns about its axis.

→ The pointer is connected to the spindle of moving coil which also get deflected due to the moving coil moment.

→ Spring controls are connected to the moving coil spindle to provide the controlling torque

→ Air friction damping is used to absorb the oscillation of the instrument.

Low power factor type dynamometer wattmeter:-

→ Ordinary electrodynamometer wattmeter can n't measure the power in circuit having low power factor without any error.

→ This happence beacuse the deflecting torque in the moving system is small for low power factor and error introduced in the pressure coil is very large at low power factor.

→ So sum special feature are incorporated in an electrodynamometer type wattmeter to make it low power factor type. This features are

1) Pressure coil current:-

→ The pressure coil current in low power factor wattmeter is generally 10 times the value employed for high power factor wattmeter so resistance of the pressure coil is decreases to allow the current flow through it.

→ If the pressure coil current will increase than more amount of deflecting torque is produced.

(II) Compensation of pressure Current Coil:-

The power loss in the pressure coil is compensate by connecting a compensating coil with the pressure coil in series.

(III) Compensation for inductance of pressure coil:-

→ Due to low power factor the value of phase angle 'ϕ' is large and it gives high error.

→ This ~~error~~ can be compensated by connecting a capacitor across a part of series resistance in pressure coil.

(IV) Low power factor type wattmeters are design with small controlling torque:-

By incorporating the above features the low power factor type wattmeter can be represented as bellow

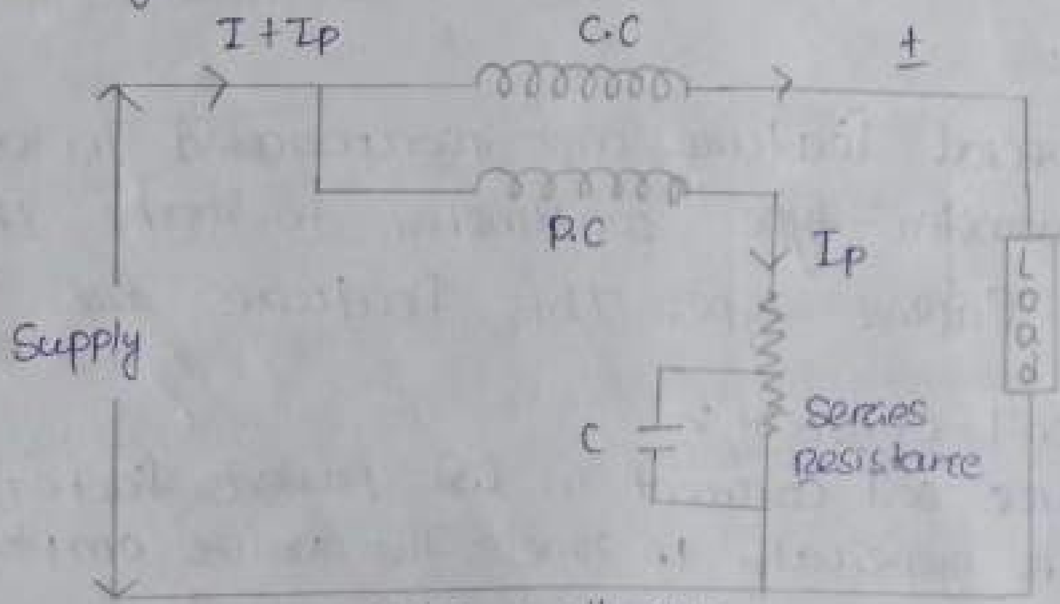


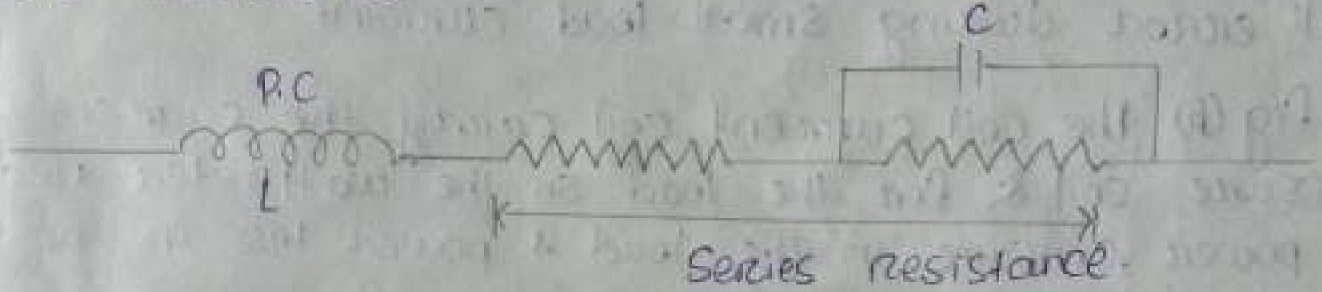
Fig: LPF type Dynamometer wattmeter

Errore in dynamometer type instrument:-

i) Error due to pressure coil inductance:-

→ Due to the pressure coil inductance the wattmeter reading can vary while measuring low power factor (lagging power factor).

→ This error can be compensation by means of connecting capacitor in parallel with a portion of pressure coil series resistance.



ii) Error due to pressure coil Capacitance:-

→ The pressure coil circuit may possess capacitance which atterse the wattmeter reading to sun extend. this effect is not present by measuring at low frequency but it's effect increases with increase in frequency.

iii) Error caused due to connection:-

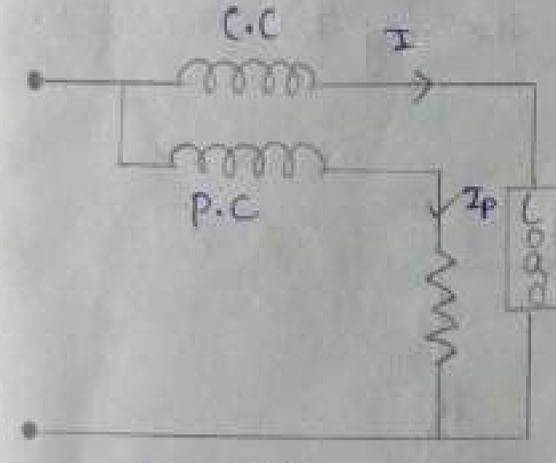


Fig (a)

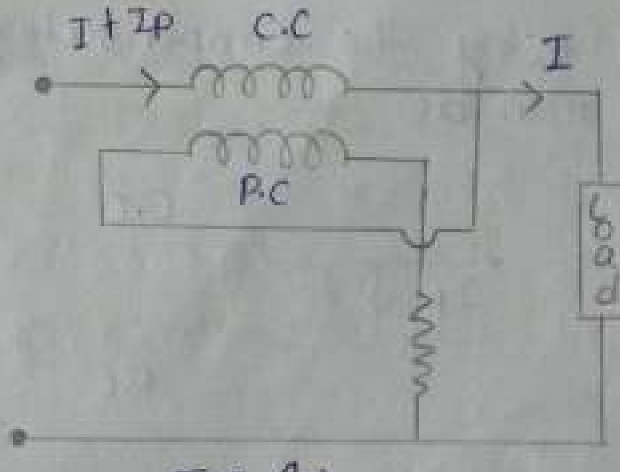


Fig (b)

→ Wattmeter can be conected two alternating ways as shown in figure a & b

→ In fig (a) the pressure coil is connected in the supply side, so the voltage drop across the pressure coil is equals to the across the current coil.

→ So the power indicated by the wattmeter power consume by the load + power loss in current coil.

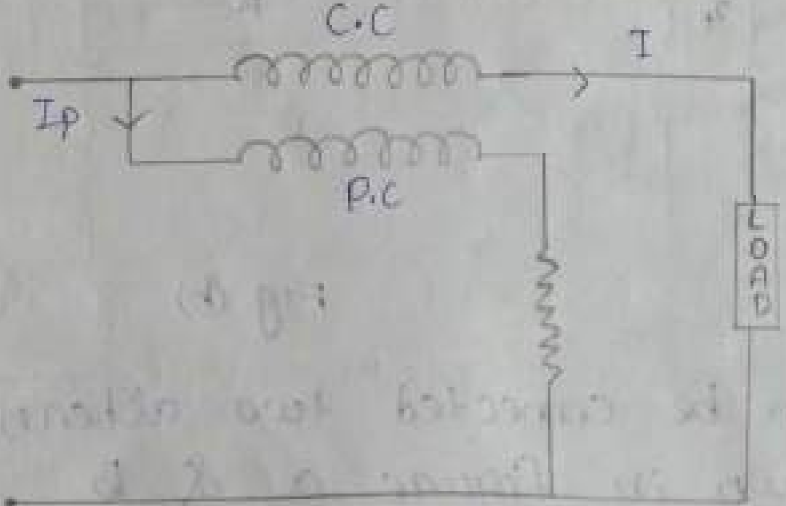
→ When the load current is small the voltage drop in current coil is small so figure (a) interduced small error during small load current.

→ In fig (b) the coil current coil carry the current for pressure coil & for the load so the wattmeter reads the power consume in the load + power loss in the pressure coil.

→ So when the load current is high but the pressure coil current is less than fig (b) arrangement is used.

→ In fig (b) current coil carries ($I + I_p$) so the magnetic field corresponding to this current is also produced to compensate this magnetic field a compensating coil is connected with series in the pressure coil which is may identical with the coil.

→ After using the compensating coil the fig (b) can be read run as



v) Eddy Current Error:-

→ Eddy Current are induced in the solid metal parts of the instrument & also within the conductor present in the instrument.

→ This current produce it's own field and alter the magnitude & phase of the current coil & pressure coil field, which cause error in the instrument.

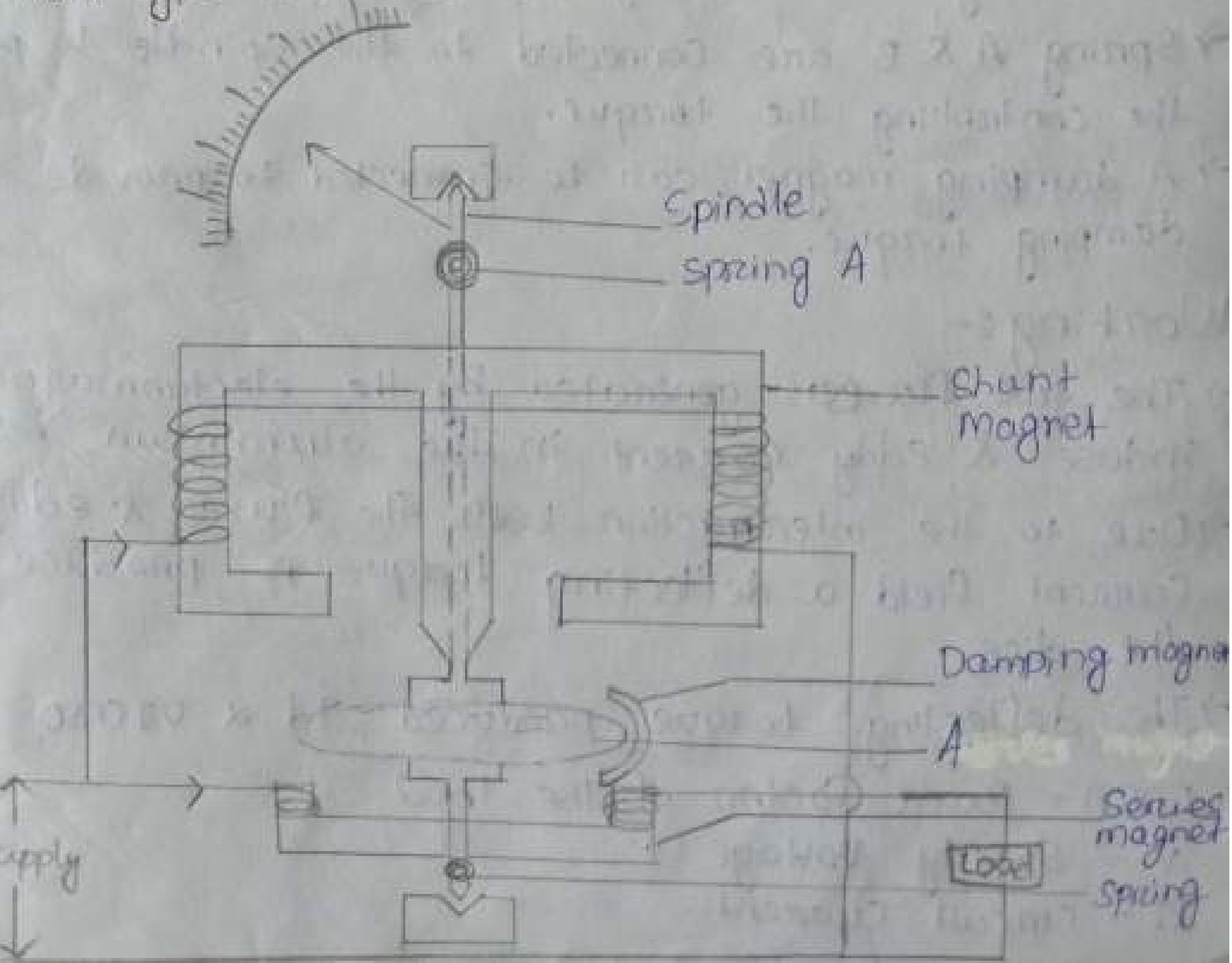
) Stray Magnetic field Error:-

• The electro dynamometer wattmeter has a relatively which magnetic field which is responsible for the generation of Td.

