# Class Note

# Electrical Measurements and Instrumentation

For $4^{Th}$ Semester

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→ Measurement is axial for us. to understand the External word.
→ measurement required tools not provied scientist to a ~~partti~~ quantity. The problem here is that the result of every measurement by a measuring instrument constent some concerity. This constate is refers to as an error.
→ Accuracy & precision. the important factor to consider ~~whi~~ will taking measurement. Both this terms replecte how close a measurement to a unknown for accepected value.
Let's discuss it detile about precision & Accuracy

## Accuracy:-

→ The ability of an instrument to measurements the accurate value is known as Accuracy. it other word. it the closeness of the measure value to standed for true value.

## Precision:-

→ The closeness of two or more measurement to each other is known as the precision of a substance. If you weight the given substance five five times & get 3.2 kg each time, then your measurement is very precisio but ~~Accu~~ necessarily accurate.

* The Different betn ~~Aqu~~ Accuracy & pricision.

| Accuracy | Pricision |
| --- | --- |
| 1. Accuracy reperseto the levle of agreement betn the actual measurement and the absolute of measurement. | 1. precision implies the level of variation that lies in the values of several measurements of the same factor. |

2. It represents how closely the result agree with the standard value. | 2. It representets how closely the result agree with one another.

3. single factor measurement. | 3. multiful measurement are needed.

## Errors:→

→ The difference between the real value & the estimated value of quantity is know as measurement. Errors.

or The deviation of the measured quantity is called. Errors.

→ An error may be positive or Negative.

## → Resolution-

→ Resolution is the ability of the measurement to system to dedicate and faithfully indicate small changes form characteristic of the measurement result.

## → Sensitivity:→

sensitivity is are absolute quantity the smallest absolute amount of change that can be dedicated by the measurement.

→ It is the ratio of change in out put of the instrument to change in put or measure value.

→ A higher sensitivity indacates the system can responced to even the smallest input.

* Classification of measuring instrument.

- Instrument
  - Mechanical Instrument
  - Electrical Instrument.
    - Absolute Indirect
    - Secondary Direct
      - Analog Instrument
        - Deflecting instrument
          - Indicating Instruments
          - Integrating Instrument
          - Recording Instrument.
        - Null Deflection.
      - Digital Instrument.
  - Electronic instrument.

Electrical indicating Instruments:-

→ Indicating instrument is fitted with a points which indicates ~~fiom~~ scale the value of the quantity being measure the moving system such as instument is useally carried by a spindle of harden steam.

→ Having its Ends tappered & highly polished to force by rodes which rest hollow, ground bearing set in steel screw.

→ This arrangement eliminated ~~fi~~ pivol frection & instruments less suitable damage by shocked & vibrations.

→ Indicating instrument possesses three essential features.
1) Deflecting ~~term~~. torque
2) Controlling ~~torque~~. ~~term~~ "
3) Damping torque. ~~term~~ "

1) Deflecting ~~torque~~ →

→ The deflecting terms is produced by a mechanical force which is produced by electric current voltage power.

2) Controlling torque →

→ The controlling terms provided the value of the deflection which depend upon the magnitude of the quantity being measure.
→ The pointer attemps stichi position when the controlling term becomes equal to the opposing terms (deflecting terms)
→ Controlling terms is usally obtained by the two following two method.
1) Spring contro 2) Gravity control.

3) Damping ~~terms~~ torque →

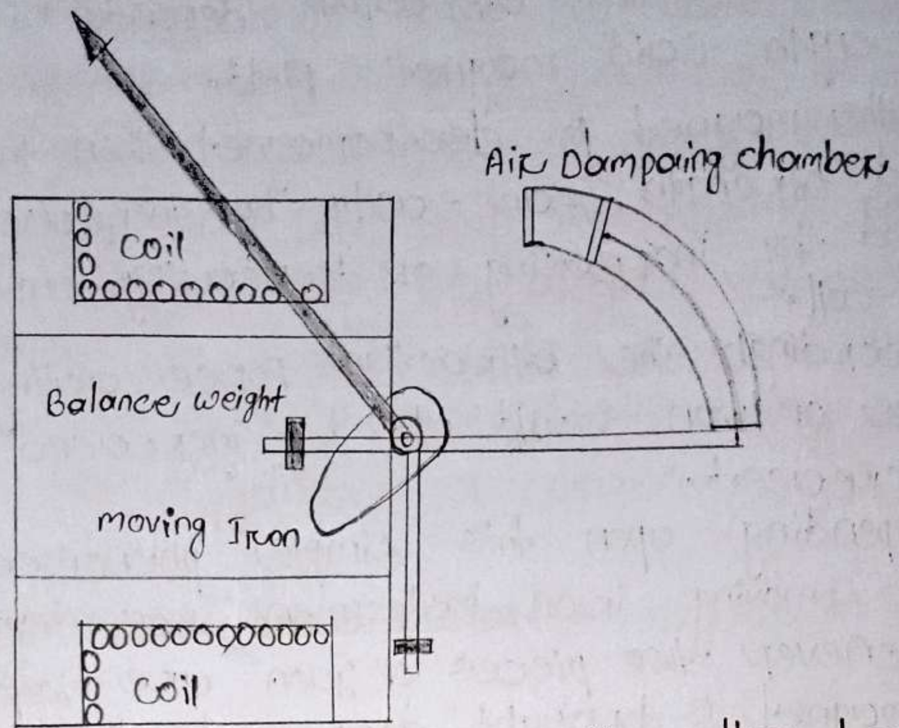
→ The damping terms able to prevent accllation of the moving system & measure the later to reach its time position quickly. The damping term of an instrument can be provided by either of the following 3 method.
1) Aire friction damping.
2) Fluid friction damping.
3) E.D. current fraction damping.

→ Moving Iron type instrument -

→ The moving iron typ instrument are one of the types of measuring instrument used for measuring voltage & current.
→ These instrument used moveable piece of iron less that diflex the pointer over the scale & hence need moving iron instrument.

→ <u>Construction:-</u>

→ Construction of moving Iron Instrument.




→ The basic construction of attraction type moving iron instrument is illustrated bellow.

→ A thin disc of soft iron is eccentrically pivoted in front of a coil.

→ This iron tends to move inward that is from weaker magnetic field to stronger magnetic field when current flowing through the coil.

→ In attraction moving instrument gravity control was used previously but now gravity control was method is replaced by spring control in relatively modern instrument.

→ By adjusting balance weight null deflection of the pointer is achieved.

→ The required damping force is provided in this instrument by air friction.

→ The figure shows a typical type of damping system provided in the instrument, where damping is achieved by a moving piston in an air syringe.

→ whenever a piece of iron is placed nearer to a magnet it would by attracted by the magnet.
→ The force of this attraction depends upon the, strength said magnetic field.
→ If the magnet is electromagnet then the magnetic field strength can easily be increased or decreased by increasing or decreasing current through its coil.
→ Accordingly the attraction force acting on the piece of iron would also be increased and decreased.
→ Depending upon this simple phenomenon attraction type moving iron instrument was developed.
→ whenever two pieces of iron are kept by side and a magnet is brought nearer to them the iron pieces will repulse each other.
→ This repulsion force is due to same magnetic poles induced in same sides the iron pieces due external magnetic field.
→ This repulsion force increases if field strength of the magnet is increased. Like case if the magnet is electromagnet, then magnetic field. strength can easily be controlled by controlling input current. to the magnet.
→ Hence if the current increases the repulsion force between the pieces of iron is increased and if the current decreases the repulsion force between them is decreased.
→ Depending upon this phenomenon repulsion type moving iron instrument was constructed.

## Ranges of Ammeter and voltmeter-

→ For a given moving-iron instrument the ampere-turns necessary to produce full-scale deflection are constant.

→ one can alter the range of ammeters by providing a shunt coil with the moving coil.

→ voltmeter range may be altered connecting a resistance in series with the coil. Hence the same coil winding specification may be employed for a number of ranges.

### Advantages:-

→ The instruments are suitable for use in AC & DC circuits.

→ The instruments are robust, owing to the simple construction of the moving parts.

→ The stationary parts of the instruments are also simple.

→ Instrument is low cost compared to moving coil instrument.

→ Torque/weight ratio is high, thus less frictional error.

### Errors-

→ Error due to variation in temperature.

→ Error due to friction is quite small as.

### Measurement of Electric voltage and current.

→ moving iron instruments are used as voltmeter and Ammeter only.

→ Both can work on AC as well as on DC.

Ammeter -

→ Instrument used to measure current in the circuit.

→ Always connected in series with the circuit and carries the current to be measured.

→ This current flowing through the coil produces

→ the desired deflecting torque.

→ It should have low resistance it is to be connected series.

Voltmeter -

→ Instrument used to measure voltage between

→ two points in a circuit.

→ Always connected in parallel.

→ current flowing through the operating coil of the meter produces deflecting torque.

→ It should have high resistance. Thus a high resistance of order of kilo ohms is connected in series with the coil of the instrument.

Ranges of Ammeter and Voltmeter -

Disadvantages -

1) Scales not uniform.

2) For low voltages range the power consuption is higher.

3) The errors are caused due to hysteresis in the iron of the operating system and due to stray magnetic field.

4) In case of A.C. measurements, change in frequency causes serious error.

5) with the increase in temperature the stiffness of the spring decreases..

## Errors-

→ Error due to variation in temperature.

→ Errors due to friction is quite small as torque-weight ratio is high in moving coil instruments.

→ Stray fields cause relatively low values of magnetizing force produced by the coil. Efficient magnetic screening is essential to reduce this effect.

→ Error due to variation of frequency causes change of reactance of the coil and also changes the eddy current induced in neighbouring metal.

→ Deflecting torque is not exactly proportional to the square of the current due to non-linear characteristics of iron material. Date-25.03.22

very imp → What is permanent Magnet moving coil or PMMC instrument? - Definition, construction, Error, Advantages & Disadvantages - circuit Globe.

→ Definition:→

→ The instrument which use the permanent magnet for creating the stationary magnetic field between which the coil moves is known as the permanent magnet moving coil or PMMC instrume.

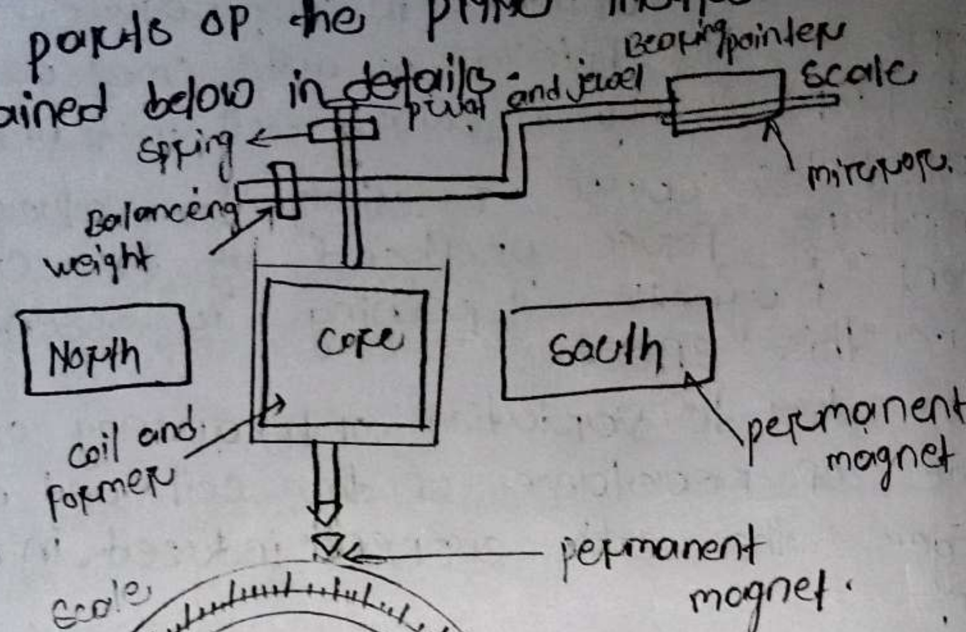
→ It operates on the principle that the torque is exterted on the moving coil placed in the field of the permanent magnet.

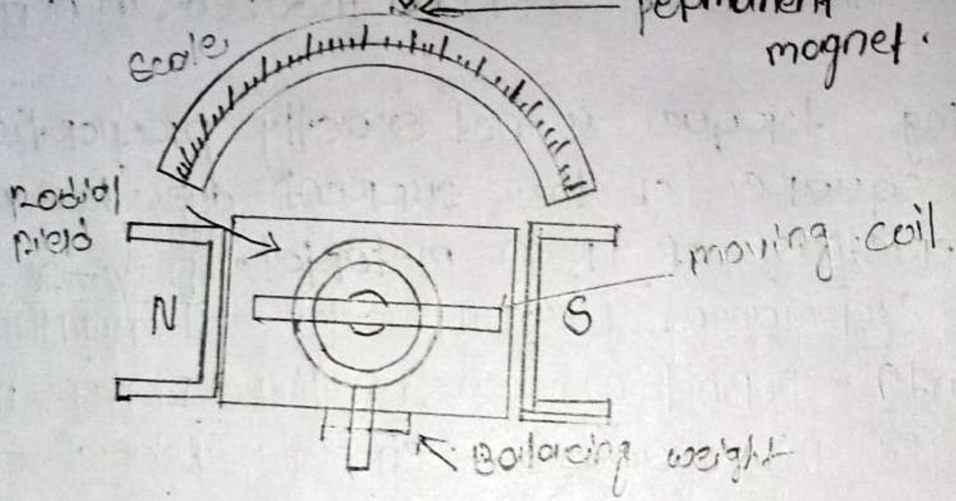
→ The PMMC instrument gives the accurate result for DC measurement.

→ Construction of PMMC instrument →

→ The moving coil and permanent magnt are the main part of the PMMC instrument.

→ The parts of the PMMC instrument are explained below in details.




→ permanent magnet moving coil instrument.

→ moving coil - The coil is the current carrying. part of the instruments which is freely moved between the stationary field of the permanent magnet.

→ The current pass through the coil deflects it due to which the magnitude of the current or voltage is determined.

→ The coil is mounted on the rectangular which is made up of aluminium.

→ The former increases the radial and uniform magnetic field between the air gap of the poles. The coil is wound with the silk cover copper wire between the poles of a magnet.

→ The coil is mounted on the rectangular former which is made up of aluminium.

→ The former increases the radial and uniform magnetic field between the air gap of the poles.

→ The coil is wound with the silk cover copper wire between the poles of a magnet.

→ Magnet system – The PMMC instrument using the permanent magnet creating the stationary magnets.

→ The Alcomax and Alnico material are used for creating the permanent magnet because this magnet has the high coercive force (The coercive force changes the magnetisation property of the magnet). Also the magnet has high field intensities.

→ Control – In PMMC instrument the controlling torque is because of the spring.

→ The springs are made up of phosphorous bronze and placed between the two jewel bearing.

→ The spring also provides the path to the lead current to flow in and out of the moving coil.

→ The controlling torque is mainly because of the suspension of the ribbon.

→ Damping → The damping torque is used for keeping the movement of the aluminium core which is moving between the poles of the permanent magnet.

→ pointer & scale – The pointer is linked with the moving coil.

→ The pointer notices the deflection of the coil and the magnitude of their deviation is shown on the scale.

→ The pointer is made of the lightweight material and hence it is easily deflected with the movement of the coil. Sometime the parallax error occurs in the instrument which is easily reduced by correctly aligning the blade of the pointer.

Torque equation for PMMC instrument.

→ The deflecting torque induces because of the movement of the coil.

→ The deflecting torque is expressed by the equation shown below.

$T_d = NBLdI$ ... equ(1)

where, N – Number of turns of coil.

B – flux density in the air gap.

L, d – the vertical and horizontal length of the side.

$G = NBLd$ .... equ(2)

I – current through the coil.

→ The spring provides the restoring torque to the moving coil which is expressed as.

$T_c = K\theta$ .... equ.③

where, K = spring constant.

$T_c = T_d$ By substituting the value of equation ① and ③ we get.

For final deflection,

$K\theta = GI$

$$\theta = \frac{GI}{k} \quad \dots \text{equ (4)}$$

$$I = \frac{k}{G}\theta \quad \dots \text{equ (5)}$$

→ The above equation shows that the deflection torque is directly proportional to the current passing through the coil.

## Error in PMMC instrument

→ In PMMC instrument the error occurs because of the ageing and the temperature effects of the instruments.

→ The magnet, spring and the moving coil are the main parts of the instruments which cause the error.

→ The different types of errors of the instrument are explained below in details.

1. Magnet – The heat and vibration reduce the lifespan of the permanent magnet.

→ The magnetism is the property of the attraction or repulsion of the magnet.

→ The weakness of the magnet decreases the deflection of the coil.

2. Springs – The weakness of the spring increases the deflection of moving coil between the permanent magnet. So, even for the small value of current, the coil show large deflection.

→ The spring gets weakened becaus of the effect of the temperature.

→ one degree rise in temperature reduces the 0.004 percent life of the spring.

3. moving coil – The error exists in the coil when their range is extended from the given limit by the use of the shunt.

→ The error occurs because of the change of the coil resistance on the shunt resistance.

→ this happens because the coil is made up of copper wire which has high shunt resistance and the shunt wire made up of magnin has low resistance.

→ To overcome from this error, the swaping resistance is placed in series with the moving coil.

→ The resistor which has low-temperature coefficient is known as the swamping resistance.

→ The swamping resistance reduces the effect of temperature on the moving coil.

Advantages of PMMC Instruments –

→ The following are the advantages of the PMMC Instruments.

1. The scale of the PMMC instruments is correctly divided.
2. The power consumption of the devices is very less.

~~0. The PMMC consumption of the devices is very less.~~

3. The PMMC instruments have high accuracy because of the high torque weight ratio.
4. The single device measures the different range of voltage, and current. This can be done by the use of multipliers and shunts.
5. The PMMC instruments use shelf shielding magnet which is useful for the aerospace application.

