ELECTRICAL MEASUREMENTS & INSTRUMENTATION

(Diploma 4TH SEM)

Prepared by
Mr. PRADEEP PARIDA
Asst. Professor
Electrical Engineering
NM INSTITUTE OF ENGINEERING & TECHONOLOGY

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← Measuring Instruments →

Some terms according to measuring instruments.,

① **Accuracy** :- It is the degree of closeness of measure value to the true value.

→ Accuracy is the conformity to the truth.

② **Precision** :- It is the Reproducibility of the same result or value again and again.

→ Precision sures consistency of the result..

→ Accuracy can be improved by recalibrating instruments.

→ highly precised instruments may not sure accuracy but for having higher accuracy the instrument must be precised.

③ **Sensitivity** :- It is the smallest amount of difference in electrical quantities that will change on instrument reading.

(or)

It is the characterisation of instruments for change in output with change in input.

If for a finite change in the input the change in output is more then the instrument is highly Sensitive.

④ Resolution :-

It is the smallest unit of measurement that can be indicated by an instrument.

→ If the resolution $= \frac{1}{1000}$ then the instrument can be read upto 3 value after decimal.

⑤ Error :- It is the deviation of measure value from actual value.

→ The main reason for error is the inability of the system to track in proper manner.

→ Error is fundamentally classified into 2 types.

① Absolute error :- It is defined as the difference of measure value to the standard value.

$$\boxed{\delta_A = A_m - A}$$

where, δ_A = Absolute error

A_m = Measure value

A = Standard value

(4) Relative error :- when the absolute error is represented in percentage then it is called as relative error.

$$\% \delta_A = \epsilon_r = \frac{\delta_A}{A} \times 100$$

(6) Tollerance :- It refers to the total allowable error within an instrument.

→ It is specially represented with + or − sign.

Type of Measuring instruments

Generally they are two types.

① Absolute instruments.

② Secondary instruments

Absolute instrument :-

In this instrument the electrical quantity is measured in terms of the instrument constant.

These instrument are used for comparision with other instruments but don't required any previous ~~calibration~~ Calibration with the aid of other instruments.

Ex- Tangent Galvanometer

Here the current is measured in terms of deflection constant.

$$I \propto \tan\theta$$

$$I = K \tan\theta$$

Secondary instruments :- These instruments are required to be calibrated ~~with~~ by comparision with an absolute instrument or any other secondary instrument which has already been calibrated again absolute instruments.

Ex- Ammeter, volt meter, watt meter etc.

→ Secondary instruments are generally used in practical labratory.

Classification of secondary instrument :-

The secondary instruments are further classified into 3 groups.

1. Indicating type
2. Recording type
3. Intigrating type.

① Indicating type :-

This is the instruments in which electrical quantity is measured by deflection of a pointer over a calibrated scale.

→ This instrument indicates the instantaneous value of the measurement quantities.

⇒ Ex - volt meter, Ammeter, etc.

(2) Recording Instrument :-

These instruments gives a continuous record of the variation of electrical quantities being measured over a time interval.

→ here a extra recording mechanism is attach in the instrument.

→ generally a pen is attach to the moving system which traces the magnitude of quantity measured on a sheet of paper,

→ These instrument records daily or annual use of power, power factor, load curve.

Ex - ~~Energy meter~~.

(3) Integrating type :-

In this instrument the electrical quantities are added up over the period of measured and then recorded, or integrated.

Ex - Energy meter.

Torque associated with indicating type instrument :-

(1) Deflecting torque (T_d)

(2) Controlling torque (T_c)

(3) Damping torque (T_{damp})

Date - 7/2/20

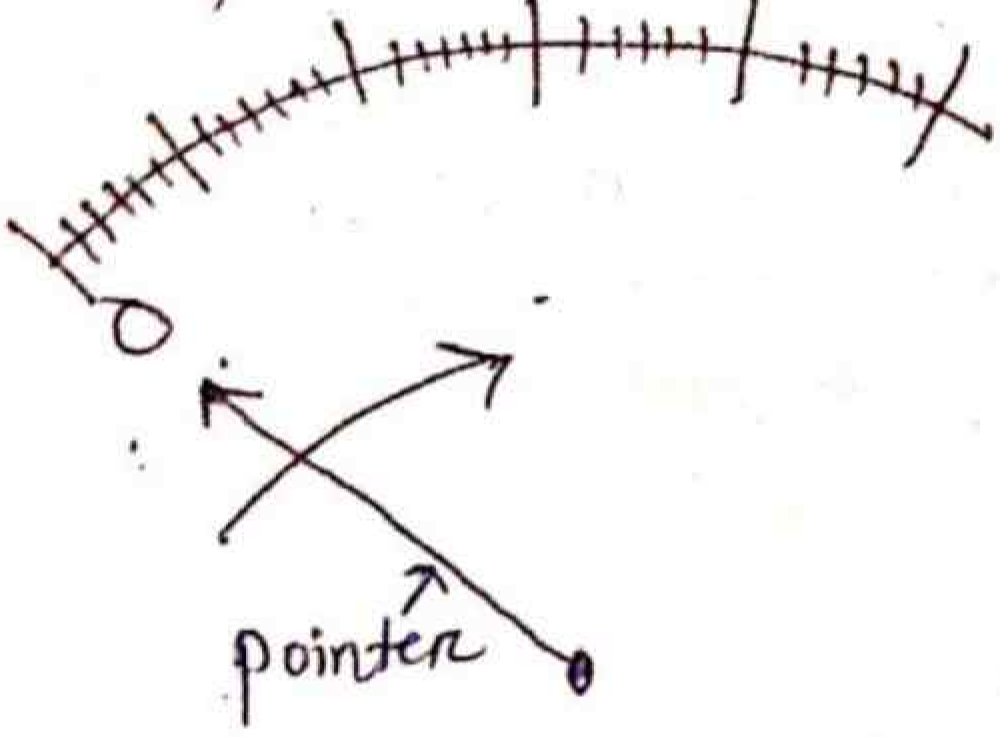
(1) Deflecting torque (T_d)

The purpose of deflecting torque is to deflect the pointer from its initial position.

→ It is represented by (T_d).

→ The direction of this torque is in forward direction.

→ This torque can be produced by the utilisation of any one of the following effect produced by current or voltage.



(i) Magnetic effect
(ii) Electro dynamic effect
(iii) Electro magnetic effect
(iv) chemical effect
(v) Thermal effect
(vi) Electro static effect

② Controlling torque (T_c)

→ The purpose of control torque is_

① It opposes the deflecting torque or it deflects the pointer propotional to the magnitude of supply voltage or current.

(ii) It brings that the pointer to initial position when the supply gets disconnected from instrument.

(iii) The direction of controlling torque is backward direction.

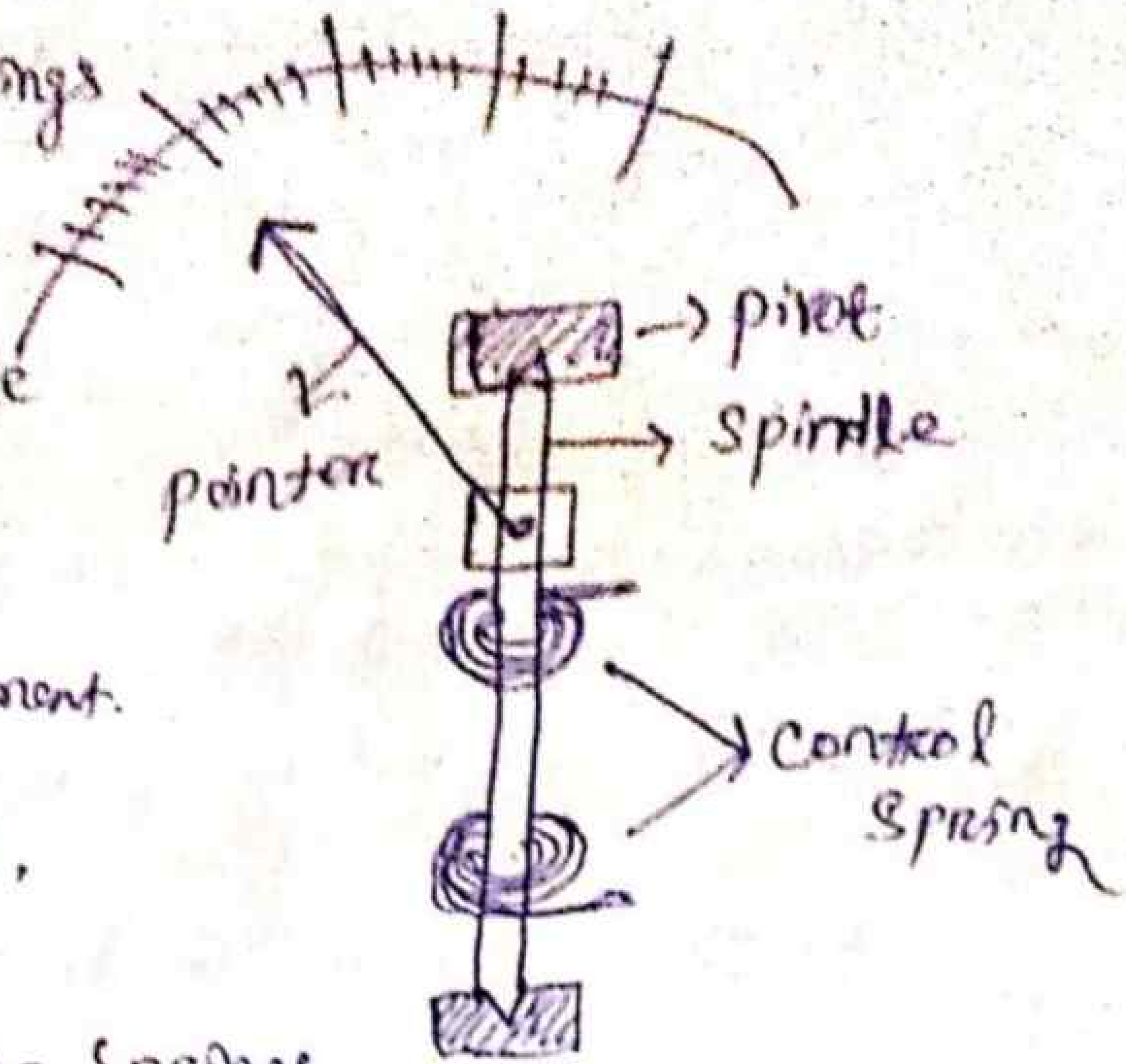
→ There are two mechanism to produce control torque.

① Spring control mechanism.

② Gravity control mechanism.

① Spring control mechanism :-

In this mechanism two springs made up of ~~phosphor~~ prosper bronze are used.



→ one spring is placed above and other is placed below the spindle of instrument.

→ Both are oppositely twisted.

→ The material used for making springs should be non magnetic, low specific resistance, low temp. coefficient of resistance.

→ when the instrument is not in use the springs are in their condition and the control torque is zero.

→ when the instrument is connected to the circuit then deflecting torque is produced and the pointer moves on the scale. so one of the spring get twisted and other spring get unwounded. the resultant twist produces the controlling torque.

→ The position when $T_d = T_c$, the pointer stops at that position.

→ Here the control torque equation is

$$T_c = \frac{\gamma b t^3 \theta}{12L}$$

$$T_c = K\theta$$

where Y = youngs modulus of spring material.
b = width of spring
t = thickness of spring
θ = Deflection of the pointer.
l = length of the spring.

Advantages of spring control mechanism,

(i) The instrument can be placed in any position that is vertical or horizontal.

(ii) This method does not increase the weight of the instrument as the spring is light.

(iii) Scale is uniform in this method.

dis advantages

(i) Temp. variation can affect the length and design of the spring so it can change the control torque.

(ii) The spring get deteriorate with the time and hence accuracy is lossed.

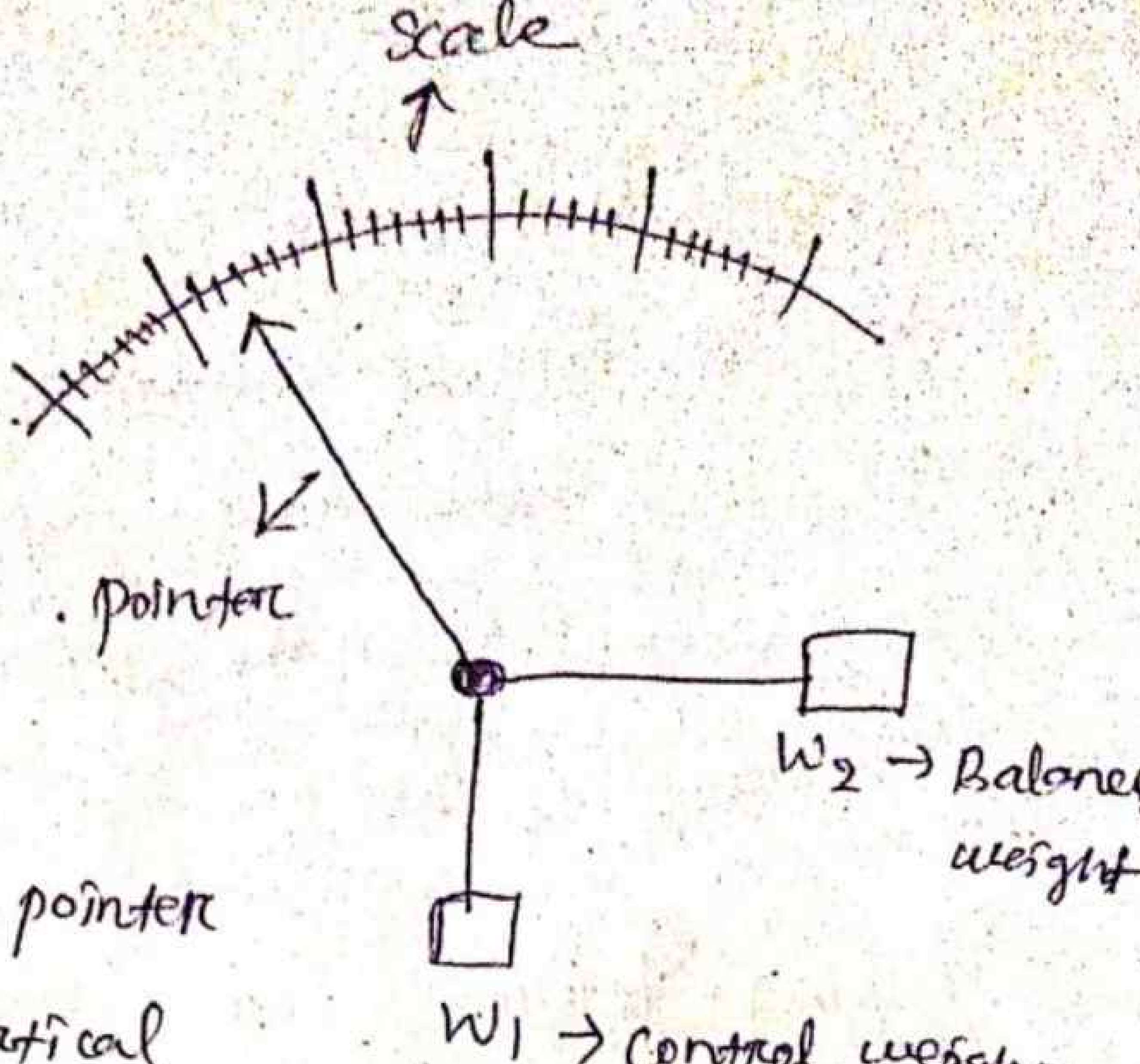
(3) Gravity control mechanism :-

In this method natural down ward pole due to gravity is employed.

→ A small weight W_1 is attach to the moving system and a W_2 is attached for balancing the W_1.

$T_C = W_1 l \sin\theta$

$T_C \propto \sin\theta$



→ At '0' position of the pointer the control weight is in vertical position and there fore no control torque is produced.

→ when the instrument is connected the circuit deflecting torque produced and the pointer is deflect by an angle θ from its initial position.

~~But due to the gravity the control weight try to~~

and the control weight also deflects by an angle θ°. But due to the gravity W_1 try to come back to its original vertical position hence ~~vertical~~ control torque is produced.

→ There are two component $W_1 \sin\theta$, $W_1 \cos\theta$, only $W_1 \sin\theta$ will produce the control torque. hence component of the control torque is $W_1 \sin\theta$.

Advantages

1. It is simple and cheap method.
2. It is not affected by temp. variation.

Dis advantages

(i) scale is non uniform so the reading become difficult.

(ii) This method increases the weight of the instrument,

(iii) This instrument should be placed always in vertical position. otherwise it may produce error in the reading.

Date-14/1/20

Damping torque :- (T_D)

It is the torque which is required to damp the oscilation of the pointer.

→ It helps to take the reading.

→ It provided by some mechanism that are,

1. air friction damping -
2. fluid friction damping
3. Eddy current damping

① Air friction damping :-

In this system the moving system (pointer) is attach with a piston which is placed in a air chamber. The piston is made up of aluminium. The air chamber is covered at the top,

→ The oscilation of pointer is damp by the movement of piston in air chamber.

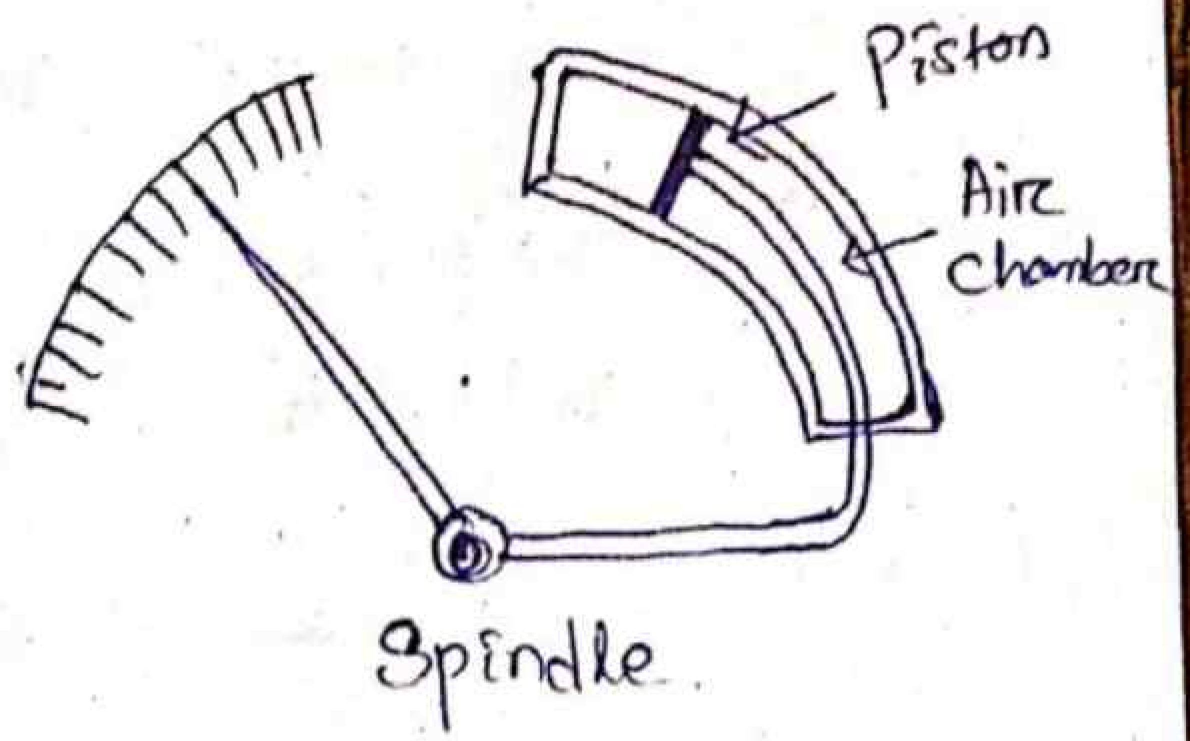
→ It is run by compression and expansion of the air.

→ It is observed that in forward oscillation the piston moves inside the chamber and the air get compressed and for backward oscillation piston moves outside the chamber so the air gets expanded.

→ This system is used in MI instruments and electro dynamometer type instruments.

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

· Fluid friction damping :-



(Fluid friction damping) (Air friction damping)

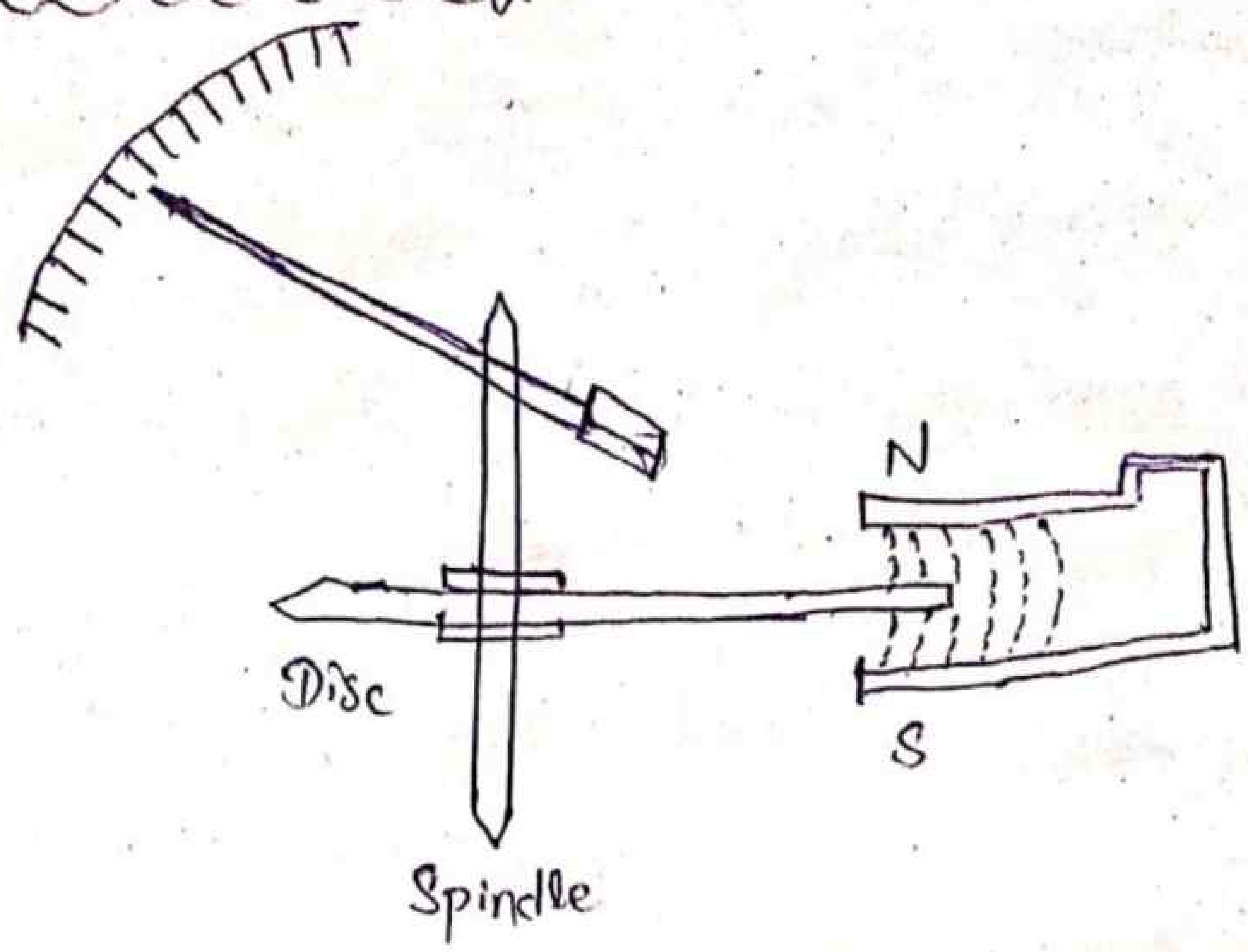
In this metho a light aluminium vanes (or) piston is attached to the moving system and made to deep into a viscous liquid.

→ generally damping oil is used as liquid.

→ When pointer starts oscillate spindles get rotated and the aluminium vane also starts rotates against the viscosity of fluid.

The opposition offered by the fluid provides damping to the oscillation.

Eddy current damping :-



→ In this mechanism a copper or aluminium disc is attach to the spindle as shown above the figure.

→ When the ~~coil~~ pointer starts oscillate the Spindles gets rotated by which aluminium disc also starts rotated. as we see that aluminium disc is rotated inside a magnetic field. so an emf is induced in the aluminium disc.

→ By which ~~an~~ current is flows through the aluminium disc which is known as Eddy current. this eddy current opposes the cause thats generate it.) That is ~~the~~ oscillation, so the damp is provided.

→ In this permanent ~~damping~~ magnet is used.

Fluid friction damping used in electro static type instruments.

Eddy current damping is the most efficient damping.