→ This magnetic field is affect by the outside stray magnetic field & causes error.

→ This error can be reduced by proper shielding of the instrument against the stray magnetic field.

Induction type Wattmeter:-



→ The induction type wattmeter is used to measure only the AC power consume by the load.

→ It works on the same principle of as a induction type voltmeter & ammeter instrument.

Construction :-

→ The induction type wattmeter consists of two laminated electro magnets known as Shunt magnet or series magnet.

→ The Series magnet is connected in series with the load and is excited by the load current.

→ The shunt magnet is connected across the load & is excited by the current proportional to voltage across the load.

→ An aluminium disc is mounted in between the two electro magnets in such a way that it cuts the fluxes produce by both the magnets.

→ Spring A & B are connected to the spindle to provide the controlling the torque.

→ A damping magnet can be connected to provide the damping torque.

Working :-

→ The two fluxes generated by the electromagnet induce & eddy current in the aluminium disc.

→ Due to the interaction betn the fluxes & eddy current field a deflecting torque is produce on the disc.

→ The deflecting torque produced $T_d \propto VI\cos\theta$

$\cos\theta$ = Power factor of the load

V = Supply voltage

I = Circuit current.

Advantages:-

The dumping torque is produced is very effective.

The induction type instrument has a very large Scale range.

Disadvantages:-

Change in atmospheric temperature can very the resistance of the moving aluminium disc which effects the deflecting torque.

CHAPTER-4

Energy Meter & Measurement of Energy:-

Energy is defined as the power consume by the load over a particular interval of time Energy = Power × time

$E = P \times t$

$E = \int_0^t P\,dt$

$E = \int_0^t VI\,dt$

If the voltage is measured in voltage & current 'I' is measured in ampere time 't' is second. than the energy consumed can be expressed in watt second unit.

1 watt second = 1 Joule

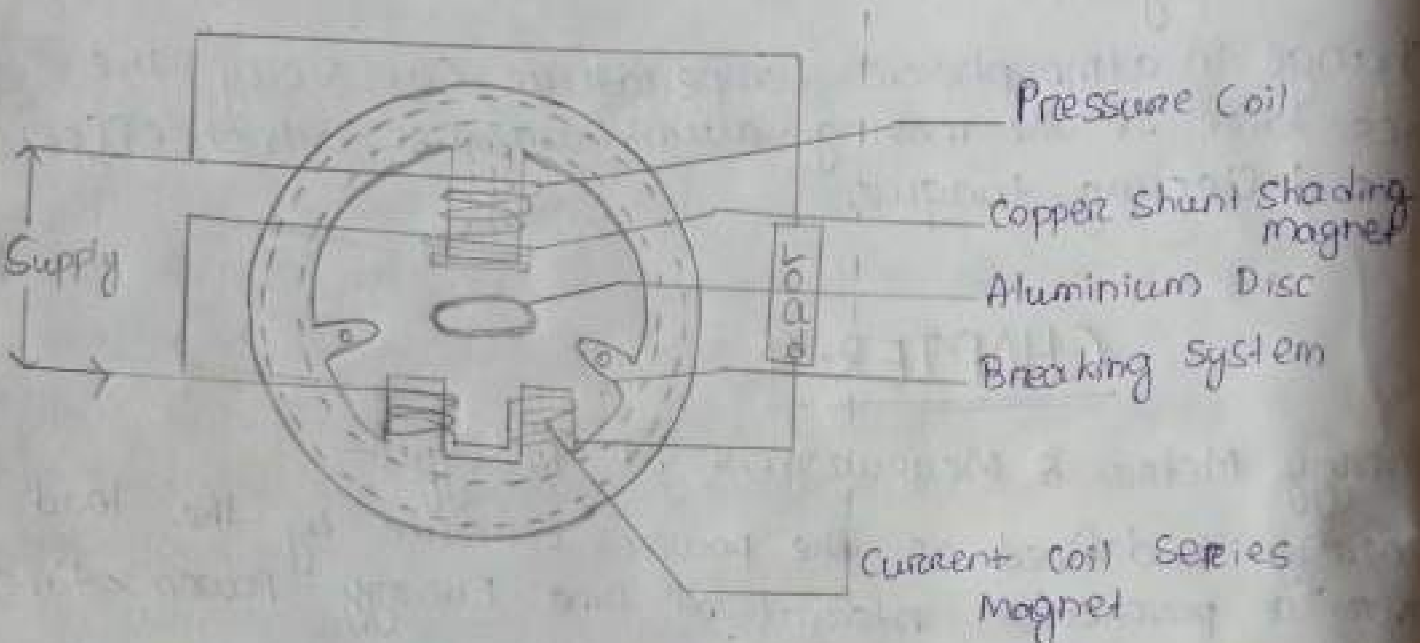
If the time interval 't' is in hour than the energy can be expressed watt hour unit.

1000 watt hour is also called as 1 unit in domestic energy meters. $\boxed{1 \text{ KWH} = 1 \text{ unit}}$

Energy meter is the device or instrument which is used to measure the ~~xxxx~~ energy consume by the load.

→ Generally induction type energy meters are universally used for measurement of energy in domestic & industrial AC circuit.

Single phase induction type energy meter:-



Construction:-

There are 4 main parts in the energy meter system which are:

1) Driving system
2) Moving system
3) Breaking system
4) Registering or Counting system

1) Driving System:-

→ The driving system consist of 2 electromagnets. one of the coil or electro-magnet is excited by the load current & is called as current coil or series magnet.

→ Another coil or electromagnet is excited by the current proportional to the voltage across the load this coil is connected across the load & is known pressure coil or shunt magnet.

→ Copper shaddings may be provided to adjust the flux produced by the shunt magnet.

2) Moving System:-

→ Moving system consists of an aluminium disc mounted on alloy shaft. This disc is present within the airgap between the series & shunt magnet.

→ A pointer is connected to the shaft or the moving system to connect it to the resistering or counting system.

3) Breaking System:-

→ A permanent magnet is position near the edge of the aluminium disc to provide the breaking system.

→ The breaking system is used to control the speed of the moving system.

→ By adjusting the position of permanent magnet breaking torque can be adjusted.

4) Resistering / Counting System:-

→ The function of a resistering & counting system is to record contineausly a number which is proporsional to the revolution of the moving system.

→ By using a series of reduction gears the pointer of the shaft drives 5 or 6 no. of pointers to display the value.

→ The above registering gear arrangement is also called as cyclometer resister.

Energy Compensations:-

1) Light load compensation / friction
2) Creap compensation
3) Overload compensation
4) Temperature compensation
5) Voltage compensation

1) Light load Compensation :-

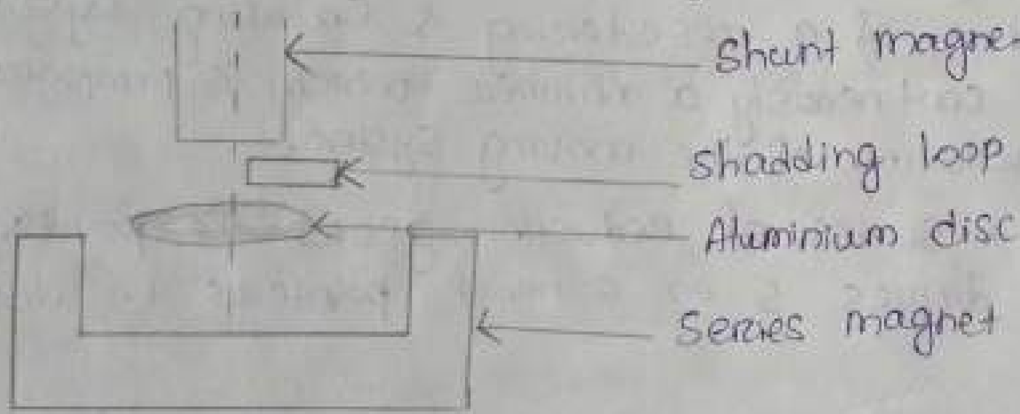
→ The jewelled pivot bearings for the spindle provides asum friction to the movement of aluminium disc.

→ During lowload & light load supply we nead to generate an extra small torque to over come this friction.

→ This is because during light load very small amount of driving torque is generated which is not sufficient to overcome the friction & move the aluminium disc.

→ To compensate this light load condition small shadding pole or loop is added in betn the center of the pole of the shunt magnet & the disc.

→ This shadding loop is slightly placed towards one side of the centre line of shunt magnet.



→ The interraction betn the portion of shadded & unshadded flux & the current induced in the disc generates a torque which can be used for friction compensation.

2) Creap Compensation :-

→ In sum meters a slow rotation of the disc is obtained even when there is no current flowing through the current coil this is known as creaping.

→ In order to prevent this creeping to diameter holes are grilled in the disc. The disc comes to rest when one of the holes in under the edge of the pole.

3) Overload Compensation:-

→ During overload codition to compensate the driving & it's proporsional to breaking torque an extra magnetic shunt are used in the device.

→ The magnetic shunt approaches & saturate & divirt the Series magnetic flux to the disc air gap. Due to this action the driving torque during the overload condition can be controlled.

4) Temperature Compensation:-

→ An increase in atmospheric temperature can increas the resistance of all copper & aluminium parts present in the device.

→ Due to this change in resistance the lag between the supply voltage 'V' & ϕ_p changes eddy current flowing in the aluminium disc also varies.

→ In order to compensate the imfact of increase in temperature the meter should be installed with proper shelding.

→ A special material meter can be used to make different parts of the device which is very less Sensitive to temperature.

5) Voltage Compensation:-

Compensation for voltage variation can be provided by using magnetic shunt to divert the flux into the disc & to the active part if it is required.

CHAPTER-5

Measurement of Speed Frequency and Power Factor

Tachometer :-

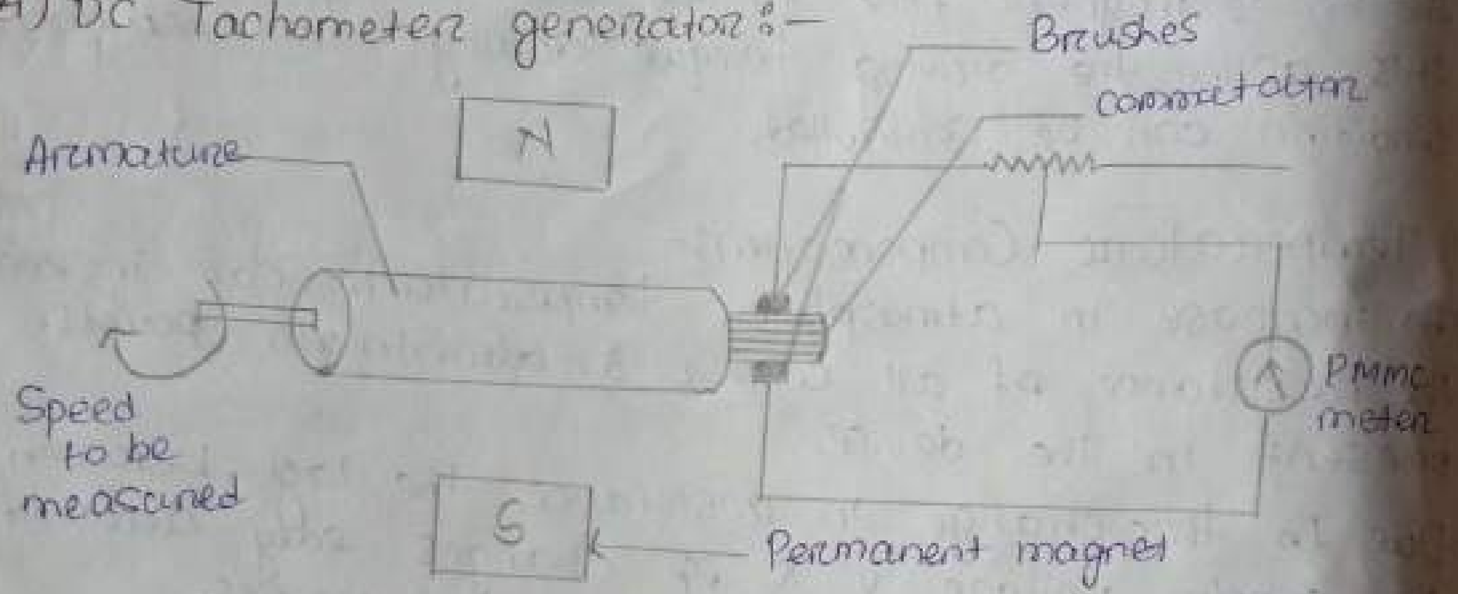
→ Tachometer is an equipment which is used for the speed measurement of any device.