Disadvantages of PMMC Instruments –

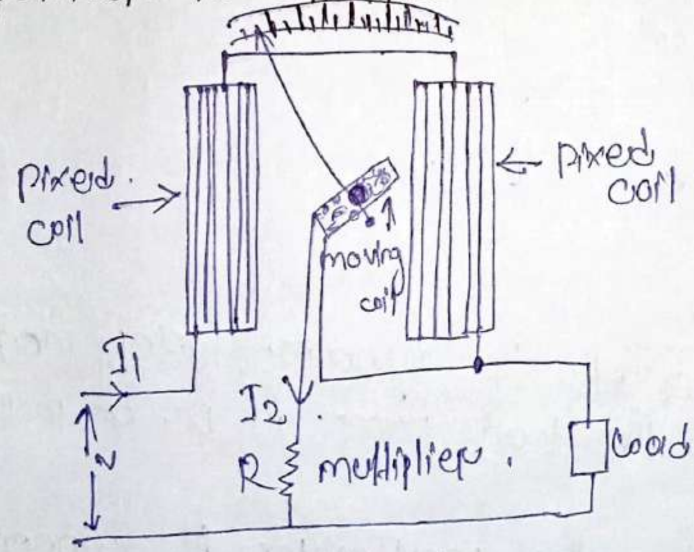
The following are the disadvantages of the PMMC instruments.

1. The pmmc instruments are only used for direct current. The alternating current varies with the time. The rapid variation of the current varies the the torque of the coil. But the pointer can not follow the fast reversal and the deflection of the torque. Thus, it cannot use for AC.

→ The cost of the PPMC Instrument is must higher as compared to the moving coil instruments.

→ The moving coil provides the electromagnetic damping.
→ The electromagnetic damping opposes the motion of the coil which is because of the reaction of the eddy current and the magnetic field.

Construction of Electrodynamometer–
→ The electrodynamometer wattmeter has a fixed coil divided into two parts and is connected is series with the load and caries the load current ($I_1$).
→ The moving coil is connected across the load through a series multiplier resistance ($R$) and carries a current ($I_2$) proportional to the load voltage.
→ The fixed coil is called as current coil and the moving coil is called as potential coil. The controlling torque is provided by two spiral springs.
→ Air friction damping is provided in electrodynamometer wattmeter.
→ A pointer is attached with the moving coil.



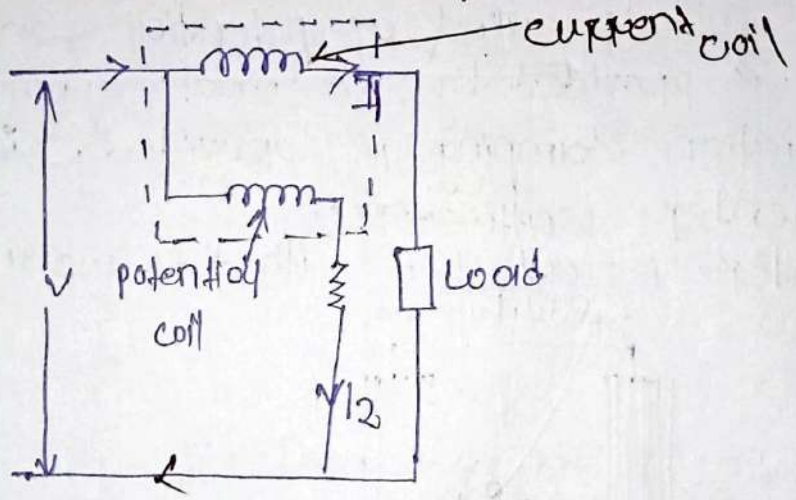

→ working principle of Electrodynamometer–
→ When electrodynamometer wattmeter is connected in the circuit to measure the electric power.
→ The current coil carries the load current and the potential coil carries a current propertional to the load voltage.

→ Because of the current in the two coils, a mechanical force acts between them due to which the moving coil (potential coil) moves and hence the pointer attached to it.

→ The pointer comes to rest at a position where the deflecting torque and controlling torque become equal.

→ When the current is reversed in the circuit, the reversal of current takes place in both the current coil and potential coil so that the direction of the deflecting torque remains unchanged.

→ Hence, the electrodynamometer wattmeter can be used for the measurement of DC as well as AC power.




Deflecting Torque -

→ The deflecting of electrodynamometer wattmeter is proportional to the load power in DC as well as AC circuit.

- DC circuit – When the wattmeter is connected in DC circuit for power measurement, the power taken by the load is $VI_1$.

Deflecting Torque $(T_d) \propto I_1 I_2$

Since the current $I_2$ is proportional to load voltage V. Thus, Deflecting Torque ($T_d$) $\propto$ $I_1 V \propto$ load power.

→ AC circuit - when the wattmeter is connected in an AC circuit to measure the load power.

→ consider at any instant, current through the load is i and voltage across the load is v and the power factor of the load is supposed to be $\cos\varphi$ lagging.

$$v = V_m \sin\theta$$

$$i = I_m \sin(\theta - \varphi)$$

Instantaneous deflecting torque $\propto v \cdot i$.

→ Due to inertia of moving system, the pointer cannot follow the rapid changes in the instantaneous power.

→ Hence the wattmeter indicates the average power.

∴ Average Deflecting torque ($T_d$) $\propto$ Average of vi over one cycle.

$$T_d \propto \frac{1}{2\pi}\int_0^{2\pi} V_m I_m \sin\theta \sin(\theta - \varphi)\, d\theta$$

$$\propto \frac{V_m I_m}{2} \cos\varphi \propto VI\cos\varphi$$

where, V and I are RMS values.

$$T_d \propto VI\cos\varphi \propto \text{load power.}$$

→ Since the controlling torque in the wattmeter is provided by spring. Thus

$$T_C \propto \theta$$

under steady state condition,

$$T_d = T_C.$$

Therefore

$$\theta \propto \text{load power.}$$

→ Hence the electrodynamometer wattmeter has uniform scale.

## Advantages-

→ can be used for measurement of AC as well as DC power.

→ They have uniform scale.

→ By proper design, high accuracy can be obtained.

## Dis-advantage-

→ The stray magnetic field may affect the wattmeter readings. In order to prevent this, the instrument should be enclosed in a soft-iron case.

→ At low power factors, serious errors may be caused by the inductance of potential coil.

## Rectifier Type Instrument - Date 30.03.2022

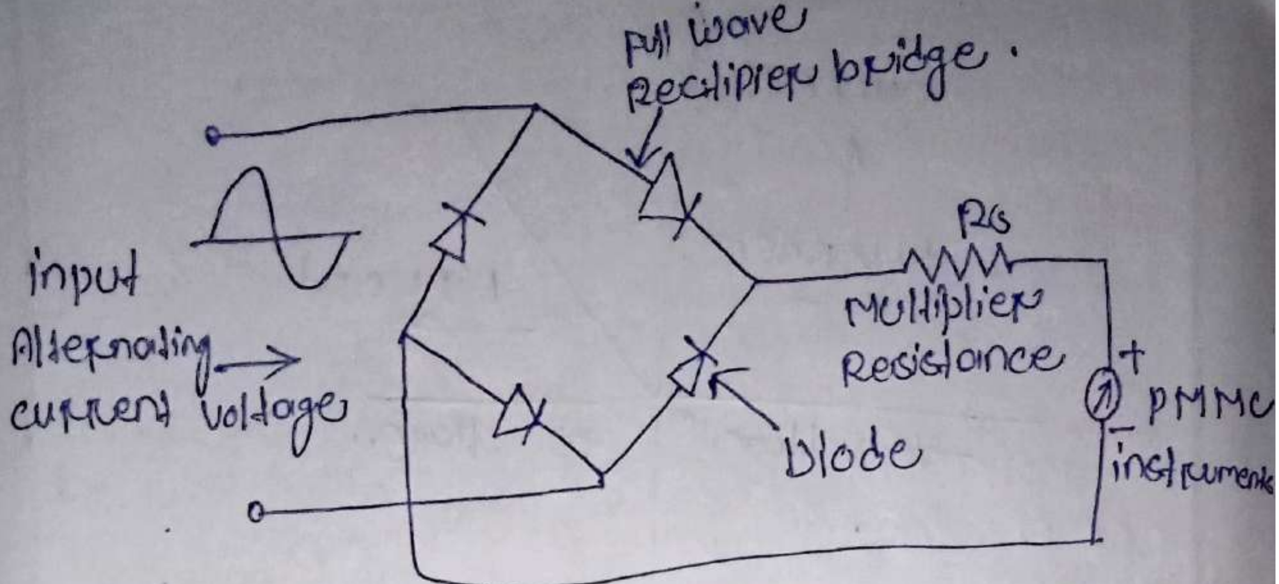
→ Definition:- The istrument which uses the rectifying element for measuring the voltage and current is known as the rectifying instruments. The rectifying element converts the alternating current to the direct current which indicates by the DC responsive meter. The PMMC uses as an indicating instrument.

→ The sensitivity of the rectifying instruments is high as compared to the moving coil and the Electrodynamometer instrument.

→ Thereby, it uses for measuring the current and voltage.

→ The circuit arrangement of the rectifier instrument shown in the figure below.

→ The device uses the four diodes which act as a rectifying element.




[Rectifier Type Instruments]

→ The multiplier resistance Rs uses for limiting the value of current so that their value does not extend more than the rating of the PMMC instrument.

Rectifying Element –

→ The rectifier element is used for the conversion of the AC to DC so that the unidirectional current flows through the PMMC instrument.

→ The copper oxide selenium cell, germanium and silicon diode are uses for making rectifying element.

→ The rectifying element offers the zero resistance when it is in forwarding bias and infinite of resistance when it is in reverse biased.

→ This property of the rectifying element use for rectification purpose.

→ Characteristic curve of Rectifying Element –

→ The characteristic curve of the rectifying circuit shown in the figure below. Ideally, the rectifying instrument does not have any voltage drops in the forward direction and no current flows in the reverse direction.

Average value of voltage.

$$V_{av} = \frac{1}{2\pi}\int_0^{\pi} V_m \sin\omega t \, d(\omega t) = \frac{1}{\pi} V_m$$

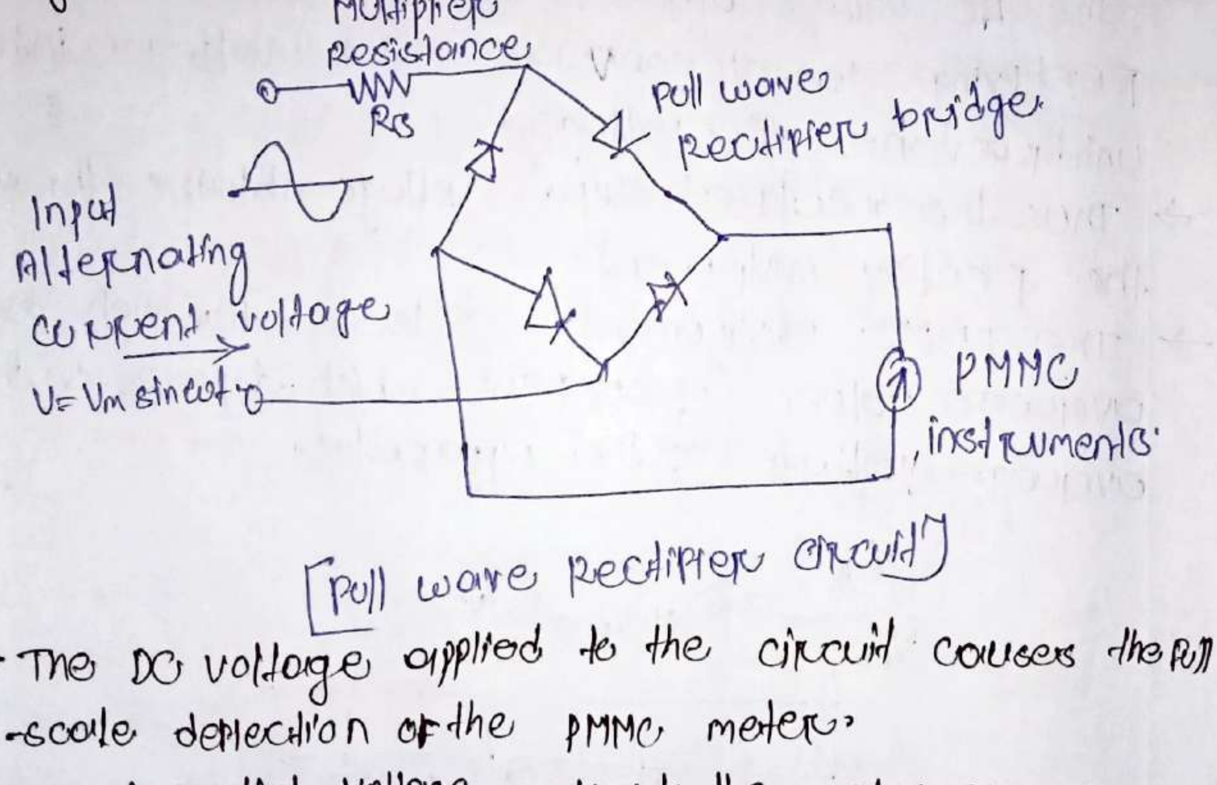
$$V_{av} = 0.318 V_m$$

$$V_{av} = 0.318 \times \sqrt{2}V = 0.45V.$$

The above calculation shows that the sensitivity of the instrument through AC is 0.45 times the current through the sensitivity of DC.

## Full wave Rectifier Instrument—

→ The circuit of full wave rectifier shown in the figure below.




[Full wave Rectifier circuit]

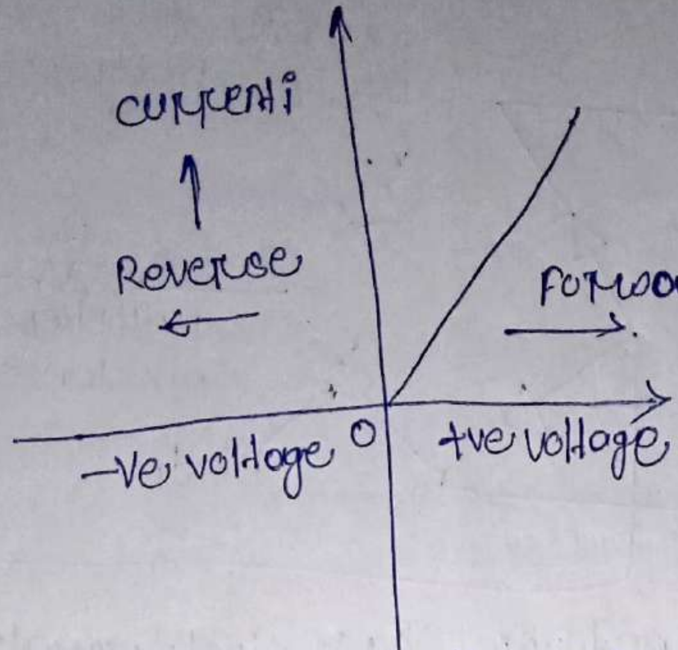
→ The DC voltage applied to the circuit causes the full-scale deflection of the PMMC meter.

→ The sinusodial voltage applies to the meter express as

$$V_{av} = \frac{1}{\pi}\int_0^{\pi} V_m \sin\omega t \, d(\omega t) = \frac{2}{\pi} V_m$$

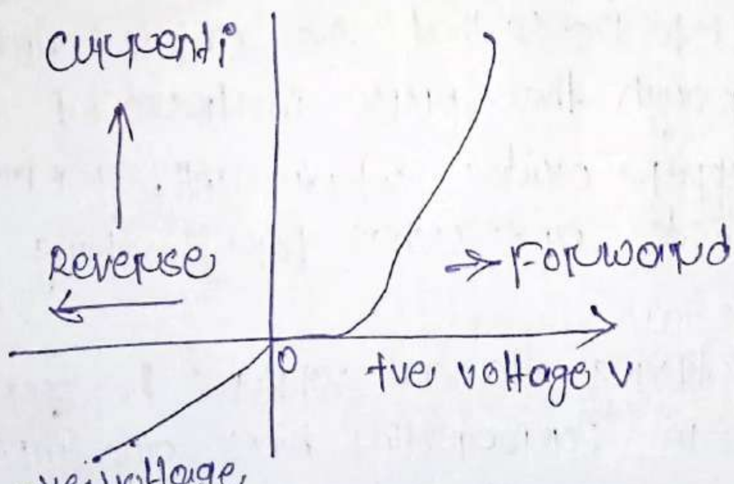
$$V_{av} = 0.636 V_m$$

$$V_{av} = 0.9V$$




[characteristic of Rectifying instrument]

→ But practically this is not possible. The real characteristic curve of the rectifying element shown in the figure below.

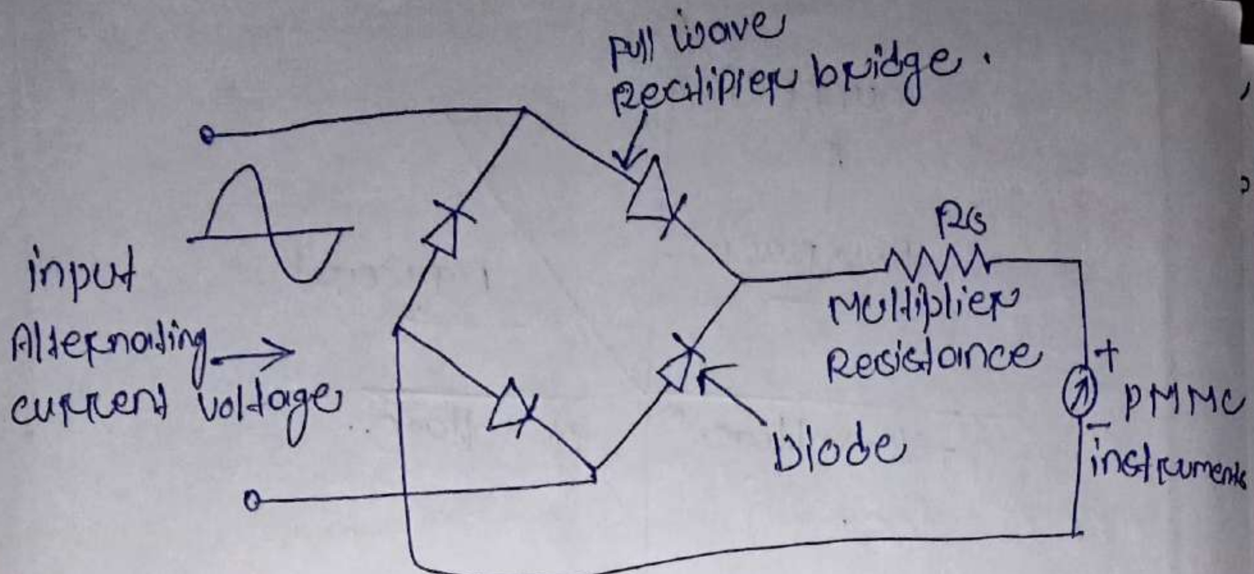



[Actual Rectifying Element]

→ Half wave Rectifier circuit

→ The figure below shows the half-wave rectifying circuit.