Classification of Instrument

(I) According to measurement,

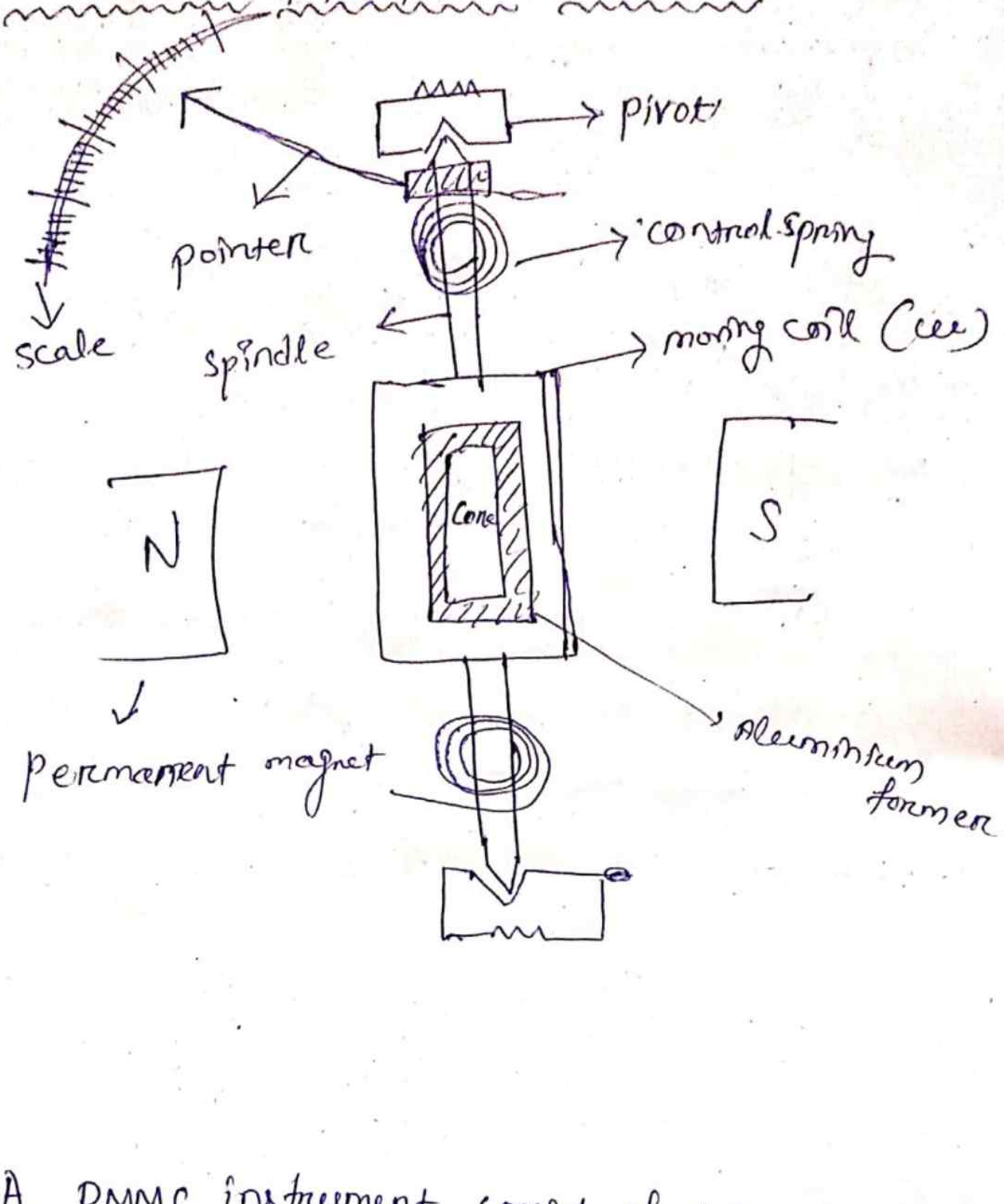
1. Voltmeters and ammeter (V, I)
2. Wattmeters and energy meter (P, E)
3. Phase and frequency meter
4. D.C. and A.C. Bridges
5. Instrument transformer

(II) According to construction and operating principle,

1. Permanent magnet moving coil instrument (PMMC)
2. Moving Iron instrument. (MI)
3. Electro dynamometer type instrument.
4. Electro static type instruments.
5. Induction type instrument.
6. Electro thermic instrument.

Date:- 18/01/20

Constreenetion of PMMC instreement



A PMMC instreement consist of two main parts moving coil and a permanent magneat along with other parts,

① Magnet system (OR) Permanent magnet :-

In this instreement the necessary magnetic field is obtained by permanent magnet.

and hence the name.

→ In earlier days horshoe magnets were used but the disadvantages with this is it has more weight so the torque by weight ratio decreases.

For better accuracy torque/weight must be greater than 1.

→ Now a days Permanent magnet with high intensity and high coree forces with 'U' shaped are used. These are generally made up of aleomax, almico, ferrites etc.

(II) Moving coil :-

It is one of the main component of PMMC instrument. It is made up of cu-coil which is wounded on a rectangular block place betn the magnetic poles.

→ The rectangular block is made up of aluminium, and it is called aluminium former, which is pivoted to the Jewel bearing for free rotation through spindle.

→ Supply or connection is given to the moving coil.

(III) Control system :-

Here, spring control mechanism is used for providing control torque.

→ Two hair spring made up of phosphorous bronze are wound on the spindle of the instrument.

(iv) Damping system :-

In this instrument eddy current damping is used. It is done by the movement of aluminium plate in the magnetic field.

(v) Scale and pointer :-

The pointer is attach to the spindle which moves over a calibrated scale.

→ Pointer is made up of aluminium because it is the lighter material having lesser inertia. so it can deflect for small deflecting force.

→ pointer is in the shape of niddle (or) arrow.

Principle :-

It works on the principle of DC motor i.e. wherever a current carrying conductor is placed inside a magnetic field it will experience a rotating force or torque.

When the supply is given to the moving coil it developes electromagnetic torque by which coil starts deflecting. This deflection of coil is carried to the pointer through spindle, and pointer deflects on the scale.

The deflecting torque can be estimated as.

$$T_d = BIlNd$$

where B = magnetic flux density
I = current to the scale
l = length of the coil
N = No of turns of coil
d = diameter of coil.

Ones the construction is completed, l, N, d are constant and since the magnet is permanent magnet, 'B' also remains constant. so now the 'Td' becomes.

$\therefore T_d = GI$ $\therefore$ $T_d \propto I$

$\Rightarrow G = BlNd$ —— (1)

here the control torque is provided by the spring so it can be expressed as

$T_c = K\theta$ —— (2)

where K is the spring constant.
θ = the angle of deflection.

~~In this instrument the damping torque is provided the damp the oscilation,~~

as we know that the pointer remains in steady position when, $T_d = T_c$.

so by equating eq^n (i) and (ii), we found that

$$\Rightarrow GI = K\theta$$

$$\Rightarrow I = \frac{K}{G\theta}$$

(or) $$\theta = \frac{GI}{K}$$

so $\boxed{\theta \propto I}$

→ From this eq^n it can be concluded that the scale is uniform.

→ In this instrument the damping torque is provided to damp the oscilation.

Application :-

(i) This instrument is used as ammeter, voltmeter

(ii) It is exclusively used for D.C. measurement i.e. DC voltage (or) DC current.

advantages :-

→ High torque by weight ratio

→ uniform scale.

→ Less power consumption

→ No hystersis loss

→ less affected by stray magnetic field.

→ can be used as ammeter, voltmeter and watt meter.

① Disadvantages :-

→ These are only used for DC measurement.

→ It is costly than other instrument.

Date-29/01/20

Extension range of PMMC type instrument :-

The PMMC instrument fundamentally developed is of very much lower rating, so it can't be suitable for measurement of higher range.

So to enable the instrument to match the practical requirements small electrical modification are made to the basic instrument that is called as Extension range of PMMC instrument.

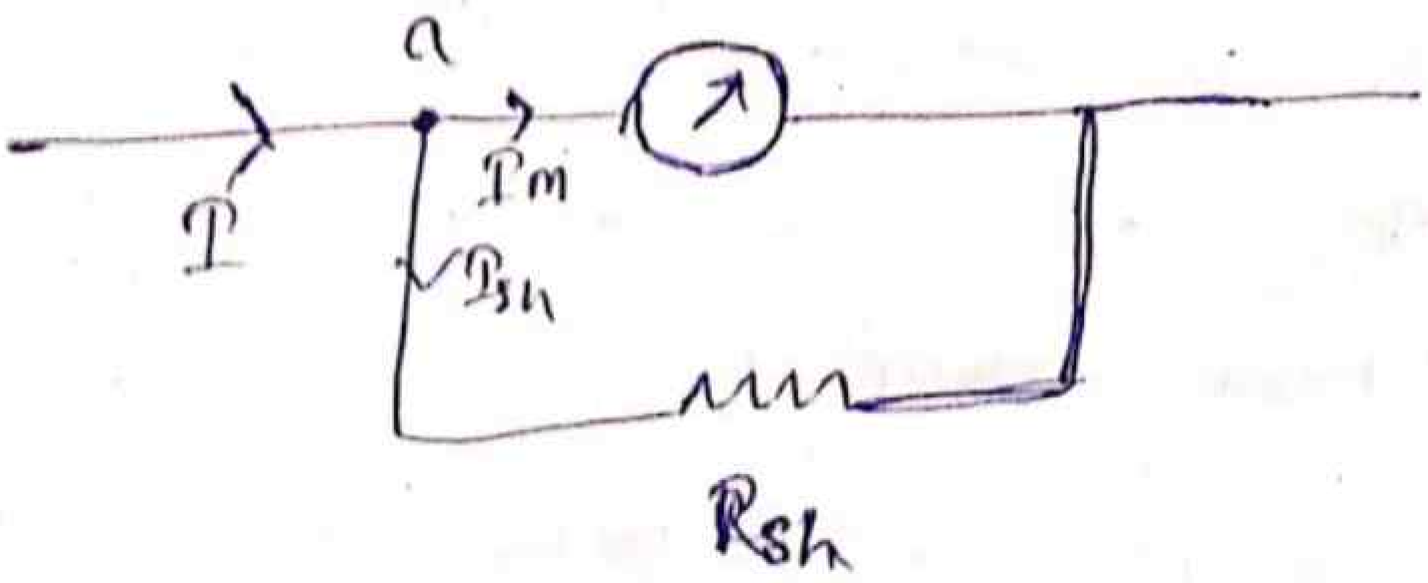
→ It is the small modification make to the instrument to measure the high range of voltage and current.

① PMMC instrument as an ammeter :-

The current rating in general can be increase by decreasing the effective resistances. The decrement of Resistance is possible by providing some path, there by the range of ammeter can be extended by providing a shunt resistance to the existing instrument.

Let's consider a PMMC ammeter as shown in the figure. Where 'I_m' through is the current through the meter, 'R_m' is the resistance of the meter.

we have to extend the value upto 'I' ampere, hence we have to provide a shunt path having resistance R_{sh}.



R_{sh} → It is the shunt resistance connected in parallel to the instrument.

Derivation :-

The voltage drop in meter path and shunt path remains constant;

i.e. $I_m R_m = I_{sh} \cdot R_{sh}$

$$\Rightarrow R_{sh} = \left(\frac{I_m R_m}{I_{sh}}\right) \quad \text{——} \quad (1)$$

Putting KCL at node 'a'.

$I = I_m + I_{sh}$

$\Rightarrow I_{sh} = I - I_m$

putting value of I_{sh} in eqn (1)

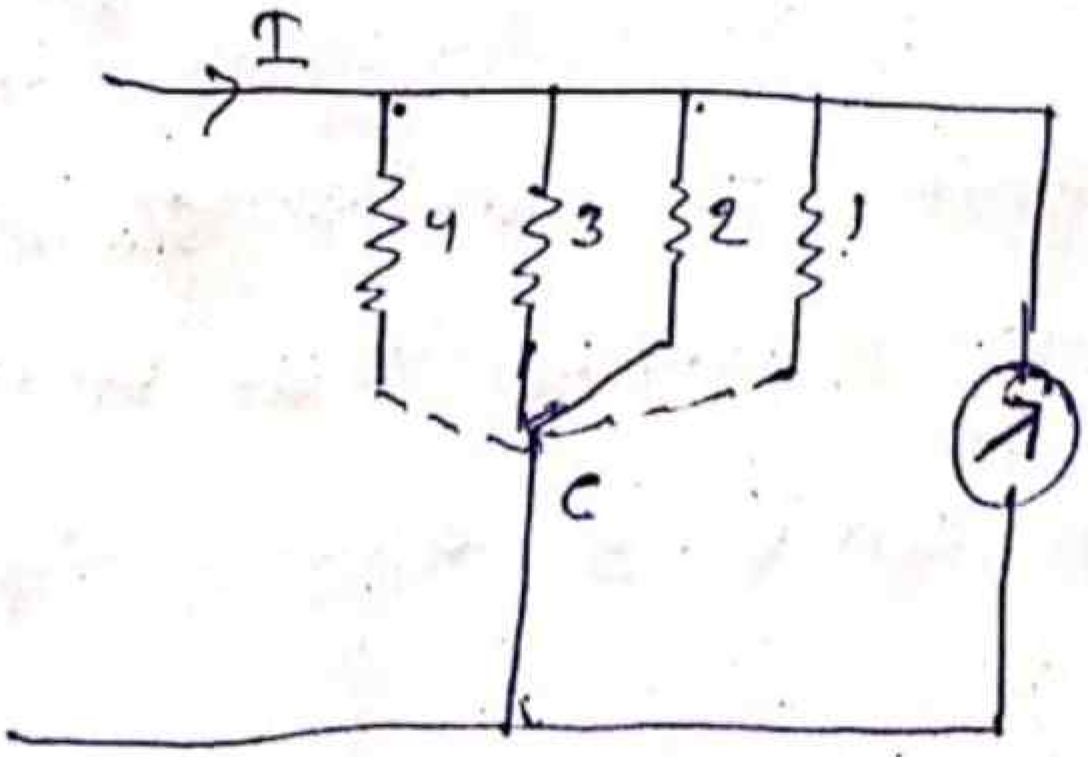
$\Rightarrow R_{sh} = \left(\frac{I_m}{I - I_m}\right) \cdot R_m$

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

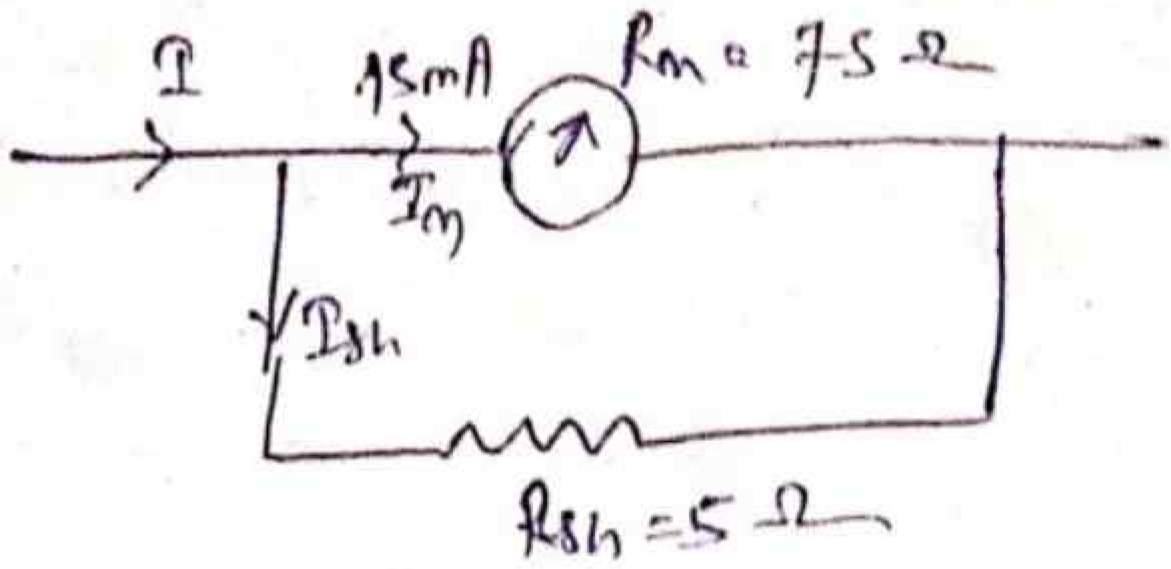
$\Rightarrow R_{sh} \quad \frac{R_m}{(N-1)}$ or $\frac{R_m}{(m-1)}$

where $N = m = \frac{I}{I_m}$ = constant or multiplication factor

when no. of shunts are connected to the ammeter its value can be extended to the different ranges. It can be shown in the figure.



(1) The PMMC instrument of rating 15 mA, 75 Ω, which shunted with a resistance of 5 Ω, then find out the overall rating of the instrument.



$\therefore R_{sh} = \frac{15 \times 75}{I_{sh}}$

$\Rightarrow 5 = \frac{15 \times 75}{I_{sh}}$

$\Rightarrow I_{sh} = \frac{15 \times 75}{5} = 225\,mAmp$

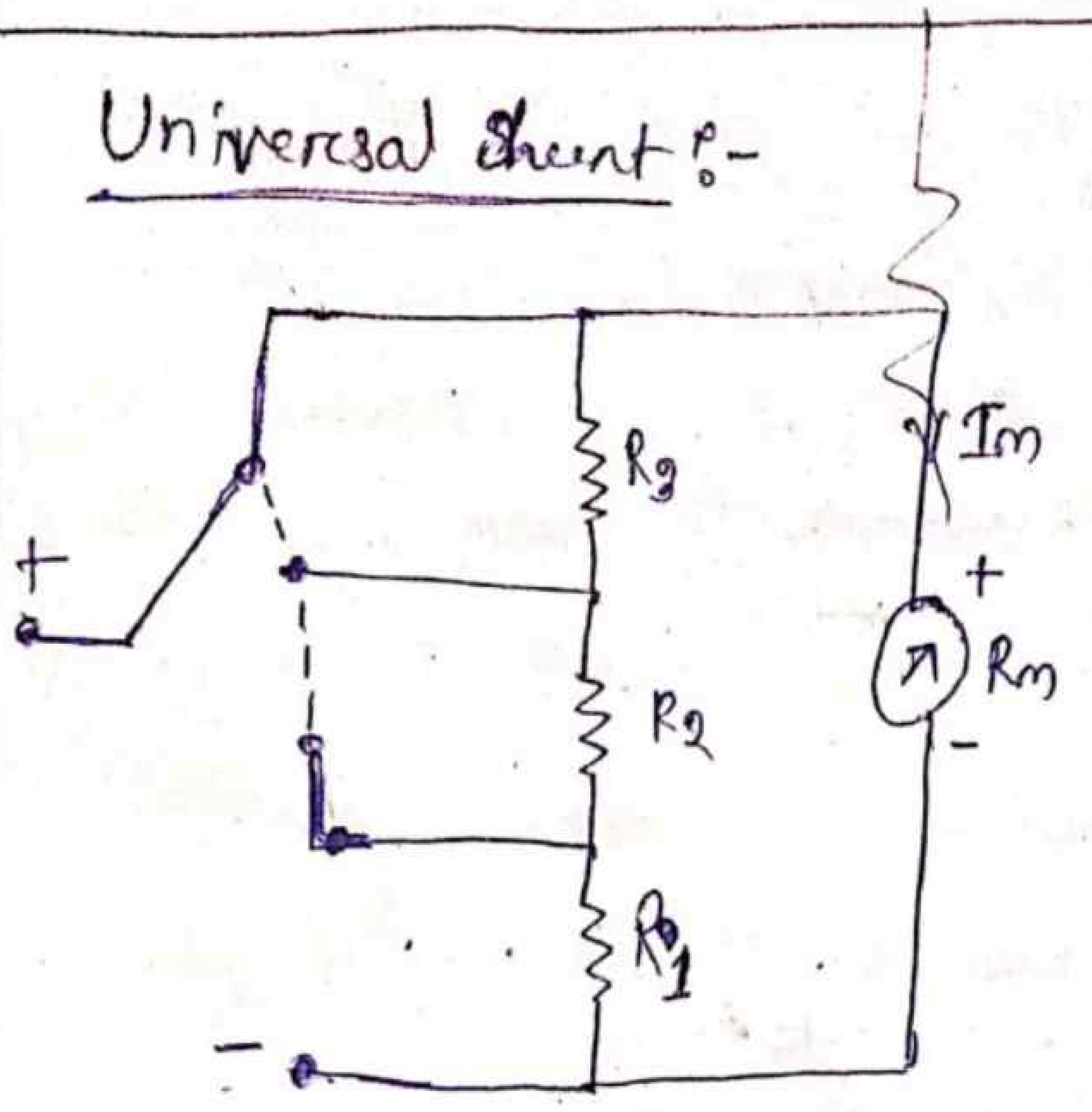
$\therefore I = I_m + I_{sh} = 15 + 225 = 240\,mAmp$

(2) A moving coil ammeter has full scale deflection of 150 A and a coil resistance 1000 Ω, then what will be the value of shunt resistance required for the instrument to be converted to read a full scale deflection of 1 amp.

(3) The full scale deflection current of an ammeter 1 mA and its internal resistance is 100 Ω. If this meter is to have scale deflection at 5 amp what is the value of shunt resistance in which used.

Date-25/01/20

Universal Shunt :-



Calculation

→ I_m, R_m are the meter current and resistance.

→ R_1, R_2 R_3 are the resistances connected in parallel with the ammeter.

→ when the switch is in position '3', R_1, R_2, R_3 are in series and attached shunt to the meter, so effective resistances minimum maximum current flows to the meter,

The voltage drop across two parallel branch are given by

$$\boxed{I_{sh} \cdot R_{sh} = I_m . R_m}$$ ⇒ $I_3(R_1+R_2+R_3) = I_m R_m$

$R_{sh} = R_1+R_2+R_3$

→ when the switch is in position '1' R_1 is parallel to $R_2+R_3+R_m$ and here the voltage drop eqn is

$I_1 R_1 = I_m (R_2 + R_3 + R_m)$

→ When the switch is in position '2' $R_1 + R_2$ is in parallel with $R_3 + R_m$, and voltage eqn becomes,

$$I_2 (R_2 + R_1) = I_m (R_3 + R_m)$$

Q. Design a universal shunt / Ayrton shunt to provide an ammeter with the current rest 1amp, 5amp, and full 10 amp. The basic meter resistance is 50Ω. full scale current reflection is 1 mA.

Soln

Given that, $I_1 = 1 amp$, $I_2 = 5 Amp$, $I_3 = 10 Amp$.

$R_m = 50 \Omega$, $I_m = 1 mA = 1 \times 10^{-3} Amp$

When the switch is in position - 1

$R_1 = 0.005 \Omega$
$R_2 = 0.005 \Omega$
$R_3 = 0.10399 \Omega$

$$1 \times R_1 = 1 \times 10^{-3} (R_2 + R_3 + 50)$$

$$\Rightarrow R_1 - R_2 \times 10^{-3} - R_3 \times 10^{-3} = 50 \times 10^{-3} \quad — (1)$$

When the switch in position - 2

$$5 \times (R_2 + R_1) = 1 \times 10^{-3} (R_3 + 50)$$

$$\Rightarrow 5R_1 + 5R_2 - R_3 \times 10^{-3} = 50 \times 10^{-3} \quad — (2)$$

When the switch is in position - 3

$$10 \times (R_1 + R_2 + R_3) = 1 \times 10^{-3} \times 50$$

$$\Rightarrow 10R_1 + 10R_2 + 10R_3 = 50 \times 10^{-3} \quad — (3)$$

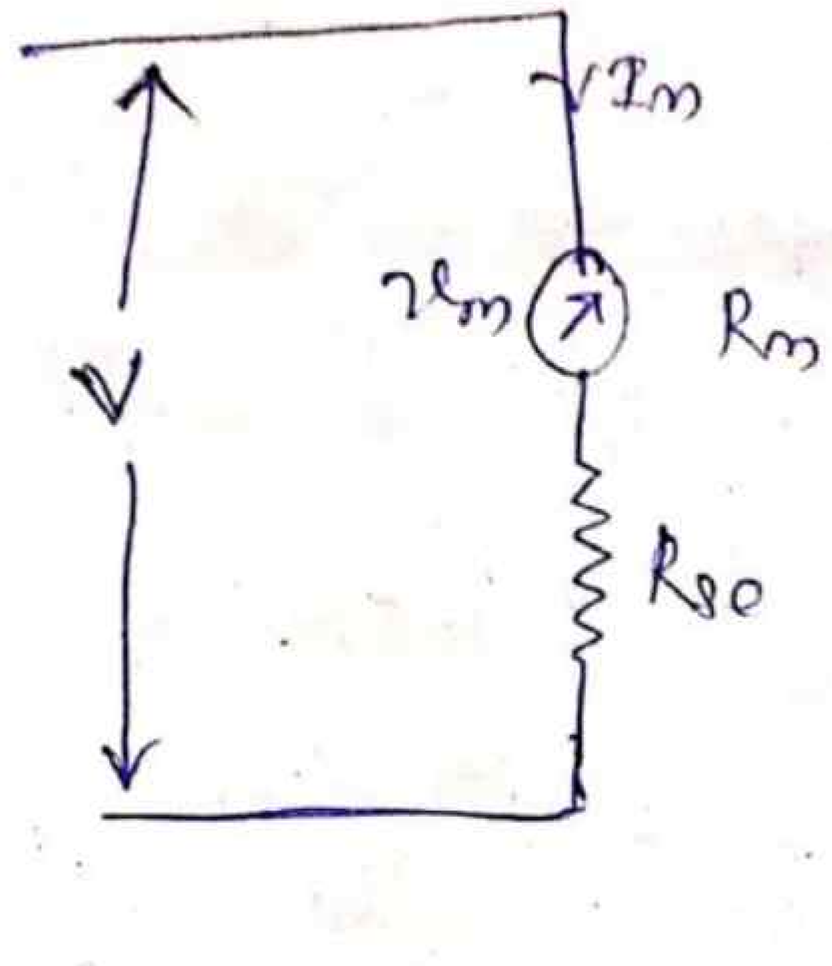
i.e. $R_1 = 0.04$, $R_2 = -0.039$, $R_3 = -4.99$

Extension range of PMMC voltmeter :-

The voltmeter is extended by increasing the resistance of the ckt. So to increase the rating of voltmeter series resistances are connected with the voltmeter.