→ It is classified in to 2 types.

(A) DC Tachometer generator

(B) AC Tachometer generator

(A) DC Tachometer generator :-



→ DC tachometer consist of a small armature which is connected to the machine whose speed is to be mesured.

→ This armature coil revolves within the permanent magnetic field.

→ Due to the rotation of armature within the magnetic field an emf is induced in the armature coil

→ This used emf is proporsional to flux speed of rotation

→ Since for this permanent magnetic field flux is constant so the generator voltage is proporsional to speed of rotation.

→ Induced emf can be collected by the help of commutator & brush arragements.

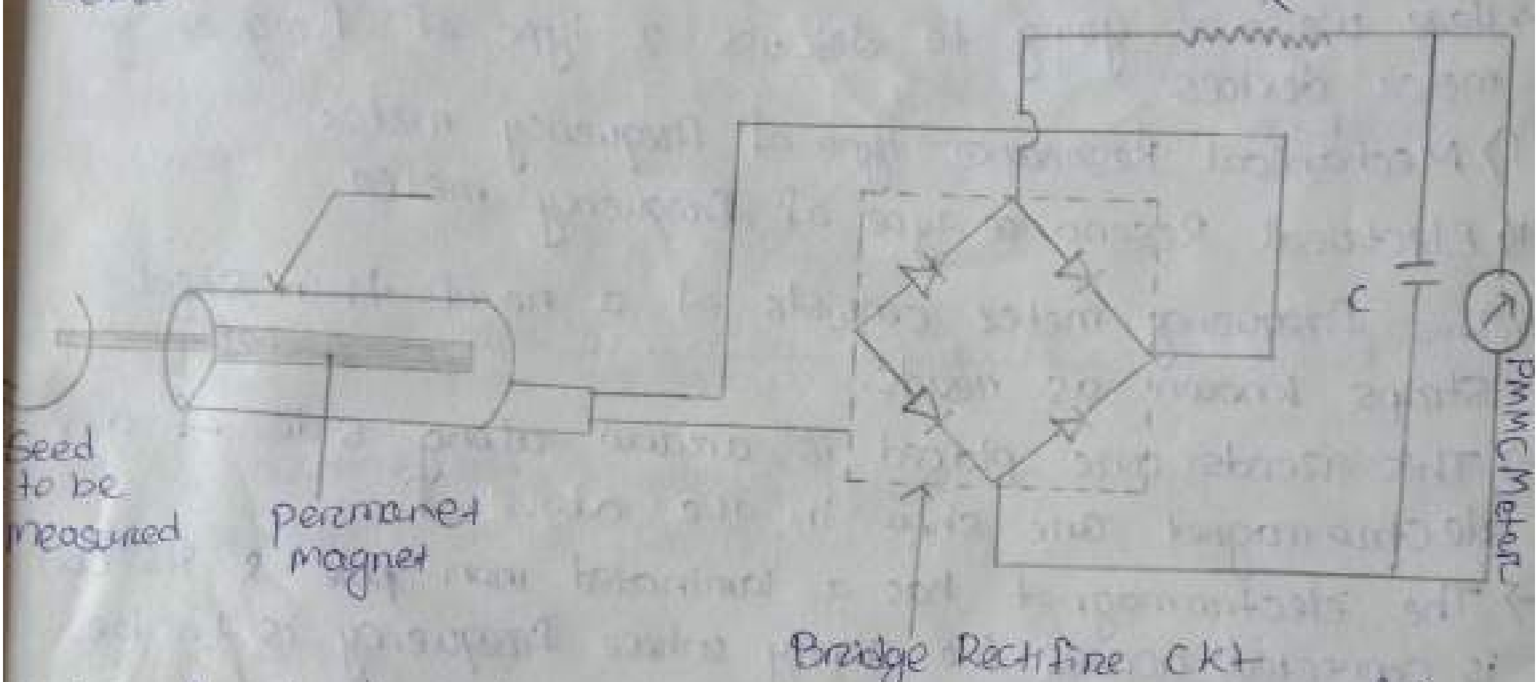
→ This voltage can be measured by using a PMMC type meter which can be calibrated with respect to speed.

(B) AC Tachometer generator :-

→ The AC tachometer generator contain rotating magnet which can be either an permanent magnet & electro magnet.

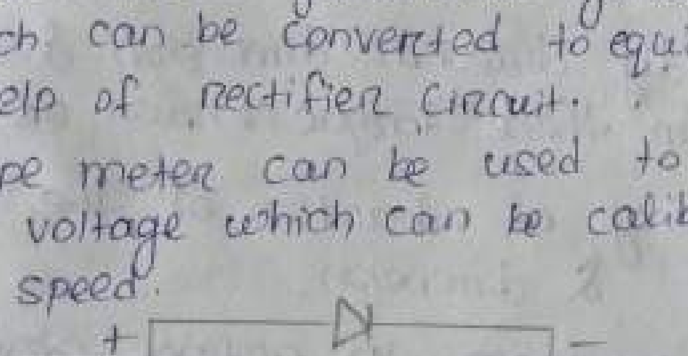
→ The AC tachometer generator generally generate AC voltage with respect to the measure speed.

→ The diagram of AC tachometer generator is show below



→ This AC tachometer generator generates output AC voltage which can be converted to equivalent DC voltage with the help of rectifier circuit.

→ A PMMC type meter can be used to indicate this generated voltage which can be calibrated w.r.t measured speed.



→ So we can easily identified the direction of speed using dc tachometer.

→ Dc tachometer required regular maintainse as the carbon brushes used in it. easily get damage.

→ Ac tachometer generator requires very less maintainance as compare to DC tachometer generator

Frequency Meter:-

→ Frequency meter is a device which is used to measure the frequency of supplied input signal.

→ Here we are going to discuss 2 type of frequency meter devices

1) Mechanical Resonance type of frequency meter

11) Electrical Resonance type of frequency meter.

→ This frequency meter consists of a no. of thin steel strips known as reads.

→ This reeds are placed is arrow along side of an electromagnet are show

→ The electromagnet has a laminated iron pole & its coil is connected across the supply whose frequency is to be measured.

→ The reeds are slidy direction dimension & carry direction weight on there torque known as flag.

→ The natural frequency of vibration of the reeds depends of an there weight & dimension.

→ This reeds are arrages in acting order of their natural frequency with a direction betn two adjacent reeds natural frequency of 0.5 Hz

→ The reed are fixed at the bottom & free to move toward torque.

Working:-

→ when the frequency meter is connected across the supplied the coil of the electro magnets carries a

... characteristics with respect to the supply frequency.

→ The force are reed varies in every half cycle so the read which has natural frequency twice of the supply frequency.

→ Satisfied the resonance condition & vibrates the motors. All the read tends to vibrate due to the supplied frequency the read which is resonance with vibrate the most & distimply visible.

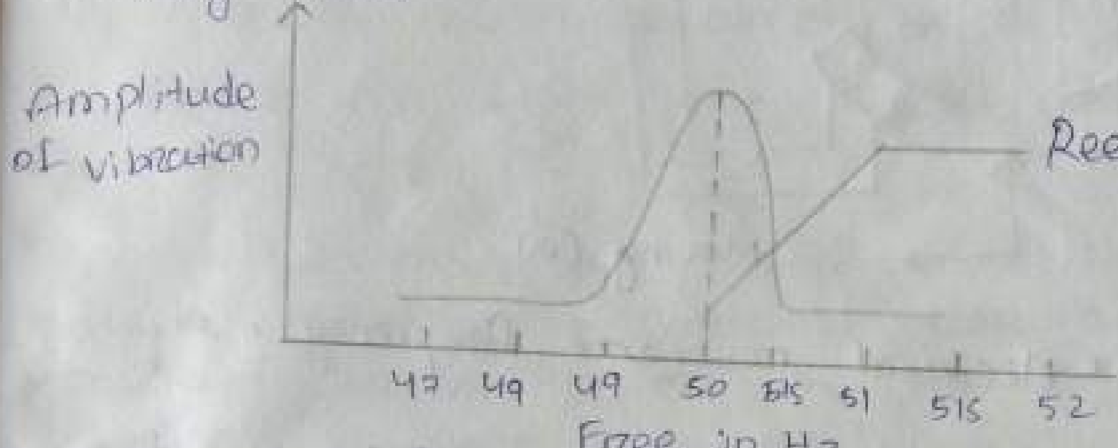


Fig:- Variation of amplitude of vibration with respect to frequency.

Disadvantages:-

→ The instrument can't be used to read small frequency value between two adjacent reeds.

→ The reliability of the reading depends open the accuracy with which the reeds are turned.

Electrical Resonance type of frequency meter:-

→ There are 2 type of electrical resonance type of frequency meter.

(i) Ferrodynamic type frequency meter

(ii) Electrodynamic type frequency meter.

Ferrodynamic type Frequency meter :-

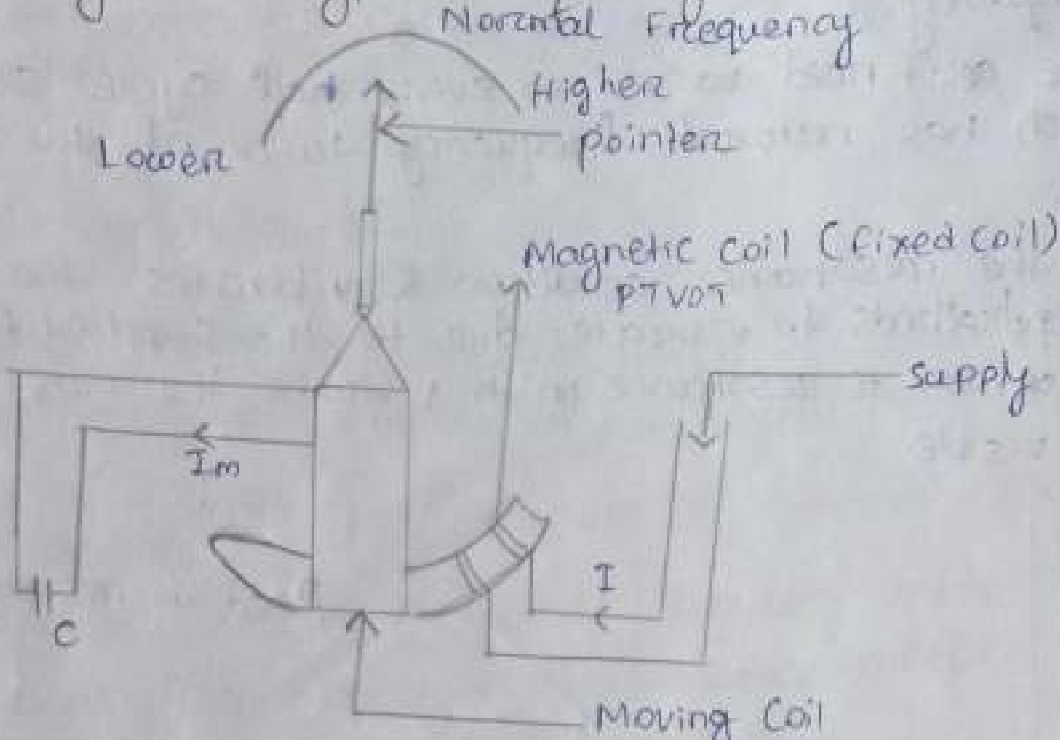


Fig :- Ferrodynamic electrical resonance frequency meter

→ The Ferrodynamic type frequency meter consists of a fixed coil which is connected across the supplied whose frequency is to be measured.