→ The rectifying element connects in series with the voltage source, resistance multiplier and the permanent moving coil instrument. The forward resistance of the diode is neglected.

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→ The copper oxide selenium cell, germanium and silicon diode are uses for making rectifying element.

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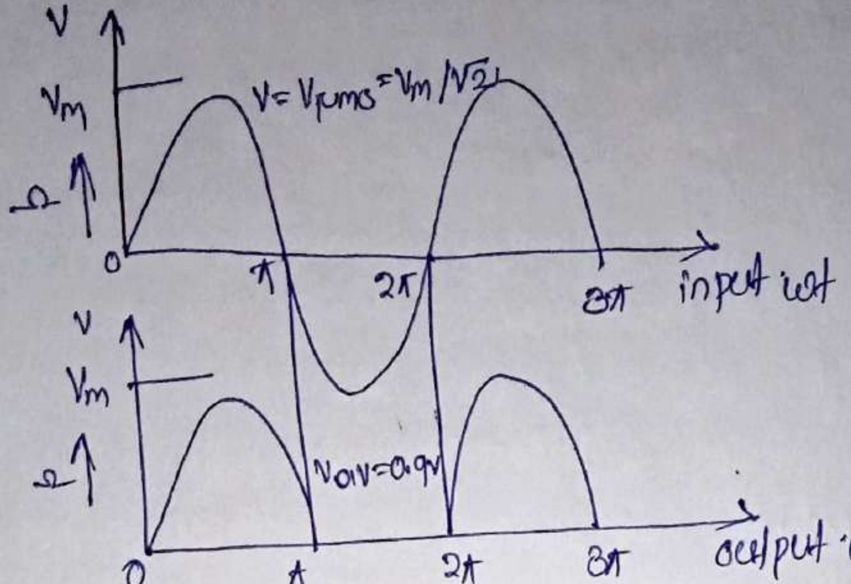
→ This property of the rectifying element use for rectification purpose.

→ characteristic curve of Rectifying Element -

→ The characteristic curve of the rectifying circuit shown in the figure below. Ideally, the rectifying instrument does not have any voltage drops in the forward direction and no current flows in the reverse direction.

→ The average calculation of AC is 0.9 times with that of the DC for the same value of voltage. or we can say that the sensitivity of the instrument along with AC is 90% with that of the DC.




Sensitivity of Rectifier Instrument:-

→ The sensitivity of the instrument shows the variation of the measured quantity from input to output. The DC sensitivity of the rectifier instrument.

$$S_{dc} = \frac{1}{I_{fs}} \, V/\Omega$$

The sensitivity of the AC rectifier type instrument depends on the type of the rectifying element use in the circuit.

→ Factors Affecting the performance of Rectifier Type Instruments—

→ The following are the factors that affect the performance of the instrument when it is used on AC.

1. Effects of waveform – The calibration of the rectifier instrument can be done regarding the RMS value of voltage and current.

→ The form factor of the half wave and the full wave rectifier type instrument fixes on the calibrated scale.

→ And If the waveform of the other form. factors applies to the device, the waveform error occurs in the reading.

2. Effect of Temperature change – The resistance of the rectifying element varies with the change in the temperature.

→ And this property of the rectifying component causes the error in the instruments.

3. Effect of Rectifying Instrument – The rectifier has the property of the imperfect capacitance. It allows the high-frequency current to pass through it.

4. Decreases in sensitivity – The sensitivity of the rectifier type instrument for AC operation is lower than that of the DC operation.

Advantages of Rectifying Instrument :

→ The following are the advantages of the rectifiers instruments.

1. The frequency range of the instruments increases from 20HZ to high-frequency range.
2. The current operating range for such type of instrument is much lower for voltmeter as compared to the other AC instrument.
3. The instrument has uniform scales for the large rang.
4. The accuracy of the instrument is ±5 percent when it is in normal operating condition.

Applications of Rectifying Instrument –

The following are the application of the rectifying instrument.

1→ The instrument uses for measuring the voltage whose range lies between 50-250V.

2→ It use as a milliammeter or micro-ammeter.

3→ The rectifying instrument use in the communication circuit for measurement.

→ The sensitivity of the rectifying the type voltmeter is less than that the sensitivity of the DC voltmeter. Thus, the loading effect of the ac rectifier voltmeter is higher than the dc voltmeter.

# INDUCTION TYPE INSTRUMENTS:-

→ The operation of induction type instruments depends on the production of torque due to reaction between two magnetic fluxes having some phase difference OR reaction between flux of an AC magnet and the eddy current induced by this flux.

→ These types of instruments are used only for AC measurement.

→ Before getting into the constructional and working details of these instruments let us first have a general look on the torque produced in these instruments.

→ The torque produced in induction type instruments depends on the two fluxes the net torque acting on the disc is.

$$T = k\omega \phi_{1m} \phi_{2m} \sin\alpha$$

where, $\phi_{1m}$, $\phi_{2m}$ = maximum fluxes produced by the current

$\alpha$ = phase difference between the two fluxes.

And if both the fluxes are produced by the same alternating current, then

$$T = k_1 \omega I_m^2 \sin\alpha$$

where, $I_m$ = maximum value of current, Therefore, torque is proportional to the square of current for a given value of frequency and angle.

→ If the disc has spring control then at some point the controlling torque will be equal to the deflecting torque which will help the disc to attain a steady deflected position. And if the disc is attached to a pointer, then this arrangement can be used for measurement of current.

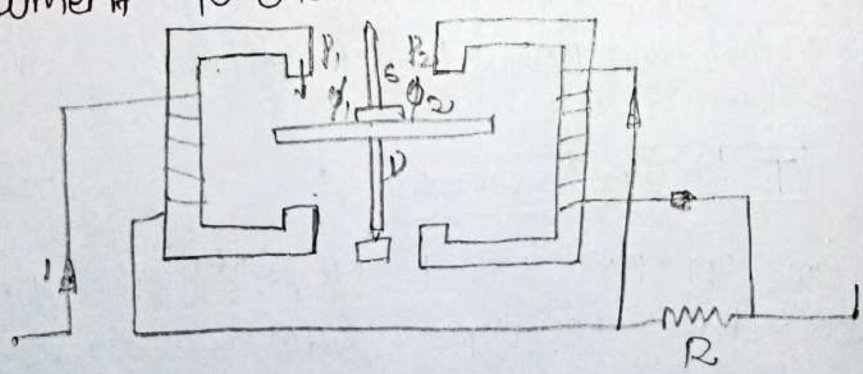
→ This was a general discussion about induction type instruments for the sake of a healthy discussion we will take on these instruments by their types.

→ Induction type instruments are of two types:

1. split - phase type.
2. shaded pole type.

1. split - phase type -

→ The diagram for the split phase type induction instrument is shown here.




→ construction:

→ In this arrangement, there are two AC magnets $M_1$ & $M_2$ which are connected in series.

→ The winding in $m_2$ is shunted by a resistance R.

→ The current in the $m_2$ winding lags with respect to the total line current.
→ This helps to develop the necessary phase angle $\alpha$ between the two fluxes.

Deflection –

→ If the hysteresis effects are neglected, then deflecting torque is

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

(where all the signs have their usual meanings as stated before)

or $T_d \propto I^2$ (If fluxes are produced by the same current)

Note that, here I is the r.m.s value of current.

Also, $T_c \propto \theta$ (Because spring control is used)

In the final deflected position, $T_c = T_d$.

Therefore, deflection $(\theta) \propto I^2$.

Damping –

→ Eddy current damping is used in this instrument.

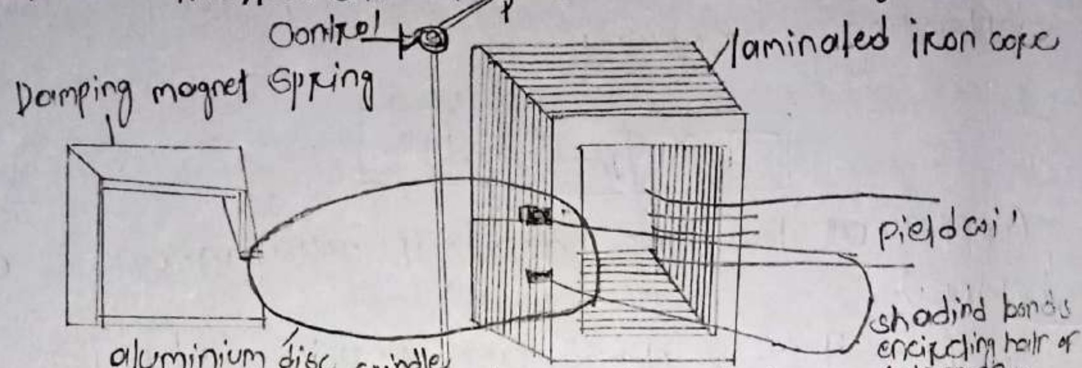
Shaded pole type –

→ Shaded pole type induction instrument uses a single winding to produce flux.
→ The flux produced by this winding is split up into two fluxes, having phase difference, with respect to each other.
→ The phase difference is usually 40 to 50 degrees and can be varied by varying the size of shading band.
→ This is done by making a narrow slot in the poles of the electromagnet.

A copper strip is placed around the smaller of the areas formed by the slot. This copper shading band acts as a short circuited secondary winding.

Construction-

→ The constructional features of a shaded pole type induction instrument are show in the figure below.




The exciting coil is placed on the poles and a current proportional to current or voltage being measured is passed through it. An aluminium disc which is mounted on a spindle is inserted in the air gap of the electromagnet. The spindle carries a pointer and has a control spring attached to it.

→ The controlling torque is provided by this spring only.

Deflection:-

→ As the net driving torque is due to the fluxes and the difference in the phase angle of these fluxes, then deflecting torque can be written as

$$T_d \propto \phi_1 \phi_2 \sin\alpha$$

If are produced by same current I, then $T_d \propto I^2$

As the instrument is spring controlled, $T_c \propto \theta$

For steady deflection, $T_c = T_d \Rightarrow \theta \propto I^2$.

## Damping -

→ Damping is provided by a permanent 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 -

→ A full scale deflection of over 300 degrees can be obtained.
→ Good damping.
→ less effect of stray magnetic fields as the operating fields are large.

## Disadvantages -

→ Errors are caused due to changes in frequency and temperature.
→ Non - uniform scale.
→ Large power consuption and high cost.
→ can be used for AC only.

Q. What is Electrodynamometer wattmeter & its working

→ ~~Definition~~ - An electrical instrument used to measure electric power in watts to any circuit. is called wattmeter. It consists of two coils like the current coil and voltage coil.

→ The current coil, which is connected in series & voltage coil is connected in parallel, wattmeters are mainly used in electrical current measurement. debugging, transmission, distribution of electrical power, power rating, consumption of electrical appliances utility frequency measurement, home appliance and many more.

→ These are Electrodynamometer wattmeter. Induction type wattmeter, Electrostatic type wattmeter let us discuss an overview of the

Imp Electrodynamometer wattmeter.

What is Electrodynamometer wattmeter?

→ Definition- Electrodynamometer wattmeter is an instrument whose working is related to the reaction between magnetic field of the fixed coil and moving coil which is connected across to the voltage (current is directly proportional to voltage). Electrodynamometer wattmeters are similar to the Electrodynamometer ammeters and voltmeters. These are mainly used to measure power.

Working principle-

→ The Electrodynamometer wattmeter working principle is very simple and easy.

→ It is based on the theory of a current-carrying conductor experiences a magnetic force when it is placed in a magnetic field.

→ Hence there will be a deflection of pointer that took place due to the mechanical force.

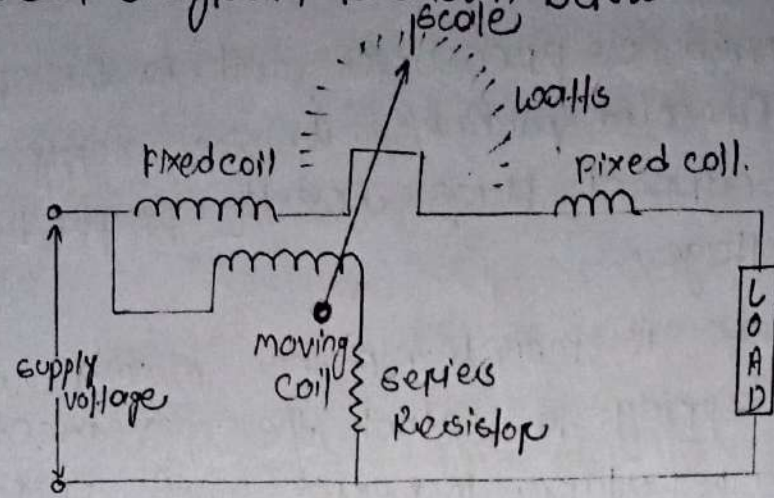
→ It contains two coils such as fixed coil (current coil) and moving coil (pressure coil or voltage coil).

→ The fixed coil is used to carry to current & connected in series with the load in any circuit.

→ The moving coil carries the current directly proportional to the voltage and connected across the voltage.

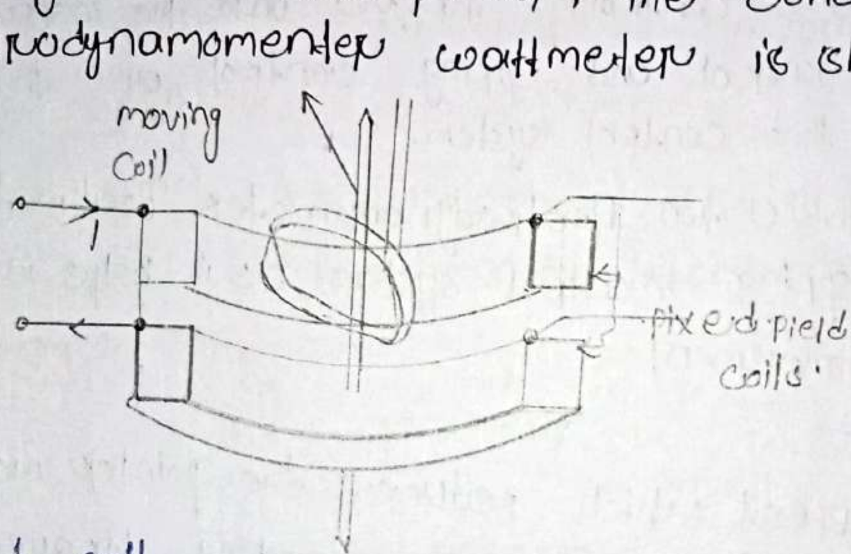
→ The value of current limited to minimum value due to large non-inductive resistance connected in series.

→ The circuit diagram is shown below..




* Construction of Electrodynamometer wattmeter

→ The construction of the Electrodynamometer wattmeter includes fixed coil, moving coil, control, damping, scales, and pointer. The construction of the Electrodynamometer wattmeter is shown below.




→ fixed coil –

→ it is connected in series with the load, which is considered as the current coil. To make construction easy and simple. it is divided into two parts. Those are two elements connected parallel to each other. It produces a uniform electric field which is very essential for working.

→ The current coil is designed in such a way that it carries approximately 20 Amperes.

→ Moving coil –
Considered as pressure coil in this instrument that is connected parallel with the supply voltage. so that current flows directly proportional to supply voltage.

→ A pointer is mounted on the moving coil with the help of spring to control the movement.

→ The temperature increase when current flow through the coil. so in order to control the flow of the current resistor is connected in series with the moving coil.

Control :-

→ It provides controlling torque onto the instruments. Gravity control and spring control are the two types in this control system.

→ Among these two Electrodynamometer wattmeters uses a spring control system as it helps in the pointer movement.

Damping :-

→ The effect which reduces the pointer movement is called damping. In this damping torque is produced because of the air friction. other type of damping are not used as they destroy the useful magneticflux.

→ Scales and pointers :-

→ It uses a linear scale as the moving coil moves linearly

→ The apparatus uses knife-edge pointers in order to remove parallax error caused due to oversights.

* Working of Electrodynamometer wattmeter

→ The Electrodynamometer wattmeter has two coils. i.e fixed & moving coils. The fixed coil is connected in series with the circuit in order to measure power consumption.

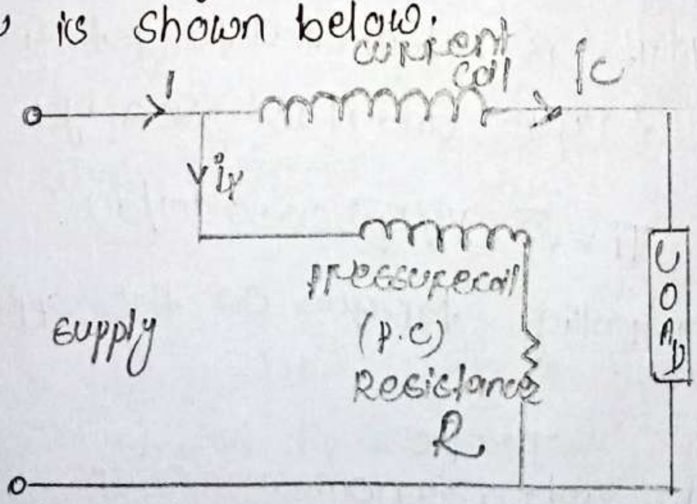
→ The supply voltage is applied to the moving coil. current across the moving coil is controlled with the help of a resistor, which is connected in series with it. moving coil on which pointer is fixed is placed in between fixed coil.

→ Two magnetic fields are generated due to the current and voltage in the fixed coil and moving coil. The pointer deflects as the two magnetic field interact.

→ The deflection is proportional to the power that is flowing through it.

Theory of Electrodynamometer wattmeter

→ The circuit diagram of the Electrodynamometer wattmeter is shown below:




→ The Instantaneous torque acting on the pointer is given by,

where 'ip' is the current flowing through pressure coil.