The series resistance connected with the voltmeter are called as multiplier.

Let's consider a PMMC voltmeter as shown in the figure.



I_m, R_m → meter current & resistance respectively.

I_{fs} = full scale deflection current

(or) I_m =

R_{se} = series resistance (or) multiplier.

V_m = voltage across meter

V = extended voltage

$$\therefore V_m = I_m R_m \quad \text{——— (1)}$$

$$V = I_m (R_m + R_{se}) \quad \text{——— (2)}$$

Dividing eqn (2) by eqn (1)

$$\frac{V}{V_m} = \frac{R_m + R_{se}}{R_m}$$

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

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

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

where N = multiplying factor.

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

Q – A voltmeter has rating 0.25 V. If we want to extend its range upto 10 V. What will be the multiplying factor.

What will be the series resistances to be connected if

$R_m = 25\ \Omega$

$$\Rightarrow 40 = \frac{R_{se}}{25} + 1$$

$$\Rightarrow 40 = 25 + R_{se}$$

$$\Rightarrow 40 \times 25 = 25 + R_{se} \quad \Rightarrow R_{se} = 40 \times 25 - 25$$

$$= 975\ \Omega$$

Material for voltmeter multiplier :-

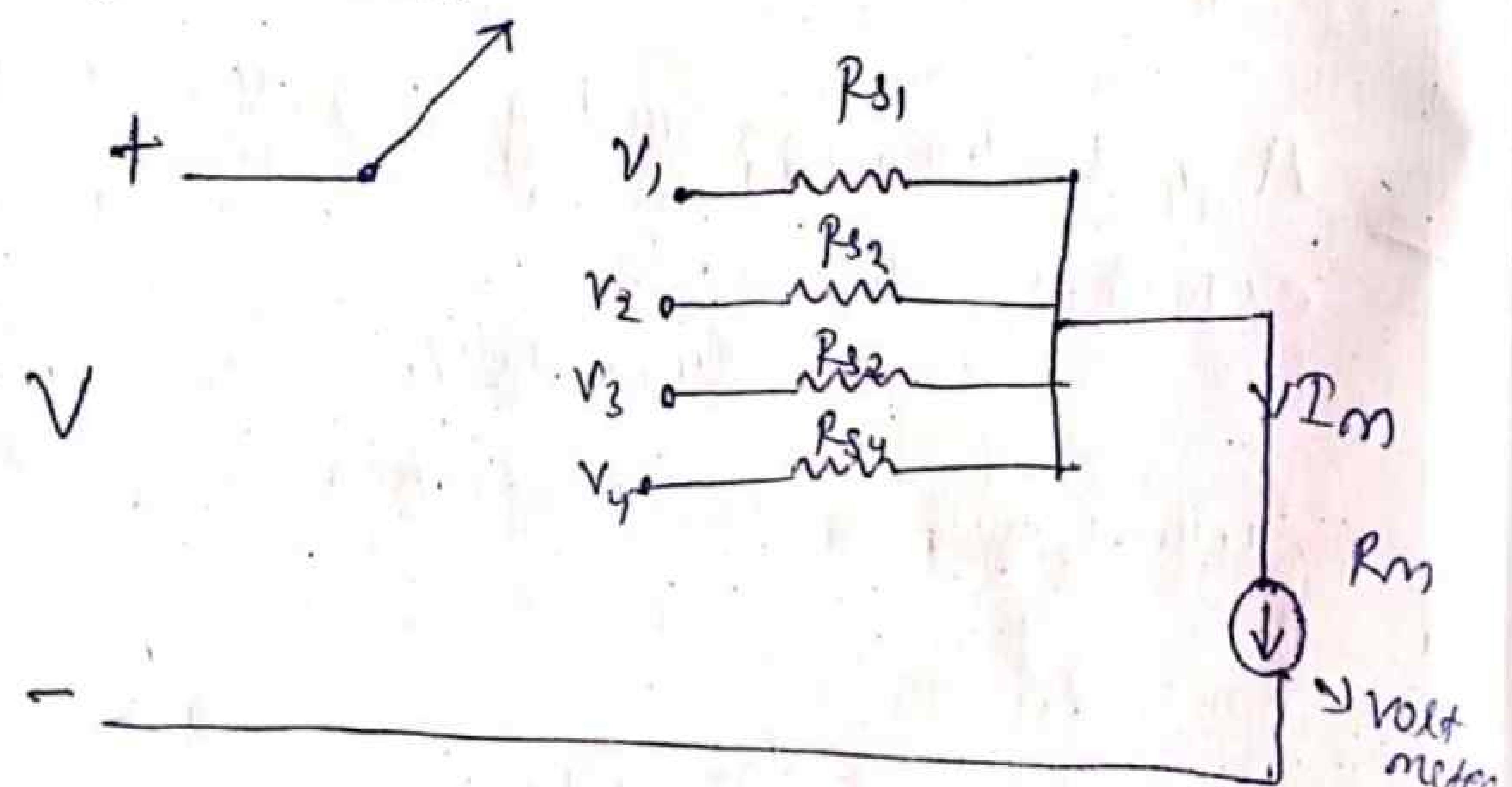
→ Their resistance should not change with time.

→ Change in their resistance with temp. should be small.

→ normally the material used for multiplier is Mn, constantan (alloy of Cu, Ni).

Extension range of voltmeter

Multirange volt meter



Multiplying factor,

$$N_1 = \frac{V_1}{V_m}, \quad N_2 = \frac{V_2}{V_m}, \quad N_3 = \frac{V_3}{V_m}, \quad N_4 = \frac{V_4}{V_m}$$

$$R_{s1} = R_m (N_1 - 1)$$

$$R_{s2} = R_m (N_2 - 1)$$

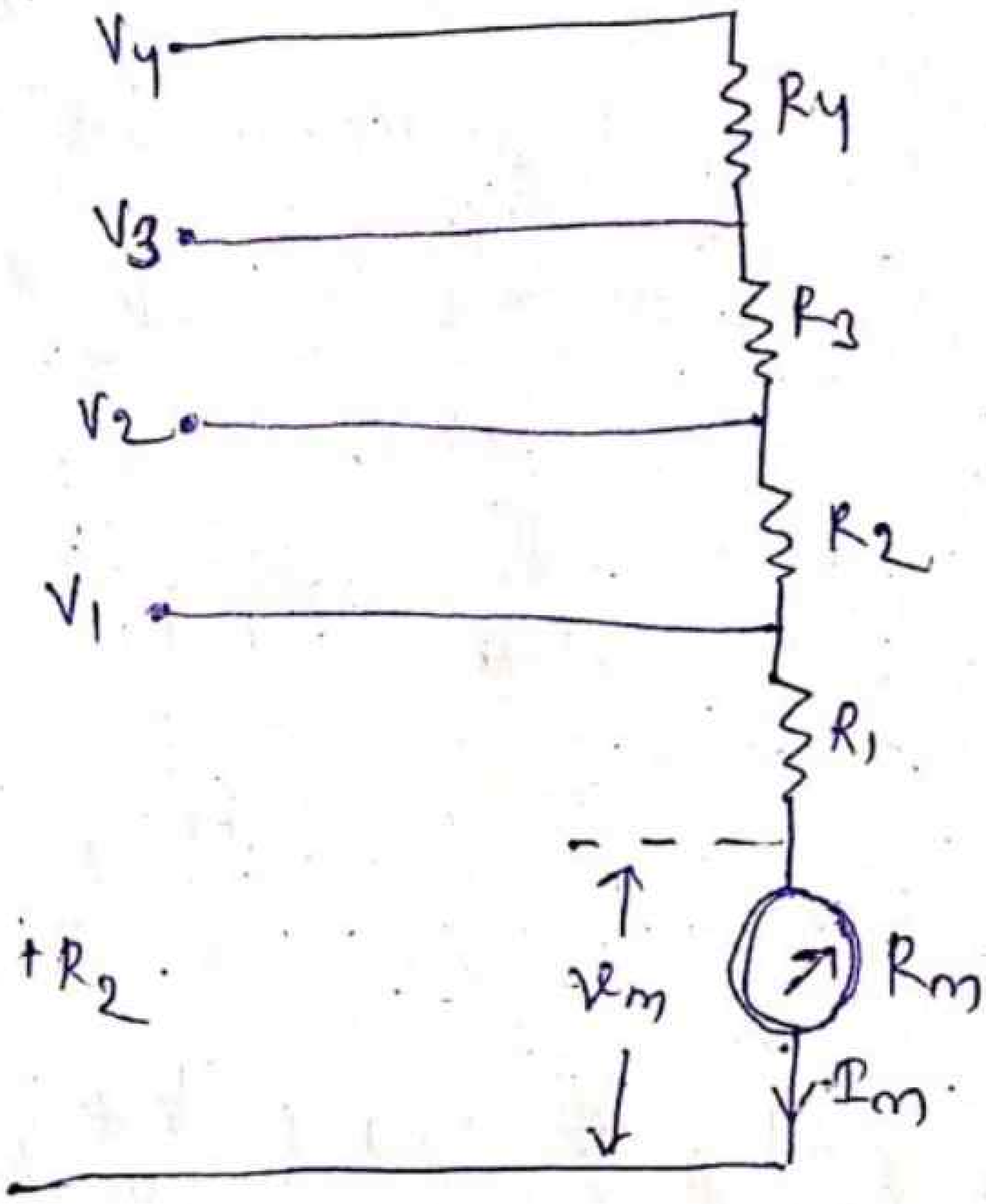
$$R_{s3} = R_m (N_3 - 1)$$

$$R_{s4} = R_m (N_4 - 1)$$

Voltmeter extension potential division method :

$R_1 = R_m (N_1 - 1)$

$N_1 = \frac{V_1}{V_m}$



R = ? $\frac{V_2}{I_m} = R_1 + R_m + R_2$

$\Rightarrow \frac{V_2}{I_m} = R_m (N_1 - 1) + R_m + R_2$

$\Rightarrow \frac{V_2}{I_m} = R_m N_1 - R_m + R_m + R_2$

$\Rightarrow \frac{V_2}{I_m} = R_m N_1 + R_2$

$\Rightarrow \frac{V_2}{\left(\frac{V_m}{R_m}\right)} = R_m N_1 + R_2$

$\Rightarrow N_2 R_m = R_m N_1 + R_2$

$\Rightarrow \boxed{R_m (N_2 - N_1) = R_2}$ ——— (i)

Similarly R_3 and R_4 becomes,

$R_3 = (N_3 - N_2) R_m \qquad N_3 = \frac{V_3}{V_m}$

$R_4 = (N_4 - N_3) R_m \qquad N_4 = \frac{V_4}{V_m}$

Q. A PMMC instrument having resistance of 100 Ω, current of 1mA is subjected for the extension of voltage range of 100V, 300V, and 600V. Find the individual resistances to be placed in series in potential division extension.

$R_m = 100\,\Omega$, $I_m = 1mA = 10^{-3}A$.

$V_1 = 100V$, $V_2 = 300V$, $V_3 = 600V$,

$V_m = I_m \cdot R_m$
$= 100 \times 10^{-3}$.

$R_{S1} = 100\left(\frac{100}{100\times10^{-3}} - 1\right)$

$= 99900\,\Omega$ $= 99.90\,k\Omega$

$R_{S2} = 100\left(\frac{300}{100\times10^{-3}} - 1\right)$

$= 299900\,\Omega$ $= 299.9\,k\Omega$

$R_{S3} = 599900\,\Omega$ =

$100\left(N_2 - N_1\right)$

$R_1 = R_m\left(N_1 - 1\right)$

$= 100\left(\frac{100}{100\times10^{-3}} - 1\right) = 99900$

$= 99.90\,k\Omega$

$R_2 = R_m\left(N_2 - N_1\right) = 100\left(\frac{300}{100\times10^{-3}} - \frac{100}{100\times10^{-3}}\right)$

$= 200 \cdot 000 \, K\Omega$

$$R_3 = \left(\frac{.600}{100 \times 10^{-3}} - \frac{.300}{100 \times 10^{-3}}\right) 100 = 300 \cdot 000 K\Omega$$

Errors in PMMC instrument :-

(i) Frictional error
(ii) Error due to coil
(iii) Error due to spring
(iv) ,, ,, magnet
(v) ,, temperature rise.

(iv) The permanent magnet are aged by heat and vibration treatment. this process results in the loss of initial magnetism but that remains is strongly head.
→ The weakening of magnets tends to decrease the deflection for a particular value of current.

(iii) · The weakening of spring with time can be reduced by careful use of material and pre-ageing during manufacture.
→ The weakening of springs tends to increase the deflection.

(v) In PMMC instruments, a $1^\circ c$ increase of temperature reduces the strength of springs by about 0.04% and reduces flux density in the air gap of the magnet by about 0.02 % , thus the net effect on the avarage, is to increase the deflection by about 0.02 % per °C.

(ii) The moving coil of a measuring instruments usually wound with copper wire having a temperature Coefficient of 0.004/°C.

→ When the instruments used as a micro ammeter or a milli ammeter and the moving coil is directly connected to the output terminals of the instrument.

→ The indication of the instrument for a constant would decrease by 0.04 percent per °C rise in temperature.

(i) The friction of the pivot in the Jewel produces a frictional torque which affects the instruments reading. This error is more serious for sensitive instruments designed for low operating torque.

→ These errors may be reduced by adopting a moving system of light construction and large deflecting torque.

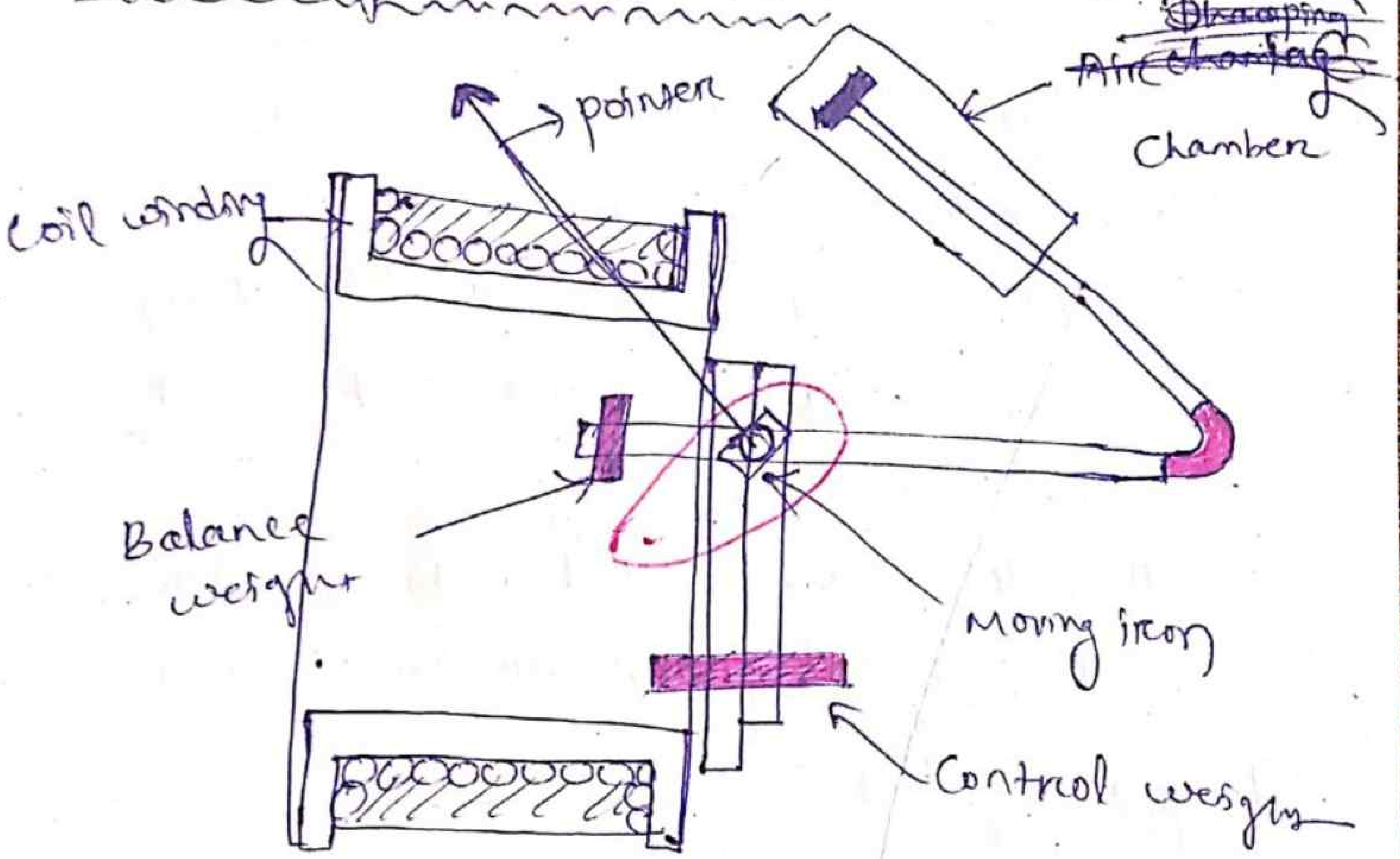
(iv) The error owing to weakening of permanent magnet can be reduced by proper attention to ageing and reasonable care in use.

(v) Change of temperature affects the instruments resistance and stiffiness of the Control Spring this is due to heating of the working coil and Other resistance coils connected internally in the instrument causing by the operating current.

Date-29/01/20

Moving iron instrument

Attraction type MI instrument :-



Construction :-

It consist of a stationary hollow cylindrical coil (Electro magnet), and are oval shaped soft iron piece is mounted eccentrically to the spindle to which pointer is attached.

→ The controlling torque is provided by gravity control method.

→ The Damping torque is provided by Air friction Damping.

Working Principle :-

When a soft iron piece is placed in a magnetic field of a current carrying coil. It is attracted towards the center of the coil or magnetic field.

Working :-

When the instrument is connected to the ckt, the operating current flows through the stationary coil. and a magnetic field is set up. by which the soft iron pieces is attracted towards the center of the coil,

thus the pointer attached to the spindle gets deflected and moves over the calibrated scale.

Torque equation :-

Deflecting torque :-

$$F \propto mH$$

where m = force act on moving iron.

H = Magnetic field strength produced by the coil.

$H \propto I$

$m \propto H$, $m \propto I$

$$F \propto I^2$$

$$\Rightarrow T_d \propto I^2$$

The deflecting torque is expressed as,

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

where T_d = Deflecting torque

L = self inductance

I = Operating current

θ = Angle of deflection

$\frac{dL}{d\theta}$ = Rate change of self inductance

Date- 01/09/2020

Controlling torque:-

when the control is gravity control

$$T_c = Wgl \sin\theta$$

and when it is spring control,

$$T_c = K\theta$$

Let's consider spring control is used, then steady state is obtained when $T_d = T_c$

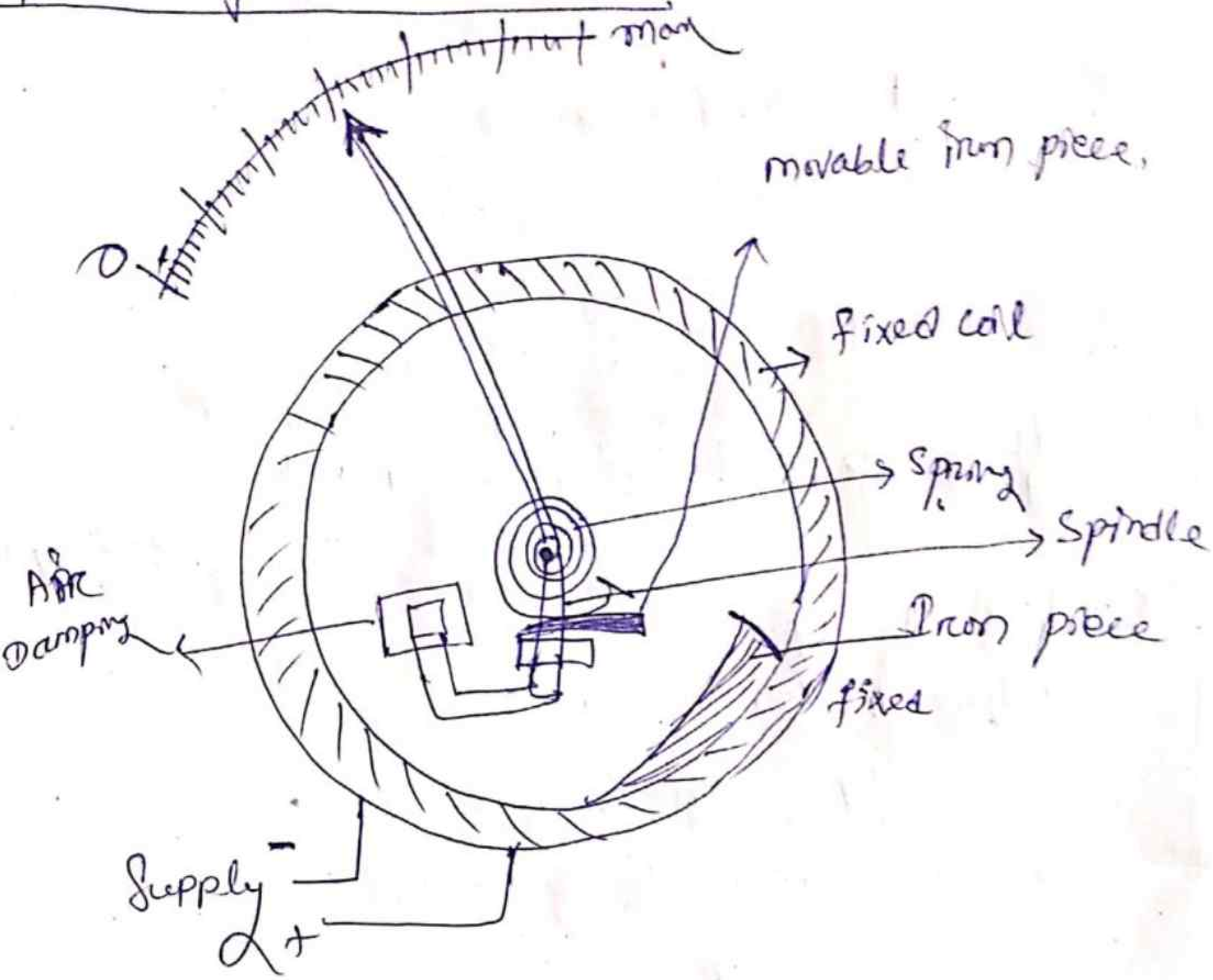
$$\Rightarrow \frac{1}{2} I^2 \frac{dL}{d\theta} = K\theta$$

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

$$\Rightarrow \theta \propto I^2$$

from this eq^n it is observed the scale is non uniform

Repulsion type MI Instrument :-



Construction :-

It consist of a fixed cylindrical hollow coil (electromagnet) which carries operating current. ~~Inst~~

→ Inside the coil two soft iron pieces i.e. rods or vens. place parallel to each other and along the axis of the coil.

→ one iron piece is fixed that is attached to the coil and another one is ~~fixed which is attached~~ movable i.e. attached to the spindle.

→ A pointer is attached to the spindle with spring

Control mechanism and air friction damping arrangement.

Working :-

When the instrument is connected to the ckt the operating current flows through the fixed coil. Due to this a magnetic field is setup along the axis of the coil this magnetic field magnetised both the iron pieces in the same polarity.

→ ① Due to this a force of repulsion acts betn two iron pieces there by the movable iron pieces moves away from fixed iron piece, so that the pointer attached to the spindle deflects over the callibrated scale.

Application of MI Instrument :-

(i) This is used as volt meter, ammeter, wattmeter etc.

(ii) This is used in both AC and D.C.

(iii) MI Instrument are used up to the frequency of 125 Hz.

Advantages :-

(i) These instruments are cheap, Robust and simple in construction.

(ii) These instruments can be used on both AC and D.C.

(iii) These instruments are reasonably accurate.

(iv) MI Instruments possesses high operating torque.