→ This fixed coil is known as magnetising coil & this coil is mounted on a laminated iron core.

→ The iron core crossection varries gradually over the length, it is maximum near the end where the magnetising coil is mounted.

→ A moving coil is pivoted over this iron core which is attached to a pointer. The moving coil terminal are connected across a capacitor (C).

Working:-

→ The capacitor reactance of the moving coil is constant but the inductive coil is not constant.

→ The inductive reactance of the moving coil depends upon the position of the moving coil over the magnetising coil.

› Suppose the frequency the supply increases then the inductive reactance (X_L) of the coil also increases. To acheived the resonance condition a torque is developed in the moving coil are described in phasor diagram.

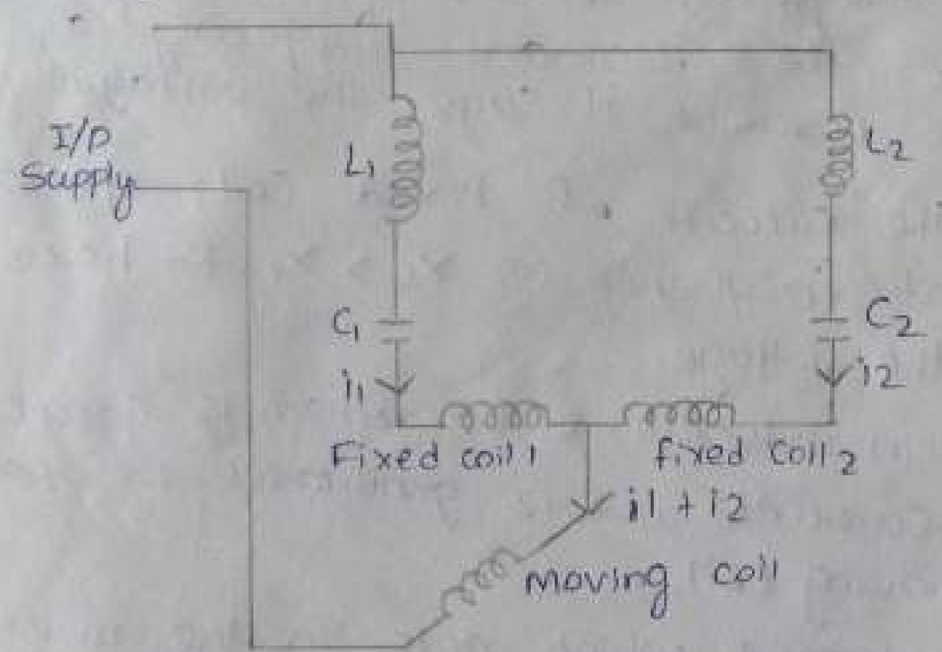
› If the supply frequency 'f' decreases from its normal value then the inductive reactance.

› Here the torque is developed to move the moving coil to achieve the resonance condition are describe.

› The moving coil with come to rest when will be equall to X_C or $f = \frac{1}{2\pi\sqrt{LC}}$.

› The torque move the coil to a position where inductive reactance = Capacitive reactance & due to moment of the moving coil the pointer also moves over the scale to show a particular frequency value.

Electrodynamometer type Frequencymeter:-



Construction:-

› In this type frequency meter one fixed coil is present which is divided into 2 parts i.e fixed coil 1 & fixed coil 2.

› Fixed coil 1 is in series with & inductance L_1 & a capacitance C_1. The value of L_1 & C_1 are choosen that its resonant frequency F_1 is slightly lower than the instrument frequency.

→ The fixed coil 2 is in series with and an inductance l_2 & a capacitance C_2. The value of l_2 & C_2 are so chossen that its resonant frequency of the instrument frequency.

→ Ex:- If 50Hz is the middle scale of the instrument frequency than $F_1 \simeq 40Hz$, $F_2 \simeq 60Hz$

$$F_1 = \frac{1}{2\pi\sqrt{l_1 C_1}} , \quad F_2 = \frac{1}{2\pi\sqrt{l_2 C_2}}$$

→ One moving coil is connected in between the fixed coil 1 & fixed coil 2 through which $I_1 + I_2$ current flows.

Working:-

→ For an applyed frequency of the ckt of fixed coil 1 operates above the resonant frequency as $X_L > X_C$. So here current i_1 lags the voltage.

→ At that time the circuit of fixed coil 2 operates below the resonant frequency as $X_C > X_L$. So here current i_2 leads the voltage.

→ Since one circuit in inductive & the other is capacitive therefore the 2 currents i_1 & i_2 generates to opposite torques on the moving coil.

→ The resultant torque which acts on the moving coil is a fcretion of frequency of the applyed voltage

→ The movement of the moving coil can be calibrated over a scale interms of frequency.

Power Factor Meter :-

→ The instrument which indicates the power factor of a load circuit to which their connected is called as power factor meter.

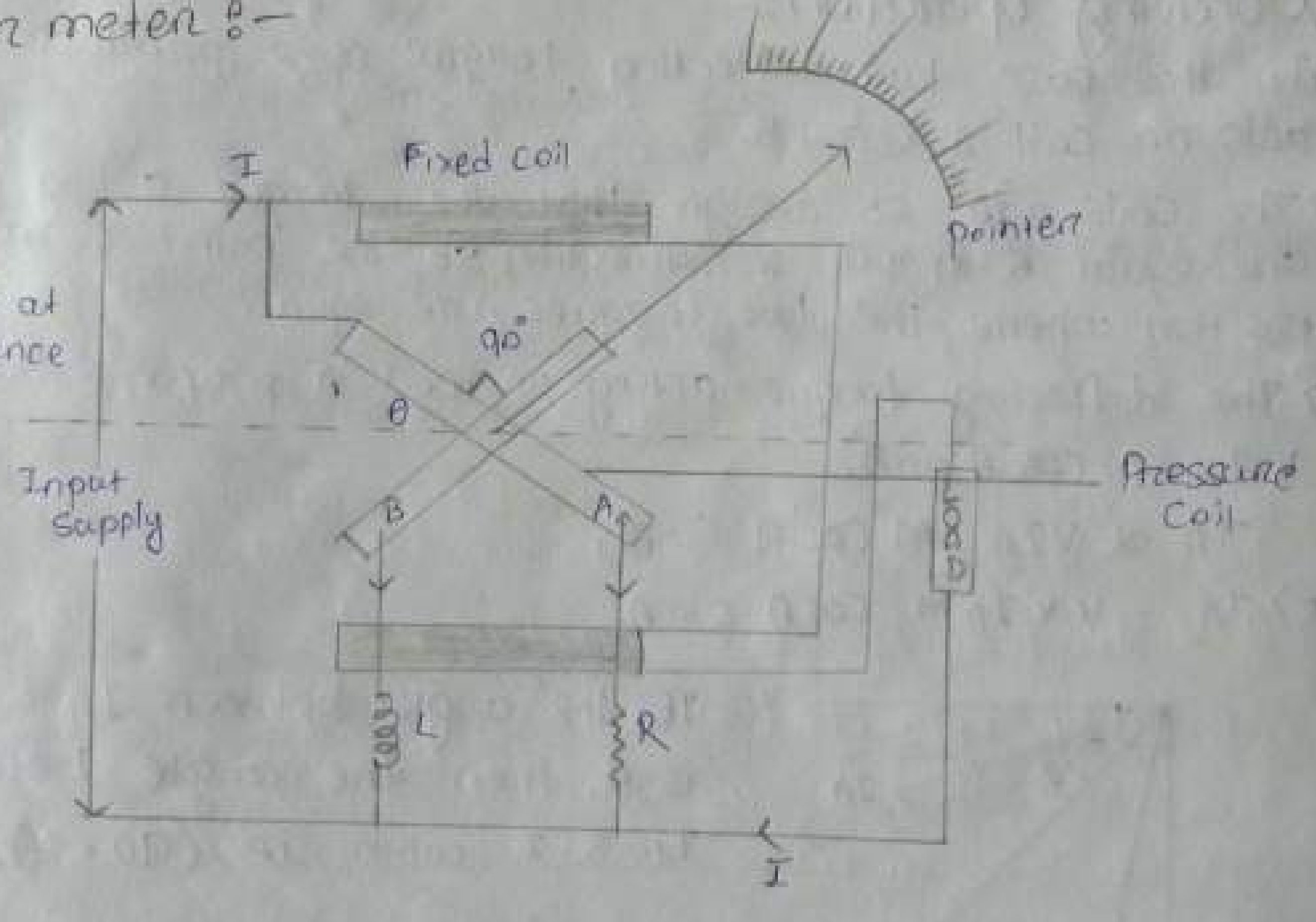
$P = VI \cos\theta$

$\Rightarrow \cos\theta = \frac{P}{VI}$

where, $\cos\theta$ is known as power factor of the load

→ So to measure the power factor current voltage & power consume in an AC ckt power factor meter is similar to wattmeter.

Single phase Electrodynamometer type power factor meter :-



Construction :-

→ The single phase electrodynamometer type power factor consist of fixed coil & pressure coil.

→ The fixed coil splits into two parts and carries the current of the circuit which is supplied to the load.

→ The pressure coil also consists of two coils that is coil A & coil B.

→ These two pressure coil pivotted on a spindle which constitute the moving system.

→ Pressure coil 'A' is connected in series with a resistance 'R' and pressure coil B is connected in series with inductance 'L'.

→ The current proportional to the voltage drop across the load flows through the pressure coil.

→ The value of R & L are so adjusted that $\boxed{R = 2\pi f L}$ the angle between the plane of the coil is made equal to 90°. The current I_B lags the voltage by 90°. current I_A is in phase with voltage is insame phase.

Working operation:-

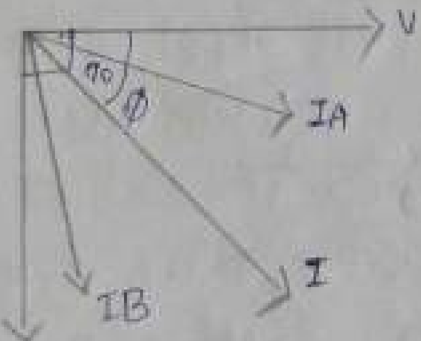
→ In this case two deflecting torque are produce which acts on coil A & coil B.

→ The coils are so design that the torque acting on it are equal & opposite in direction so the pointer takes a position where the two torques are equal.

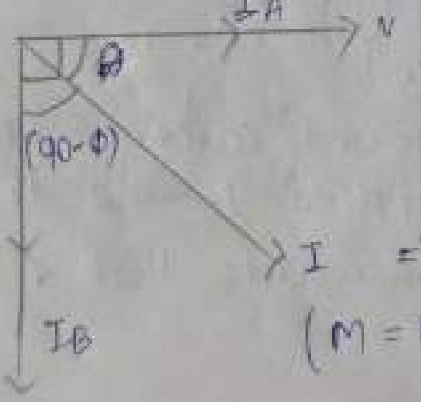
→ The deflecting torque acting on coil 'A' proportional to $V I_a M \cos\theta \sin\theta$.

$$T_A \propto V I_A M \cos\theta \sin\theta$$

$$\Rightarrow T_A = K V I_A M \cos\theta \sin\theta$$



If the angle between IA & I is Ø, then the angle between IB & I with be (90 - Ø).