→ The eqn for the voltage in a circuit across the pressure coil is.

$$v = \sqrt{2} I \sin(\omega t - \phi)$$

→ The current will be in phase with the voltage if a purely resistive pressure coil is used. The value of the current is,

$$I_p = V/R_p = \sqrt{2}(VI/R_p) \sin \omega t = \sqrt{2} I_p \sin \omega t.$$

→ The current flowing through the current coil when it is lagged by the voltage in phase angle is,

$$i_p = \sqrt{2} I \sin(\omega t - \phi)$$

→ The current value is very small in the pressure coil.

→ Hence it is considered as the coil total load current. The torque acting on the coil is,

$$T_i = \sqrt{2} I \sin(\omega t - \phi)\, dm/d\theta$$

0 to T limit is integrated to get average deflection torque and it is given by:

$$T_i = \sqrt{2}(VI/R_p) \cos\phi\, dm/d\theta.$$

The controlling torque on the spring is.

$$T_c = k\theta$$

Errors in electrodynamometer wattmeter.

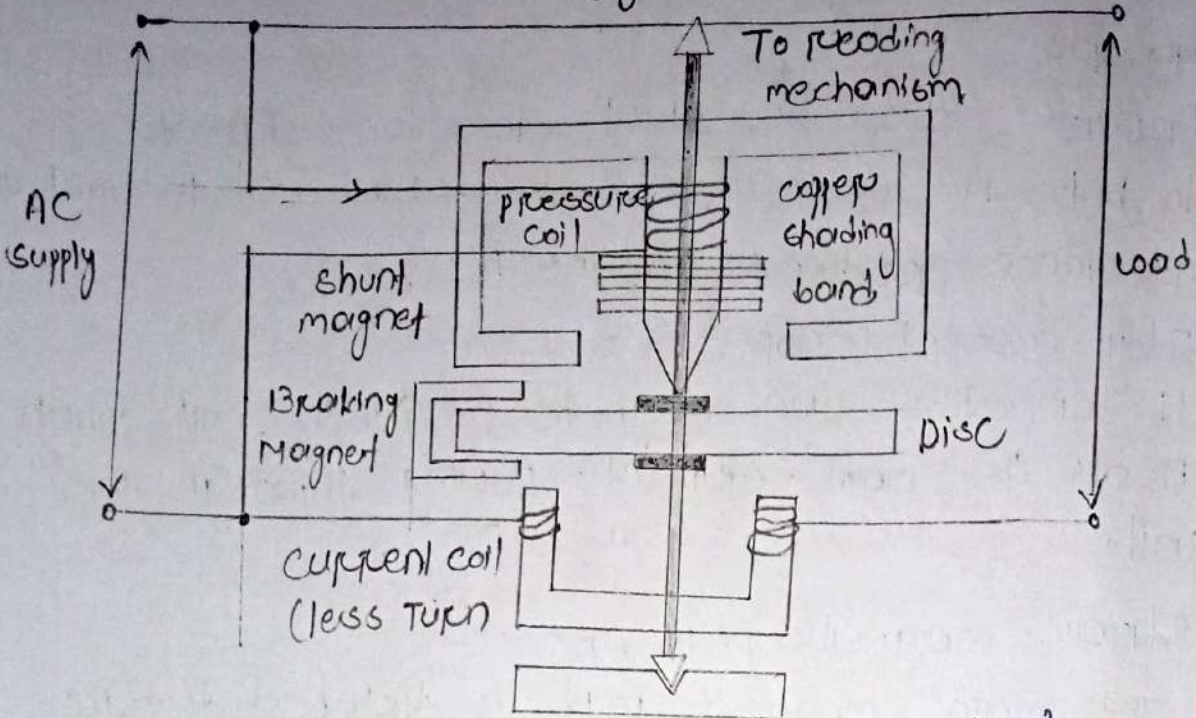
→ pressure coil inductance :- The pressure coil has some inductance because of which current is lagged by voltage. Hence power factor becomes lagging and leads to a high reading.

→ pressure coil capacitance:-
→ pressure coil also has capacitances that increase the power factor. This leads to reading errors.
→ Errors caused by mutual Inductance Effect:-
→ In between pressure and current coil the mutual inductance produces an error.
→ Eddy current Error :-
→ It creates own magnetic field in the coil which effects the main current flowing through the coil.
→ Stray magnetic field Error:-
→ The main magnetic field is distrbed due to this. This affects the reading of the instrument.
→ Temperature Error:-
→ change in the pressure coil resistance is caused due to variations in temperature. Due to this the temperature variation, the controlling torque produced by the spring movement is also affected.

Energy meter:-
→ Definition :- The meter which is used for measuring the energy utiliese by the electric load is known as the energy meter.
→ The energy is the total power consumed and utilised by the load at a particular interval of time
→ It is used in domestic and industrial. AC circuit. For measuring the power consumption the meter is less expensive and accurate.

Construction of Energy meter :-

→ The construction of the single phase energy meter is shown in the figure below.




(Inductione Type Energy meter)

The energy meter has four main parts.

They are the :-

1. Driving system.
2. moving system.
3. Braking system.
4. Registering system.

1. Driving system :-

→ The electromagnetic is the main component of the driving system. It is the temporary magnet which is excited by the current flow through the coil.

→ The core of the electromagnet is made up of silicon steel lamination. The driving system has two electromagnets.

→ The upper one is called the shunt electromagnet and the lower one is called series electromagnet.

→ The series electromagnet is excited by the load current flow through the current coil.

→ The coil of the shunt electromagnet is directly connected with the supply and hence carry the current proportional to the shunt voltage. This coil is called the pressure coil.

→ The centre limb of the magnet has the copper band. These bands are adjustable. The main function of the copper band is to align the flux produced by the shunt magnet in such a way that it is exactly perpendicular to supplied voltage.

2. moving system–

→ The moving system is the aluminium disc mounted on the shaft of the alloy. The disc is placed in the air gap of the two electromagnets.

→ The eddy current is induced in the disc because of the change of the magnetic field. This eddy current is cut by the magnetic flux.

→ The interaction of the flux and the disc induces the deflecting torque.

→ when the devices consume power the aluminium disc starts rotating and after some number of rotations, the disc displays the unit used by the load.

→ The number of rotations of the disc is counted at particular interval of time. The disc measured the power consumption in kilowatt hours.

3. Braking system:– The permanent magnet is used for reducing the rotation of the alluminium disc

→ The aluminium disc induces the eddy current because of their rotation.

→ The eddy current cut the magnetic flux of the magnet and hence produces the braking torque.

→ This breaking torque opposes the movement of the disc, thus reduces their speed.

→ The permanent magnet is adjustable due to which the braking torque is also adjusted by shifting the magnet to the other radial position.

4. Registration (counting mechanism)-

→ The main function of the resistance or counting mechanism is to record the number of rotations of the aluminium disc. Their rotation is directly proportional to the energy consumed by the loads in the kilowatt hour.

→ The rotation of the disc is transmitted to the pointers of the pointers of the different dial for recording the different readings.

→ The reading in kwh is obtained by multiply the number of rotations of the disc with the meter constant. The figure of the dial is shown below.

Working of the Energy meter-

→ The energy meter has the aluminium disc whose rotation determines the power consumption of the load.

→ The disc is placed between the air gap of the series and shunt electromagnet.

→ The shunt magnet has the pressure coil, and the series magnet has the current coil.

→ The pressure coil creates the magnetic field because of the supply voltage and the current coil produces it becaus of the current.

→ The field induces by the voltage coil is lagging by 90 on the magnetic field of the current coil because of which eddy current induced in the disc.

→ The interaction of the eddy current & the magnetic field causes torque, which exerts a force on the disc. Thus, the disc starts rotating.

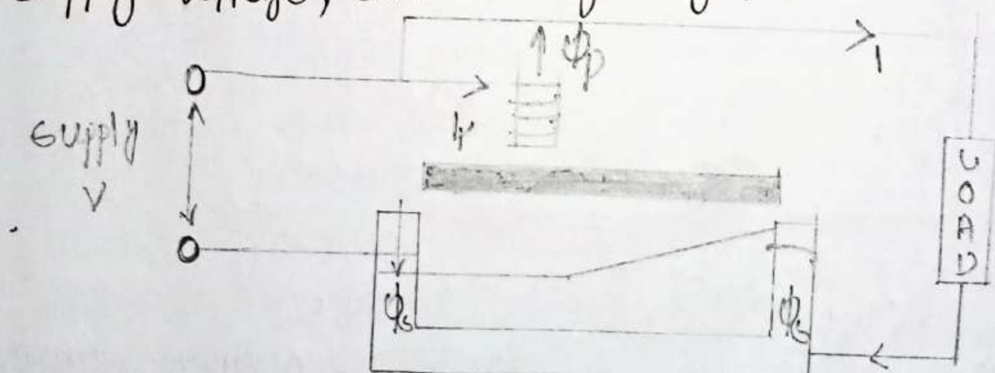
→ The force on the disc is proportional to the current and voltage of the coil. The permanent magnet controls their rotation.

→ The permanent magnet opposes the movement of the disc and equalises it on the power consumption.

→ The cyclometer count the rotation of the disc.

→ Theory of Energy meter.

→ The pressure coil has the number of turns. which makes it more inductive. The reluctance path of their magnetic circuit is very less because of the small length air gap. The current $I_p$ flows through the pressure coil because of the supply voltage, and it lags by 90°.




(working of energy meter)

→ The $I_p$ produces the two $\phi_p$ which is again divided into $\phi_{p1}$ and $\phi_{p2}$. The major portion of the flux $\phi_{p1}$ passes through the side gap because of low reluctance. The flux $\phi_{p2}$ goes through the disc & induces the driving torque which rotates the aluminium disc.

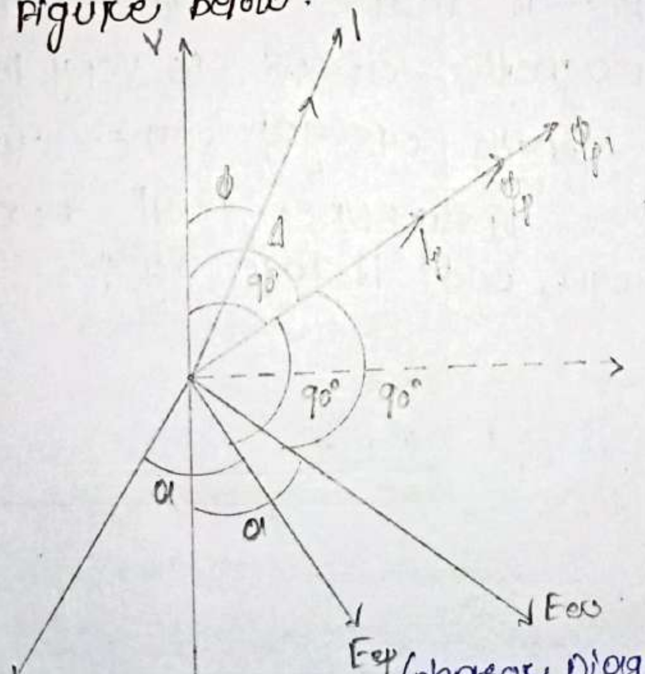
→ The flux $\phi_p$ is proportional to the applied voltage, & it is lagged by an angle of 90°. The flux is alternating and hence induces an eddy current Iep in the disc.

→ The load current passes through the current coil induces the flux $\phi_s$. This flux causes the eddy current Ies on the disc.

→ The eddy current Ies interacts with the flux $\phi_p$ and the eddy current Iep interacts with $\phi_s$ to produce the another torque.

→ These torques are opposite in direction and the net torque is the difference between these two.

→ The phasor diagram of the energy meter is shown in the figure below.




(phasor Diagram of Energy meter)

Let:

V – applied voltage.

I – load current.

$\phi$ – the phase angle of load current.

$I_p$ = pressure angle of load.

$\Delta$ – the phase angle between supply voltage and pressure coil flux.

f - frequency
z - impedance of eddy current
$\alpha$ - the phase angle of eddy current paths.
$E_{ep}$ - eddy current induced by flux.
$I_{ep}$ - eddy current due to flux.
$E_{er}$ - eddy current due to flux.
$I_{es}$ - eddy current due to flux.

The speed of the rotation is directly proportional to the power.

Total number of revolution = $\int N dt = k \int VI \sin(A - \phi)$

If $A = 90°$, total number of revolutions.

$$= k \int VI \cos\phi \, dt.$$

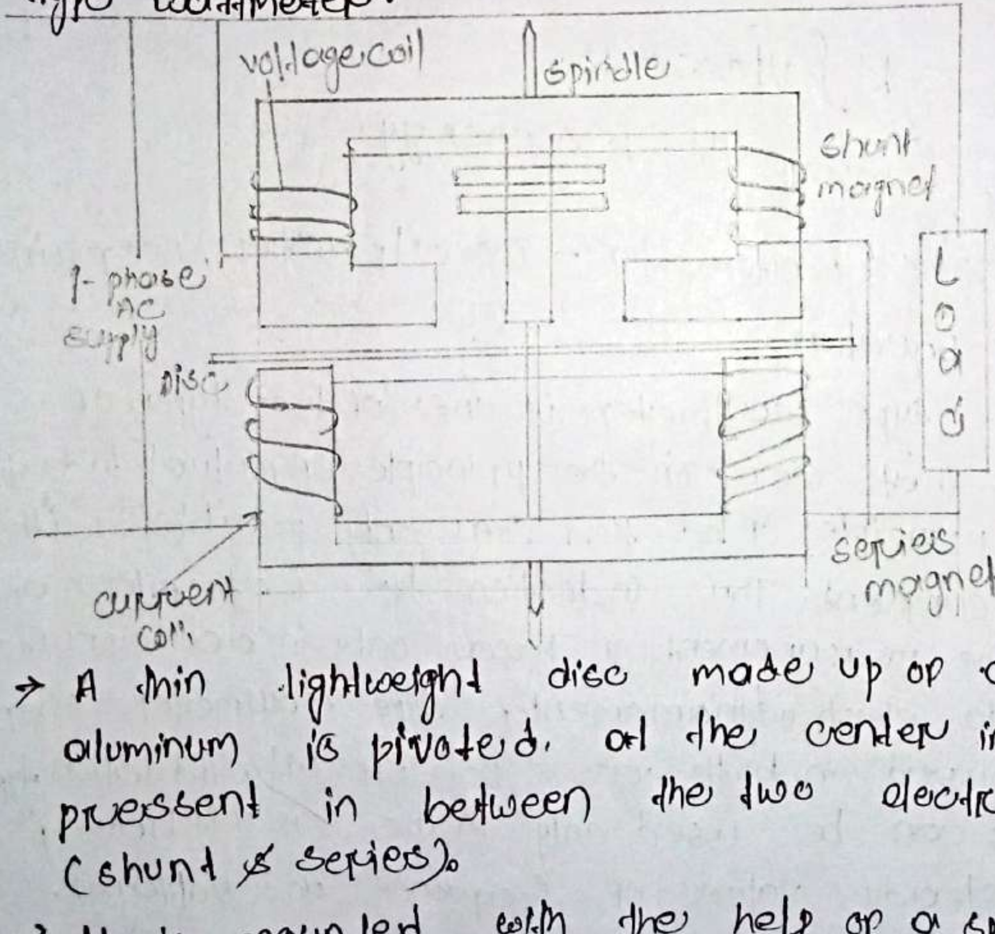
$$= k \int \text{power } dt = k \times \text{energy}.$$

Induction type wattmeter - construction, working & Torque Equation.

→ Induction type wattmeter is one of the types of wattmeters that work on the principle of mutual induction.
→ Since the principle of induction can only possible with alternating current. Thus induction type wattmeters are used for the measurement of power only in ac circuit. Compared to electrodynamometer type wattmeters where it can be used in both ac & DC circuit, induction type wattmeters can be used only in the circuit having relatively steady values of frequency and voltage.

Construction of induction type wattmeter:-
→ It mainly consists of two laminated electromagnets wound with conductors known as shunt and series magnets.

→ The upper electromagnet is known as a shunt magnet.
→ It consists of three limbs, the side limbs carry the winding and it is connected across the load.
→ These windings are excited by the current proportional to the voltage across the load, hence they are called voltage coils.
→ The lower electromagnet is connected in series with load in which power is to be measured & is known as a series magnet. It carries the windings called current coil and it is excited proportionally to the load current.
→ The below shows the construction of an induction-type wattmeter.




→ A thin lightweight disc made up of copper or aluminum is pivoted at the center in the airgap present in between the two electromagnets (shunt & series).
→ It is mounted with the help of a spindle so that the disc can rotate, which is turn rotates the spindle. A pointer is attached at top of the spindle and rotates with the spindle over the scale.

working of induction type wattmeter:-

→ The working principle of induction type wattmeter is similar to induction type voltmeter and ammeter.

→ The shunt magnet that carries two voltage coils are connected in series and other ends are connected across the load.

→ They are wounded in such a way that both circulate a flux through the central limb. In order to make the resultant flux lag behind the applied voltage by 90°. Shading bands are placed on the central limb.

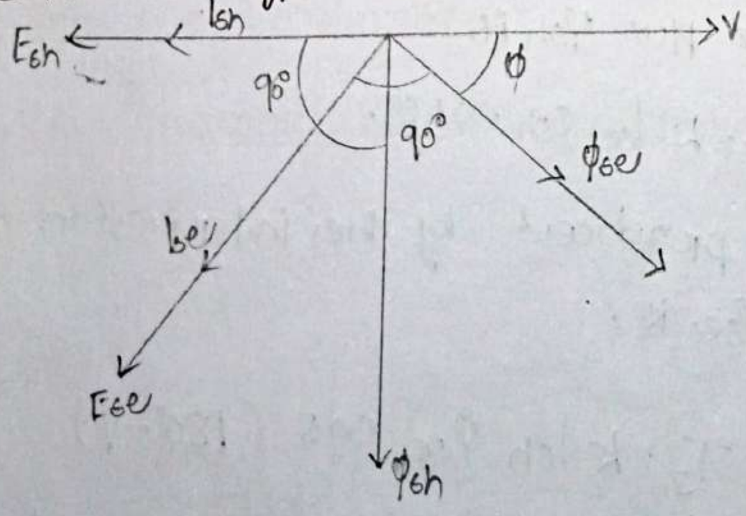
→ Similarly the series magnet that carries two current coils are connected in series & are wound in such a way that, they produce flux in the same direction.

→ When the disc cuts the two fluxes i.e from the shunt & series magnet. The combined effect of these changing fluxes on the disc induces eddy current in it.