Disadvantages :-

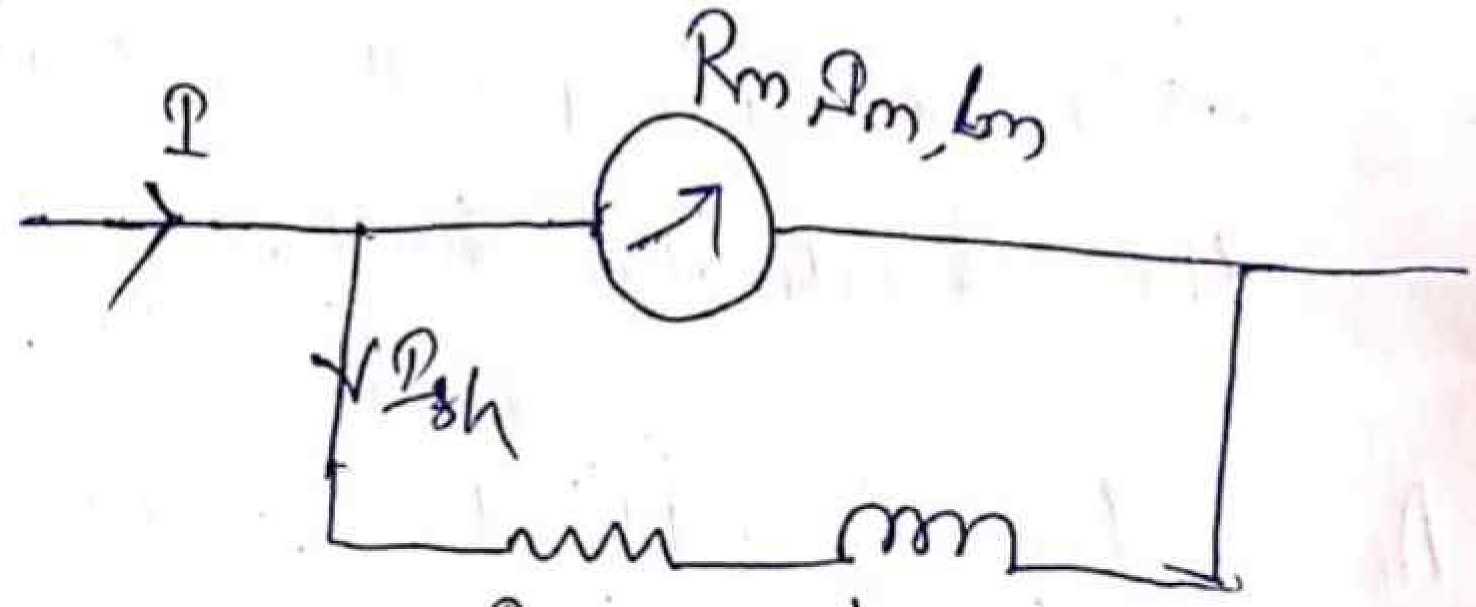
(I) MI Instruments have non uniform scale.

(II) These instruments are not very sensitive.

(III) Power consumption is quite high.

(IV) Errors are introduced due to change in frequency in case of AC measurement.

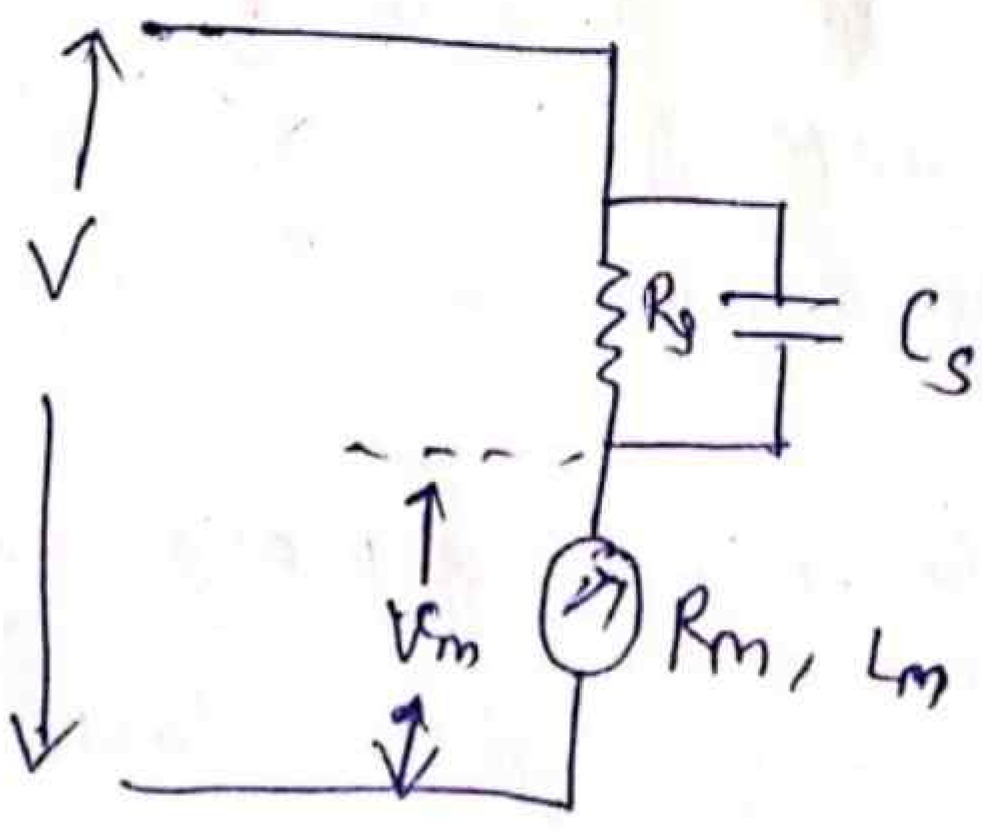
MI Instruments as ammeter :-



$Z_1 = Z_2$

$\Rightarrow \frac{L_{sh}}{R_{sh}} = \frac{L_m}{R_m}$ (Time constant)

MI Instrument as voltmeter :-



$C_s = 0.41 \frac{L_m}{R_s^2}$

Error in MI instruments :-

There are two types of error which occur in moving iron instruments.

(1) Errors with both A.C. and D.C. work :

(a) Hysteresis error.

~~(b) Stray magnetic field error,~~

(b) Temperature error.

(c) Friction error.

(2) Errors with A.C. work only :-

(a) Frequency error

(b) Error due to reactance of instrument coil.

(c) Error due to eddy current.

~~(d) Error due to wave form.~~

(a) Hysteresis error :- It is a serious type of error in MI instruments when used on D.C. circuits. The effect of this error is that the readings are higher when current increases than when it decreases.

This error can be reduced by employing vanes of mumetal (i.e. mumetal is magnetic material having low hysteresis loss and high permeability) and by working it over a low range of flux densities.

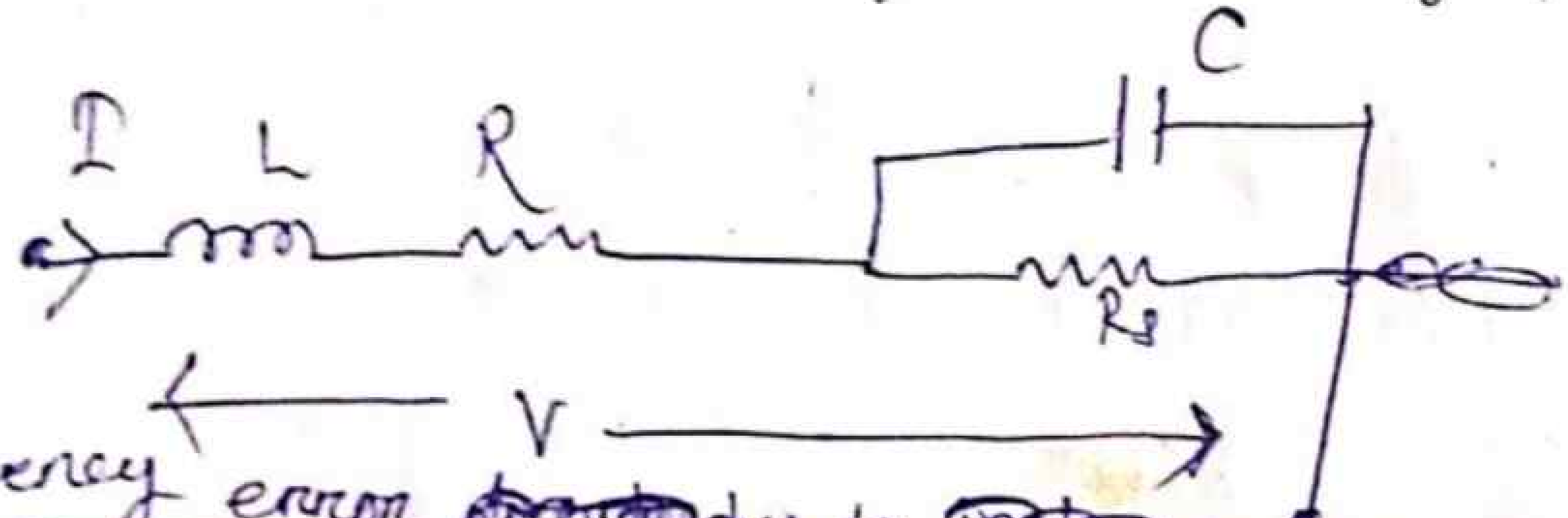
(b) Temperature error is due to change of temperature that affects the instrument resistance and stiffness of the control spring.

(c) Friction error is due to the friction of moving parts this can be avoided by making torque - weight ratio high.

(d) <u>Frequency errors</u>- chang in frequency may be cause errors due to change of reactance of the operating coil and also to the changes in magnitude of eddy current set up in the metal parts of instrument near the operating coil.

(e) <u>error due to the instrument coil</u> the change in instrument coil reactance owing to change in frequency causes serious error in case of volt meters.

(f) <u>Eddy current</u> error affects both ammeters and volt meters equally. the frequency error may be compensated for by connecting a suitable capacitor 'c' in the parallel with swamping resistance R ($C = L/R^2$, if frequency is not too high).



<u>Frequency error due to reactance coil</u> :-

In case of volt meter a series resistance is connected with the coil. where I is the instrument current, & 'V' is the applied voltage.

as we know that, $I = \frac{V}{Z}$

$$Z = (R + R_S) + jX_L$$

$$\Rightarrow I = \frac{V}{\sqrt{(R+R_S)^2 + (\omega L)^2}}$$

$$\Rightarrow I = \frac{V}{\sqrt{(R+R_s)^2 + \omega^2 L^2}}$$

$$\Rightarrow \boxed{T_d \propto I \propto \frac{1}{\omega}}$$

from this relation we know that td depends on the current through the coil and current is inversely proportional to the frequency, so for given voltage deflecting torque is less at high frequency than low frequency.

This can be compensated by connecting a capacitor 'c' across the series resistance 'R_s'.

Frequency error due to change in magnitude of eddy current setup in metallic ~~conductor~~ part.

This error is caused by the eddy current induced in the iron part of the instrument.

hence there will be change in main magnetic field due to induced field.

→ This can affect the operating current and also frequency.

→ This can be minimized by reducing the metallic part of the instrument.

Date - 4/2/2020

Electrodynamometer type instrument

Construction :-

It consists of a fixed coil, which is splited into two parts and placed parallel to each other.

→ The fixed coils are cone to eliminate the hysteresis loss.

→ A moving coil is placed in betn the fixed coil.

→ The moving coil is attached on the spindle with spring and pointer (or) moving system.

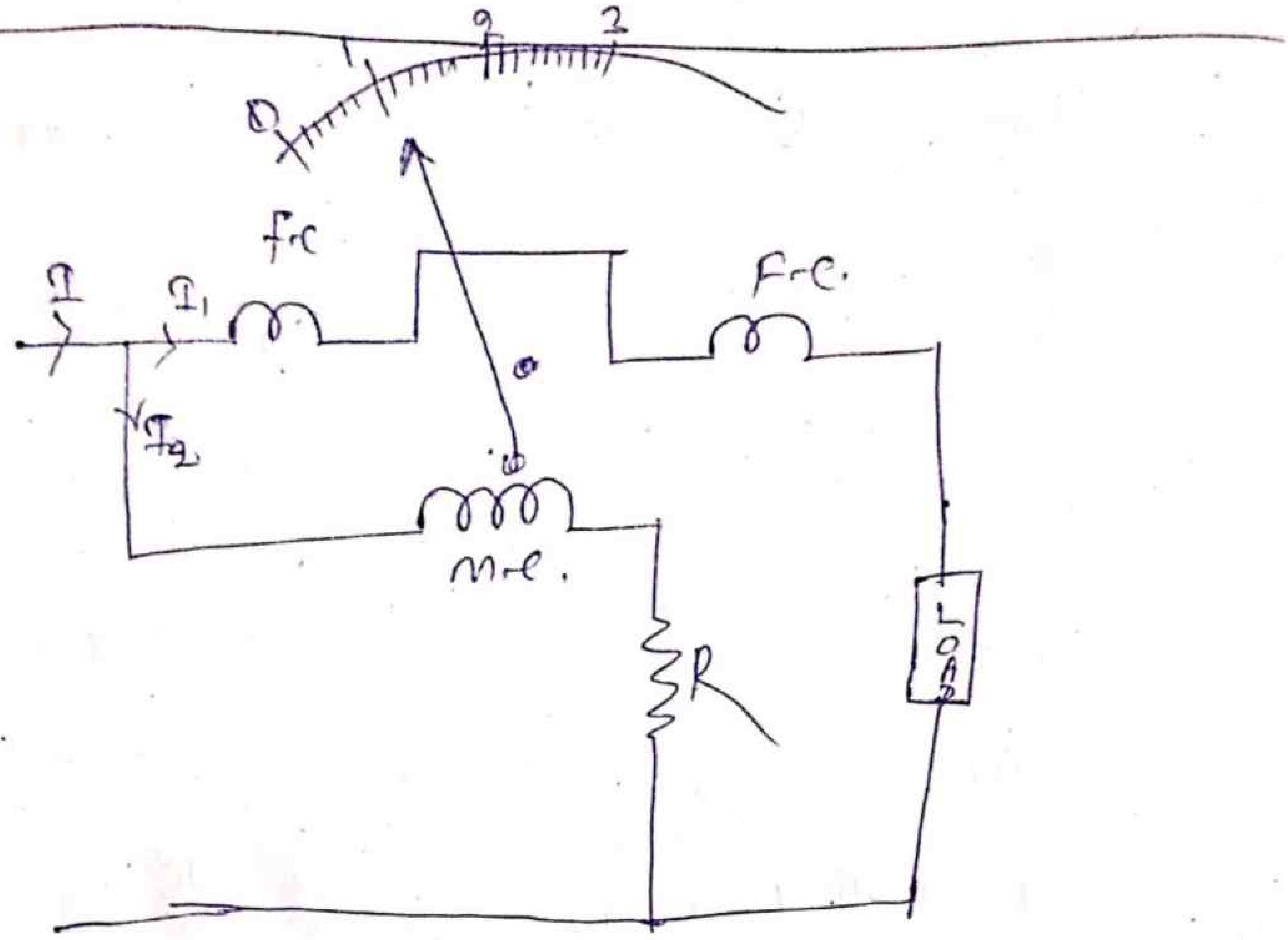
→ A high resistance is connected in series with the moving coil to limit the current.

→ The connection of fixed coil and moving coil are different by their uses as an ammeter, voltmeter & watt meter.

→ The control torque is provided by spring control mechanism and Damping torque is provided by air friction damping.

Principle :-

When a current carrying moving coil is placed in the magnetic field of produced by current carrying fixed coil then a force is exhausting on the coil sides of the moving coil and deflection takes place.



the fixed coil are connected in series with the load. and the moving coil is connected in parallel with the load.

Operation :-
when the load is connected to the instrument and supply is given to the instrument then current starts flowing through both the coil.

Let, I_1 = current flowing through F.C.

I_2 = current " " M.C.

$I_1 \propto I_{load}$ and $I_2 \propto V_{load}$.

Both the coil produced magnetic field around them, the operating field (F_m) is produced by the fixed coil. and another magnetic field (F_R) is produced by the moving coil.

Then both the field interact with each other and the magnetic field produced by moving coil tries to come in line with operating magnetic field, due to which moving coil gets deflected and by which pointer deflects.

The deflecting torque produced can be estimated as

$T_d \propto I_1 I_2$

$T_d = I_1 I_2 \frac{dm}{d\theta}$ (for DC)

where m = mutual inductance betn fixed coil.

and $\frac{dm}{d\theta}$ = It is the rate of change of mutual induction w.r.t angle of deflection.

For AC

T_d can be estimated as

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

where I_1, I_2 → RMS value

Controlling torque :-

As control torque is provided by spring control T_c can be represented by,

$$\boxed{T_C = K\theta}$$

The pointer remains steady position when both the torques are equal i.e. $\boxed{T_C = T_d}$

(i) For dc

$$T_d = T_c$$

$$\Rightarrow I_1 I_2 \frac{dm}{d\theta} = K\theta$$

$$\Rightarrow \boxed{\theta = \frac{1}{K} I_1 I_2 \frac{dm}{d\theta}}$$

(ii) For AC

$$T_d = T_c$$

$$\Rightarrow I_1 I_2 \frac{dm}{d\theta} \cos\theta = K\theta$$

$$\Rightarrow \boxed{\theta = \frac{1}{K} I_1 I_2 \cos\theta \frac{dm}{d\theta}}$$

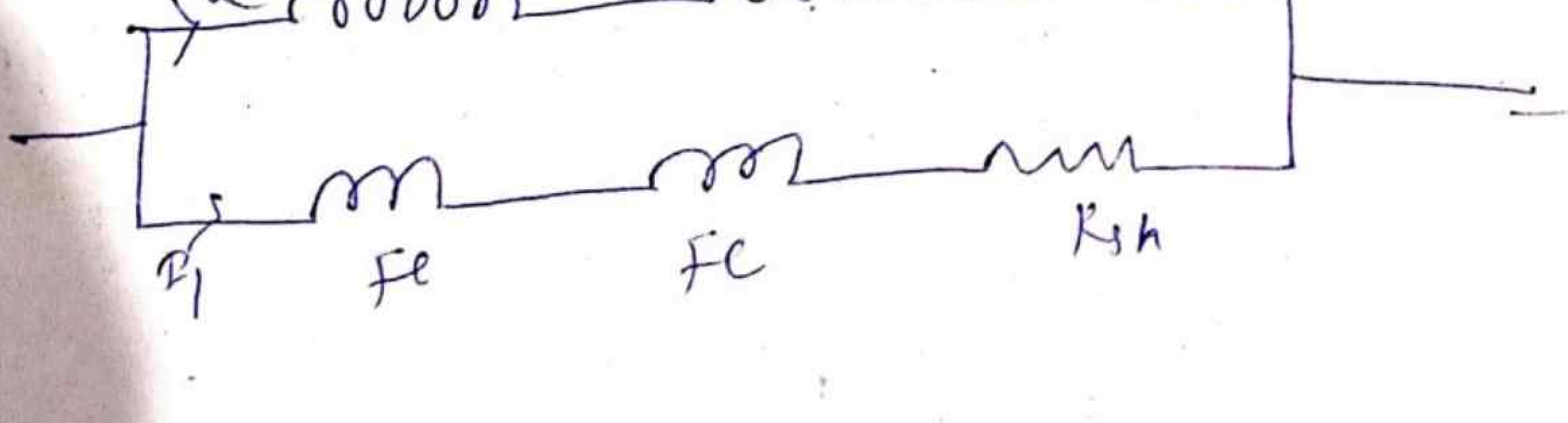
Application :-

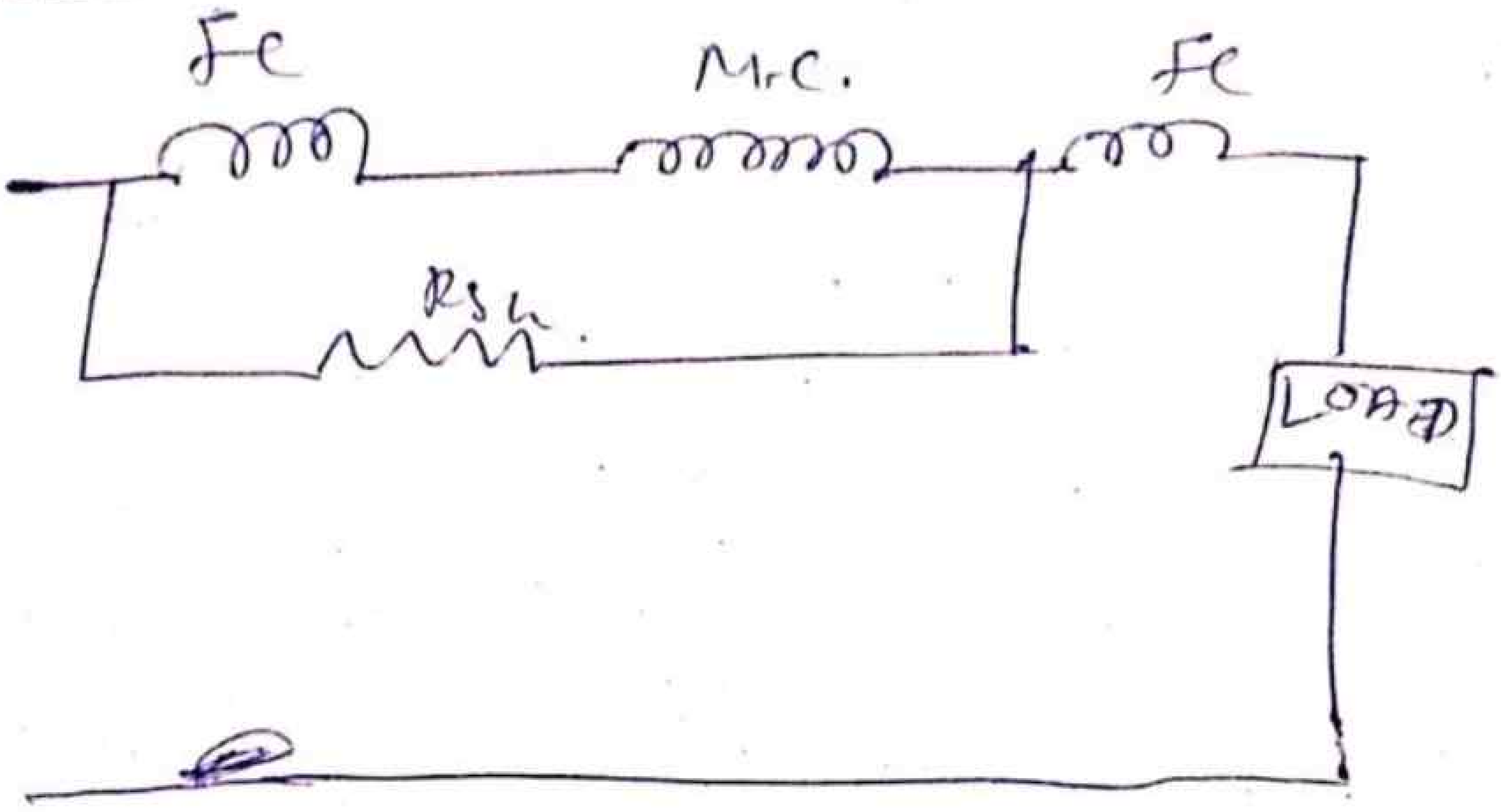
-> Dynamometer type instruments can be used as ammeter, voltmeter, watt meter.

-> These are used in both AC and dc measurement.

-> This instruments is known as transfer instrument, because if it is callibrated on DC it can be used in ac.

Dynamometer type instrument as an ammeter :-





for measurement of current the resistance of instrument kept low so that a shunt resistance is connected in the fixed coil branch which is shown in the figure. here the relation betn deflection and current.

→ This type of connection is adopted for currents > 100mA.

for operating current less than 100mA fixed coil and ~~fixed~~ moving coil are connected in series.

Dynamo meter type instrument as volt meter:-

The sensitivity of voltmeter can be increased by increasing the

So that both the coils are connected in series which are shown in the figure.

Relation betn angle of deflection and current is as

$$\theta = \frac{1}{K} I_1 I_2 \frac{dm}{d\theta}$$

hear, $I_1 = I_2 = I = \frac{V}{Z}$.

where V = load voltage

Z = impedance of the ckt.