The torque acting on pressure coil 'B'.

$$T_B \propto V I_B \cos(90-\phi) \sin(90+\theta)$$

$$\Rightarrow T_B = K V I_B \cos(90-\phi) \sin(90+\theta)$$

(M = Mutual inductance betwee coil A & coil B)

Since $T_A = T_B$

$\Rightarrow KVI_A M \cos\phi \sin\theta = KVI_B \cos(90-\phi) \sin(90+\theta)$

$\Rightarrow \cos\phi \sin\theta = \cos(90-\phi) \sin(90+\theta)$

$\Rightarrow \cos\phi \sin\theta = \sin\phi \cos\theta$

$\Rightarrow \cos\phi \sin\theta - \sin\phi \cos\theta = 0$

$\Rightarrow \sin(\theta-\phi) = 0$

$\Rightarrow \sin(\theta-\phi) = \sin 0$

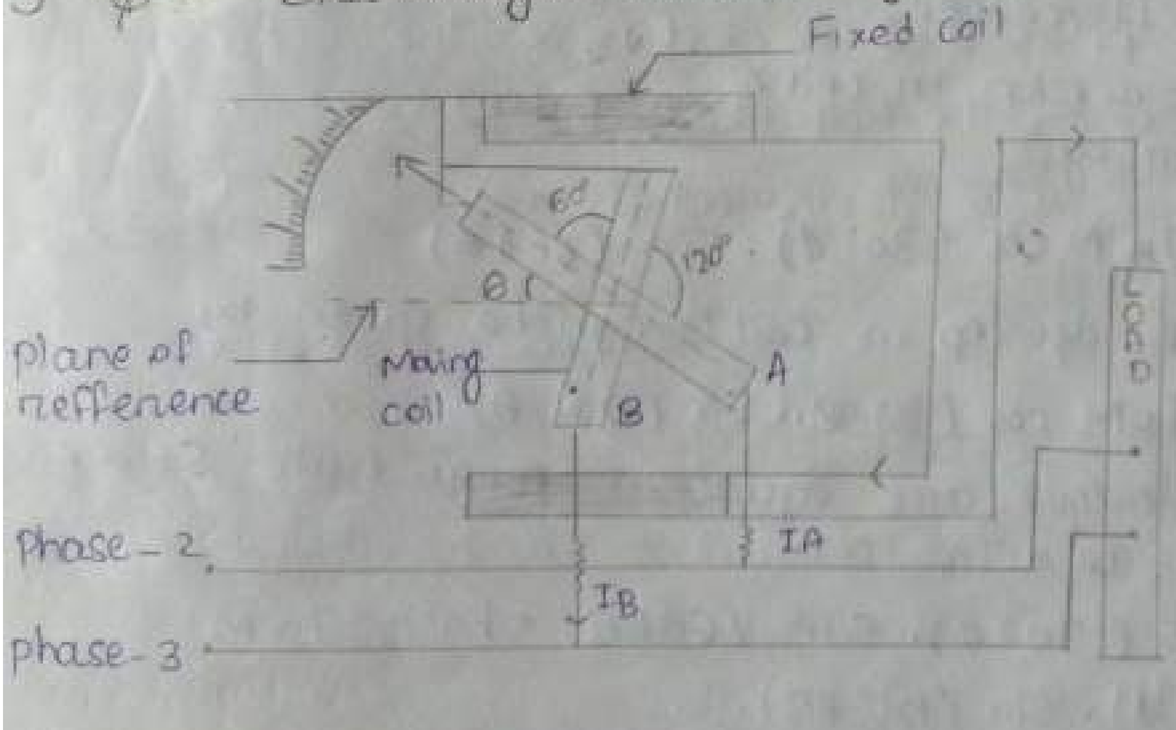
$\Rightarrow \theta - \phi = 0$

$\Rightarrow \boxed{\theta = \phi}$

⇒ So the deflection of the Instrument with respect to pressure coil A' is the meassure of phase angle of the circuit.

⇒ The scale of the instrument can be calibrated cosine of the phase angle that is power factor.

3- ϕ Electrodynamometer type power factor meter:-



Construction:-

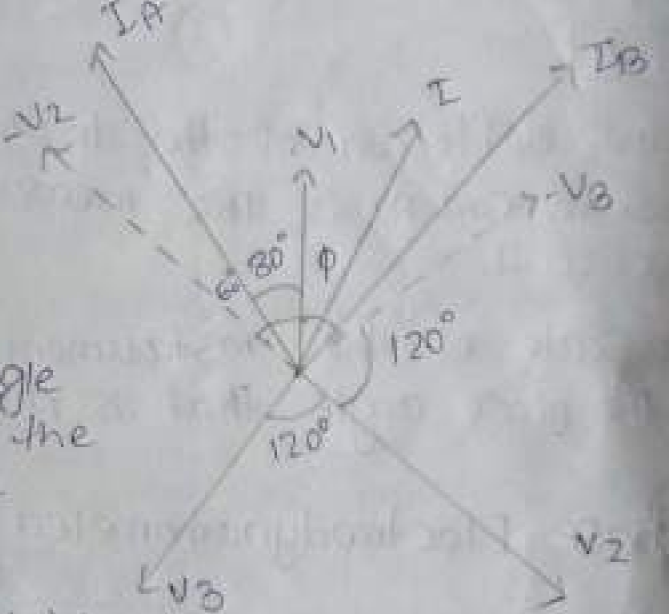
⇒ The above figure shows the construction & connection of a 3-phase electrodynamometer type power factor

⇒ The two moving coils of the meter are should placed that the angle between their place is 120° this two coils are connected across two different phase of the supply circuit.

→ Each of this two coils has series resistance through which it is connected to the phase angle. The voltage applyed across coil 'A' is V_{12} & the current flowing through it is I_A.

→ The voltage applyed across coil 'B' is V_{13} & the current flowing through it is I_B. The two moving coils are placed in between the segments of fixed coils.

Working:-



→ The torque developed in coil 'A' & coil 'B' are equal & opposite in direction.

→ Let 'ϕ' is the phase angle of the circuit & 'θ' is the angular deflection w.r.t plane of refference.

→ The torque develop in coil 'A' can be given by.

$T_A = k V_{12} I_A M \cos(30+\phi) \cdot \sin(60+\theta)$

→ The torque develop in coil 'B' can be given by

$T_B = k V_{13} I_B M \cos(30-\phi) \cdot \sin(120°+\theta)$

→ This two torque are equal in magnitude so we can write, $T_A = T_B$

→ $V_{12} I_A M \cos(30+\phi) \cdot \sin(60+\theta) = k V_{13} I_B M \cos(30-\phi) \cdot \sin(120°+\theta)$.

→ ~~This two torque are equal in magnitude so we can write, TA = TB~~

Since the voltage drop & the current flowing through the two coils are same

So $V_{12} = V_{13}$ & $I_A = I_B$

$\Rightarrow \cos(30+\phi) \cdot \sin(60+\theta) = \cos(30-\phi) \cdot \sin(120+\theta)$

$\Rightarrow (\cos 30 \cdot \cos\phi - \sin 30 \cdot \sin\phi)(\sin 60^\circ \cdot \cos\theta + \cos 60^\circ \sin\theta)$

$= (\cos 30^\circ \cos\phi + \sin 30 \cdot \sin\phi)(\sin 120^\circ \cos\theta + \cos 120^\circ \sin\theta)$

$\Rightarrow \left(\frac{\sqrt{3}}{2} \cdot \cos\phi - \frac{1}{2} \cdot \sin\phi\right)\left(\frac{\sqrt{3}}{2} \cos\theta + \frac{1}{2} \sin\theta\right) = \left(\frac{\sqrt{3}}{2} \cos\phi + \frac{1}{2} \sin\phi\right)$
$\left(\frac{\sqrt{3}}{2} \cos\theta - \frac{1}{2} \sin\theta\right)$

$\Rightarrow \frac{3}{4} \cos\phi \cdot \cos\theta - \frac{\sqrt{3}}{4} \sin\phi \cdot \cos\theta + \frac{\sqrt{3}}{4} \cos\phi \sin\theta - \frac{1}{4} \sin\phi \sin\theta = \frac{3}{4} \cos\theta \cdot \cos\phi - \frac{\sqrt{3}}{4} \cos\phi \sin\theta + \frac{\sqrt{3}}{4} \sin\phi \cos\theta - \frac{1}{4} \sin\phi \sin\theta$

$\Rightarrow -\frac{\sqrt{3}}{4} \sin\phi \cos\theta + \frac{\sqrt{3}}{4} \cos\phi \cdot \sin\theta = -\frac{\sqrt{3}}{4} \cos\phi \sin\theta + \frac{\sqrt{3}}{4} \sin\phi \cos\theta$

$\Rightarrow \cos\phi \cdot \sin\theta - \sin\phi \cdot \cos\theta = \sin\phi \cdot \cos\theta - \cos\phi \cdot \sin\theta$

$\Rightarrow \sin(\theta-\phi) = \sin(\phi-\theta)$

Sinse the angular deflection of the pointer from the plane of reffepence is equal to the phase angle of the circuit. So the pointer movement can be calibrated interms of power factor ($\cos\phi$)

CHAPTER – 6

Measurement of Resistance, Inductance & Capacitance :-

Resistance Measurement :-

Resistance are catagorised into 3 catagory

1- Low resistance (Below 1 Ω or ≤ 1 Ω)

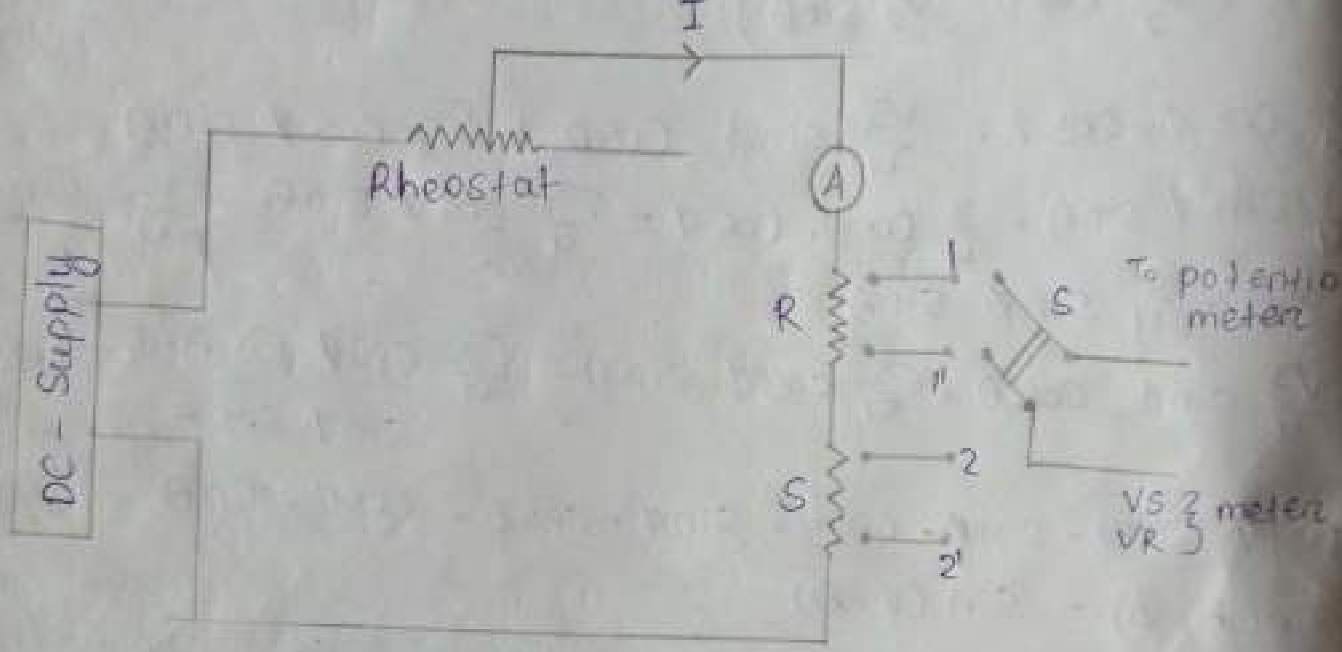
2- Medium resistance (1 - 100 kΩ)

3- High resistance (More than 100 or ≥ 100 kΩ)

Low resistance Measurement by potentiometer Method:-

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

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



→ The above ckt is used to measure the unknown resistance with the help of a potentiometer.

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

→ In the above ckt R' is the unknown resistance whose value is to be measured & S' is the known Standard resistor.

→ The ckt Current is control with the help of a rheostat. A double through switch is used to connected 1,1' or 2,2' points.

→ The double throw switch is connected to a potentiometer to measure the voltage drop in unknown resistor 'R' (V_R).