→ Therefore a deflecting torque is produced on the disc due to the interaction of field produced by the eddy currents. This causes to rotate the disc, thereby the spindle and pointer. To control deflecting torque, springs are provided that produce controlling torque.

## Torque Equation:-

→ The below shows the phasor diagram on the operation of the induction type wattmeter.




Let,

V = voltage to be measured.

I = current to be measured.

- $\varphi$ = phase angle between current & voltage.
- $\varphi_{se}$ = flux produced by series magnet.
- $\varphi_{sh}$ = flux produced by shunt magnet.
- $E_{sh}$ = Emf induced in the disc by the shunt magnet flux.
- $I_{sh}$ = Eddy current in the disc caused by emf $E_{sh}$.
- $E_{se}$ = Emf induced in the disc by the series magnet flux
- $I_{se}$ = Eddy current in the disc caused by emf $E_{se}$.

→ Assuming the disc is full resistive, the eddy current $I_{se}$ induce by the emf $E_{se}$ will be in phase with it.

→ So we can see that eddy current $I_{se}$ lags behind the current I by 90°. Thus there will be a phase difference of 90° between $I_{se}$ and $\varphi_{se}$.

→ The flux $\varphi_{sh}$ induces an emf $E_{sh}$ in the disc, which lags behind the $\varphi_{sh}$ by 90° since the disc is resistive the eddy current $I_{sh}$ caused by $E_{sh}$ will be in phase with it.

→ Thus there will be a phase difference of 90° between $I_{sh}$ & $\varphi_{sh}$.

→ The torque produced by the interaction of current $I_{se}$ & flux $\varphi_{sh}$ is.

$$T_1 = k\, I_{se}\, \phi_{sh} \cos\phi.$$

The torque produced by the interaction of current $I_{sh}$ & flux $\varphi_{se}$ is,

$$T_2 = k\, I_{sh}\, \varphi_{se} \cos(180° - \phi)$$

Therefore, the resultant torque produced is.

$$= k\, I_{se}\, \varphi_{sh} \cos\phi - k\, I_{sh}\, \varphi_{se} \cos(180° - \phi)$$

$= k[I_{sh}\phi_{sh}\cos\phi + I_{sh}\phi_{se}\cos\phi]$

$= k[k_1 VI\cos\phi + k_2 VI\cos\phi]$

$\therefore T_d \propto VI\cos\phi$.

Hence the deflecting torque produced is proportional to the ac power to be measured in the circuit.

Advantages of induction type wattmeter:-

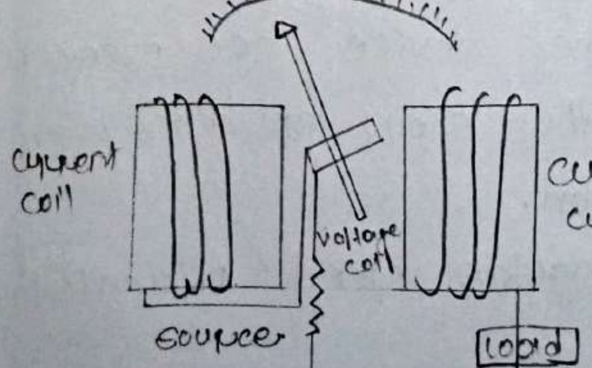
- The scale is uniform.
- They provide good damping.
- There is no effect of stray field.

Dis-advantages of induction type wattmeter:-

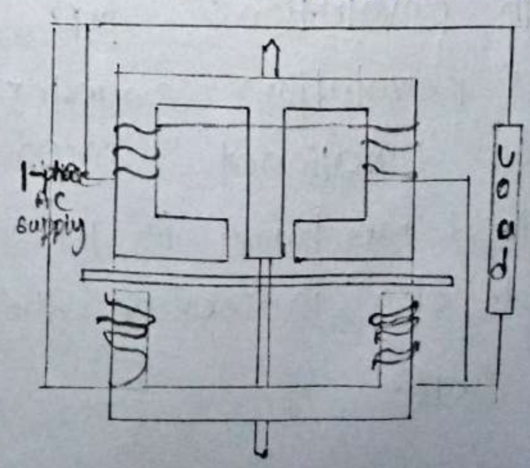
- can be used only for ac power measurement.
- Low accuracy due to heavy moving system.
- Temperature changes can affect the readings by introducing error.
- power consumption is more.

Difference Between Dynamometer wattmeter & induction type wattmeter:

Electrodynamometer wattmeter.




Induction type wattmeter.



| | |
|---|---|
| → The current coil is split into two parts, but a single pressure coil. | → Both current and pressure coils split into two parts each, placed on each of two arms of the two magnets. |
| → The pressure coil current is very high. | → The pressure coil current is small. |
| → The pressure coil is the moving coil. | → None of the coils are moving, rather there is an aluminium disc placed in betn the two electromagnets that move. |
| → can be used for the measurement of power both in AC as well as DC circuit. | → can only be used for the measurement of power in AC circuit. |
| → The pointer is attached to the moving (pressure) coil. | → The pointer is attached to the aluminum disc. |
| → can be used in circuits even with the fluctuating frequency and voltage. | → can be used with circuits having relatively steady values of frequency and voltage. |
| → fluid friction damping is used | → Eddy current damping is used. |

→ what is Tachometer and its uses?

→ The tachometer is a measuring instrument that is used to measure the operating speed of an engine in revolutions per minute. It is also known as a revolution counter. The device can measure the rotational speed of the shaft or disc when the machine is in motion.

→ It also indicates the angular speed of a rotating shaft.

→ This instrument is usually used to estimate traffic speed and volume flow. It is used in cars, aircraft or other vehicles. It shows the rate of rotation of engine crankshaft along with the marking that displays the safe range of rotational speed.

* Working principle of Tachometer:

→ An electric ~~Fee~~ tachometer works on the principle of relative motion between the magnetic field and shaft of the coupled device.

→ The motor of tachometer works as a generator, i.e it produces the voltage based on the velocity of the shaft.

→ It counts the number of rotations the crankshaft is making per minute. It is essential for the user to know the RPM of the engine and its operating range to avoid unnecessary damages. The device works on either an alternating or direct current.

Types of Tachometer:-

→ Contact type:- This type of tachometer is usually fixed to the machine or electric motor. It works by bringing a freely spinning wheel in contact with a rotating shaft or disc. The shaft drives the wheel to generate the pulses.

→ These pulses are then read by a tachometer and measured in revolution per minute. It can also calculate the linear speed and distance.

→ Non-contact type:- It is also known as photo tachometer or non-touch tachometer. This type of device doesn't need any physical contant with the rotating shaft.

→ It uses a laser, infrared light, or other light sources to take the measurements.

→ The device sends out the beam of light. This beam reflects each time a tape makes a full rotation. The receiver needs to count these reflections during the process to measure the rotational speed in RPM. This type of tachometer is efficient, durable, accurate, and compact.

→ Electronic tachometer :- It is made up of electronic components used to measure the engine speed.

→ It measures the speed in revolution per minute. It is mainly used in the dashboard of the car to measure the driving speed. It uses a magnetic pickup placed near a rotating engine to generate electric pulses. These pulses have frequency proportional to the engine speed.

→ Analog tachometer :- It is an electronic instrument that counts machine revolution based on time period. It reads the frequency with which coil's current changes the direction. In case the engine turns more quickly, the change in the magnetic field becomes more radical by generating the higher voltage.

→ Digital tachometer :- It is a digital device that measures the speed of the rotating object.

→ It is an optical encoder that identifies the angular velocity of a rotating shaft or motor.

→ It is commonly used in automobiles, airplanes, medical, and instrumentation applications.

→ Time measuring tachometer :- It calculates the speed by measuring the time interval betn incoming pulses. It is more suitable for measuring low speed with high accuracy.

→ Frequency measuring tachometer :- It calculates the speed the measuring the frequency of the pulses. The revolution of the device depends on the rotating shaft and is suitable for measuring the high speed. The modern version comes with a sophisticated digital circuit to perform the count, storage, calculation, display and reset to deliver output in rpm.

→ Mechanical tachometer :- It has a centrifugal force on a rotating mass to stretch or compress a mechanical spring. It uses a series of the consecutively tuned reeds to identify engine speed. It displays the engine speed by indicating vibration frequency of the machine.

→ Accuracy, precision, contact, non-contact type, range, acquisition time, portable/fixed, analog/digital, and cost are the important factors that are considered while selecting the right type of tachometer.

Application :-

1. It is used to measure rotational speed.
2. It can measure the flow of liquid with the help of an attached wheel with an inclined angle.
3. It is applicable for the medical sector to measure the blood flow rate of the patients.
4. It is used in vehicles to display the rate of engine crankshaft rotation.

Conclusion :-

→ The tachometer is one of the crucial elements in industrial motor control. Few of it's basic functions include monitoring of motor's speed, counting, process control, and ratio/draw application. whereas, it is applicable for equipment like conveyors, windmill, rotary, feeders, grinders, dryers, augers, elevators etc.

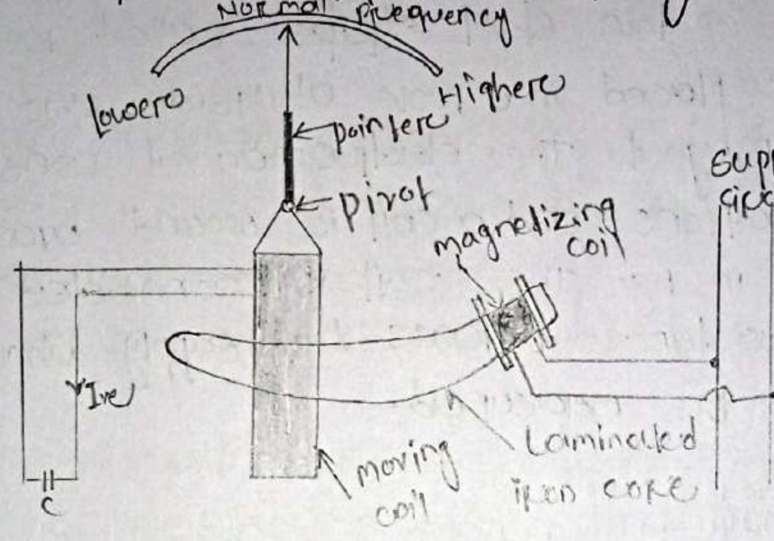
→ And the suitable industries include power plants, recycling and chemical plants, automotive and material handling, food and beverage, papermills, etc. Now ensure the safety of your equipment and automobile by measuring the working speed of an speed or an engine and maintaining the safe speed range withe the help of a tachometer.

Electrical Resonance type frequency meter:-

→ frequency meter:- There are used to measure supply frequency These are these are used at generating stations & substation. A frequency meter is an instrument that displays the frequency of the periodic electrical signal.

Electrical Resonance frequency meter:- It is a types of frequency meter which is used to measure frequency range 45HZ to 55HZ of AC supply.

Construction:- It consistes of a fixed coil which is connected across the supply whose frequency is to the measured. This coil is called magnetizing coil. The magnetizing coil is mounted on a naminated iron core. The iron core has a accrose section which varies gradually over the length, being maximum near the end where the magnetizing coil is mounted. & minimum at the other end. A moving coil is pivoted over this iron core. A pointer is attached to the moving coil. The terminals of the moving coil are connected to a suitable capacitor. there is no provision for a controling force.




* working :- Due to the current in moving coil the moving coil produces a flux in phase with the current. This flux flows along with the extendend core of the fixed coil. Therefore with the current. This flux flows along with the ~~extended core of the fixed coil.~~ induces an emf across the moving coil. obviously this induced emf lags the flux by 90°. Since it is a coil the moving coil will have some inductance. Agaain. as it is connected across a capacitor it will have some capacitive reactance also.

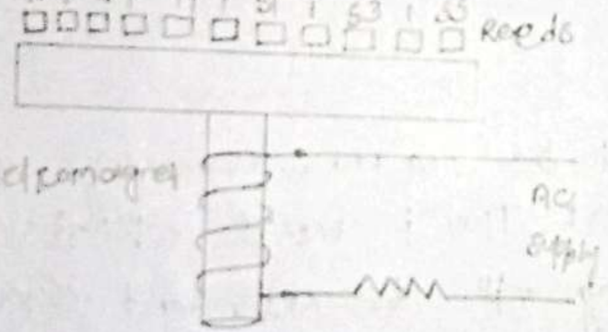
Mechanical Resonance type Frequency meter

→ A mechanical resonance type frequency meter indicate the supply frequency of the circuit directly and is very much convenient for most practical purpose.

→ It is very simple instrument and has got an advantages of given reading free from errors due to change in temperature, waveform and magnitude of the applied voltage.

Construction of mechanical Resonance type Frequency meter:–

→ A vibrating reed frequency meter consists of a number of thin steel strips called reeds. These reeds are placed in a row alongside and close to an electromagnet. The electromagnet consists of thin laminations and a coil is wound around it as shown in fig. The coil is connected in series with a resistance across the supply whose frequency is to be measured.




(vibrating reed type frequency meter)

→ The approximate dimension of the vibrating reeds are about A mm wide and 1/2 mm thick. The reeds are not similar to each other but differ either in their dimensions or weight carry different flags their tops. This is done to vary the natural frequency of vibration of each reed.

→ The reeds are fixed at the bottom end and are free at the top end. The flage at the top of reeds are painted white. and the frequency is read directly from the instrument by observing the scale mark opposite to the reed which is vibrating most.

→ The reeds are arranged is ascending order of natural frequency the difference in frequency is usually 1Hz.

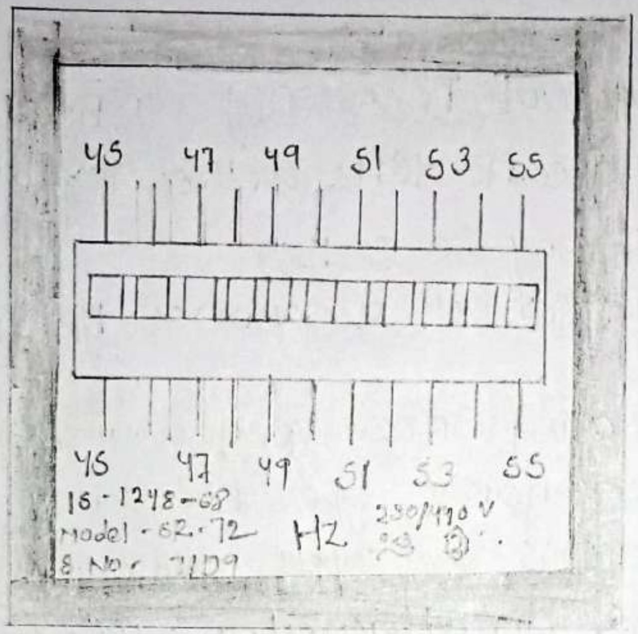
→ Thus the natural frequency of first reed may be 45 Hz, of the second 46Hz, of the next 47Hz and so on of the last may be 55Hz.

Working of mechanical Resonance type frequency meter:

→ when the vibrating reed frequency meter or. mechanical resonance type frequency meter is connected across the supply whose frequency is to be measured an alternating current I flows through the coil of an electromagnet which produce a force of attraction on the reeds. The force of attraction is proportionl to the square of the current therefore. it varies at twice the supply frequency. Hence a force of exerted on the reeds at every half cycle.

→ All the reeds thus tend to vibrate, but only the one whose natural frequency is double. that of supply will vibrate appreciably. mechanical is obtained in the case of this reed The frequency is determind, therefore by noting the scale reading opposite the reed that vibrates with maximum amplitude.

→ The tuning in these meters is so sharp that as the excitation frequency changes from resonant frequency the amplitude of vibration decreases rapidly becoming negligible for a frequency which is slightly away from resonant one.




* How to measure low resistances? (Resistance measurement methods)

→ The resistances of the values of less than or equal to 1 Ω are classified as low resistances. For example, the resistances of armatures and series windings of large machines, ammeter shunts, contacts etc.

Measurement of low Resistances:-

For the measurement of low resistances, the following methods are used-

- Ammeter - voltmeter method.
- potentiometer method.
- kelvin Double Bridge method.

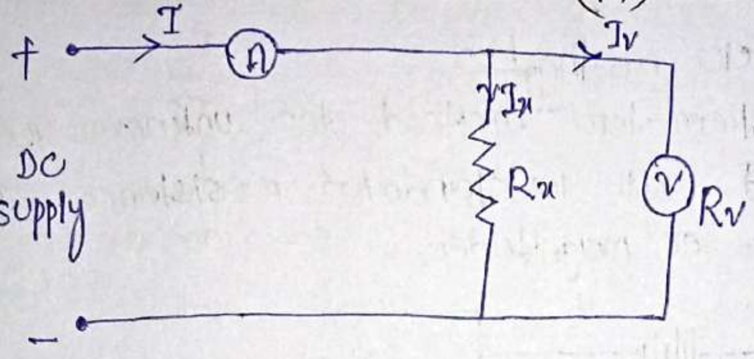
→ Ammeter-voltmeter method:-

→ In this method, current through the unknown resistor ($R_x$) and the potential drop across it are simultaneously measured. The readings are obtained by ammeter & voltmeters respectively.

→ There are two ways in ammeter and voltmeters may be connected for measurement as,

Case-1

→ when voltmeter is directly connected across the resistor then the ammeter measures current flowing through the unknown resistance ($R_x$) and the voltmeter.




→ current through ammeter = current through ($R_x$) + current through voltmeter.

$$I = I_{R_x} + I_V$$

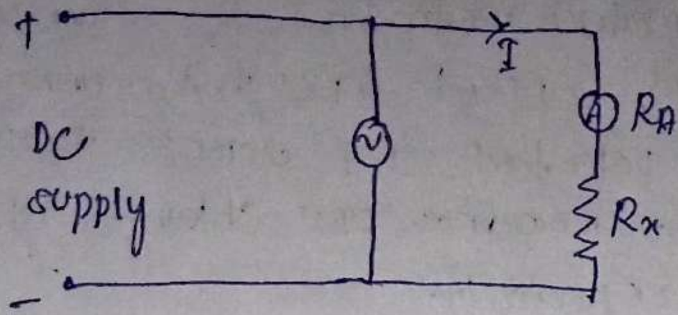
$$\Rightarrow I_{R_x} = I - I_V$$

Therefore, the value of unknown resistance,

$$R_x = \frac{V}{I_x} = \frac{V}{I - I_V} = \frac{V}{I - (V/R_V)} \quad \dots (1)$$

Case-2

→ when the ammeter is connected such that it measures only the current flowing the unknown resistor ($R_x$). then the voltmeter measures voltage drop across the ammeter and $R_x$.