So putting this value in above eqn we found that.

$$\Rightarrow \theta = \frac{1}{K} I^2 \frac{dm}{d\theta}$$

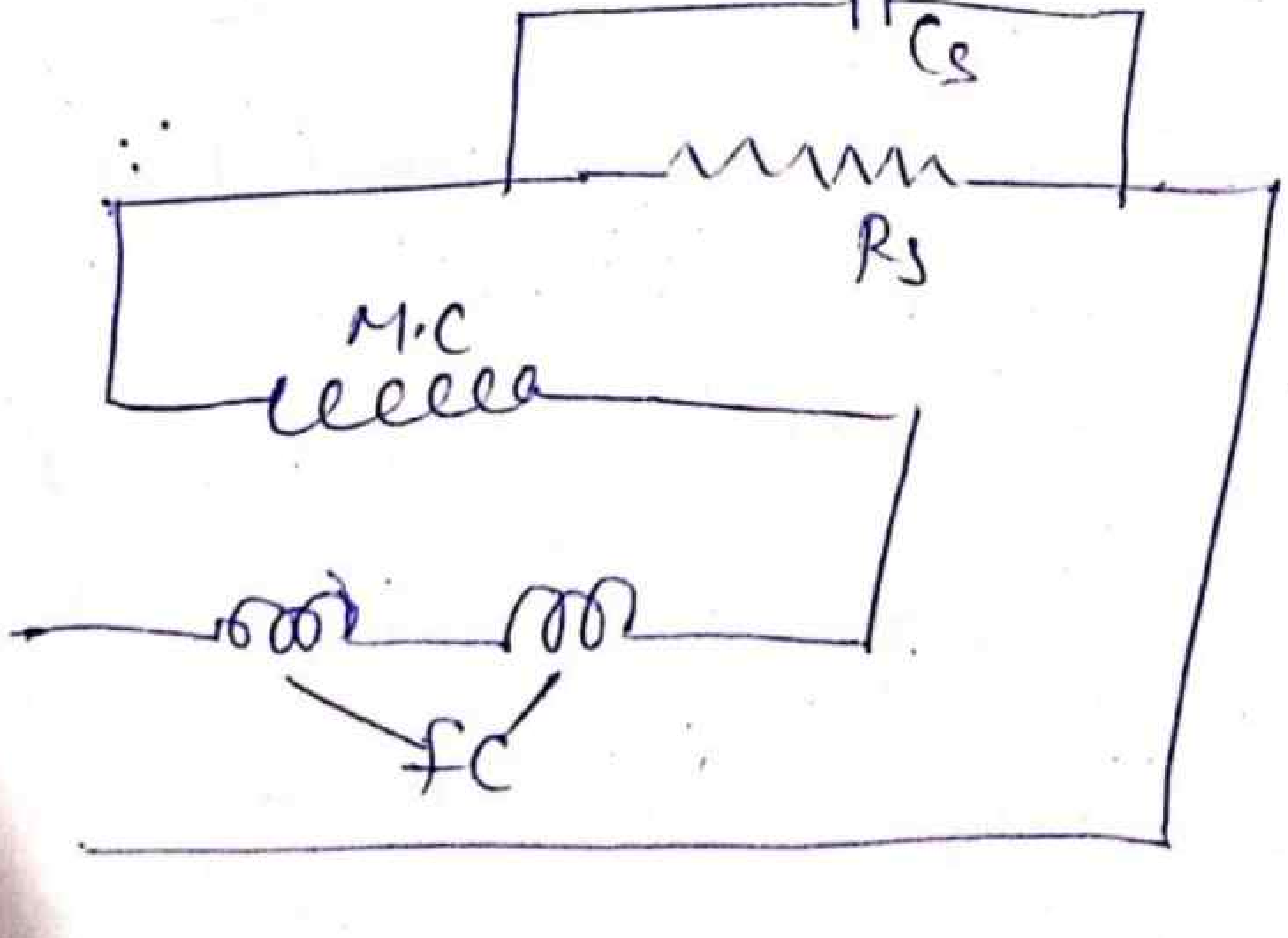
$$\Rightarrow \theta = \frac{1}{K} \frac{V^2}{Z^2} \frac{dm}{d\theta}$$

~~we~~ from this we found that,

$$\theta \propto V^2.$$

So in this instrument the scale is non uniform.

~~Electrodynamometer type instrument as an wattmeter:-~~



Date - 5/2/20

Error in dynamometer type instrument :-

① Frictional error :- here the coils are air core so the magnetic field produced is small. there fore it requires large no. of ampere turns to create necessary deflecting torque. This results heavy moving system. So it has small torque by weight ratio.

Due to heavy moving system frictional error (or) losses in this instrument is large. as compare to other instruments.

here hysteresis loss is also zero, as the coils are air core.

② Temp. error :-

This instruments considerable amount of power so self heating in this instrument is appreciable. to compensate this swamping resistance made up of manganin are used.

③ Error due to stray magnetic field :-

Since the operating field produced by fixed coil is weaker in comparison to other instruments this is more sensitive to stray magnetic field.

④ Frequency error :-

A change in frequency causes error

① due to change in reactance of the operating coil.

(ii) due to change in magnitude of eddy current set up in the metallic part of the instrument.

Advantages :-

(i) This instruments can be used on both AC and DC.
(ii) It is free from hysteresis and eddy current errors.
(iii) It follows square law callibration.
(iv) Ammeter upto 10 amp and voltmeter upto 600V can be constructed with precision grade accuracy.
(v) Because of precision grade accuracy and same calibration for dc and AC measurement this instrument used as transfer instruments.

Disadvantages :-

(i) It has non uniform scale.
(ii) small torque by weight ratio.
(iii) Large Frictional error.
(iv) Costly as compare to PMMC and MI Instruments.
(v) Easily affected by stray magnetic field.
(vi) sensitivity of instrument is very low due to poor deflecting torque.

Induction type instrument :-

In this instrument the deflecting torque is produced by the principle of induction. hence the name. this instrument is only used for AC measurement.

Working principle :-

When a disc of conducting material is placed in a rotating magnetic field (or) magnetic field produced by electromagnet with some phase difference then eddy currents are induced in it.

→ The reaction betn rotating flux and eddy current creates torque which rotates the disc. by which pointer gets deflected.

Induction type instrument is of two types,

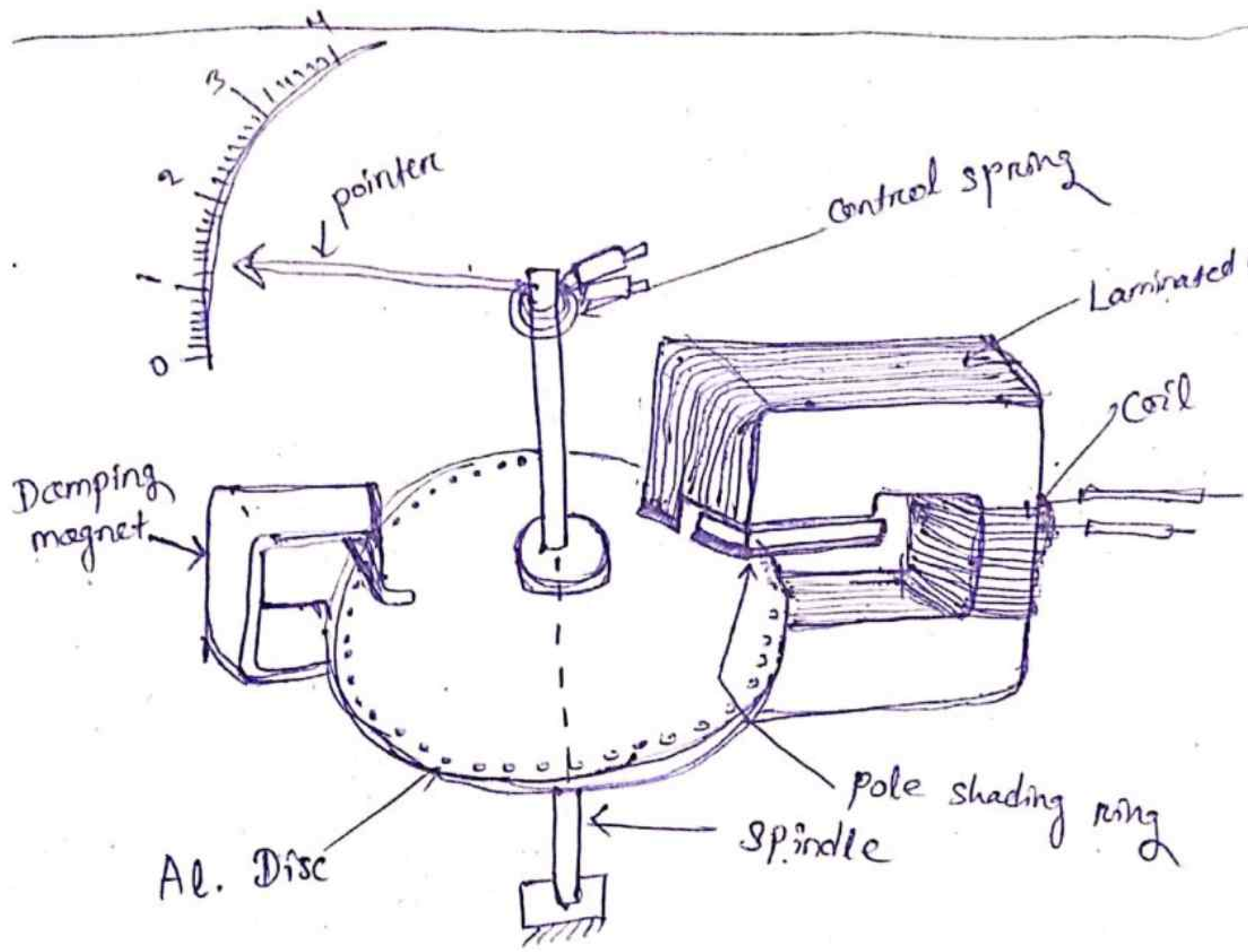
(i) Shaded pole type.

(ii) split phase type.

(i) Shaded pole type :-

Construction :- It consists of electromagnet which is ~~sealed in~~ shaded in one part to provide phase difference betn the fluxes.

The shape of the core is same as transformer in betn the poles. A disc is placed which is attached in the spindle. The moving system i.e. pointer & the control system is also attach to the spindle. and a



damping magnet (break magnet) is provided in other end of the disc.

working :-

when the supply is given to the coil of electromagnet it draws two different current i.e. I_1 and I_2 due to different resistance (or) reluctances.

Due to this two fluxes are set up that is ϕ_1 and ϕ_2. This ϕ_1 and ϕ_2 have some phase difference betn them. So a rotating magnetic field is set up.

As this magnetic links with aluminium disc. Then emf is induced in the disc by which eddy current are set up in the disc.

Let the eddy currents are I_{e_1} and I_{e_2} due to the interaction of ϕ_1 and I_{e_2} and ϕ_2 and I_{e_1}.

The torques are produced in the disc. Let the torque

Let the torque are , $T_1 \propto \phi_1 I_{e2}$

$$\Rightarrow T_1 = K \phi_1 I_{e2} \cos(90+\beta)$$

$$\Rightarrow \boxed{T_1 = -K \phi_1 I_{e2} \sin\beta}$$

$$T_2 \propto \phi_2 I_{e1}$$

$$\Rightarrow T_2 = K \phi_2 I_{e1} \cos(90-\beta)$$

$$\Rightarrow \boxed{T_2 = K \phi_2 I_{e1} \sin\beta}$$

$$\therefore T_d = T_2 - T_1 \text{ (or) } T_1 - T_2$$

$$\Rightarrow T_d = T_2 - T_1 = 2K \phi_1 \phi_2 \sin\beta$$

$$\Rightarrow T_d \propto \phi_1 \phi_2$$

$$\Rightarrow T_d \propto I^2$$

Then the deflecting torque can be estimated by the resultant of T_1 and T_2.

So $T_d = T_2 - T_1$ (β = phase difference betn ϕ_1 and ϕ_2)

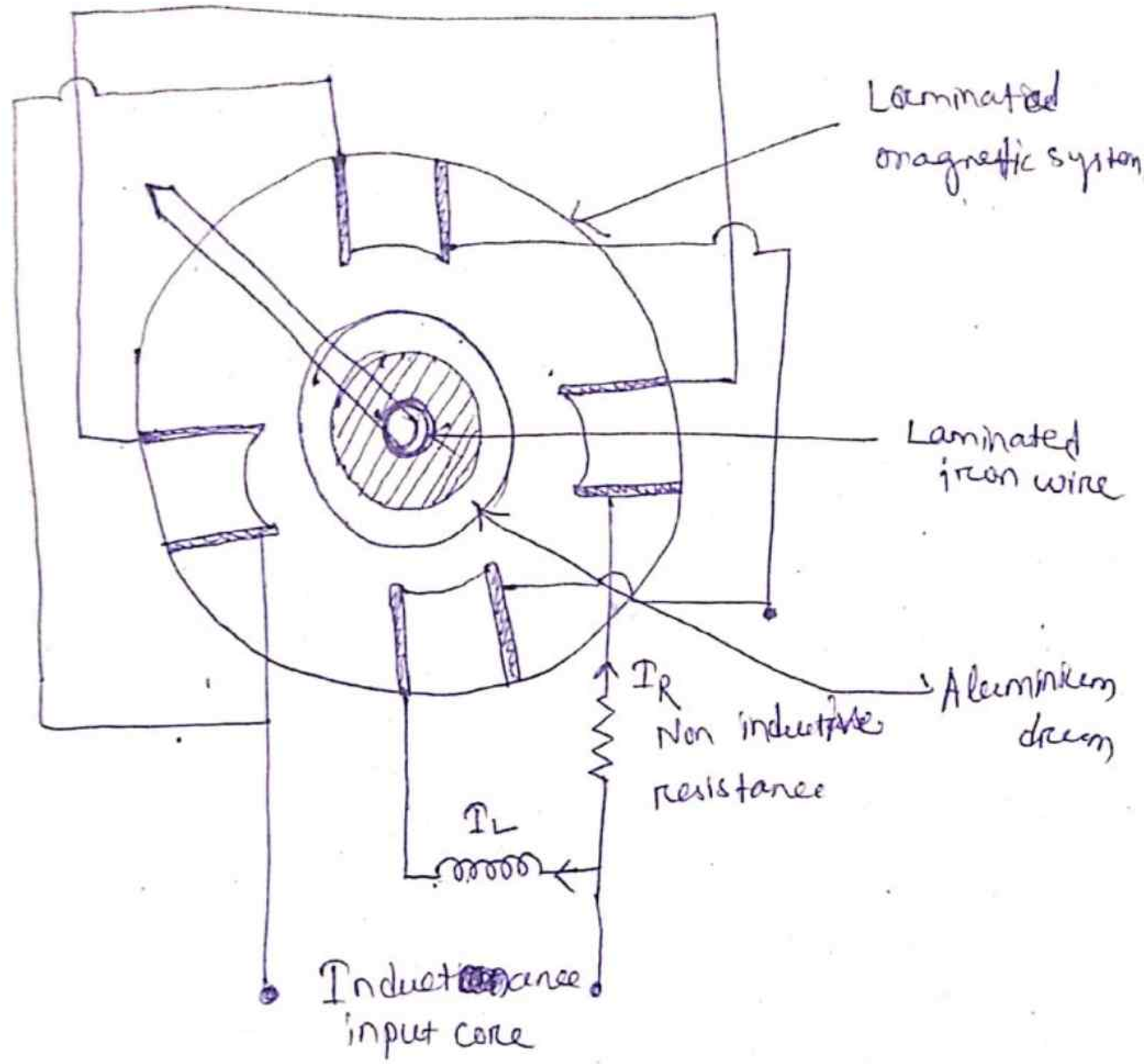
(I = operating current/supply current)

here the control spring is provided by spring control mechanism and damping is by break magnet.

more the phase split more be the phase difference.

Date- 8/2/2020

Split phase type :-



Construction :-

It consists of a laminated magnet with the pairs of poles at right angle to each other. coils are wounds on the poles and opposite poles are connected in series and the coils on the the 2 pairs of poles are connected in parallel,

one set of coil is connected through an inductance and another with a high resistance to create a phase difference of 90°.

The input to both coils is the current to be measured.

in the center of the yoke ~~coil~~ in coil and aluminium drum is placed.

__Working :-__

When the instrument is connected to the ckt a rotating magnetic field is setup due to this eddy currents are induced in the drum, and the torques are produced by the interaction of eddy current and opposite flux.

The deflecting torque is resultant of 2 torques here also control torque is provided by spring.

__Advantages :-__

1. efficient damping
2. High torque by weight ratio.
3. cheap as compare to MI Instrument.
4. Accuracy lable is high.

__Disadvantages__

1. Non uniform scale
2. Large power consumption
3. exclusively used for AC measurement,

Date- 3/2/2020

Measurement of Resistance, Inductance & Capacitance

Measurement of Resistance :-

According to range resistance is divided in 3 parts,

① Low resistance ($R < 1$)

② Medium resistance (R (1-100kΩ))

③ High resistance. ($R > 100k\Omega$)

① Low resistance :-

The resistance below one ohm are considered as low resistance. for measuring this we use,

① Kelvin's double bridge method

② Potentiometer method.

② Medium resistance :- The resistance betn 1Ω-100kΩ are considered as medium resistances. all household and commercial appliances resistances are in this range.

These are generally measured by,

① Substitution method

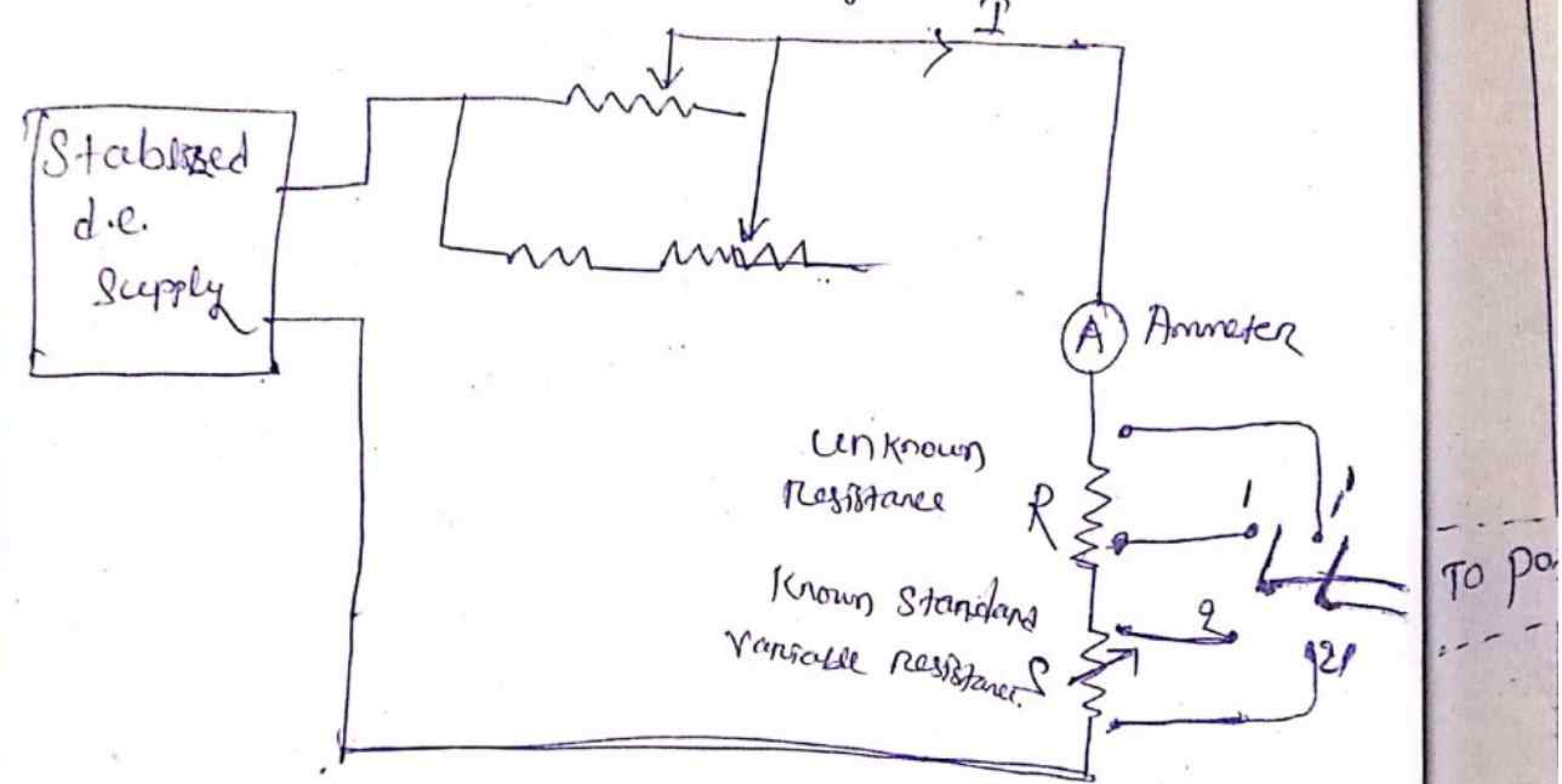
② Wheat stone bridge method.

③ High resistance :- The resistances of value of greater than 100kΩ are considered as high resistances.

usually insulation resistances are in this range.

for measuring this MΩ meter (or) megger is use.

Measurement of low resistance by potentiometer



Explanation

This method is used for measuring unknown low resistance. This can be done by comparing the unknown resistance with standard resistance.

here the voltage drop across known and unknown resistance is measured by potentiometer.

here the R → unknown value whose value is to be measured,

S → standard known resistance,

Rheostat:-

It is used for controlling the magnitude of current in the ckt.

Ammeter :- used for measuring the ckt current.

DPDT switch :- This is used for connecting the resistances to potentiometer.

operation :- when the switch is in position 1-1' the unknown resistances R is connected to the potentiometer.

Let the voltage be 'V_R' and from dc supply let the current is 'I'.

As R and S are connected in series the same current i.e. I is flowing through them.

potentiometer

from this we can write that $V_R = IR$ — ①

when the switch is in position 2-2', S is connected to the potentiometer,

Let the voltage is V_S,

$$V_S = I_S \text{ ——— } ②$$

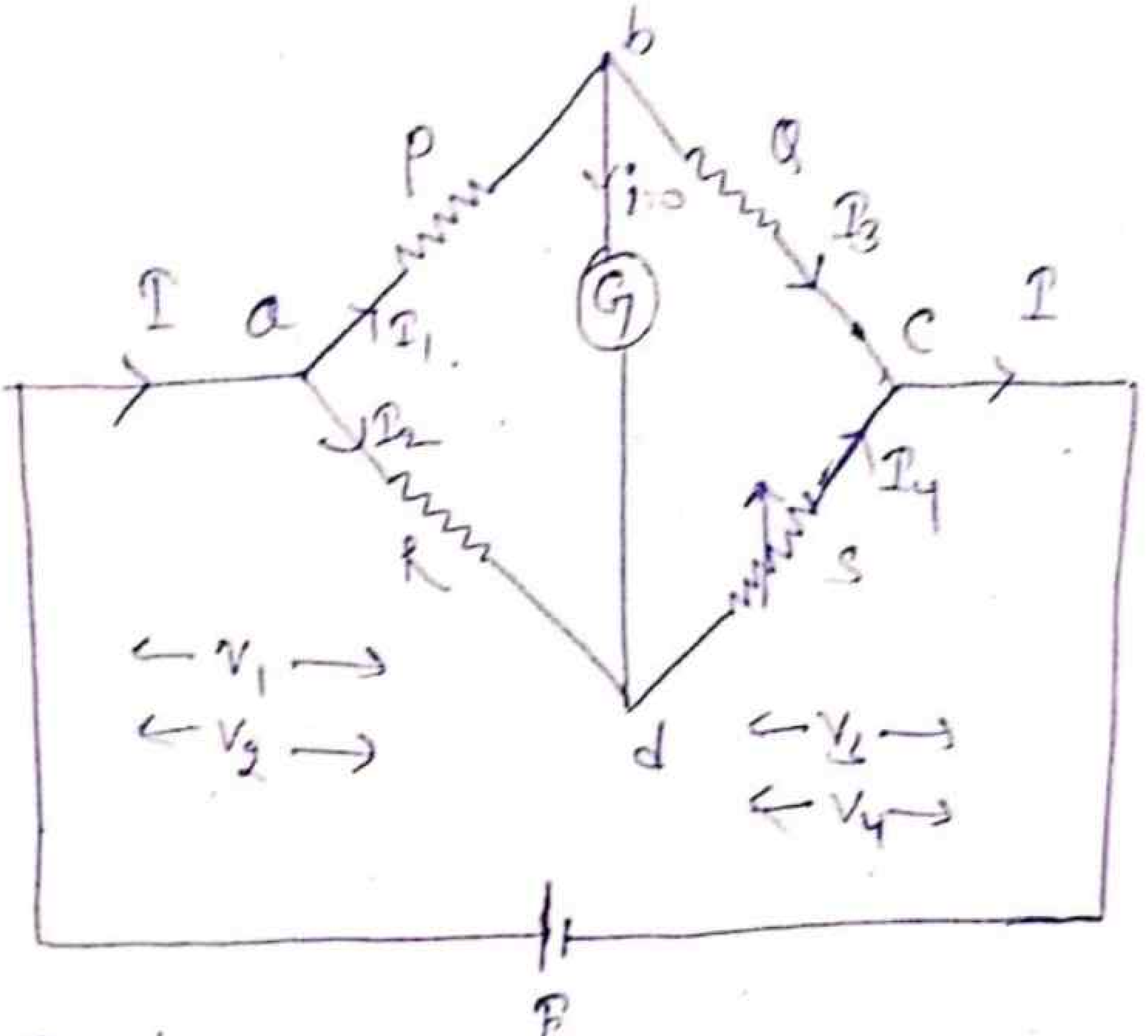
By diving eqn ① by ② we get,

$$\frac{V_R}{V_S} = \frac{IR}{IS}$$

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

Date- 10/3/2020

Measurement of medium resistance by Wheatstone bridge method.



Construction :-

Wheatstone bridge is used for measurement of medium resistance. This bridge works on the principle of null deflection (or) balance bridge condition. the Construction of bridge is as follows.

→ It consist of 4 arms in which the unknown Resistances whose value is to be measure. is kept ~~capture~~ in first arms.

→ here two Resistances are known that is (Q & R) kept ~~and are cap~~ in 2nd and 3rd arm. and the Standard Variable known resistance S is kept in 4th branch.

→ And a Galvanometer is connected betn the point d and c as shown in the figure and a battery or emf is connected betn a and b.

The bridge is works on the principle of the null deflection i.e. when the current through galvanometer is zero.

Balancing condition is the condition to study or analysis the bridge. at balanced condition 'i' = 0.

$V_1 \rightarrow$ Voltage across point ad.

$V_2 \rightarrow$ Voltage across point bc

$V_3 \rightarrow$ Voltage across point db.