→ when the switch is connected 1,1' the voltage drop $V_R = I \times R \Rightarrow I = \frac{V_R}{R}$ —— eq^n ①

→ When the switch is connected 2, 2' than voltage drop $V_S = I \times S \Rightarrow I = \frac{V_S}{S}$ ——— eqⁿ ②

→ From eqⁿ ① & ② we get that,

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

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

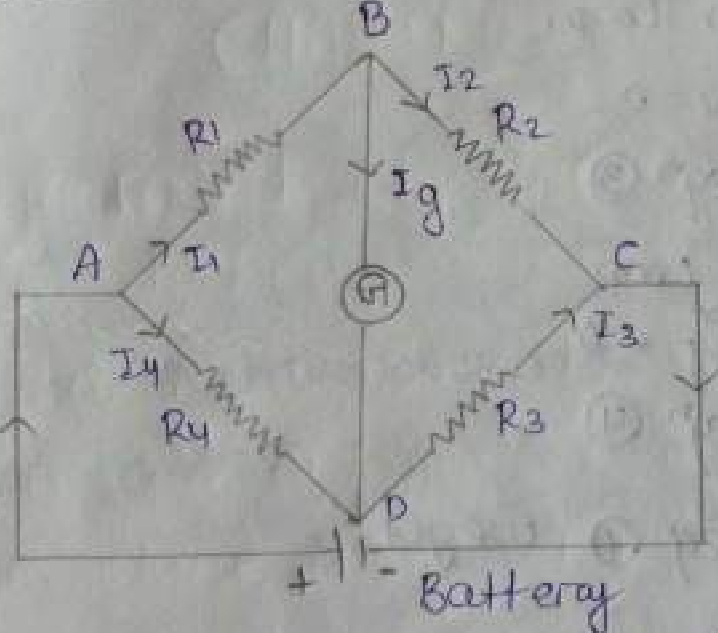
→ Since the value of standard resistance 'S' is accurately known, V_R & V_S value can be detected from potentiometer, the unknown resistance 'R' value can be easily calculated.

Medium resistance Measurement by wheat stone bridge method :-

→ Wheat stone is an electrical ckt in which 4 no. of resistors are connected in a bridge structure.

→ Out of this 4 resistance 3 resistance are known & 1 resistance is unknown.

→ The wheat stone bridge ckt can be used to calculate the value of unknown resistance.



→ Consider the 4 resistance R_1, R_2, R_3 & R_4 which are connected in the wheat stone bridge.

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

→ Let I_1, I_2, I_3 & I_4 are the current flowing through the resistance.

→ A null type galvanometer is connected between B & D junction & 'I_g' is the current flowing through the galvanometer.

→ Consider R_3 is the variable resistor whose value is show adjusted that the galvanometer show null deflection. At this condition $I_g = 0$.

→ At this balancing condition:-

At junction B,

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

$$\Rightarrow \boxed{I_1 = I_2} \text{ ——— eq}^n \text{ (1)}$$

At junction D,

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

$$\Rightarrow \boxed{I_4 = I_3} \text{ ——— eq}^n \text{ (2)}$$

Applying KVL, in ABD Loop.

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

$$\Rightarrow \boxed{I_1 R_1 = I_4 R_4} \text{ ——— eq}^n \text{ (3)}$$

Applying KVL in BCD Loop

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

$$\Rightarrow \boxed{I_2 R_2 = I_3 R_3} \text{ ——— eq}^n \text{ (4)}$$

Dividing eq^n (3) with eq^n (4) we get:-

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

Using eq^n (1) & (2)

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

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

This condition is known as balancing condition of wheatstone bridge.

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

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

There are two types of wheatstone bridge ckt:-

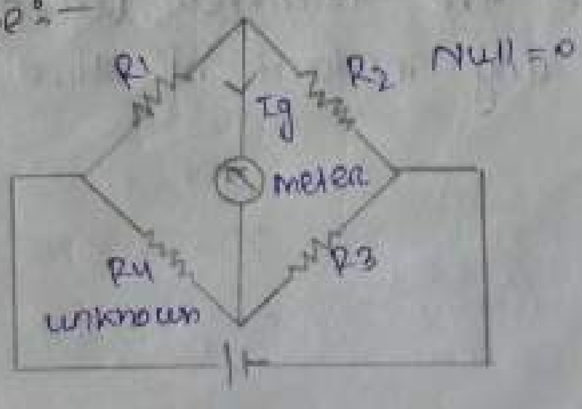
1- Null balance type

2- Deflection type

Null balance type:-

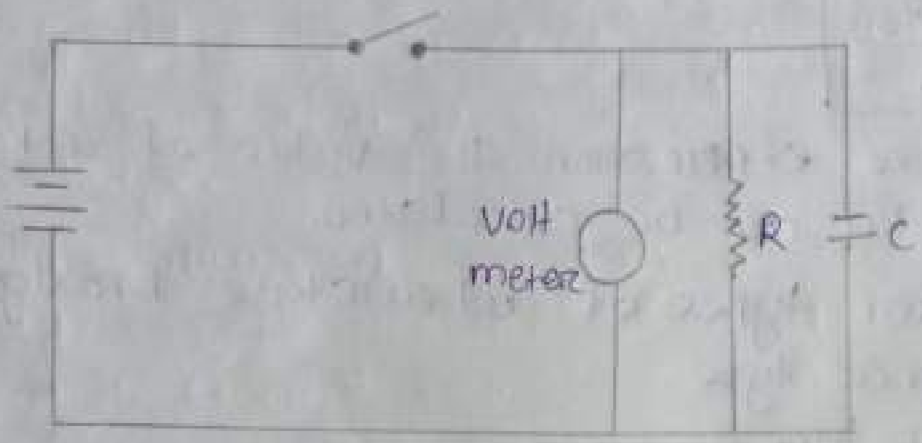
The adjustment of variable resistor Rs is calibrated interms of unknown resistance R_4

Deflection type:-



→ The current I_g is proportional to the unknown resistance R_4, when the bridge is unbalanced.
→ A PMMC type instrument can be connected to measure the 'I_g' current & the meter is calibrated interms of unknown resistance R_4.

High resistance measurement by loss of charge method :-



→ The high resistance can be measured by using 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 measured is connected in parallel with a capacitor 'c' & a voltmeter.

Working :-

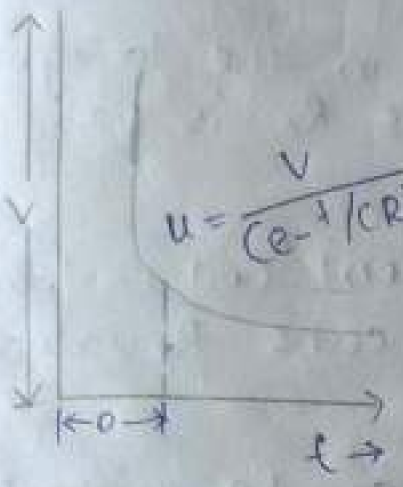
→ The capacitor is charged to a suitable voltage by using a battery.
→ After that the capacitor is allowed to discharge.
→ During the discharge the terminal voltage across the capacitor or at any instant of time 't' can be given by

$$V = Ve^{(-t/CR)}$$

$$\rightarrow \boxed{\frac{V}{u} = e^{-t/CR}}$$

$\Rightarrow \ln\left(\frac{V}{u}\right) = {-t}/{CR}$

$$\Rightarrow R = \frac{-t}{C \ln\left(\frac{V}{u}\right)} = \frac{-t}{C \times 2.3 \log\left(\frac{V}{u}\right)} = \frac{0.434t}{C \log\left(\frac{V}{u}\right)}$$



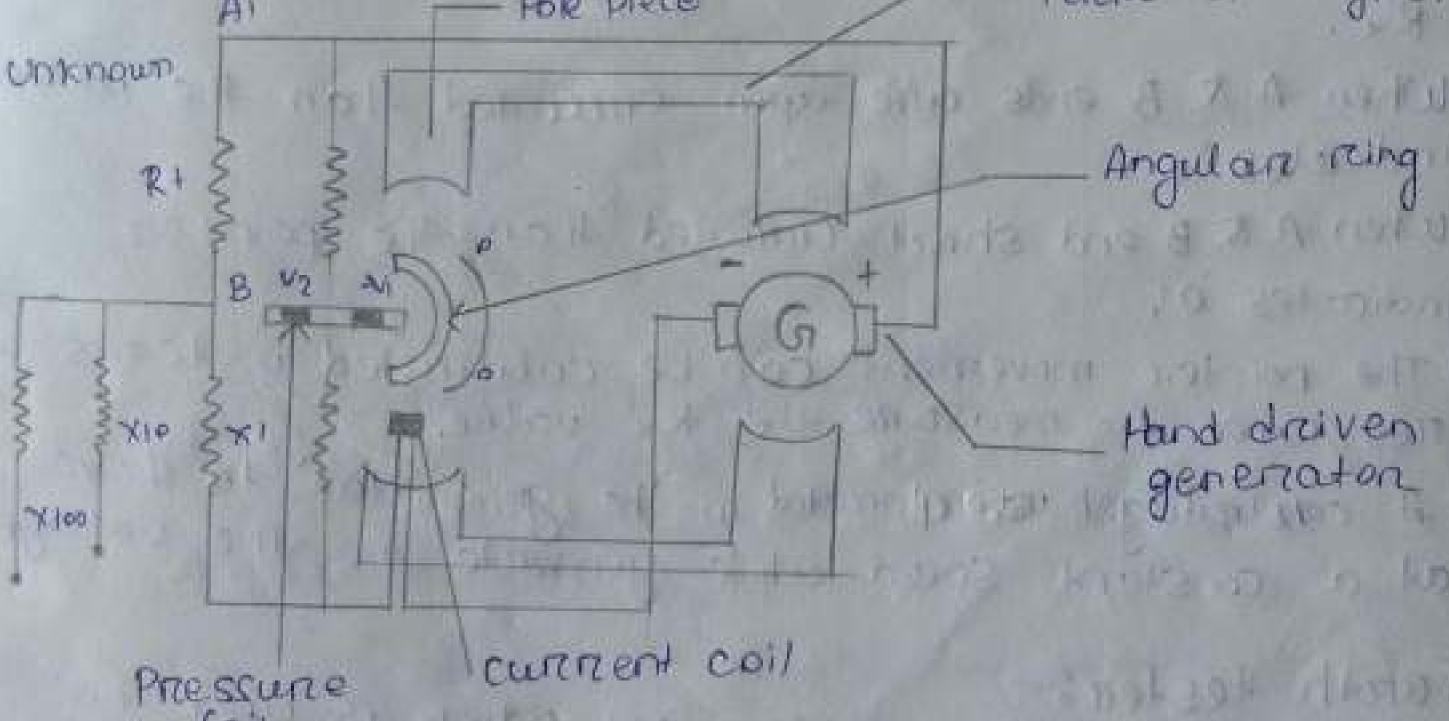
u is the instantaneous value of voltage across a capacitor at any instant of 't'

$$\boxed{R = \frac{-0.4343t}{C \log\left(\frac{V}{u}\right)}} \text{ — eq}^n \text{ 1}$$

→ In eqⁿ 1 if u, t, V & C values are known to us than the unknown resistance at can be calculated

Megger:-

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



→ It is a modified PMMC type instrument. This instrume contains 1 current coil & 2 pressure coils.

→ The pressure coils are V_1 & 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 its magnetic field.

→ When the current in the current coil in the large than the pointer indicates 0 which means R_x is very small.

→ Similarly when the current in current coil is low it indicates over than scale which means R_x 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 current resistance R_x can vary the current flowing through 'f' coil & 'c' coil. So the movement of pointer can be affected by the unknown resistance 'R_x'.

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

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

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

→ A centrifugel 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 pres

in a low resistance coil, so that it can carry the excess current to the earth without any distoraction.
→ The eart soil resistance is affected by the moisture constain of the soil. So periodic testing of earth resistance is required to make the earthing system more effective.