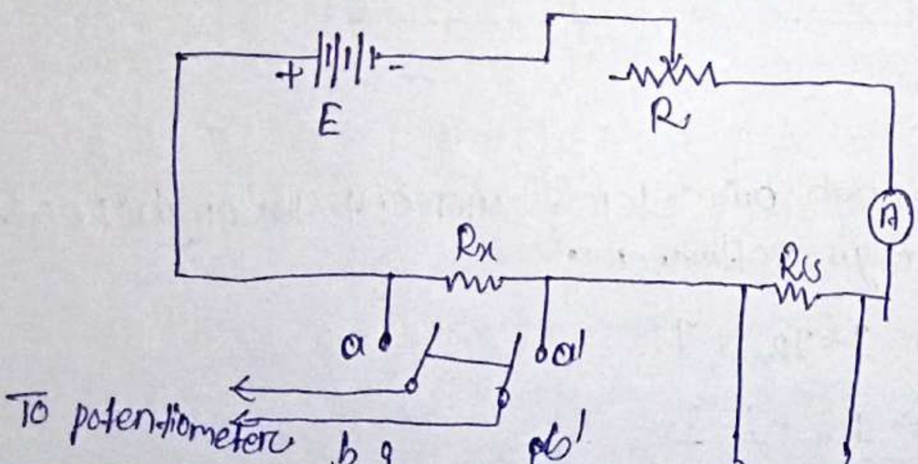

Therefore

$$V = IR_A + IR_x = I(R_A + R_x)$$

$$\Rightarrow R_x = \frac{V}{I} - R_A \quad \text{.....(2)}$$

potentiometer method :-

→ In the potentiometer method, the unknown resistance is compared with a standard resistance of the same order of magnitude.




→ The circuit consists of an unknown resistance ($R_x$), a rheostat (R) and a standard resistance ($R_s$) all are connected in series across a low voltage, high current supply.

→ The value of $R_s$ should be known and of the same order of $R_x$. The current flowing in the circuit is adjusted so, that the potential difference across each resistor is about 1v.

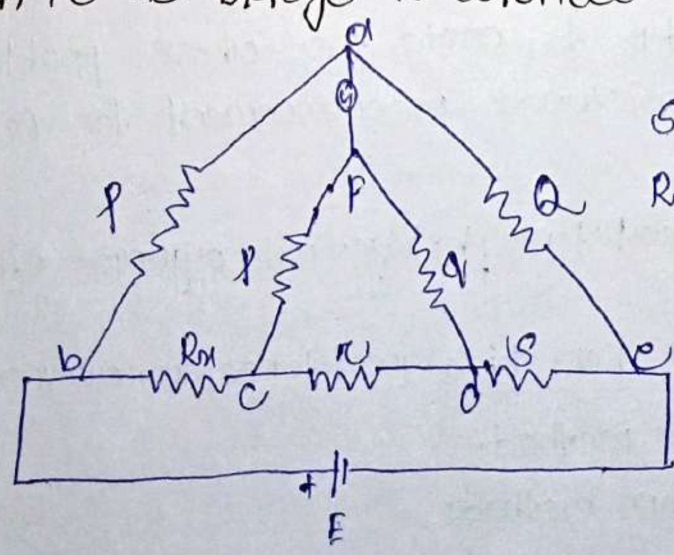
→ Now, the voltage drop across both the standard resistance ($R_s$) and unknown resistance ($R_x$) are measured by a potentiometer. The ratio of the two potentiometer readings gives the ratio of Rx and Rs i.e.

$$\frac{R_x}{R_s} = \frac{V_{Rx}}{V_R}$$

→ kelvin Double Bridge method :-

→ The kelvin double bridge is a modified version of wheatstone bridge and used to measure the low resistance with higher accuracy. This bridge is called double bridge since the circuit contains a second set of ratio arms (p and q).

→ This second set of ratio arms connects the galvanometer (G) to a point p at the appropriate potential difference between c and d and this eliminates the effects of yoke resistance r. The galvanometer show zero reading when potential at a equals to the potential at p, i.e the bridge is balanced.




S = Standard Resistance
Rx = Unknown Resistance

Therefore, the value of unknown resistance can be given by,

$$R_x = \frac{PS}{Q} + \frac{pr}{p+q+r}\left(\frac{P}{Q} - \frac{p}{q}\right)$$

Since, the ratio of resistances of arms p and q is the same as the ratio of P and Q. Thus.

$$\frac{p}{q} = \frac{P}{Q}$$

Substituting in the above expression, we get.

$$R_x = \frac{PS}{Q}$$

The eq. (4) is the work equation of kelvin double bridge.

→ **Loss of charge method for measuring High Resistance circuit, Derivation & Errors.**

→ The loss of charge method is used to measure resistance greater than 100kΩ or 0.1mΩ. The drawback of the wheatstone bridge is that, It cannot to be used to measure the high value of resistance of the order of 1mΩ because of the reduction in the sensitivity to unbalance caused by the high resistance values. Also the high resistance measurements are inaccurate due to leakage over the insulation of the bridge arms.

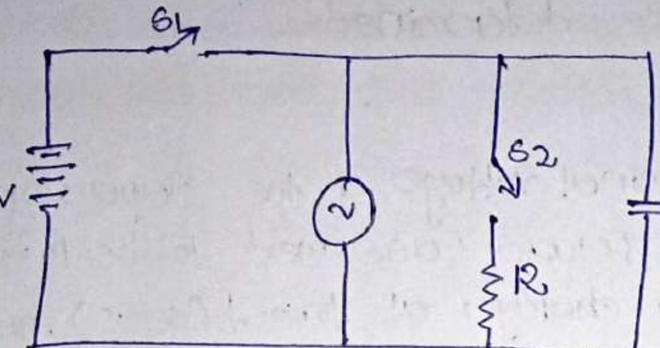
→ Hence, in order to avoid the above problems while doing high resistance measurement the following methods are used.

- A modified wheatstone bridge with a guard circuit can be used.
- other methods for high resistance measurements like.
- Loss of charge method.
- Direct Deflection method.
- megohm bridge method.
- Megger.

→ In this let us see about the measurement of high resistance using the loss of charge method.

→ Loss of charge method:-

→ This method is especially used for the measurement of the very high value of resistance like the insulation resistance of cables and machines, high resistance circuits like vacuum tubes, leakage resistance of the capacitor, the surface resistivity of the material, and insulation resistance of the transformer winding. The basic idea is based on the charging and discharging of a known value capacitance.




→ The figure above shown the circuit connections for the loss of charge method. where, R is the unknown resistance to be measured, 'c' is a known value capacitor placed across R, V is an electrostatic type voltmeter to measure the voltage across the parallel combination of R and C.

→ The circuit is driven by a battery having a voltage V. $S_1$ and $S_2$ are the switches used for charging and discharging the capacitor. It is assumed that the internal resistance of the voltmeter and leakage resistance of the capacitor is infinite. The sequence of operation can be explained as follows,

when switch $S_1$ closed and $S_2$ open:-

→ with switch $S_1$ closed and $S_2$ open, the capacitor charges to a particular voltage. The voltage across 'C' is measured by the voltmeter V and is noted down.

→ When switch $S_1$ open and $S_2$ closed :-
With switch $S_1$ open and $S_2$ closed, the battery is disconnected and the unknown resistance R gets connected across C. Now the capacitor discharges through R. During this, the capacitor voltage is measured by the voltmeter.

→ Taking the above two readings of voltmeter, we get two equations solving the two equations, the value of unknown resistance can be determined.

## Derivation:-

→ If $V_c$ be the terminal voltage of the capacitor consisting of capacitance 'C' Farad (assumed to be lossless) and Q (coulomb) be the charge at time t (secs). Then the charging current i is.

$$i = -\frac{dQ}{dt} = -\frac{d(CV_c)}{dt} = -C\frac{dV_c}{dt} \quad \cdots (1)$$

$$i = \frac{V_c}{R} \quad \cdots (2)$$

Equating equations 1 & 2, we get,

$$\frac{V_c}{R} = -C\frac{dV_c}{dt}$$

$$\frac{dV_c}{dt} = \frac{-1}{CR}\,dt$$

Applying integration on both sides, we get.

$$\ln V_c = \frac{-1}{CR} + \ln A$$

A = Arbitrary constant

Applying initial conditions to the above equation. At $t=0$, $V_c$ (i.e the voltage at which capacitor in initially charged), therefore,

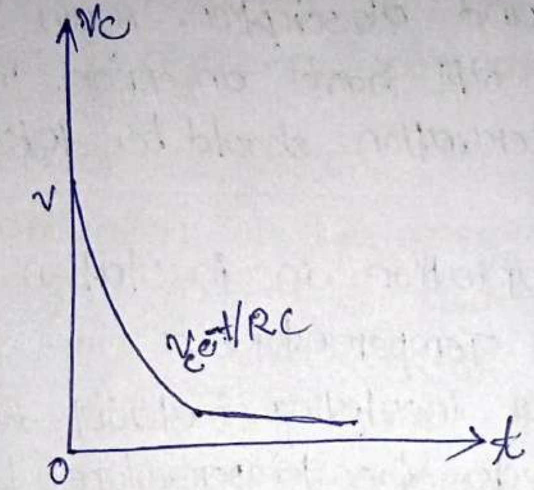
$$A = V$$

$$\ln v_c = \ln v - \frac{1}{CR}$$

$$\frac{1}{CR} = \ln \frac{v}{v_c}$$

$$R = \frac{1}{C\ln\frac{v}{v_c}} = \frac{0.4343t}{C\log_{10}\frac{v}{v_c}}$$

→ The below graph shown the variation of $v_c$ with respect to $t$. If the value of the resistance to be measured is very large, then the time taken for the voltage to fall is quite large. Hence, this method is tedious and time consuming.




→ However, the accuracy of the voltage measured depends upon methods implemented to reduce errors. otherwise, errors are introduced while computing the ratio (E/V), thereby causing an error in the measurement of insulation resistance. In order to obtain high accuracy, a drop in voltage i.e. $(v - v_c)$ is taken instead of $v_c$.

$$R = \frac{0.4343t}{C\log_{10}\frac{v}{v - v_c}}$$

Errors in loss of charge method:-

→ There are certain possible errors in the loss of charge method. The errors must be minimized, otherwise, an appreciable amount of error is introduced while measuring insulation resistance.

Errors due to Leakage and Absorption:-

→ Every insulating body will have some leakage current since we can't get an ideal insulator. The value of this leakage current is quite significant with respect to the current under measurement. Due to this results will not be accurate. Hence in order to reduce the error due to leakage, the insulation resistances of the capacitors and voltmeter must be very high.

→ Also, every insulation material will have an absorption effect. The net current flowing is the sum of currents due to resistance and absorption. Again due to this effect, the readings will have an error. In order to reduce it, the observation should be taken for a long period of time.

Error due to variation in insulation Resistance due to variation in Temperature:-

→ The resistance of insulating material is a function of temperature whenever the temperature increases, the resistance decreases, and hence the current flowing through the material increases. As we known that the temperature is variable quantity. Therefore the resistance, as well as current, vary along with it. Hence in order to have accurate results, resistance along with the temperature at which the test was performed must be specified.

Error due to time of Application of voltage:-

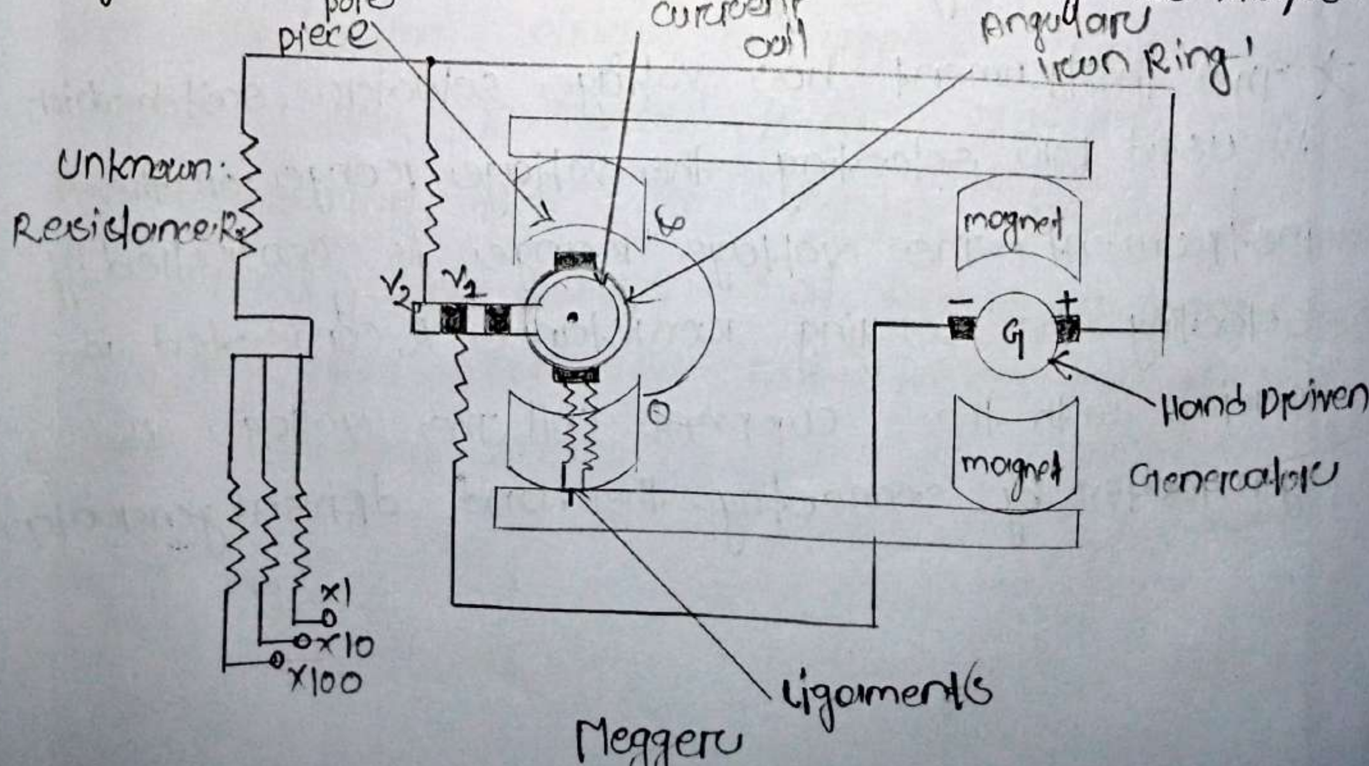
→ The effect of absorption is associated with almost all the insulating materials. The value of current due to absorption effect is not constant but varies with the time for which voltage is applied. The value of the absorption current is different at a different between instances of time. Hence due to this accuracy of the measurement will be lost.

## Megger:-

Definition:- The megger is the instrument uses for measuring the resistance of the insulation. It works on the principle of comparison, i.e. the resistance of the insulation is compared with the known value of resistance. If the resistance of the insulation is high, the pointer of the moving coil deflects towards the infinity, and if it is low then the pointer indicates zero resistance. The accuracy of the megger is high as compared to other instruments.

### construction of megger:-

→ The construction of the megger is shown in the figure below. The megger has one current coil and the two voltage coils $V_1$ & $V_2$. The voltage coil $V_1$ is passed over the magnet connected to the generator. When the pointer of the pmmc instrument deflects towards infinity it means that the voltage coil remains in the weak magnetic field and thus experienced the very little torque.




Megger

The torque experienced by the coil increases when it moves inside the strong magnetic field. The coil experience the maximum torque under the pole paces and the pointer set at the zero end of the resistance scale.

→ For improving the torque, the voltage coil $v_2$ is used. The coil $v_2$ is so allocated that when the pointer deflects from infinity to zero coil movesinto a stronger magnetic field.

→ In megger, the combined action of both the voltage coil $v_1$ & $v_2$ are considered. The coil comprises a spring or variable stiffness. It is stiffnear the zero end of the coil and becomes very weak near the infinity end of the spring.

→ The spring compresses the low resistance portion and opens the high resistance of the spring, which is the great advantage of the megger because it is used for measuring the insulation of the resistance which is usually very high.

→ The instrument has voltage selector switch which is used for selecting the voltage range of the instrument. The voltage range is controlled by selecting the varying resistance R connected in series with the current coil The voltage is generated by connecting the hand driven generator.

→ working of megger:-

→ The testing voltage is usually 500, 1000 or 2500 V which is generated by the hand driven generator. The generator has centrifugal clutch due to which the generator supplied the constant for the insulation test. The constant voltage is used for testing the insulation having low resistance.

→ The megger has three coils two pressure coils and one current coil. The pressure coil rotates the moving coils in the anticlockwise direction whereas the current coil rotates it in the clockwise direction.

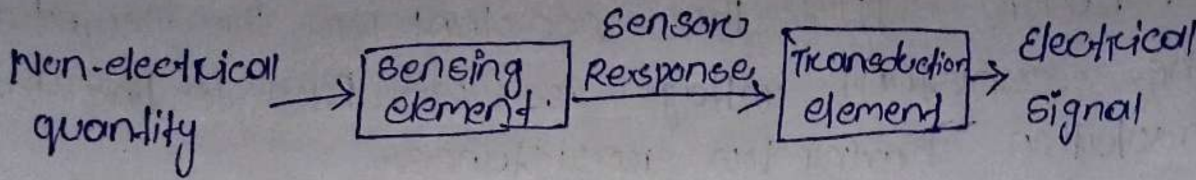
→ when the unknown resistance is connected in the circuit, the pointer of the moving coil becomes stable. The pressure coil and the current coil balance the pointer and set it in the middle of the scale.

→ The deflection of the pointer is directly proportional to the voltage applied to the external circuit. when the testing circuit is applied across the megger and, if there is no shorting throughout the insulation, then the pointer deflects towards the infinity. which shows that the resistance has high insulation. For low resistance, the pointer moves towards zero.

Transducer

* What is a Transducer?

→ A transducer is an electron device that converts energy from one from to another. is known as the tranduction.




Some common examples of tranducers include loud-speakers, microphones, thermometers and LEDS.

→ why do we need a transducer?