$V_4 \rightarrow$ Voltage across point cb.

$$\left.\begin{aligned} I_1 = I_3 \quad & P/P+Q \\ I_2 = I_4 \quad & E/R+S \end{aligned}\right\} \text{——} (1)$$

As the potential betn d and b are same in balanced condition then $V_1 = V_2$ and $V_3 = V_4$ —— (2)

$$\Rightarrow I_1 P = I_2 R$$

from eqn (1) and (2)

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

$$\Rightarrow P(R+S) = R(P+Q)$$

$$\Rightarrow PR + PS = RP + RQ$$

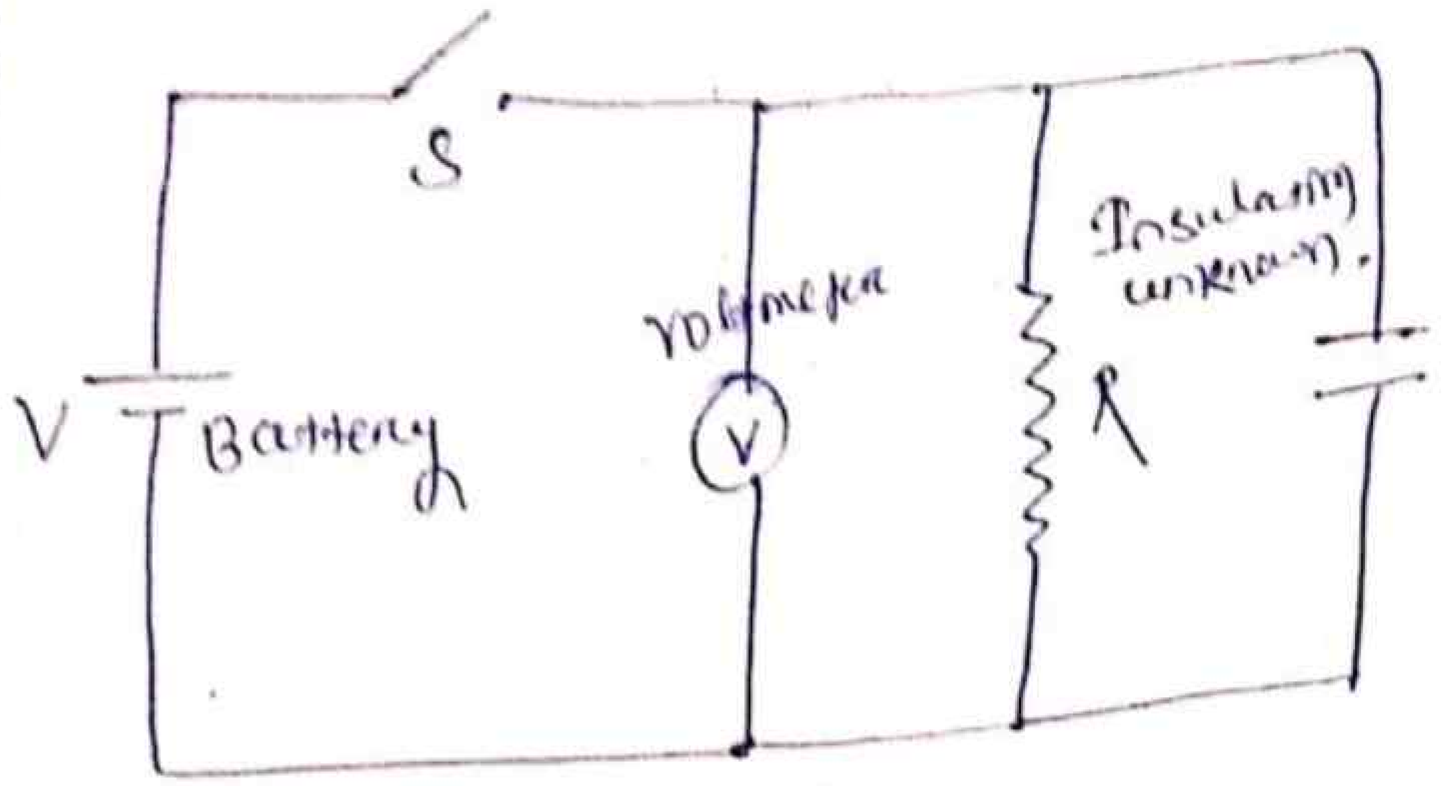
$$\Rightarrow PS = RQ$$

$$\Rightarrow \boxed{R = \frac{PS}{Q}}$$

This is the expression for unknown resistance in terms of known resistances.

Here the balancing condition is obtained by varying the S = standard variable known resistance.

Measurement of high resistance by using loss of Charge method:



$$V_0 = V_0 e^{-t/\tau}$$

$$V_i = V_0 e^{-t/RC}$$

$$\frac{V_i}{V_0} = e^{-t/RC}$$

$$\Rightarrow \log \frac{V_i}{V_0} = \frac{-t}{RC}$$

$$R = \frac{t}{C \log\left(\frac{V_i}{V_0}\right)} = \frac{0.4343\, t}{C \log \frac{V_i}{V_0}}$$

→ In this method the insulating resistance 'R' to be measured is connected in parallel with a capacitor 'C' and an electrostatic voltmeter.

→ The capacitor is charged to some suitable voltage by means of battery having voltage 'V' and is then allowed to discharge through the resistance the terminal voltage is observed over considerable period of time during discharge.

→ The voltage **ACROSS the** capacitor at any instant 't' after the application of voltage is,

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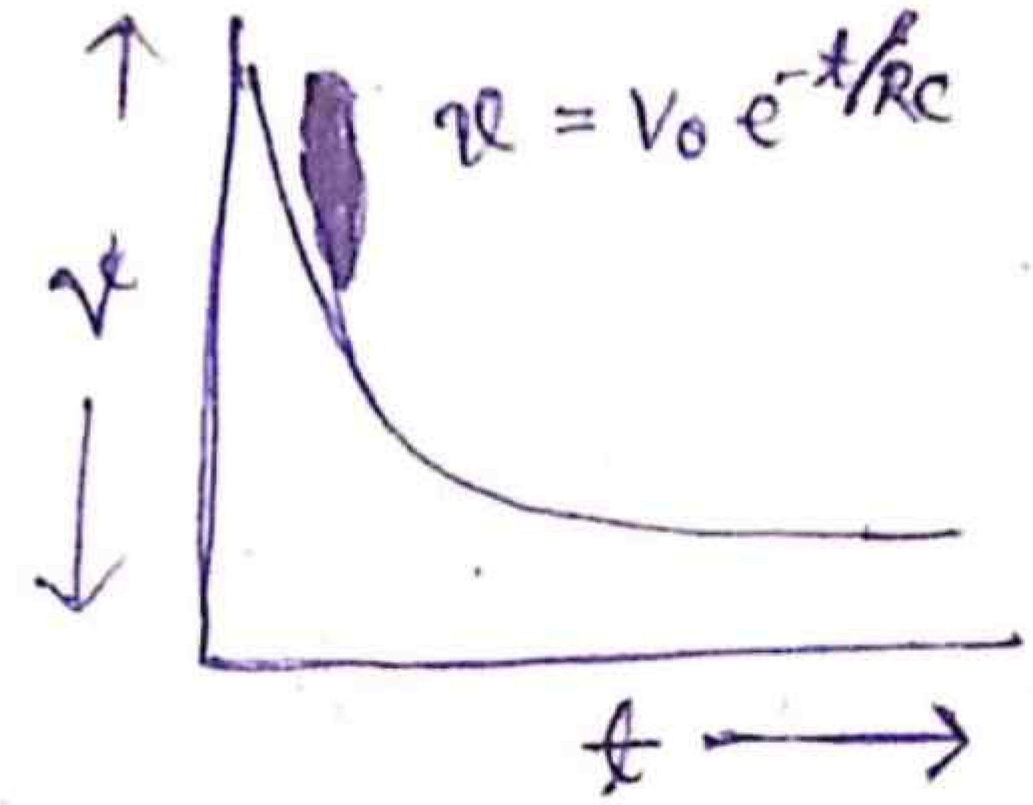
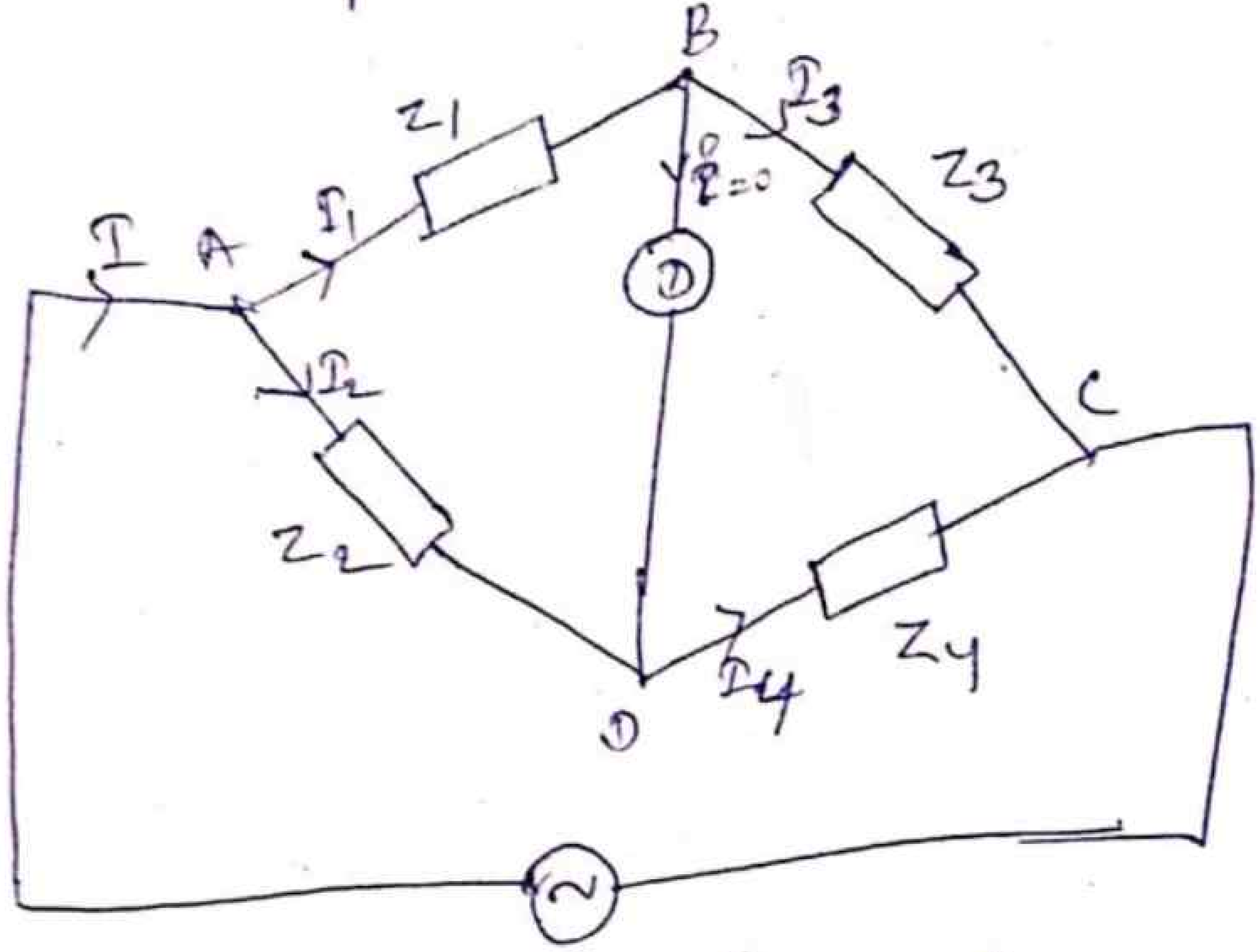
If V_i, V_0, C & t are known. then the value 'R' can be computed.



Date-11/2/2020

Balancing condition for AC Bridge :-



$e = E_m \sin \omega t$

At Balance condition : $i_D = 0$

i.e. $I_1 = I_3$, $I_2 = I_4$

$E_1 = E_2$ $\qquad E_3 = E_4$

$\Rightarrow I_1 Z_1 = I_2 Z_2$ — (i) $\qquad \Rightarrow I_3 Z_3 = I_4 Z_4$

$\Rightarrow I_1 Z_3 = I_2 Z_4$ — (ii)

from eqn (i) and (ii)

$\Rightarrow \frac{I_1}{I_2} = \frac{Z_2}{Z_1}$ $\qquad \Rightarrow \frac{I_1}{I_2} = \frac{Z_4}{Z_3}$

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

$\Rightarrow Z_2 Z_3 = Z_1 Z_4$

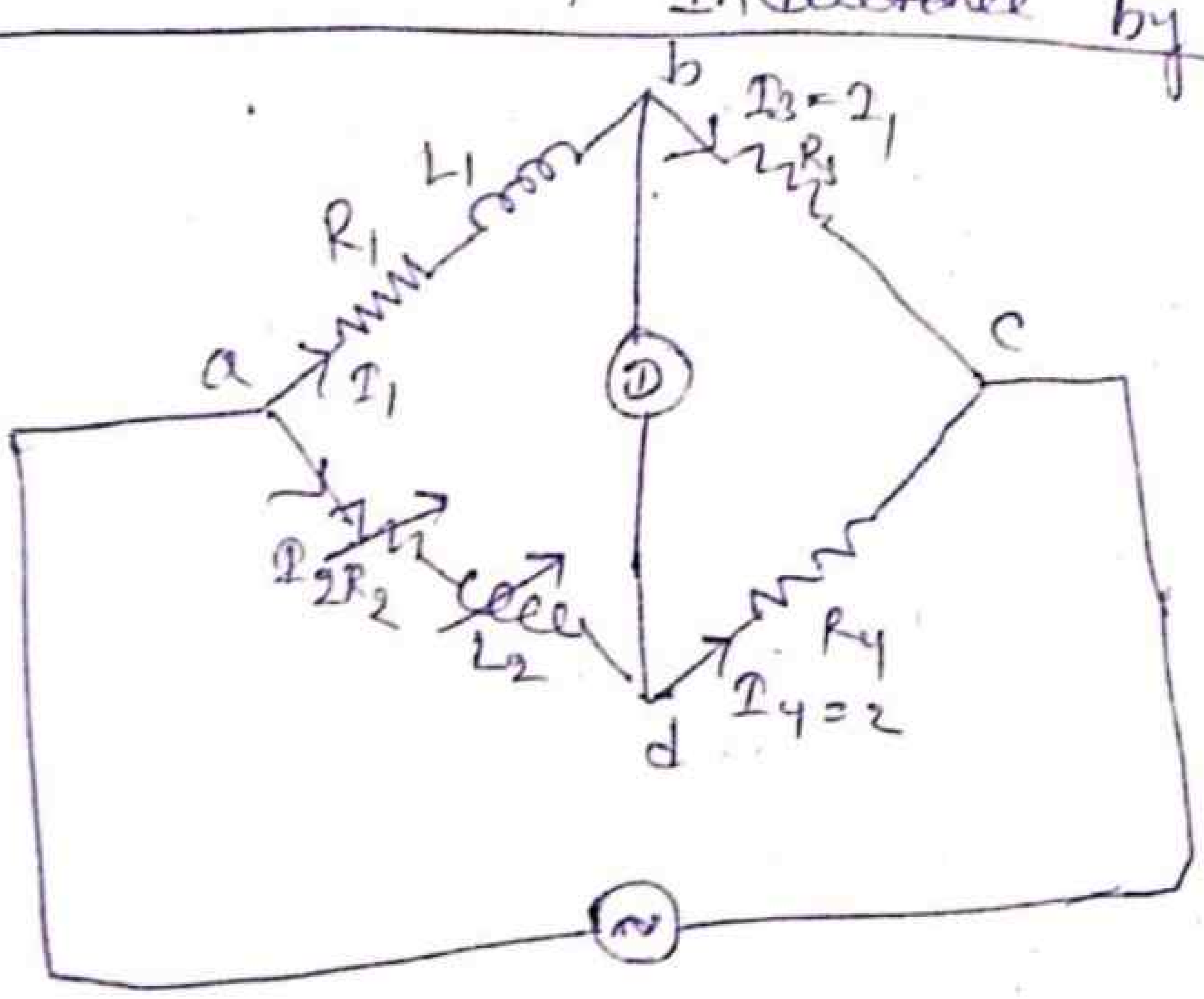
$\Rightarrow Z_1 Z_4 = Z_2 Z_3$

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

$$\Rightarrow \boxed{|Z_1||Z_4| \angle \theta_1 + \theta_4 = |Z_2||Z_3| \angle \theta_2 + \theta_3}$$

$$\Rightarrow \boxed{\begin{array}{l} |Z_1||Z_4| = |Z_2||Z_3| \\ \angle \theta_1 + \angle \theta_4 = \angle \theta_2 + \angle \theta_3 \end{array}}$$

(1) <u>Measurement of Inductance by maxwell bridge</u>



It is the first formulated bridge for measurement of Inductance, In this bridge the unknown value of inductance 'L_1' is callibrated in terms of known value of inductance L_2.

The bridge is as shown in the figure.

where $L_1 \rightarrow$ unknown inductance of resistance R_1

$L_2 \rightarrow$ variable inductance.

$R_2 \rightarrow$ variable resistance connected in series with L_2.

$R_3, R_4 \rightarrow$ known non-inductive resistance.

The bridge is balanced by adjusting the value of L_2 R_2.

at balance condition, current through the detector $(i) = 0$.

$$Z_1 Z_4 = Z_2 Z_3$$

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

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

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

By Equating real part we get,

$$\therefore R_1 R_4 = R_2 R_3$$

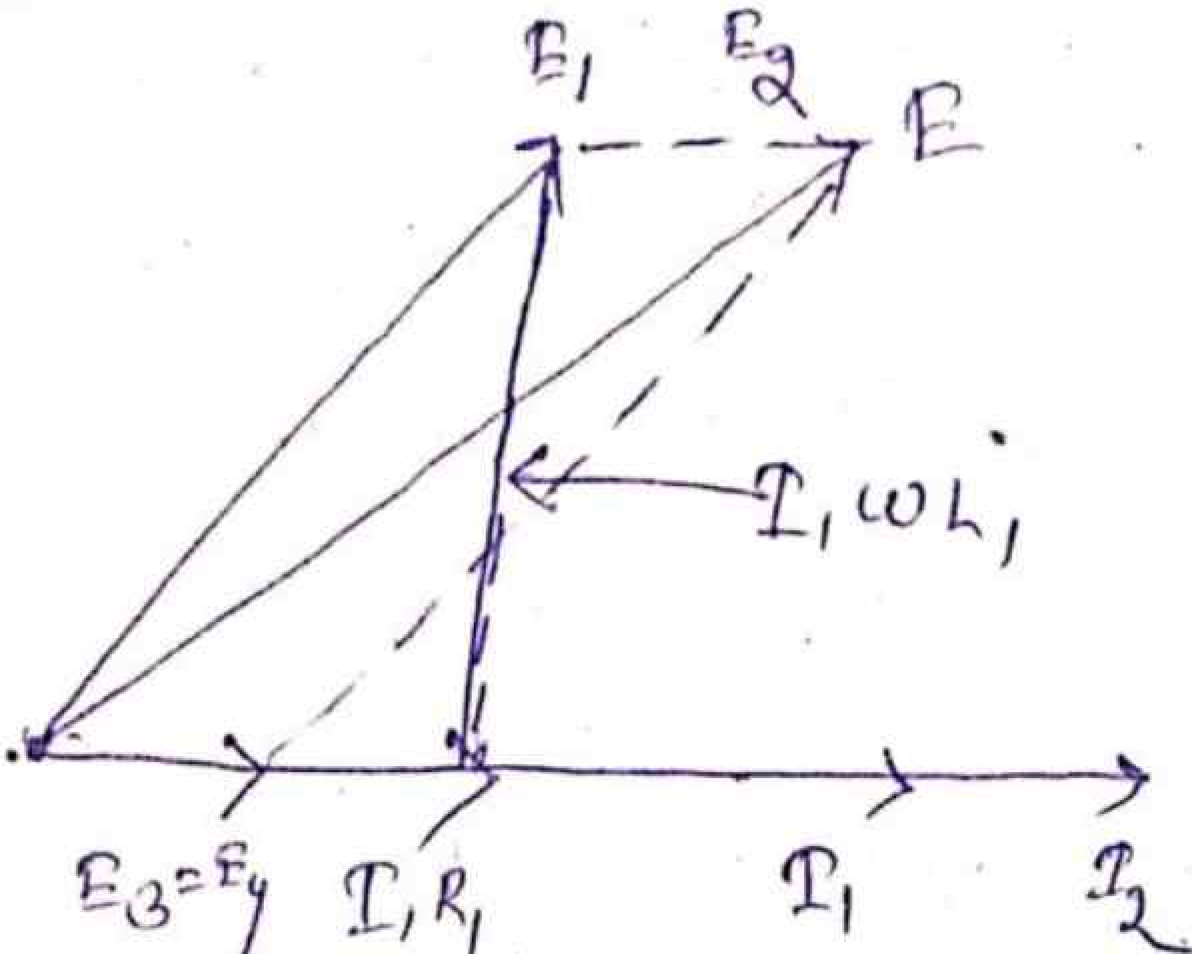
$$\therefore \boxed{R_1 = \frac{R_2 R_3}{R_4}}$$

By equating Imaginary part, we get.

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

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

Phasor diagram :-



Advantages :-

① Expression for R_1, L_1 are simple ② they donot depend on frequency.

③ $R_1 L_1$ are independent of each other..

Disadvantages :-

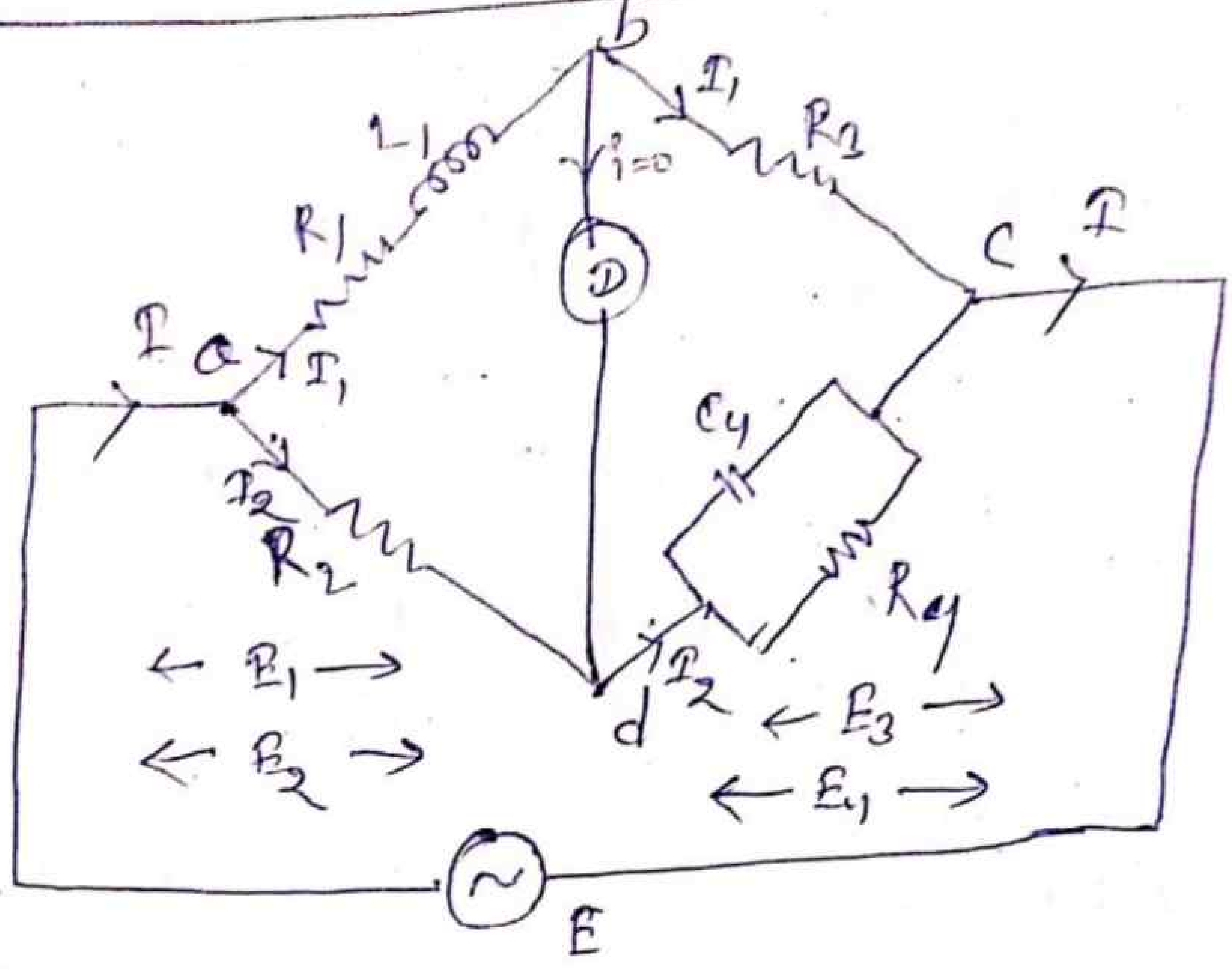
①. variable inductor used is costly bulky.

Date- 13/02/2020

Maxwell's L-C bridge

In this bridge the unknown inductance is measure in terms known variable capacitance.

→ The variable capacitance is used to adjust ~~the~~ and get the condition of null deflection.



$L_1 \rightarrow$ unknown inductance

$R_1 \rightarrow$ effective Resistance of L_1

$R_2, R_3, R_4 \rightarrow$ known non-inductive resistance

$C_4 \rightarrow$ variable standard capacitor.