Construction:-

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

(i) Current reversal
(ii) Rectifier

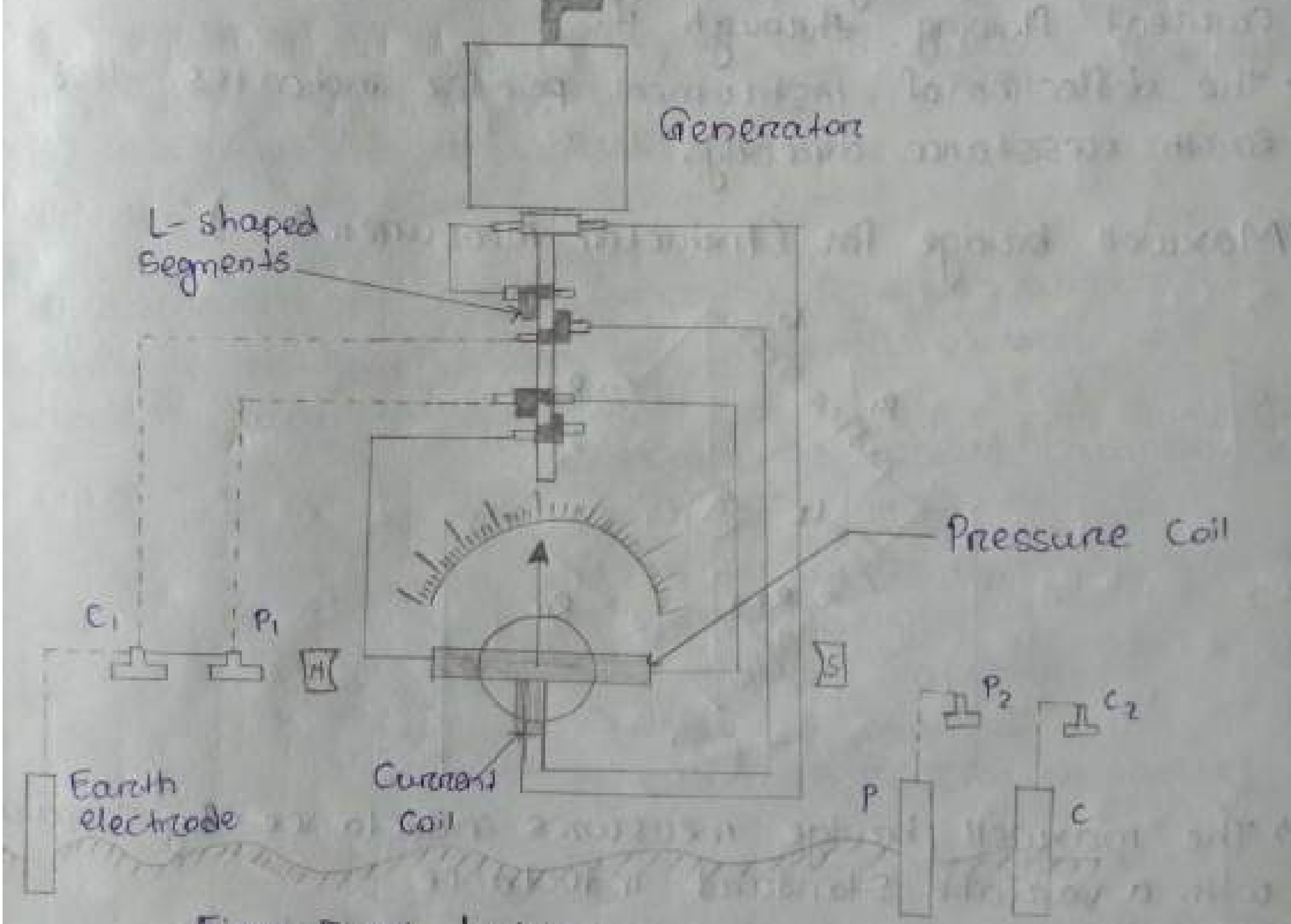


Fig:- Earth tester

→ This instrument consists of commutators made up of L-shaped segments.
This segments are mounted on the shaft of the generator.

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

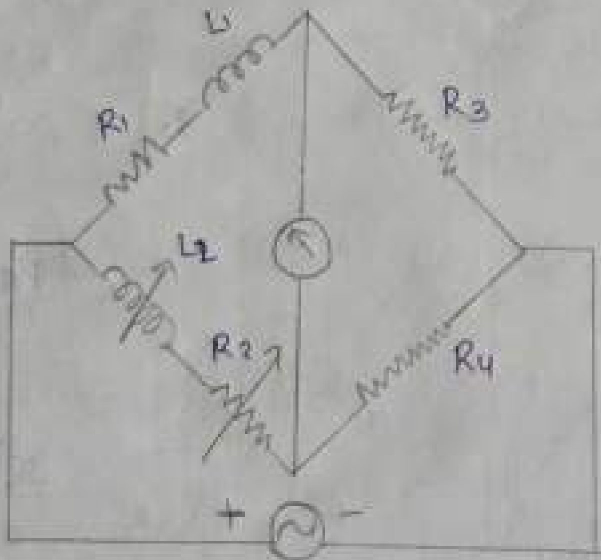
→ The earth tester has four terminal P_1, P_2 C_1 & C_2 two terminal P_1 & C_1 are shorted are connected to earth electrode.

→ 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 & the current flowing through it.

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

Maxwell bridge for (Inductor Measurement) :-



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

→ In the above circuit L_1 = unknow inductance

L_2 = variable inductance

R_1, R_3, R_4 = known resistance

R = 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

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

$\Rightarrow L_1 R_4 = L_2 R_3$

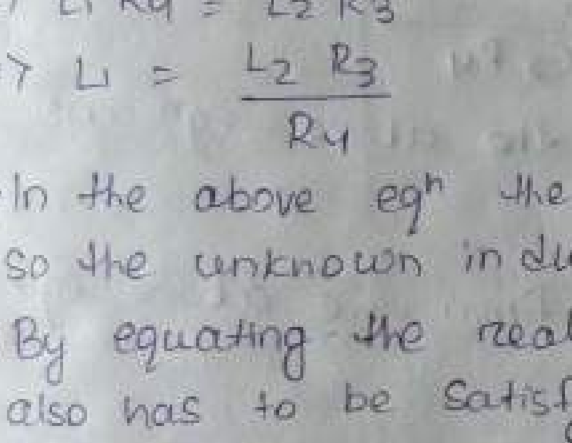
$\Rightarrow L_1 = \frac{L_2 R_3}{R_4}$

⇒ 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 $R_1 R_4 = R_2 R_3$, this condition also has to be satisfy.

Measurement of capacitance by Schering bridge :-

Schering bridge is used for the measurement of unknown capacitance.



C_1 = Capacitor where 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

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

$\Rightarrow Z_1 Z_4 = Z_2 Z_3$

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

$$\Rightarrow \left(r_1 + \frac{1}{j\omega C_1}\right) = \frac{R_3}{j\omega C_2} \times \left(\frac{1+j\omega C_4 R_4}{R_4}\right)$$

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

$$\Rightarrow \frac{R_3}{j\omega C_2 R_4} + \frac{j\omega C_4 R_3 R_4}{j\omega C_2 R_4}$$

$$= -j \times \frac{R_3}{\omega C_2 R_4} + \frac{C_4 R_3}{C_2}$$

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

Comparing the real part from the above eq^n we get $r_1 = \frac{C_4 R_3}{C_2}$ ———— eq^n (1)

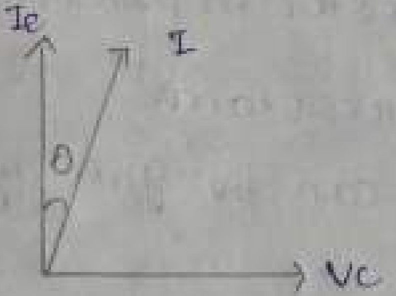
Comparing the imaginary part from the above eq^n we get $\frac{1}{\omega C_1} = \frac{R_3}{\omega C_2 R_4}$

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

$$\Rightarrow \boxed{C_1 = \frac{C_2 R_4}{R_3}} \text{ ———— (2)}$$

So the unknow resistance 'C_1' can be detect from eq^n (2) C_2, R_4 & R_3 values are known.
So 'C_1' can be calculated. This dissipation factor can be given by $\tan\theta = \omega C_1 r_1$

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



Multimeter :-

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

There are 2 types of multimeter available
1- Analog multimeter
2- Digital Multimeter

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 value 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 ohm meter when a battery & a resistance network is connected.

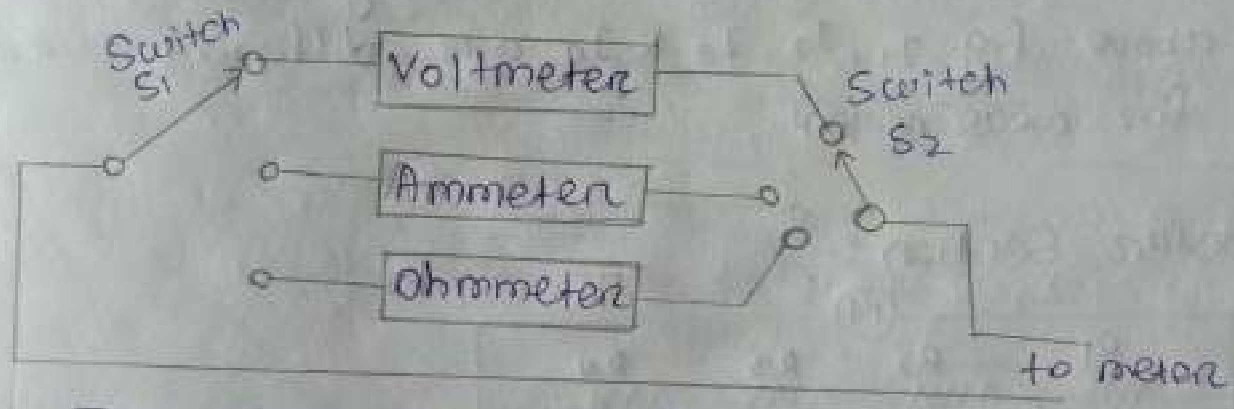
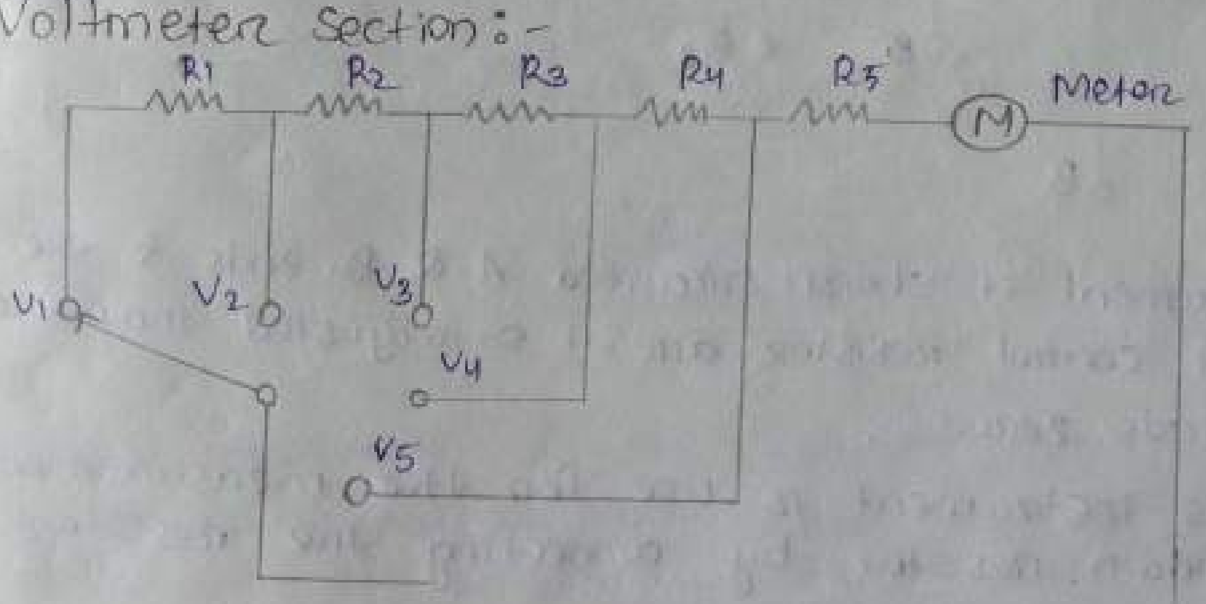


Fig:- Block diagram of multimeter

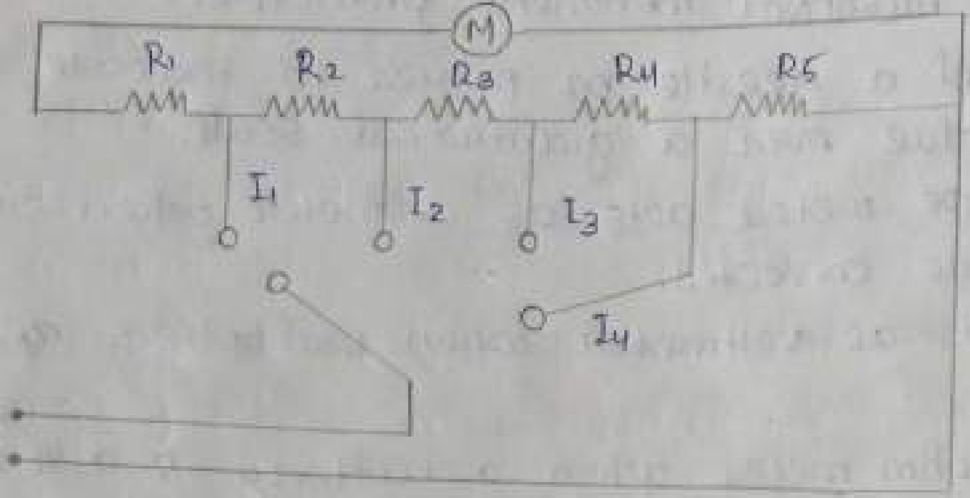
Voltmeter section:-



→ Multipliers are connected in series ... type wattmeter.