→ To determine the exact magnitude of physical force such as temperature and pressure is difficult. But, if these physical force are converted into an electrical signal, then their values can be easily determined using a meter - The primary function of transducers is to convert to physical force into an electrical signal so that it can be easily handled and transmitted for measurement.

→ Advantages of converting a physical quantity into an electrical signal.

→ Here, we have listed the various advantages of converting a physical quantity into an electrical signal.

- Electrical signals are easily transmitted and processed for measurement.
- Electrical signals process less friction error.
- Small power is needed to control the electrical systems.
- Amplification and attenuation of electrical signal are easy.
- The measuring instrument used for measuring the electrical signal is very compact and accurate.

→ part of Transducer:-

→ A transducer consists of the following two important parts

- Sensing element.
- Transduction element.

→ Transducers have other vital parts such as signal processing equipment, amplifiers and power supplies.

Sensing element:-

→ It is the part of a transducer that responds to the physical. The response of the sensing element depends on the physical phenomenon.

Transduction Element:-

→ The transduction elements of the transducer converts the output of the sensing element into an electrical signal.

→ The transduction element is also called the secondary transducer.

Types of Transducers:-

→ There are two types of transducers, as follows.

- Input Transducer.
- output Transducer.

what is an Input Transducer?

→ An input transducer or a sensor takes in physical energy and converts it into an electrical signal that can be read. A microphone, for example, converts physical sound waves into an electrical signal that can be transferred through wires.

→ what is an output Transducer?

→ An output transducer, or an actuator, takes in electrical signals & converts them into other forms of energy. A lamp converts electricity into light and a motor, on the other hand, converts electricity into motion.

- Factors to consider while selecting a transducer:
- Transducers should have high input impedance and low output impedance to avoid the loading effect.
- A transducer should be highly sensitive to desired signals and insensitive to unwanted signals.
- Transducers should be able to work in corrosive environments.
- The transducer circuit should have overload protection to to withstand overloads.

Transducer Efficiency:-

→ Transducer efficiency is defined as the ratio of output power in the desired from to the total power input. Mathmatically the ratio is represented as follows.

$$E = \frac{Q}{P}$$

→ P represents the input in the above ratio, and Q represents the power output in the desired form. The efficiency of the transducer always falls between 0 and 1.

→ No transducer is 100% efficint. Some power is always lost in the conversion process. This loss is manifested in the form of heat. In incandascent lamps of certain wattage, only a few watts are transformed into visible light. Most of the power is dissipated as heat. Due to this an incandescent lamp is a bad transducer interms of efficiency.

Applications of Transducer:-

→ A transducer measures load on the engines.

→ They are used to detect the movement of muscles. this process is known as acceleromyograph.

→ Transducers are used in an ultrasound machine.

→ The transducers in a speaker convert electrical into acoustic sound.

→ A transducer is used in the antenna to convert electromagnetic waves into electrical signal.

→ Difference Between a Transducer and a Sensor

→ A sensor is a device that measures a physical quantity for example, in a mercury thermometer, the mercury simply expands when the temperature rises to give a reading for the user. Here there are no electrical inferences or changes. On the other hand, a transducer, measures similar quantities as a sensor but the signal in a transducer is converted from one from to the another. This is the reason why transducers are also referred to as energy converters.

| Transducers | Sensors |
| --- | --- |
| → It converts energy from one form to another. | → It senses physical quantities and converts it into a readable form. |
| → Cable extension transducer, linear transducer & microphones are some example of transducers. | → Thermistors, pressure switches and motion sensors are some examples of sensors. |

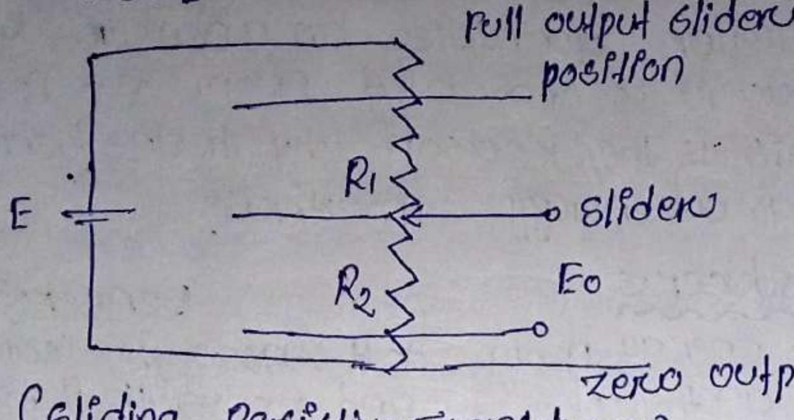
## Resistive Transducer:-

Definition: The transducer whose resistance varies because of the environmental effects such type of the transducer is known as the resistive transducer. The change in resistance is measured by the ac or dc measuring devices. The resistive transducer is used for measuring the physical quantities like temperature, displacement, vibration etc.

→ The measurement of the physical quantity is quite difficult. The resistive transducer converts the physical quantities into variable resistance which is easily measured by the meters. The process of variation in resistance is widely used in the industrial applications.

→ The resistive transducer can work both as the primary as well as the secondary transducer. The primary transducer changes the physical quantities into a mechanical signal, and secondary transducer directly transforms it into an electrical signal.

Example:- The circuit of the sliding resistive transducer is shown in the figure below. The sliding contacts are placed on the resistive element. The slider moves horizontally. The movement of the slider changes the value of the resistive element of the transducer which is measured by the voltage source E.




(Sliding Resistive Transducer)

The displacement of the slider is converted into an electrical signal.

Advantages of Resistive Transducer:-

→ The following are the advantages of the resistive transducer.

1. Both the AC and DC current or voltage is appropriate for the measurement of variable resistance.
2. The resistive transducer gives the fast response.
3. It is available in various sizes and having a high range of resistance.

working principle of Resistive Transducer:-

→ The resistive transducer element works on the principle that the resistance of the element is directly proportional to the length of the conductor and inversely proportional to the area of the conductor.

$$R = \rho L / A$$

where R - Resistance in ohms.

A - cross-section area of the conductor in meter square

L - Length of the conductor in meter square.

ρ - the resistivity of the conductor is materials in ohm meter

→ The resistive transducer is designed by considering the variation of the length area and resistivity of the metal.

Applications of Resistive Transducer:-

→ The following are the application of the resistive transducer.

1. potentiometer:-

→ The translation and rotatory potentiometer are the example of the resistive transducers. The resistance of their conductor varies with the variation in their lengths which is used for the measurement of displacement.

2. Strain gauges:-

→ The resistance of their semiconductor material changes when the strain occurs on it. This property of metals is used for the measurement of the pressure, force - displacement etc.

3. Resistance Thermometer:-

→ The resistance of the metal changes because of changes is temperature. This property of conductor is used for measuring the temperature.

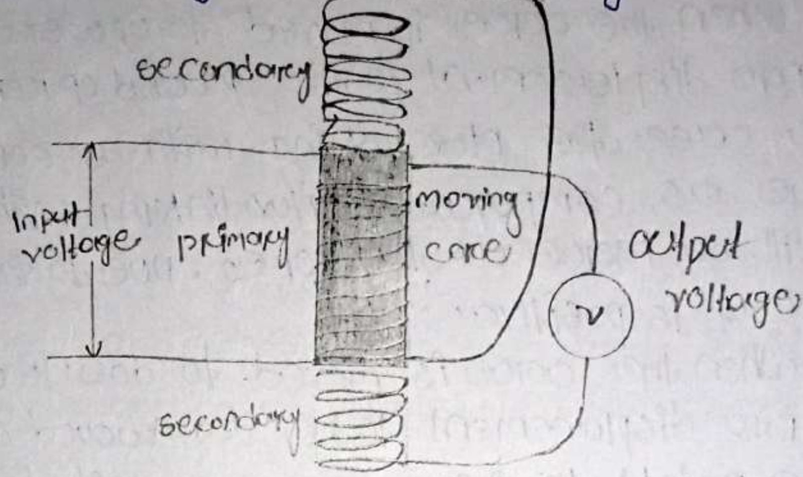
4. Thermistor:-

→ It works on the principle that the temperature the coefficient of the thermistor material varies with the temperature. The thermistor has the negative temperature coefficient. The Negative temperature coefficient means the temperature is inversely proportional to resistance.

→ The iron core is generally of high permeability which helps in reducing harmonics and high sensitivity of LVDT.

→ The LVDT is placed inside a stainless steel housing because it will provide electrostatic and electromagnetic shielding.

→ The both the secondary windings are connected in such a way that resulted output is the difference between the voltage of two windings.

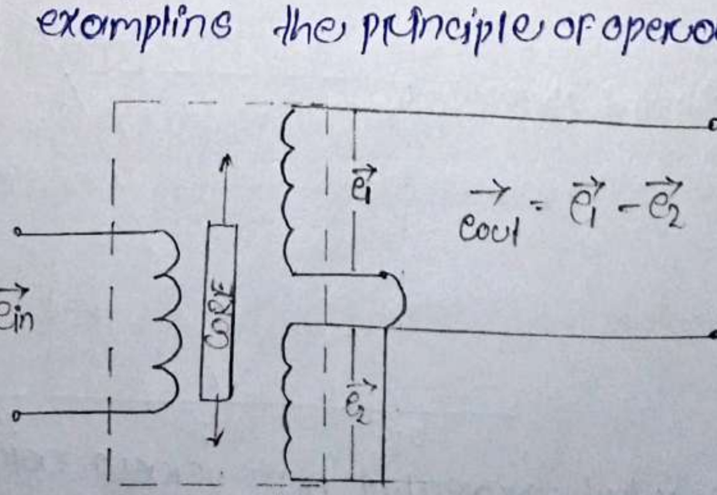



principle of operation and working :-

→ As the primary is connected to an AC source so alternating current and voltages are produced in the secondary of the LVDT. The output in secondary $S_1$ is $e_1$ and in the secondary $S_2$ is $e_2$. so the differential output is,

$$e_{out} = e_1 - e_2$$

→ This equation examplins the principle of operation of LVDT.

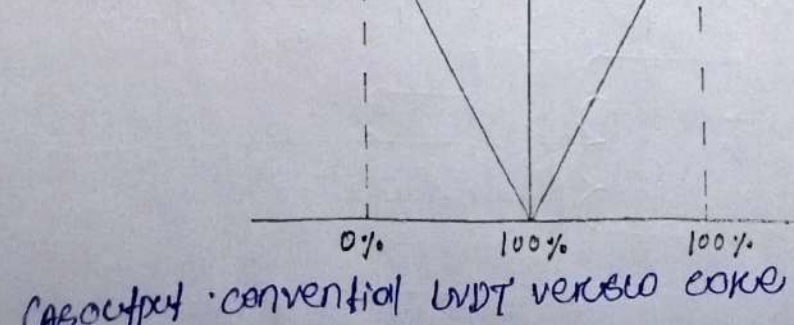


Now three cases arise according to the locations of core, which explains the working of LVDT are discussed below as,

- CASE-1- when the core is at null position (for no displacement)
when the core is at null position then the flux linking with both the secondary windings is equal so the induced emf is equal in both the windings. so for no displacement the value of output eout is zero as $e_1$ & $e_2$ both are equal. so it shows that no displacement took place.
- CASE-II - when the core is moved to upward of null position (for displacement to the upward of reference point)
→ In this the case the flux linking with secondary winding $S_1$ is more as compared to flux linking with $S_2$. Due to this $e_1$ will be more as that of $e_2$. Due to this output voltage eout is positive.
- CASE-III - when the core is moved to downward of Null position (for displacement to the downward of the reference point). In this case magnitude of $e_2$ will be more as that of $e_1$. Due to this output eout will be negative and shows the output to downward of the reference point.

→ output vs core displacement A linear curve shows that output voltage varies linearly with displacement of core.

LVDT's As output magnitude




(As output conventional LVDT versus core Displacement)

→ Some important point about magnitude & sign of voltage induced in LVDT.

- The amount of change in voltage either negative or positive is proportional to the amount of movement of core and indicates amount of linear motion.
- By noting the output voltage increasing or decreasing the direction of motion can be determined.
- The output voltage of an LVDT is linear function of core displacement.

## Advantages of LVDT:-

- High Range - The LVDTs have a very high range for measurement of displacement. they can used for the measurement of displacement ranging from 1.25 mm to 250 mm
- No Frictional losses:- As the core move inside the hollow frams so there is no losses of displacement input as friction loss.
- High input and High sensitivity:- The output of LVDT is so high that is does'nt need any amplification process a high sensitivity.
- Low power consumption:- The power is about 1w which is very as compared to other to other transducers.
- Direct conversion to Electrical signals - They convert the linear displacement to electrical voltage which are easy to process.

## Disadvantages of LVDT:-

- LVDT is sensitive to stray magnetic fields so it always requires a setup to protect them from stray magnetic fields.
- LVDT gets affected by vibrations and temperature.

→ It is concluded that they are advantageous as compared than any other inductive transducer.

Applications of LVDT:-

→ We use LVDT in the applications where displacements to be measured are ranging from a fraction of mm to few cms. The LVDT acting as a primary transducer converts the displacement to electrical signal directly. The LVDT can also act as a secondary transducer. Eg. the Bourdon tube which acts as a primary transducer and it converts pressure into linear displacement and then LVDT converts this displacement into an electrical signal which after calibration gives the readings of the pressure of fluid.

## capacitive Transducer:→

**Definition** :- The capacitive transducer is used for the measuring the displacement, pressure & other physical quantities. It is a passive transducer that means it requires external power for operation.

→ The capacitive transducer works on the principle of variable capacitances. The capacitance of the capacitive transducer changes because of many reasons like overlapping of plates, change in distance between the plates and dielectric constant.

→ The capacitive transducer contains two parallel metal plates. These plates are separated by the dielectric medium which is either air, material, gas or liquid. In the normal capacitor the distance between the plates are fixed, but in capacitive transducer the distance between them are varied.

→ The capacitive transducer uses the electrical quantity of capacitance for converting the mechanical movement into an electrical signal.

→ The input quantity causes the change of the capacitance which is directly measured by the capacitive transducer.

→ The capacitors measure both the static and dynamic changes. The displacement is also measured directly by connecting the measurable devices to the movable plate of the capacitor. It works on with both the contacting and non-contacting modes.

**principle of operation →**

→ The equations below express the capacitance betn the plates of a capacitor.

$$C = \varepsilon A / d$$

$$C = \varepsilon_r \varepsilon_0 A / d.$$

where A = overlapping area of plates in $m^2$.

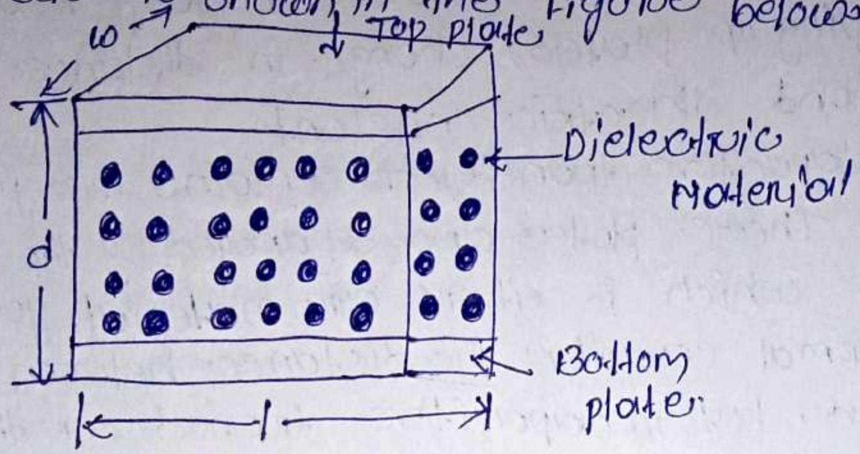
d = the distance between two plates in meters.

$\varepsilon$ = permittivity of the medium in F/m.

$\varepsilon_r$ = relative permittivity.

$\varepsilon_0$ = the permittivity of free space.

→ The schematic diagram of a parallel plate capacitive transducer is shown in the figure below.




(parallel plate capacitive Transducer)

→ The change in capacitance occurs because of the physicals variables like displacement, force, pressure, etc. The capacitance of the transducer also changes by the variation in their dielectric constant which is usually because of the measurement of liquid or gas level.

→ The capacitance of the transducer is measured with the bridge circuit. The output impedance of transducer is given as

$$X_C = 1/2\pi f C$$

where, C = capacitance.

f = frequency of excitation in Hz.

The capacitive transducer is mainly used for the measurement of linear displacement. The capacitive transducer uses the following three effects:-

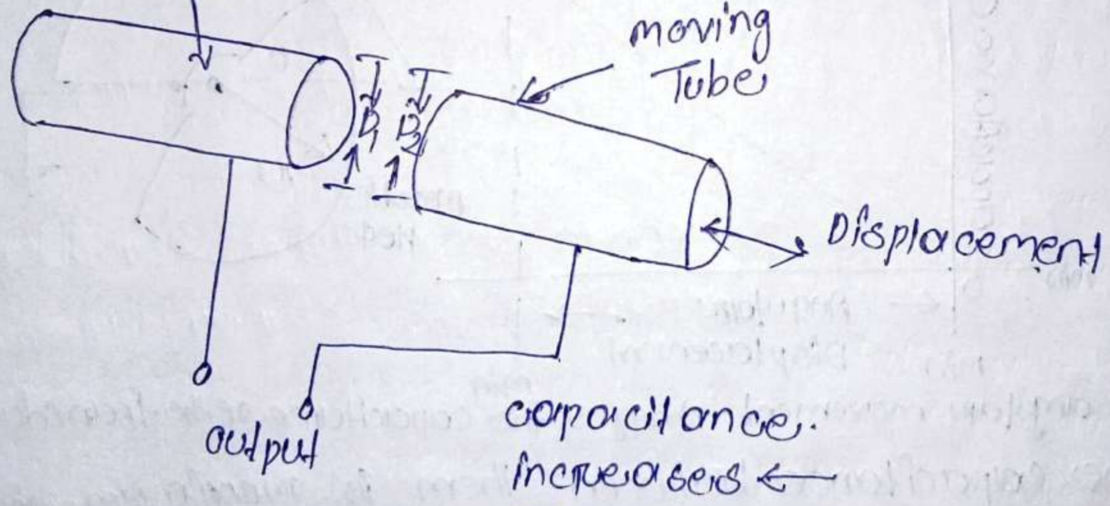
(1) variation in capacitance of transducer is because of the overlapping of capacitor plates.