The bridge is analysed when it is in the balance condition i.e. at balance condition,

$$Z_1 Z_4 = Z_2 Z_3$$

$Z_1 = R_1 + j\omega L_1$, $\quad Z_3 = R_3$

$Z_2 = R_2$ $\quad Z_4 = \dfrac{R_4 \cdot \frac{1}{j\omega C_4}}{R_4 + \frac{1}{j\omega C_4}}$

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

$\therefore Z_1 Z_4 = Z_2 Z_3$

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

$$\Rightarrow R_1 R_4 + j\omega L_1 R_4 = R_2 R_3 (1 + R_4 j\omega C_4)$$

$$\Rightarrow R_1 R_4 + j\omega L_1 R_4 = R_2 R_3 + R_2 R_3 R_4 j\omega C_4$$

By equating Real part.

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

By equating imaginary part.

$$j\omega L_1 R_4 = R_2 R_3 R_4 j\omega C_4$$

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

The quality factor $(Q) = \frac{\omega L_1}{R_1} = \frac{\omega R_2 R_3 C_4}{\frac{R_2 R_3}{R_4}}$

$$\Rightarrow \frac{\omega L_1}{R_1} = \omega R_4 C_4$$

Uses :-

This bridges are use for measurement of inductance over wide range at high power factor ~~and~~ but used for measurement of low quality factor i.e $Q < 10$.

Advantages:-

The value of L_1 and R_1 are independent of frequency.

→ The value of L_1 and R_1 are independent if we choose R_4 and C_4 variable.

Dis advantages

~~It is~~

Measurement of Capacitance

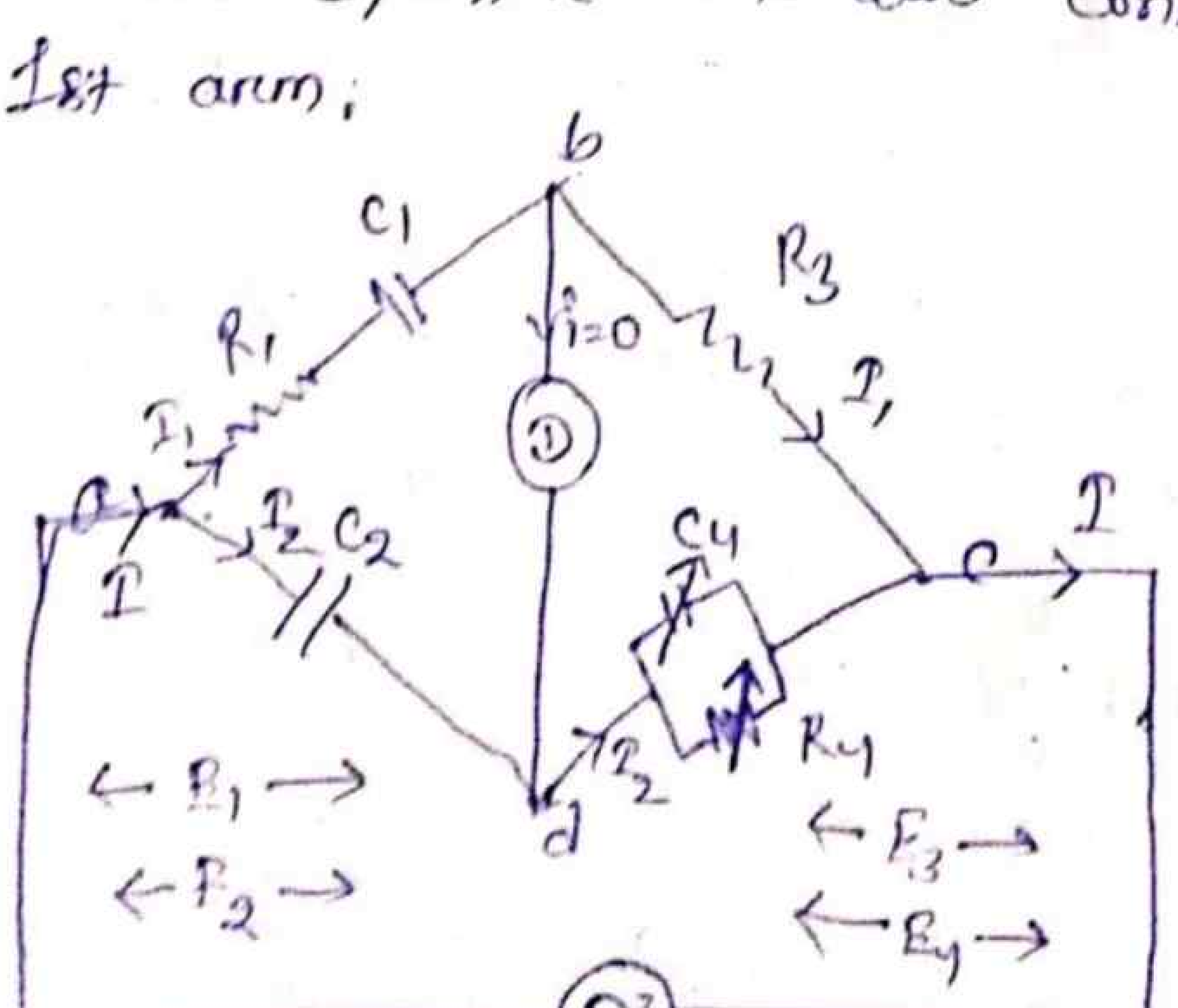
* Scheoring Bridge :-

It is the most general form of bridge for measurement capacitance over wide range.

→ this uses a variable capacitor for balancing.

→ A static capacitor is also connected in 1st arm;

→



$C_1 \rightarrow$ unknown capacitor whose capacitance is to be measuring

$R_1 \rightarrow$ series resistance connected with capacitor 'C_1'.

$C_2 \rightarrow$ A standard capacitor.

$R_3 \rightarrow$ non inductive resistance.

$C_4 \rightarrow$ variable capacitor

$R_4 \rightarrow$ variable non inductive resistance connected in parallel with C_4.

At balance condition,

$$Z_1 Z_4 = Z_2 Z_3$$

$$Z_1 = R_1 + \frac{1}{j\omega C_1} \quad Z_2 = \frac{1}{j\omega C_2} \quad Z_3 = R_3$$

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

$$\therefore Z_1 Z_4 = Z_2 Z_3$$

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

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

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

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

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

By equating ~~Real~~ Imaginary part,

$\Rightarrow R_4 j\omega C_1 R_1 = \frac{R_3 C_1 R_4 j\omega C_4}{R C_2}$

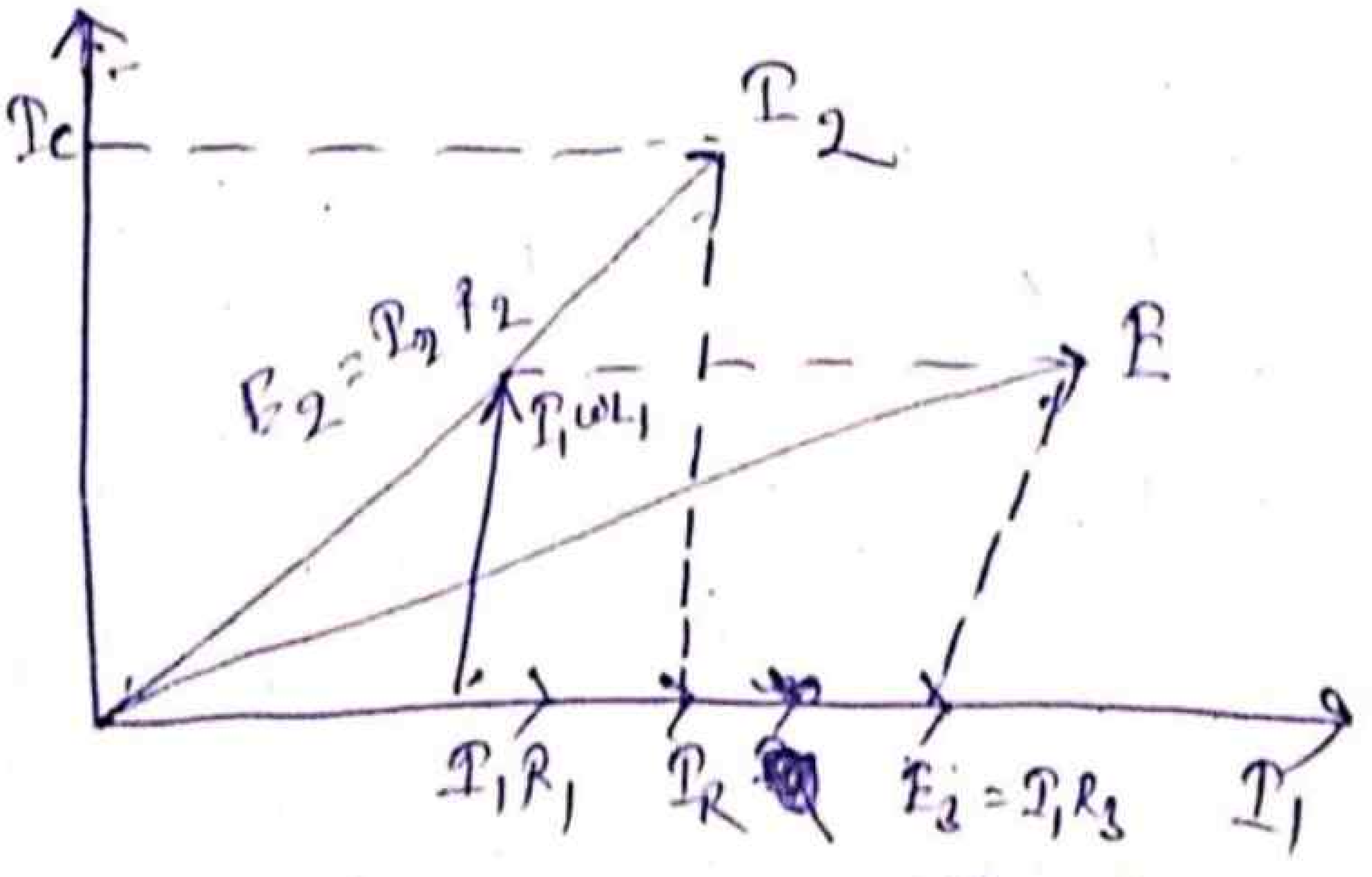
$$\Rightarrow \boxed{R_1 = \frac{R_3 C_4}{C_2}}$$

By equating ~~Imaginary part~~ real part,

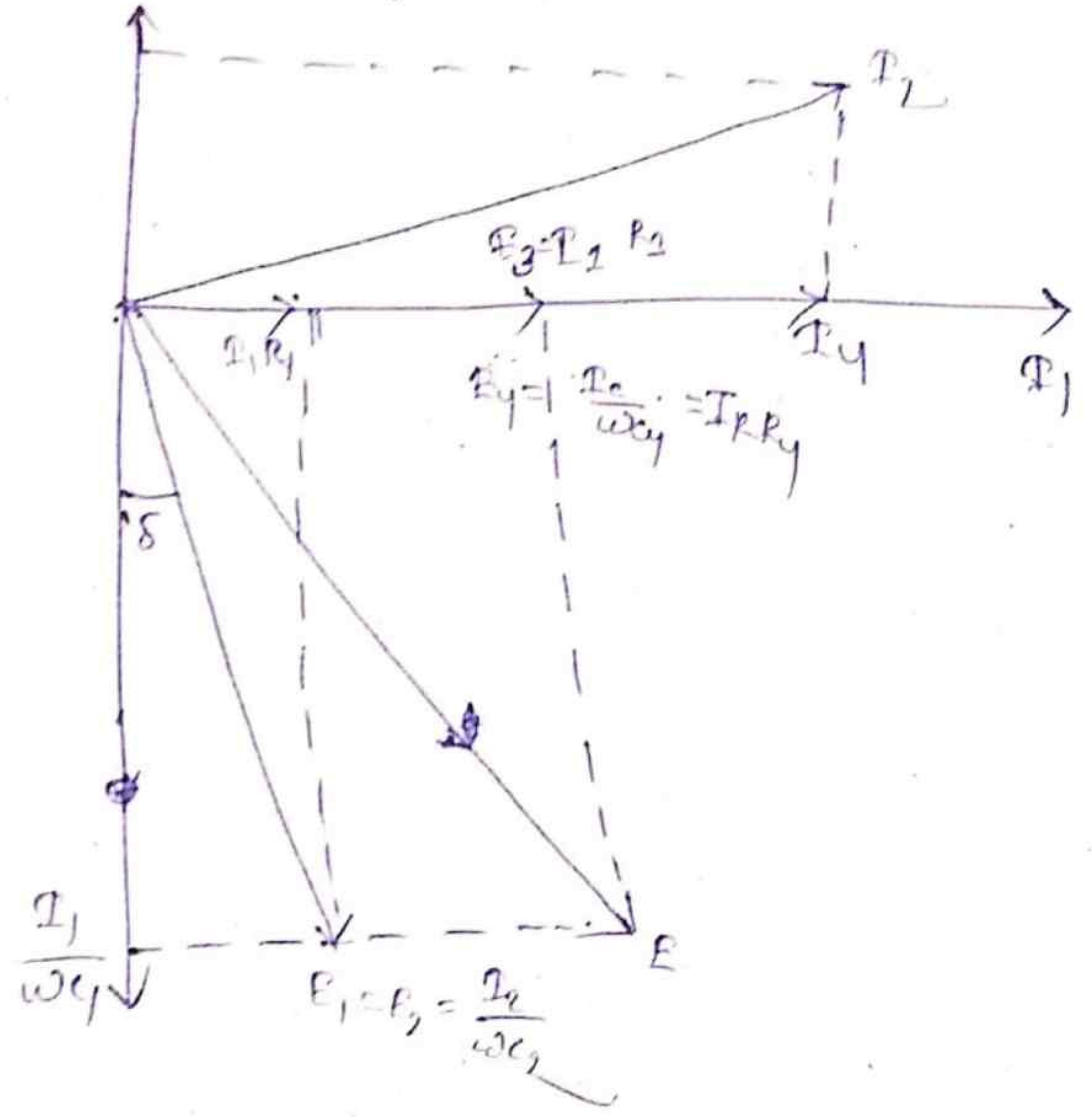
$R_4 = R_3 \frac{C_1}{C_2}$

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

Phasor diagram of Maxwell's L-C bridge



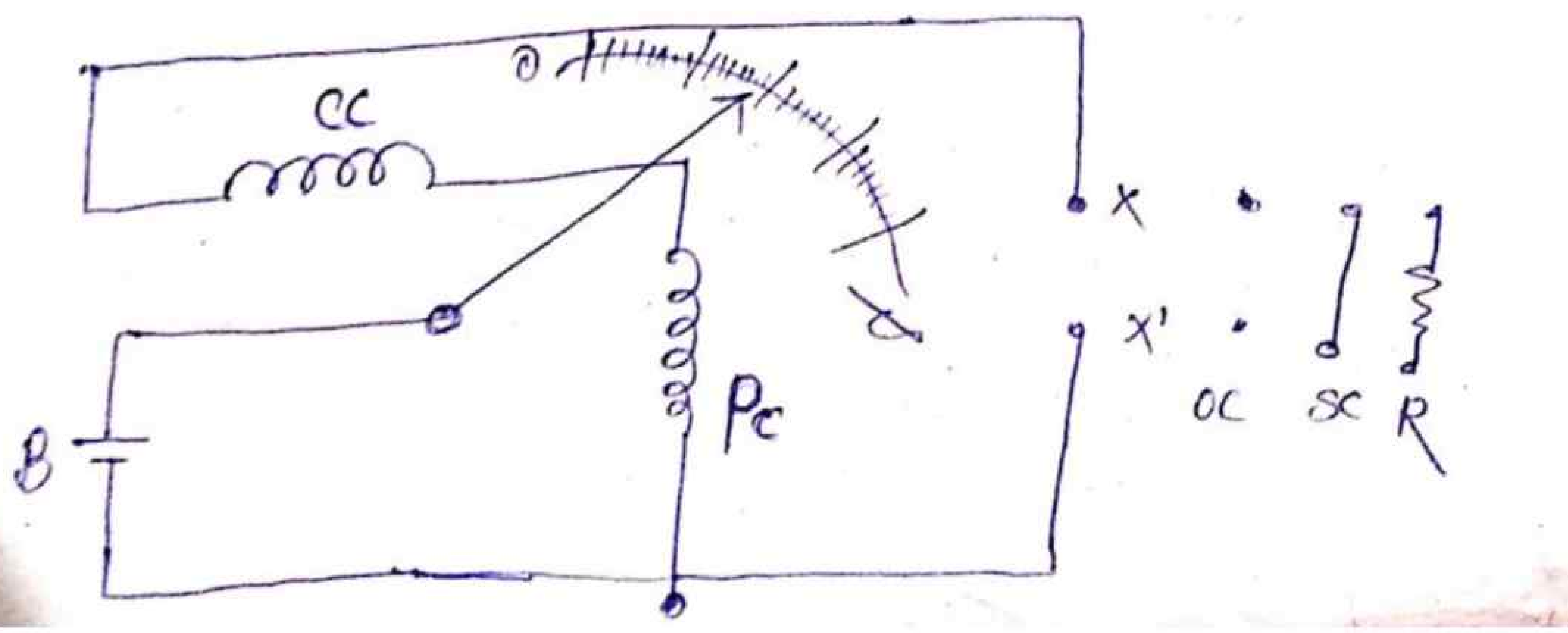
phasor diagram of Shering bridge



Date- 15/02/2020

Ohm-meter

It is used for the measurement of medium resistance even though the instrument scale is calibrated for infinite. Its accuracy can be maintained upto 100 kΩ.



Scanned with CamScanner

Operation

The operation of this instrument, can be explain in three steps.

The value of resistance whose value is to be measured is connected across the terminal $x - x'$.

1. when no resistance is connected in bet^n $x - x'$ it is considered as open circuit.
In this case pointer gives maximum deflection i.e. ∞.

2. when $x - x'$ is short circuited, in this case the meter indication should be zero because in short circuit $R = 0$.
In this case the current flowing through current coil is maximum, so it will exhaust maximum magnetic pole.

3. Any intermediate value of resistance is connected bet^n $x - x'$. In this case both the coils will share the current proportionally and exhaust proportional magnetic pole on the pointer. There by pointer stands at a particular position on the scale corresponding to value of R.

Scanned with CamScanner

Megger :-

Megger is portable measurement which is used to measure high resistance i.e. Insulation resistance of electrical machinery or system.
It can be battery operated or mechanically operated, and keeps a direct reading in ohms.

Megger comes in the range of 50, 500, 1000, 2500, 5000 volt etc.

① Electronic type (Battery operated)

In this case battery is used to provide d.c. voltage. It is also known as electrical megger. The important part of this megger are

(i) Digital display
(ii) Testing wire
(iii) Selection switches
(iv) indicator

Digital display :-
used to show the insulation resistance value in digital.

Testing wire :- Two wire leads for connecting megger with an external electrical system for testing.

Selection switches :-
It is used to select different parameter range provided in the megger.

Indicator :- Different indicators are incorporated into the instrument to give a visual and audible indication when the instrument is on, for a warning parameter states

Date-17/2/20

Advantages

(i) High accuracy.

(ii) Easy to operate.

(iii) Digital display makes it easy to read the insulation resistance value.

(iv) Robust and safe to use.

(v) Less maintanance as compare to other type.

(vi) Handdy and compact to carry.

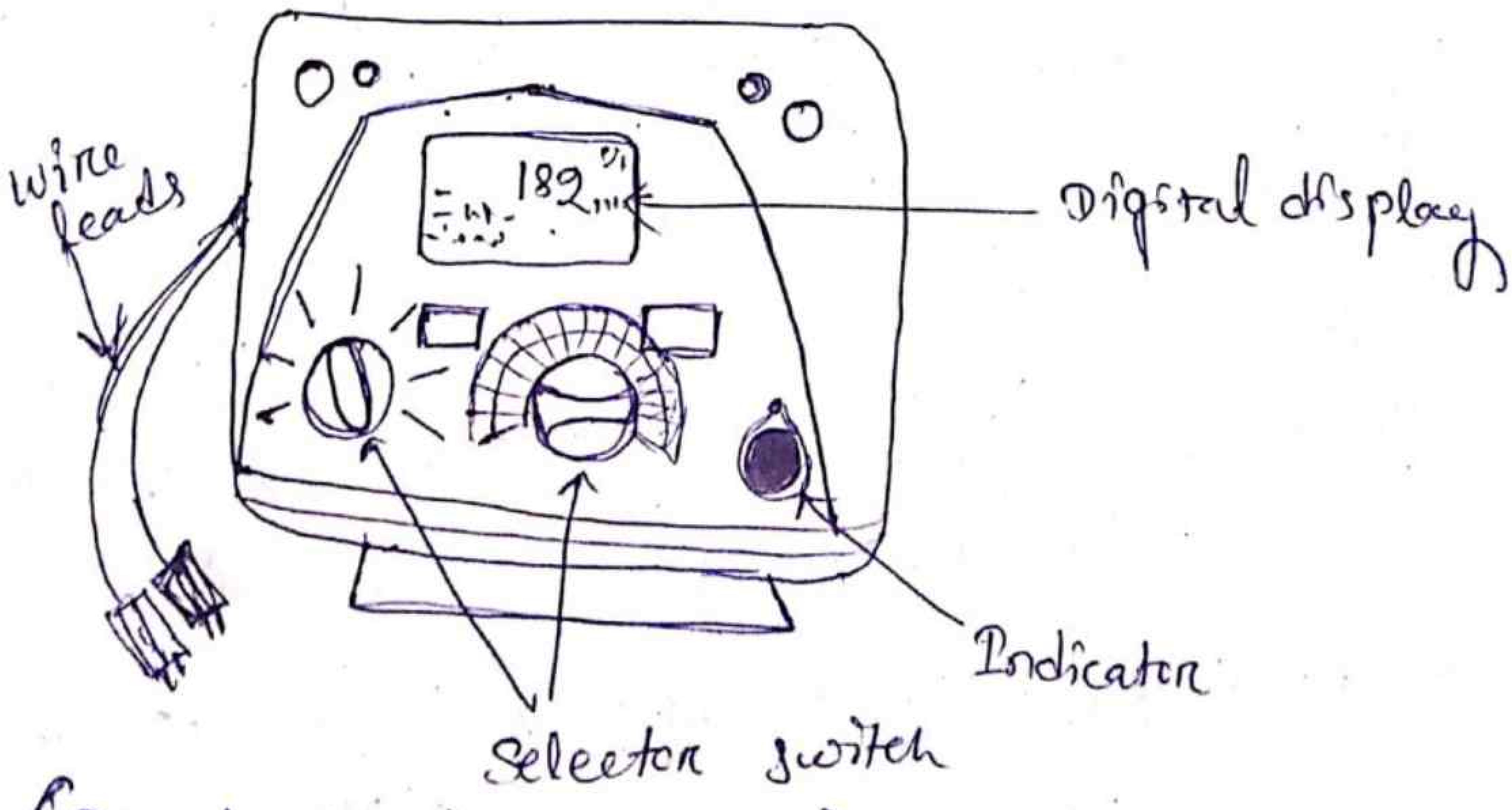
(vii) Less time consuming operation.

Disadvantages :-

(i) It requires an external source of energy i.e. dry shape or battery.

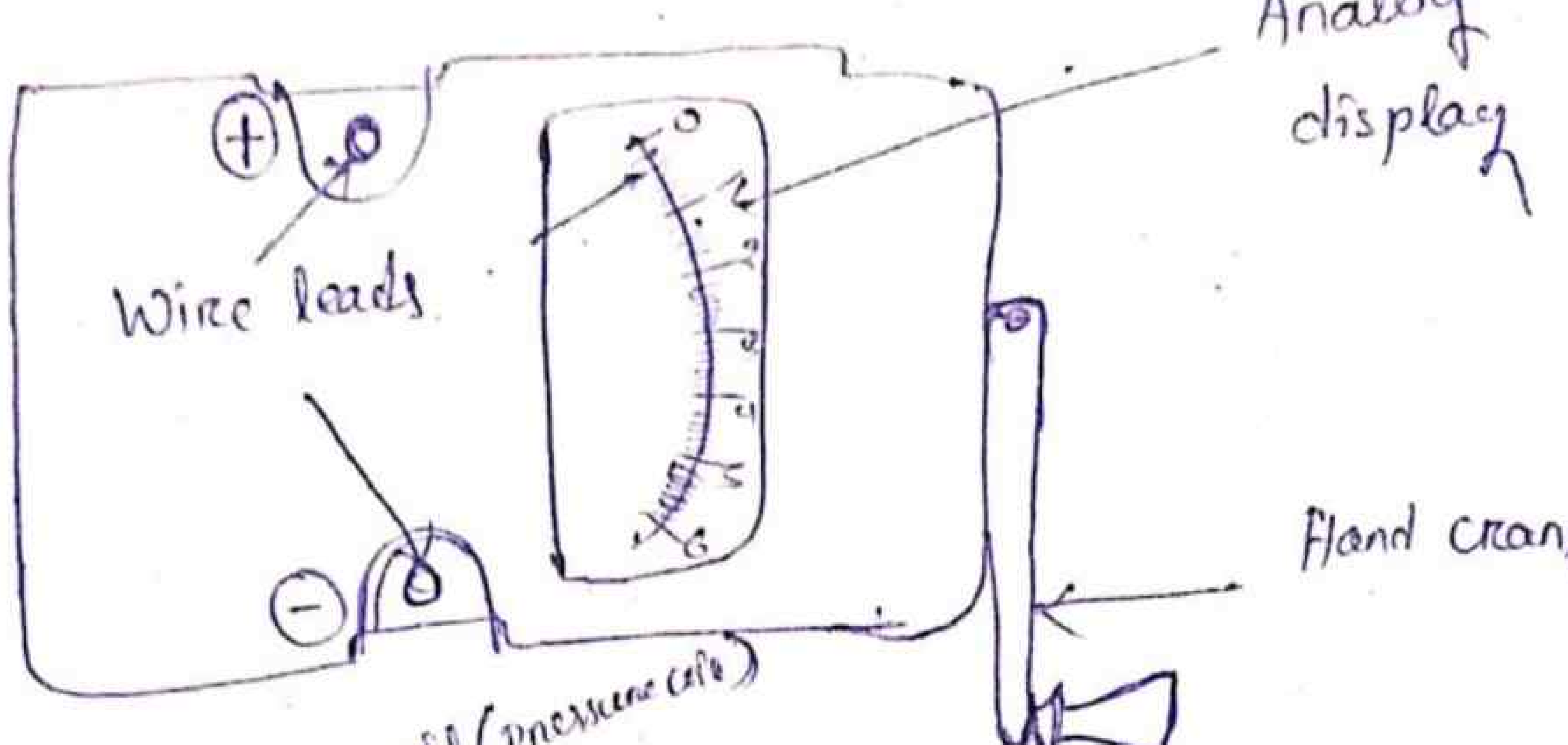
(ii) high initial cost.