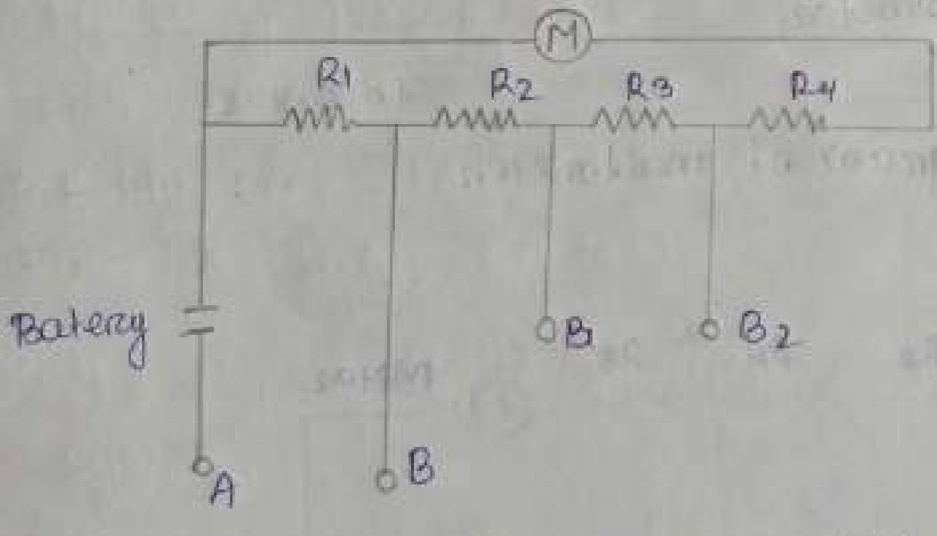
→ In the above figure V_1, V_2, V_3, V_4 & V_5 are the different voltage ranges for measurement.

Ammeter Section:-



Shunt resistors are connected parallely with the mete[r]
In the above fig. I_1, I_2, I_3 & I_4 are different curren[t] ranges for measurement.

Ohm meter Section:-



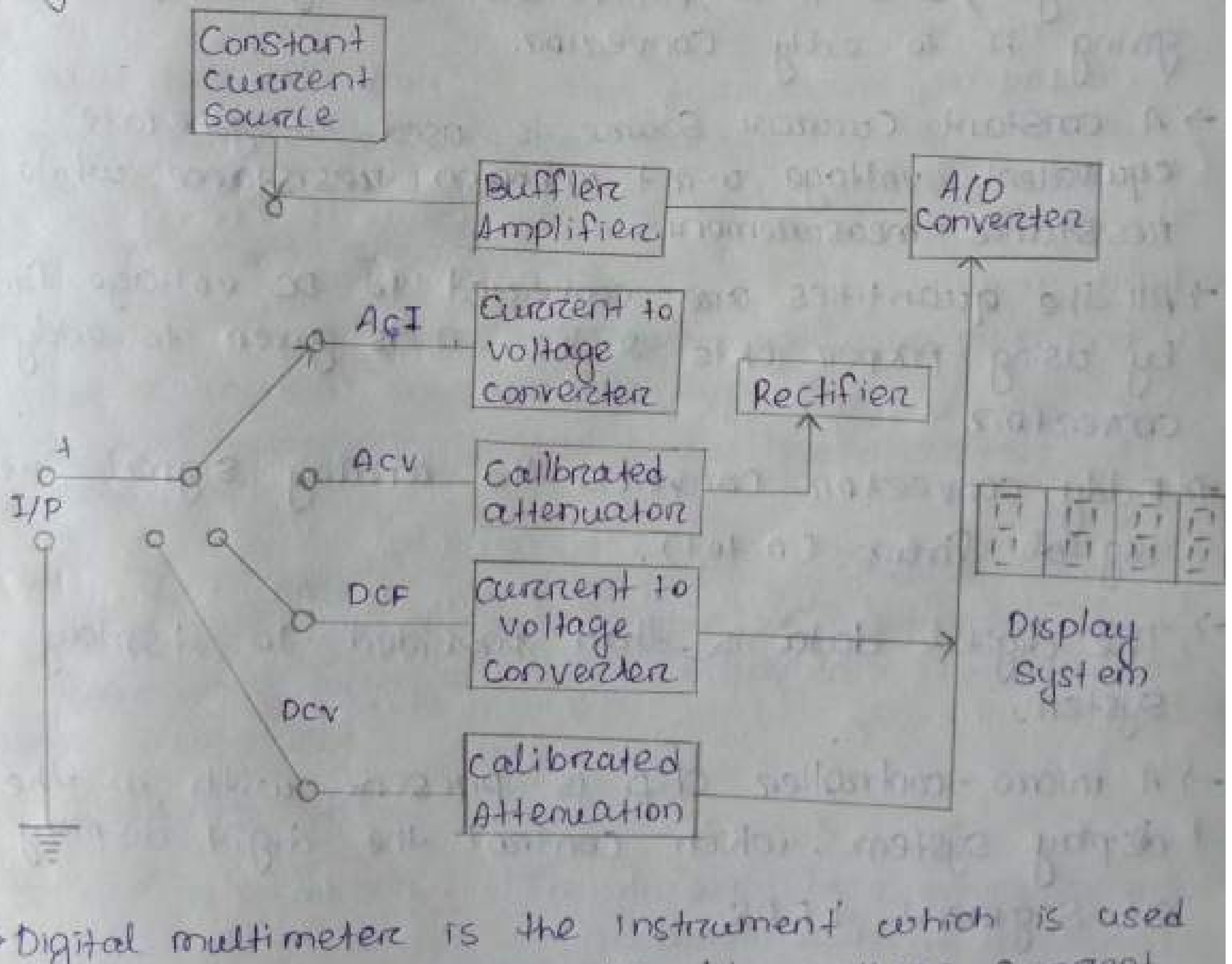
→ This instrument it short circuited A & B ends & the adjustment control resistor are it so adjusted that th[e] meter reads zero.

→ Then this instrument is use for the measurem[ent] 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 then 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 & DC voltage.

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

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

→ AC voltage & DC voltage are attenuated (decreas 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 while 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 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

Sensors and Transducer:-

What is transducers:-

→ Transducers is a device which can convert or transduce one from of energy into another form.

Sensors are special type of transducer which are used to sense or detect physical parameters & provides output generally used electrical form.

Ex:- Speaker, potentiometer, turbine etc.

Classification of Tranducers:-

Basic upon the output produced by transducers elements, transducers are catogorise into two type.

Mechanical Transducers:- This transducers produced output interm of mechanical energy i.e, displacement. Speed.

Ex:- Turbine, Baurden tube

Electrical Transducers:- This transducers produced output interms of electrical energy.

Ex:- LVDT transducer, Straingauge piezo electric sensor etc.

Active Transducers:- The transducers which can generate electrical output interms of voltage or current with out 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 & current are known as passive transducers.

Ex:- LVDT, straingauge, potentiometer etc.

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

Resistive Transducer :-
The output resistance of this transducers changes w.r.t input parameters.
E:- ① Potentiometer ② Thermistor resistance thermometer straingauge.

Inductive Transducers :-
The o/p inductance of this transducer changes w.r.t input parameter.
Ex:- LVDT

Capacitive Transducers :-
The o/p Capacitance of this transducers changes w.r.t input parameter
(i) Variable area type Capacitive transducer
(ii) Variable air gap type capacitive transducer.

Note :-
→ The transducer which directly connected to the physical parameter being measured is known as primary transducer & the transducer which are connected to the primary transducer are known as secondary transducer.

Resistive Transducer :-
→ The resistance of this transducer changes w.r.t change in i/p parameter.
→ These are passive transducer ie external supply is require to generate voltage or current as o/p.

Potentiometer:-

→ Potentiometer is a type of displacement sensor. simply it is turn as POT stands for potentiometer.

→ Pot meter consists of & uniform resistive element & a sliding contact this sliding contact is known as slider or wiper.

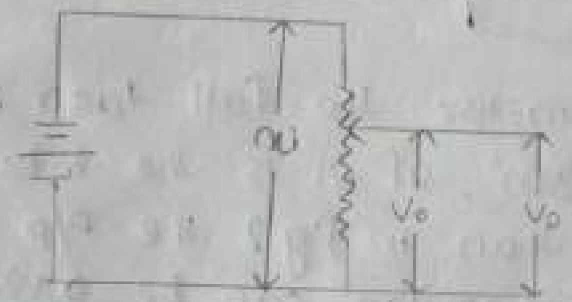
→ The motion of the sliding contact may be translatorzing or rotational.

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

(I) Linear Potentiometer

(II) Angular potentiometer

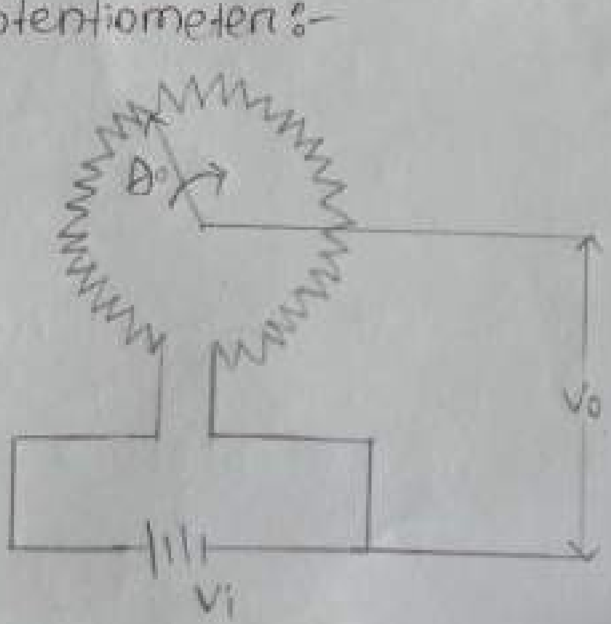
Linear potentiometer:-



→ In this transducer the resistive element is leanear in shape so it is called as linear potentiometer.

→ Linear potentiometer is used to measure linear displacement.

Angular Potentiometer:-



→ In this transducer the resistive element is present in a circular shape.

→ This angular potentiometer is used to measure angular displacement.

Theory:-

→ The resistive of the potentiometer is a very clean wire made up of platinum & nickel alloy.

→ If, from fig 1, if v_i is the i/p supply voltage
v_o is the o/p voltage
x_i is the total length of resistive element.

→ x_o is the displacement made by the wiper than the o/p voltage generated by the potentiometer can be given by $\boxed{V_o = \frac{x_o}{x_i} \times V_i}$

→ For angular potentiometer the full turn of the wiper may be approximate 300°. If θ_i is the total angular turn by the wiper. Than in fig 2 the o/p voltage developed by the potentiometer can be given by.

$$\boxed{V_o = \frac{\theta_o}{\theta_i} \times V_i}$$

→ The o/p of the potentiometer varies linearly w.r.t the i/p displacement the characteristics of potentiometer can be given by.