(2) The change in capacitance is because of the change in distances between the plates.

(3) The capacitance changes because of dielectric constant.

→ The following methods are used for the measuring displacement.

(1). A transducer using the change in the Area of plates — The equation below shows that the capacitance is directly proportional to the area of the plates. The capacitance changes correspondingly with the change in the position of the plates.



(capacitive Transducer)

→ The capacitive transducers are used for measuring the large displacement approximately from .1mm to several cms. The area of the capacitive transducer changes linearly with the capacitance and the displacement. Initially, the nonlinearity occurs in the system because of the edges, otherwise it gives the linear response.

→ The capacitance of the parallel plates is given as

$$C = \frac{\varepsilon A}{d} = \frac{\varepsilon x \omega}{d} F$$

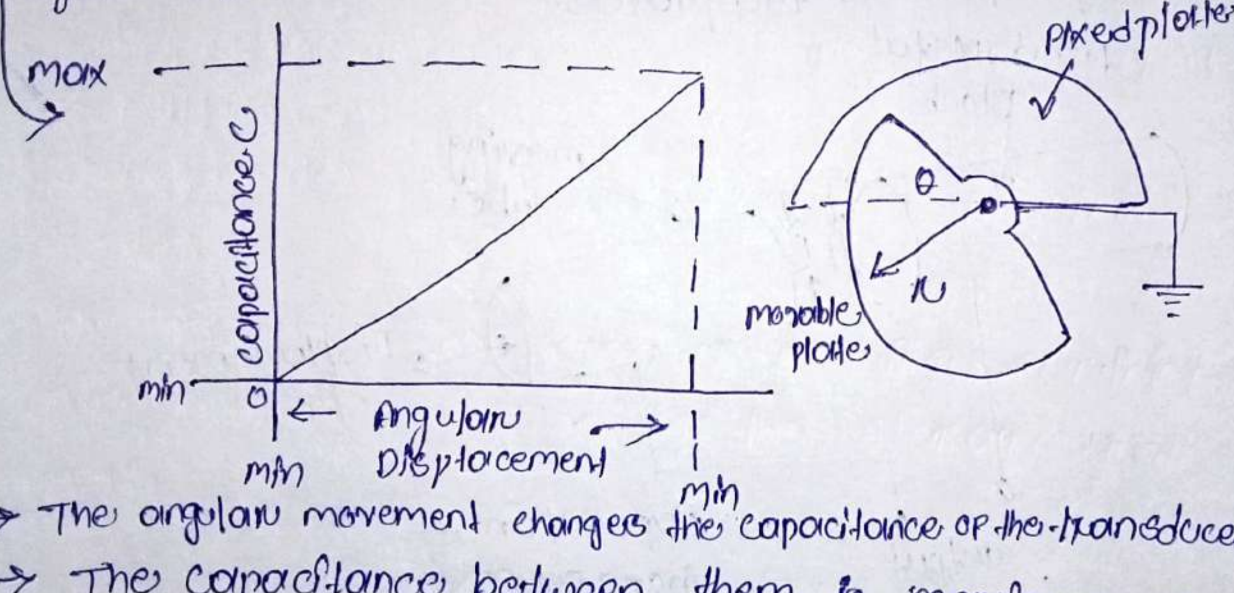
→ where x - the length of overlapping part of plates.
ω = the width of overlapping part of plates.

→ The sensitivity of the displacement is constant. & therefore it gives the linear relation between the capacitance and displacement.

$$S = \frac{\partial C}{\partial x} = \varepsilon \frac{\omega}{d} F/m$$

→ The capacitive transducer is used for measuring the angular displacement. It is measured by the movable plates shown below. One of the plates of the transducer is fixed, and the other is movable.

→ The phasor diagram of the transducer is shown in the figure below.




→ The angular movement changes the capacitance of the transducers.

→ The capacitance between them is maximum when these plates overlap each other. The maximum value of capacitance is expressed as

$$C_{max} = \frac{\varepsilon A}{d} = \frac{\pi \varepsilon r^2}{2d}.$$

→ The capacitance at angle θ is given expressed as,

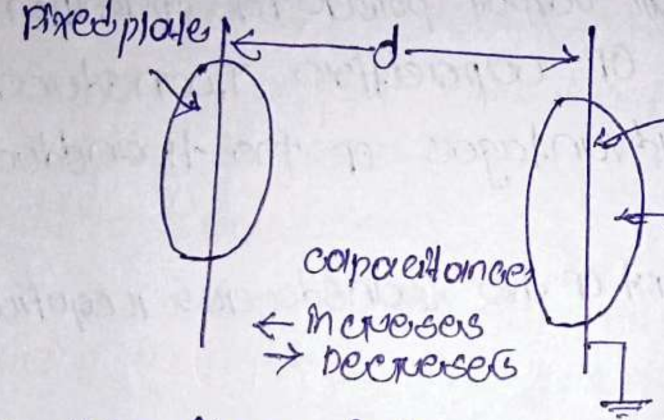
$$C = \frac{\varepsilon \theta r^2}{2d}$$

→ θ - angular displacement in radian.
→ The sensitivity for the change in capacitance is given as.

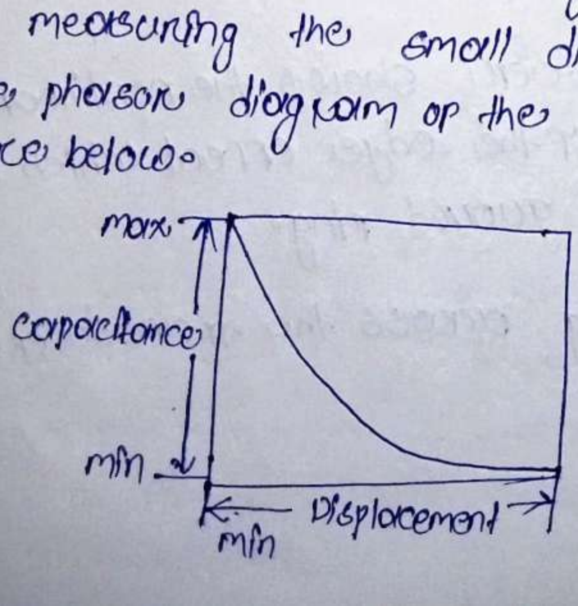
$$S = \frac{\partial C}{\partial \theta} = \frac{\varepsilon r^2}{2d}$$

→ The 180° is the maximum value of the angular displacement of the capacitor.

(2). The transducer using the change in distance betn the plates — The capacitance of the transducer in inversely proportional to the distance between the plates. The one plate of the transducer is fixed and the other is movable. The displacement which is to be measured links to the movable plates.




→ The capacitance is inversely proportional to the distance because of which the capacitor shows the nonlinear response. Such type of transducer is used for measuring the small displacement.
→ The phasor diagram of the capacitor is shown in the figure below.



The sensitivity of the transducer is not constant and vary form places to places.

→ Advantages of capacitive Transducer →

The following are the major advantages of capacitive transducers.

1. It requires an external force for operation & hence very useful for small systems.
2. The capacitive transducer is very sensitive.
3. It is good frequency response because of which it is used for the dynamic study.
4. The transducer has high input impedance hence they have a small loading effect.
5. It requires small output power for operation.

→ Disadvantages of capacitive Transducer →

→ The main disadvantages of the transducer are as follows.

① The metallic part of the transducers require insulation.

② The frame of the capacitor requires earthing for reducing the effect of the stray magnetic field.

③ Sometimes the transducer shows the nonlinear behaviours because of the edge effect which is controlled by using the guard ring.

④ The cable connecting across the transducer causes an error.

## Uses of capacitive Transducer:→

→ The following are the uses of capacitive transducer.

① The capacitive transducer uses for measurement of both the linear and angular displacement. It is extremely sensitive and used for the measurement of very small distance.

② It is used for the measurement of the force & the pressures. The force or pressure, which is to be measured is first converted into a displacement change the capacitances of the transducer.

③ It is used as a pressure transducer is some cases, where the dielectric constant of the transducer changes with the pressure.

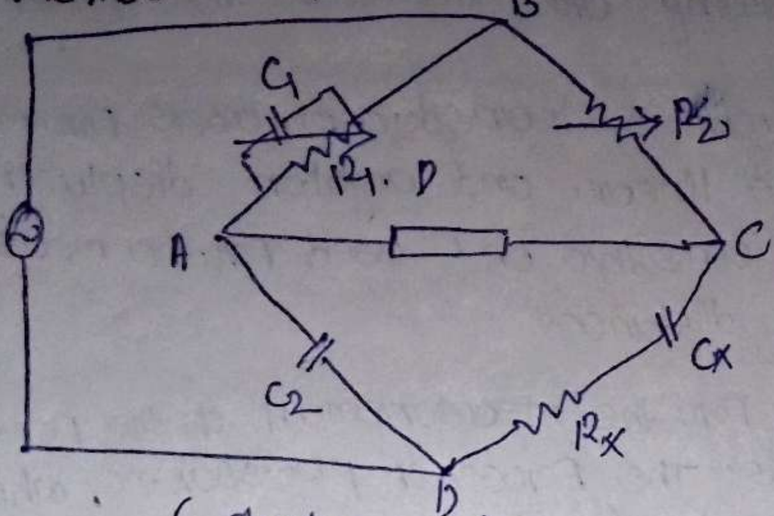
④ The humidity in gases is measured through the capacitive transducer.

⑤ The transducer uses the mechanical modifier for measuring the volume, density, weight etc.

→ The accuracy of the transducer depends on the variation of temperature to the high level.

* Explain measurement of capacitance by schering bridge method.

**Ans**




(Shering Bridge)

→ The type of bridge is used to measure unknown capacitors, dielect. loss and power factor.

Now at the balance condition.

$$Z_{AB} \cdot Z_{CD} = Z_{AD} \cdot Z_{BC}$$

But, $Z_{AB} = \left(R_1 \parallel \frac{1}{j\omega C_1}\right)$

$$Z_{CD} = R_x - j/\omega C_x$$

$$= \left(R_x - j/\omega C_x\right)$$

$$Z_{BC} = Z_{AD} = -j/\omega C_2 = \frac{1}{j\omega C_2}$$

$$\Rightarrow Z_{AB} = \frac{R_1 \times \frac{1}{j\omega C_1}}{\left(R_1 + \frac{1}{j\omega C_1}\right)}$$

$$\therefore \frac{R_1 \times \frac{1}{j\omega C_1}}{R_1 \times \frac{1}{j\omega C_1}} \left(R_x + \frac{1}{j\omega C_x}\right) = \left(R_2 + \frac{1}{j\omega C_2}\right)$$

$$\Rightarrow \frac{\frac{R_1}{j\omega C_1}}{\frac{j\omega R_1 C_1 + 1}{j\omega C_1}} \times \frac{j\omega R_x C_x + 1}{j\omega C} = \frac{R_2}{j\omega C_2}$$

$$\Rightarrow \frac{R_1}{1 + j\omega R_1 C_1} \times \frac{j\omega R_x C_x}{j\omega C_x} = \frac{R_2}{j\omega C_2}$$

$$\Rightarrow R_1(1 + j\omega R_x C_x) = \frac{C_x R_2 (1 + j\omega R_1 C_1)}{C_2}$$

$$\Rightarrow R_1 C_2 (1 + j\omega R_x C_x) = C_x R_2 (1 + j\omega R_1 C_1)$$

$$\Rightarrow R_1 C_2 + j\omega R_1 C_2 R_x C_x = C_x R_2 + j\omega R_1 R_2 C_1 C_x$$

⇒ Equating the real parts.

$$\Rightarrow C_x R_2 = R_1 C_2$$

$$\Rightarrow \boxed{C_x = \frac{R_1 C_2}{R_2}}$$

The pf will be measured by putting.

$$\frac{R_x}{Z_x} = \frac{R_x}{R_x + j\omega C_x} = \frac{R_x}{\sqrt{R_x^2 + \left(\frac{1}{\omega C_x}\right)^2}}$$

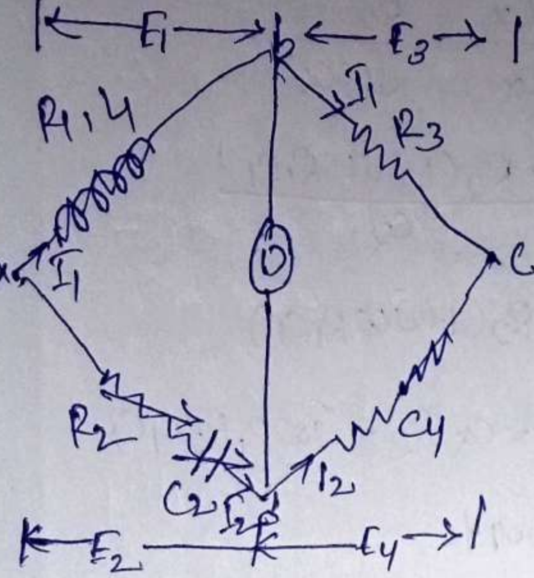
→ The dissipation factor (D) of the series RC circuit is found out to be

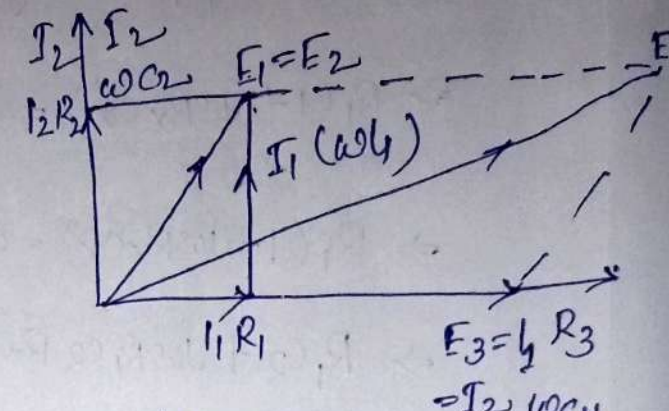
$$\boxed{D = \frac{R_x}{C_x} = \omega C_x R_x}$$

$Z_3$ = Impedance of arm bc = $R_3$

* Measurement of inductance by Owen Bridge method.

**Ans** Owen Bridge method to measure Inductance. This bridge is used to measure the inductance in terms of capacitance. The connection diagram & phasor diagram is drawn below!




(PHASOR DIAGRAM)
(Fig 2)

$L_1$ = unknown self-inductance of resistance $R_1$

$R_2$ = variable non-inductance resistance.

$R_2$ = variable non-inductance resistance

$C_2$ = variable standard capacitor.

$C_4$ = fixed standard capacitor

$R_3$ = fixed non-inductive resistance.

∴ $Z_1$ = Impedance of ab arm.

$= (R_1 + j\omega_1 L_1)$

$Z_2$ = Impedance of arm ad.

$$= R_2 - \frac{j}{\omega C_2} = R_2 + \frac{1}{\omega C_2}$$

$Z_3$ = Impedance of arm bc $= R_3$

$Z_4$ = Impedance of arm cd.

$= \frac{1}{j\omega C_4}$.

Acc to balance condition of bridge.

$$Z_1 Z_4 = Z_2 Z_3$$

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

$$\Rightarrow \frac{R_1}{j\omega C_4} + \frac{L_1}{C_4} = R_2 R_3 + \frac{R_3}{j\omega C_2}$$

$$\Rightarrow \frac{-jR_1}{\omega C_4} + \frac{L_1}{C_4} = R_2 R_3 - \frac{jR_3}{\omega C_2}$$

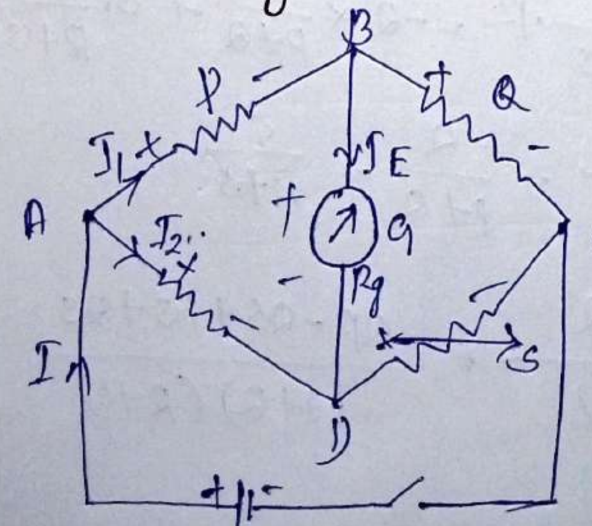
Equating the real terms,

$$\frac{L_1}{C_4} = R_2 R_3 \Rightarrow L_1 = R_2 R_3 R_4$$

Equating the imaginary terms,

$$\frac{R_1}{\omega C_4} = \frac{R_3}{\omega C_2} \Rightarrow R_1 = R_3 \cdot \frac{C_4}{C_2}.$$

* Explain measurement of medium resistance by the wheatstone bridge method.



In a wheat stone bridge the unknown resistance 'S' can be measured as follows.

→ Let the galvanometer shows null deflection as soon as the switch is on. Thus this condition is known as balanced condition.

∴ Galvanometer current $(I_g) = 0$

Applying KVL to the loop ABDA

$-I_1 \times P - I_g R_g + I_2 R = 0$ —— (i)

Similarly by applying KVL in loop BCDB

$-Q \times (I_1 - I_g) + S(I_2 + I_g) + I_g R_g = 0$ —— (ii)

putting $I_g = 0$

∴ Equation (i) becomes.

$-I_1 \times P + I_2 R = 0$ —— (iii)

and equation (ii) becomes,

$-Q(I_1) + S(I_2) = 0$ —— (iv)

$\therefore -I_1 \times P + I_2 R = -Q \times I_1 + S I_2$

but $I_1 = \frac{V}{P+Q}$

$I_2 = \frac{V}{R+S}$

$\therefore -\frac{V}{P+Q} \cdot P + \frac{V}{R+S} \cdot R = -Q \times \frac{V}{P+Q} + S \cdot \frac{V}{R+S}$

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

or, $\frac{-PR - PS + PR + QR}{(P+Q)(R+S)} = \frac{-QR - QS + PS + QS}{(P+Q)(R+S)}$

or, $2PS = 2QR$

or, $\Rightarrow S = \frac{QR}{P}$ . which is the unknown resistance.