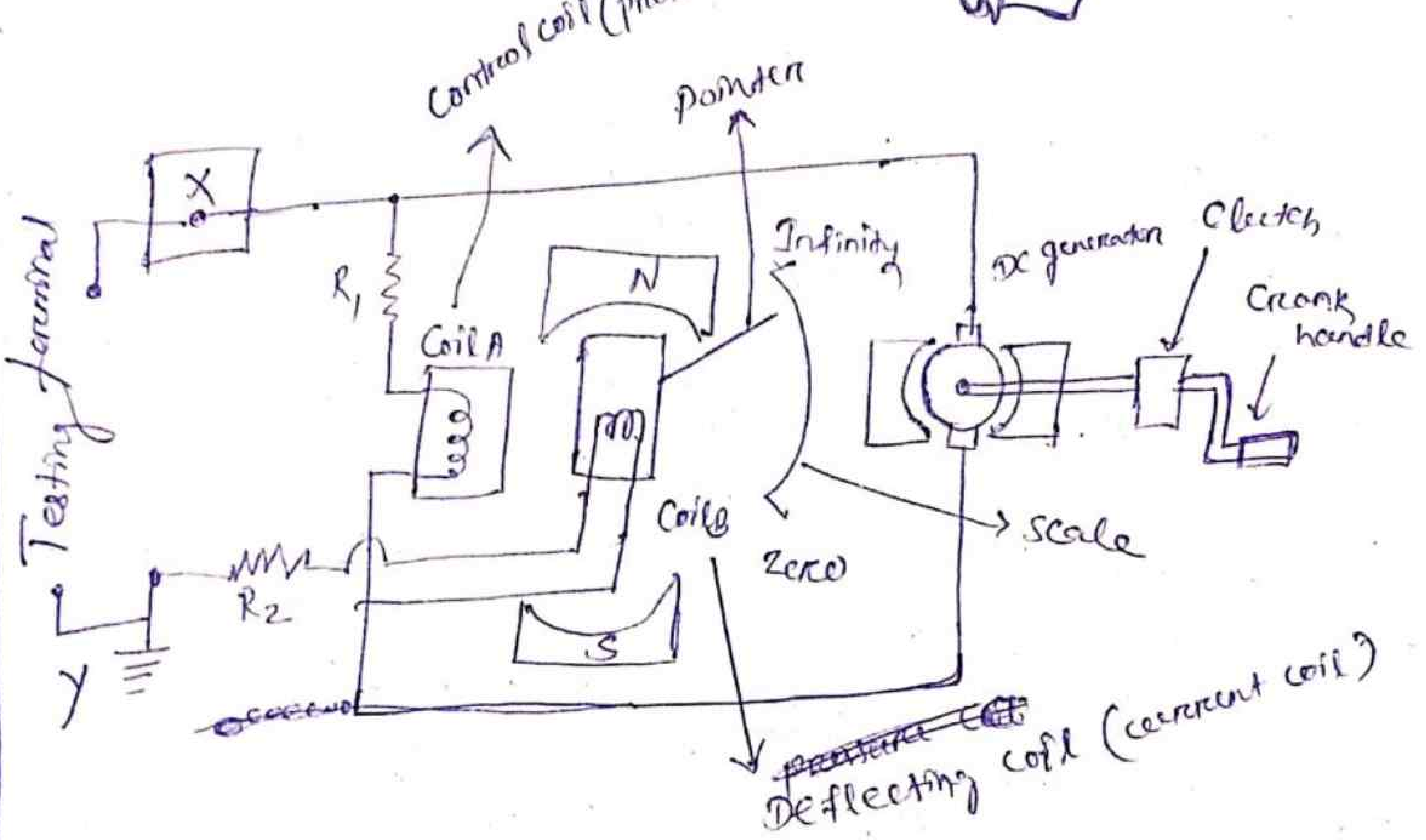
Hand held megger :-



(Electronic type megger)

Hand held megger :-





Construction :-

(i) Analog display :- Used for ~~provide~~ displaying insulation resistance value by pointer,

(ii) Hand crank :- A hand crank is provided which can be rotated to generate the required voltage.

(iii) Wire leads :- These are provided to connect the megger with electrical system or testing material

(iv) control and deflecting coil :- These are normally mounted at right angle to each other and connected || to the d.c. generator.

(v) Permanent magnet :- Used to produce magnetic field.
ii) Ohm meter and dc generator.

(vi) Pointer & Scale :- A pointer is attach to the coil and end of the pointer float on a scale which is in the range from zero to infinitive.

(vii) DC Generator :- In this megger the testing voltage is supplied by DC generator.

(viii) PCR & CCR :- These are the resistance are connected in series with pressure coil and current coil respectively. These are used to limit the current flowing through them.

→ These are also used for preventing the damage.

Earth tester

Date. 19/2/20

Working principle :-

It works on the principle of motor i.e. whenever a current carrying conductor is placed inside a magnetic field then the emf is induced in the conductor. The reading of the megger is resistance which is directly proportional to the voltage and inversely proportional to the current.

Operation :-

When the electrical circuit is being tested (x, y) is is opened the current is only flowing through the control coil hence the torque is only due to control coil. this torque is directly proportional to the voltage.

hence this is maximum, and the pointer shows infinitive. that means no shorting through out the ckt and has minimum resistance within the ckt under test.

(ii) If there is short circuit betn X-Y then all the current will be passing through the deflecting coil. In this case the torque due to current coil is maximum and torque due to control coil is zero, hence the reading of the instrument is zero, that means no resistance is in the path.

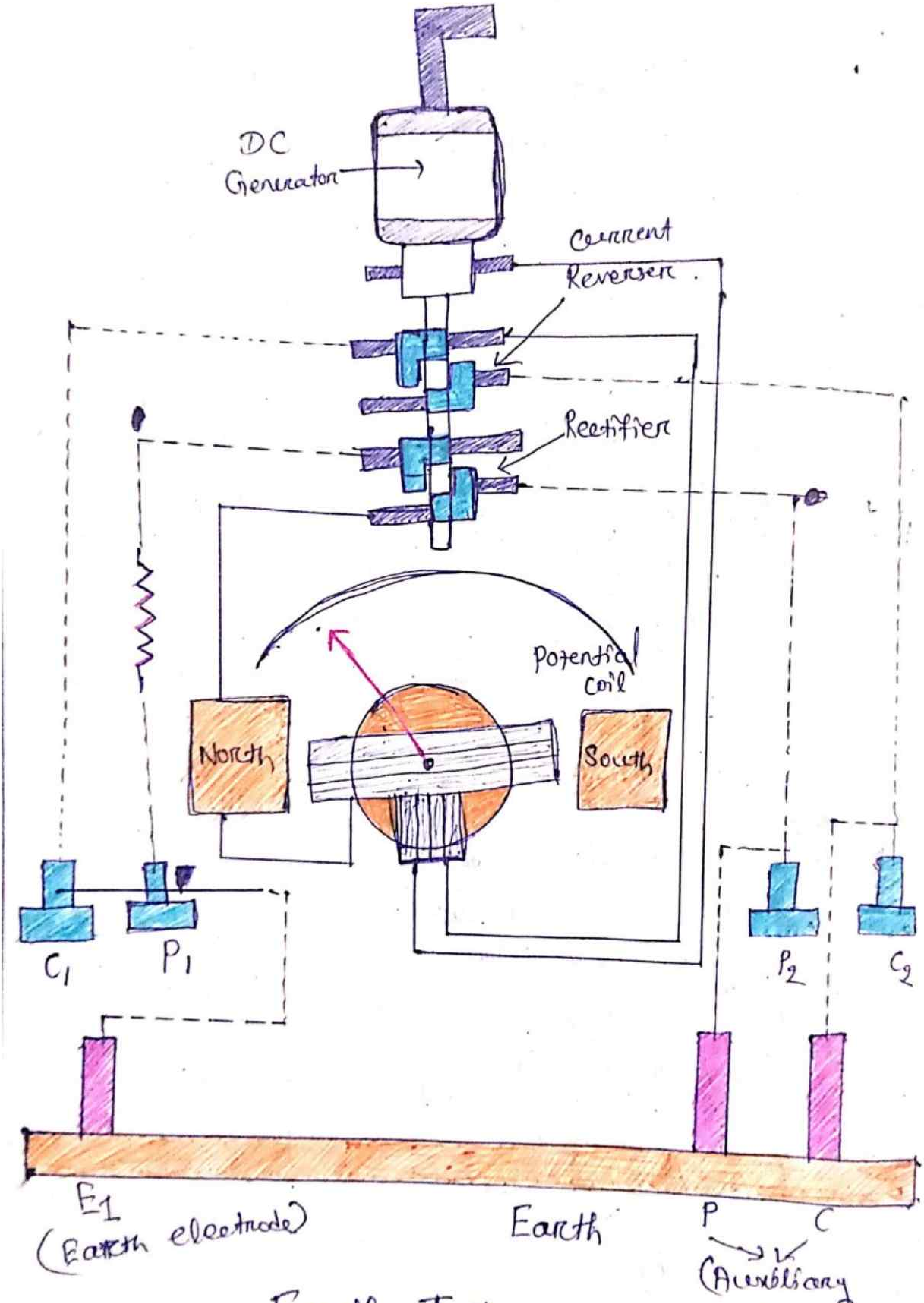
(iii) If there is an intermidiate betn X-Y then current flows through both the coil and the torque is due to both coil. The resultant torque of them is acted on the pointer and due to this pointer remains betn zero to infinity.

Date- 20/2/20

The instrument used for measurement of earth resistance is known as earth tester. It is a special type of megger which sence Ac through earth and DC through measuring in addition to that it has a rectifier and a rotating current reversal, these are mounted on the shaft of DC generator.

It has two pair of pressure coil and current coil i.e. P_1, C_1 and P_2, C_2.

P_1, C_1 are shorted to form a common point which is connected to earth electrode under test i.e. E.



Earth Tester

→ The current to the earth is sent by this electrode. The other two terminal C_2 & P_2 are connected to auxiliary electrode C and P. The value of earth resistance is indicated by the instrument directly when it's handled is rotated ~~uniform speed~~ in uniform speed.

→ The earth resistance = $\frac{\text{Voltage drop bet}^n \text{ E \& P}}{\text{Current through earth path}}$

→ here a potential coil is directly connected to DC generator and the pointer is also attached to the potential coil.

Requirement of earth tester :-

All the equipment of power system is connected to the earth through the earth electrode. The earth protects the equipment and personnel from the fault current. The fault current through the earth electrode passes to the earth, thus protects the system from damage.

→ The earth tester is use to test or find the low resistance ground to provide earth electrode.

→ The earth resistance should be less than 1Ω for power station, and should be less than 5Ω for sub-station.

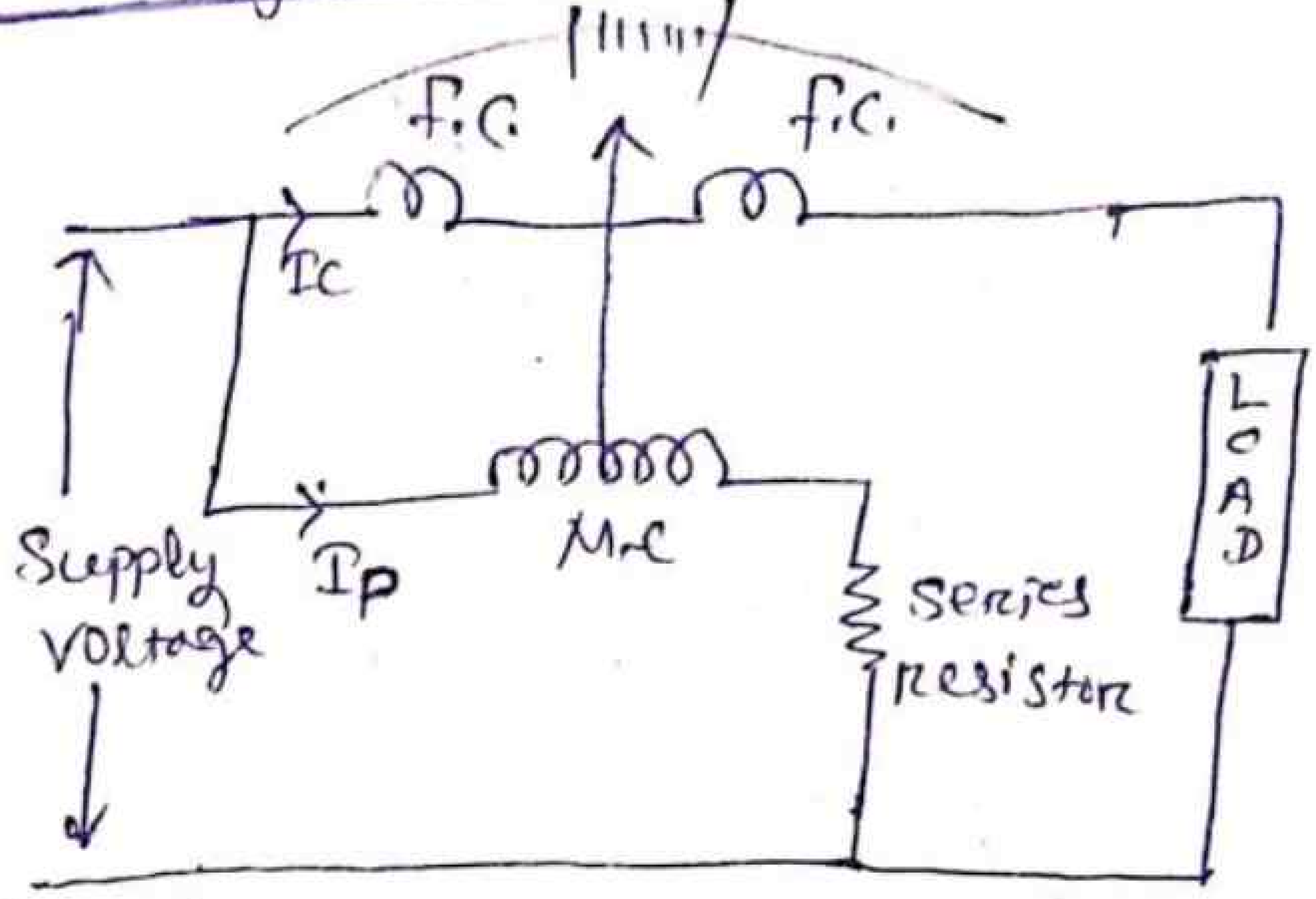
Wattmeter & Measurement of power | Date - 24/2/20

~~Construc~~ Wattmeter - Measuring instrument used for measurement of power

Electrodynamometer type Wattmeter :-

Introduction :-

The instrument whose working depends on the reaction betn the magnetic field of moving coil and fixed coil is known as electrodynamometer type wattmeter.



→ here the operating field is produced by fixed coil.

→ It is used for measurement of power in both AC and DC ckt.

Construction :-

① fixed coil (F.C or CC)

→ Fixed coil is splited into two equal parts & these are placed ||el to each other.

→ fixed coil is used to produced operating magnetic field in the instrument.

→ fixed coil is connected in series with the load that's why considered as current coil.

→ It carries the current propotional to the load current.

$(I_C \propto I_L)$

→ fixed coil is designed to carry current of approximately to carry 20 Amp.

→ Fixed coils are air core to avoid hysteresis loss.

(2) Moving coil :- (MC (or) PC)

→ The moving coil is considered as pressure coil of the instrument. It connects ||el with the supply voltage.

→ The current flows through it is directly proportional to the supply voltage.

→ The moving coil is placed betn two fixed coil and the pointer is mounts on the moving coil.

→ A high value of resistance is connected in series ~~connected~~ with the moving coil to limit it's current.

(3) Control system :-
Here the control torque is provided by spring control mechanism.

(4) Damping system :- Here air friction damping is used.

(5) Scale & pointer :- A pointer is attached on the moving coil which graduates over the callibrated scale.

Working principle :-

When a current carrying moving coil is placed in the magnetic field produced by current carrying fixed coil then a force is exerted on the coil sides of the moving coil and deflection takes place.

When the power is to be measured in the ckt the wattmeter is connected in the ckt. then current flows through both the coil.

→ The current coil carries the current 'I_c' proportional to the load current and the pressure coil carries the current 'I_p' which is propotional to the supply voltage.

→ Then the fixed coil produces field 'F_m' and moving coil produces field 'F_r'. Now ~~the~~ both the field interact with each other and the field 'F_r' tries to come in line with main magnetic field 'F_m', which produces ~~a~~ deflecting torque in moving coil.

→ Thus the pointer attached to the spindle gets deflected.

The deflecting torque is estimated as,

$$\therefore T_d = I_p I_c \frac{dm}{d\theta} \text{ (for dc)}$$

$$\therefore T_d = I_p I_c \cos\phi \frac{dm}{d\theta} \text{ (for AC)}$$

Control torque :- As spring control is used the control torque is given by.

$$T_c = K\theta$$

The pointer will remains stop at equilibrium position that is when $T_c = T_d$.

$$\Rightarrow I_p I_c \frac{dm}{d\theta} = K\theta \quad (\text{for dc})$$

$$\Rightarrow \boxed{\theta = \frac{1}{K} I_p I_c \frac{dm}{d\theta}}$$

$$\Rightarrow I_p I_c \cos\phi \frac{dm}{d\theta} = K\theta \quad (\text{for AC})$$

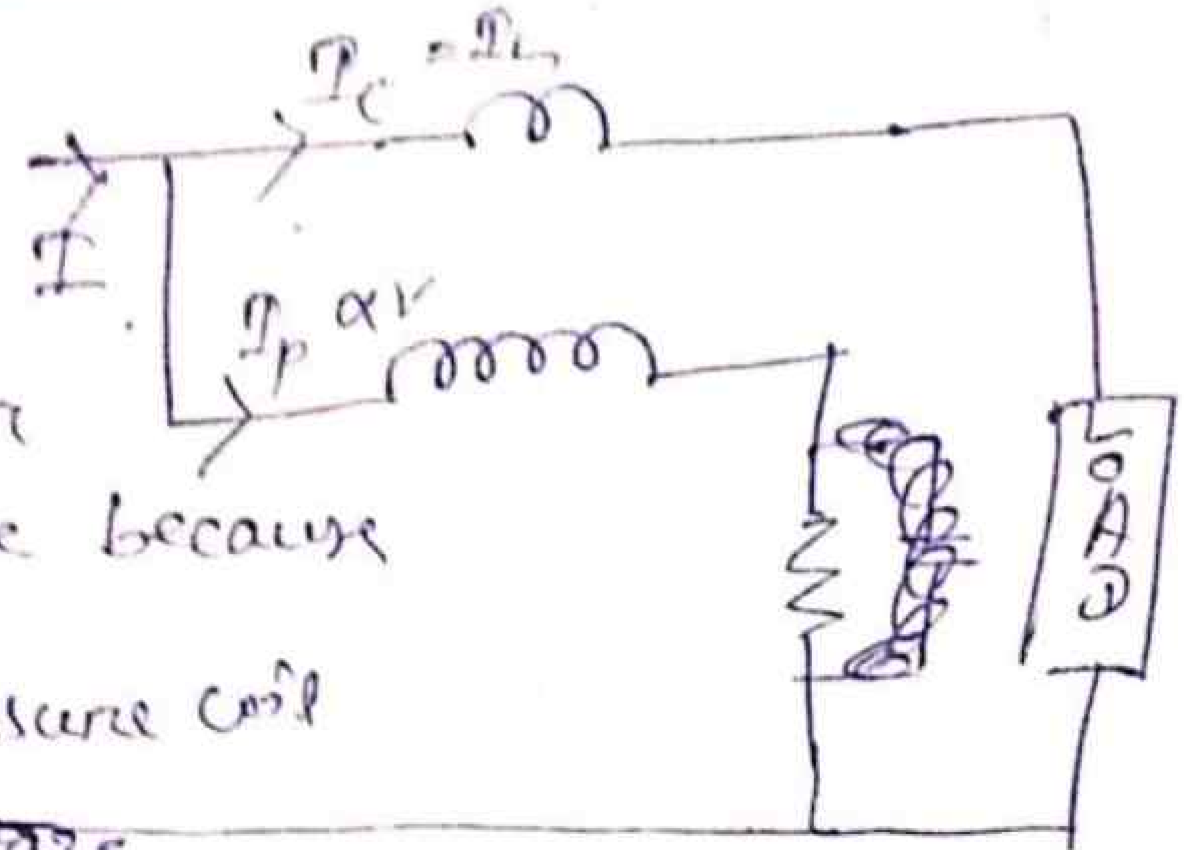
$$\boxed{\theta = \frac{1}{K} I_p I_c \cos\phi \frac{dm}{d\theta}}$$

Errors in dynamometer type wattmeter :-

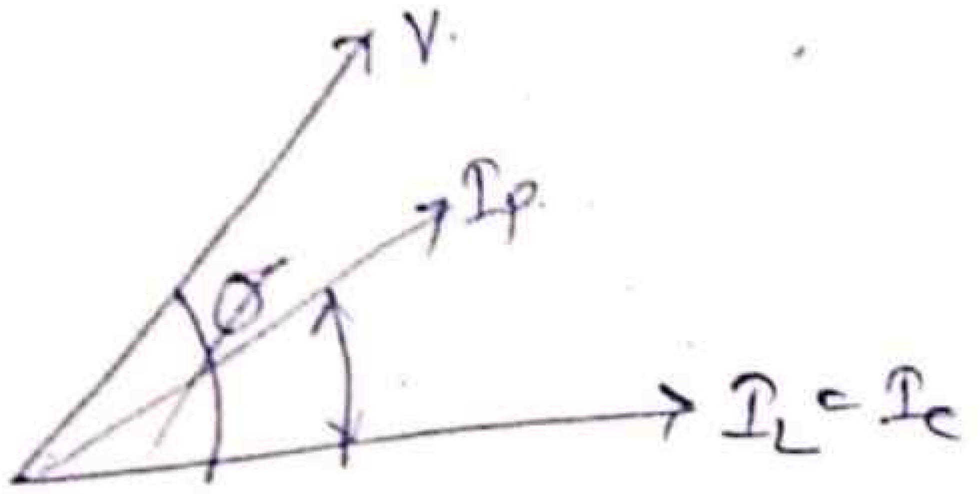
(i) Error due to PC inductance.
(ii) Error " PC capacitance
(iii) " due to connection
(iv) " " mutual inductance effect.
(v) Eddy current error
(vi) Error due to stray magnetic field.
(vii) Temperature error

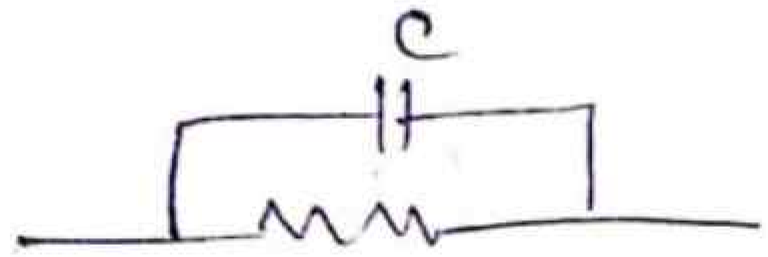
(i) Error due to PC inductance :-

The pressure coil of electro dynamo meter type wattmeter has some inductance because of this inductance the current of pressure coil lags behind the voltage.



Thus the power factor of the wattmeter becomes lagging & the meter reads high value in lagging P.F. & low in leading P.F. this arises error in the instrument





$T_d = I_p I_c \cos\phi$

To compensate this a capacitor is connected . In parallel with a portion of series resistance.

(ii) Error due to pc capacitance :-

→ The pc has capacitance along with inductance. This capacitance is mainly due to inter term capacitance of series resistance. The capacitance increases the p.f of instrument hence causes error.

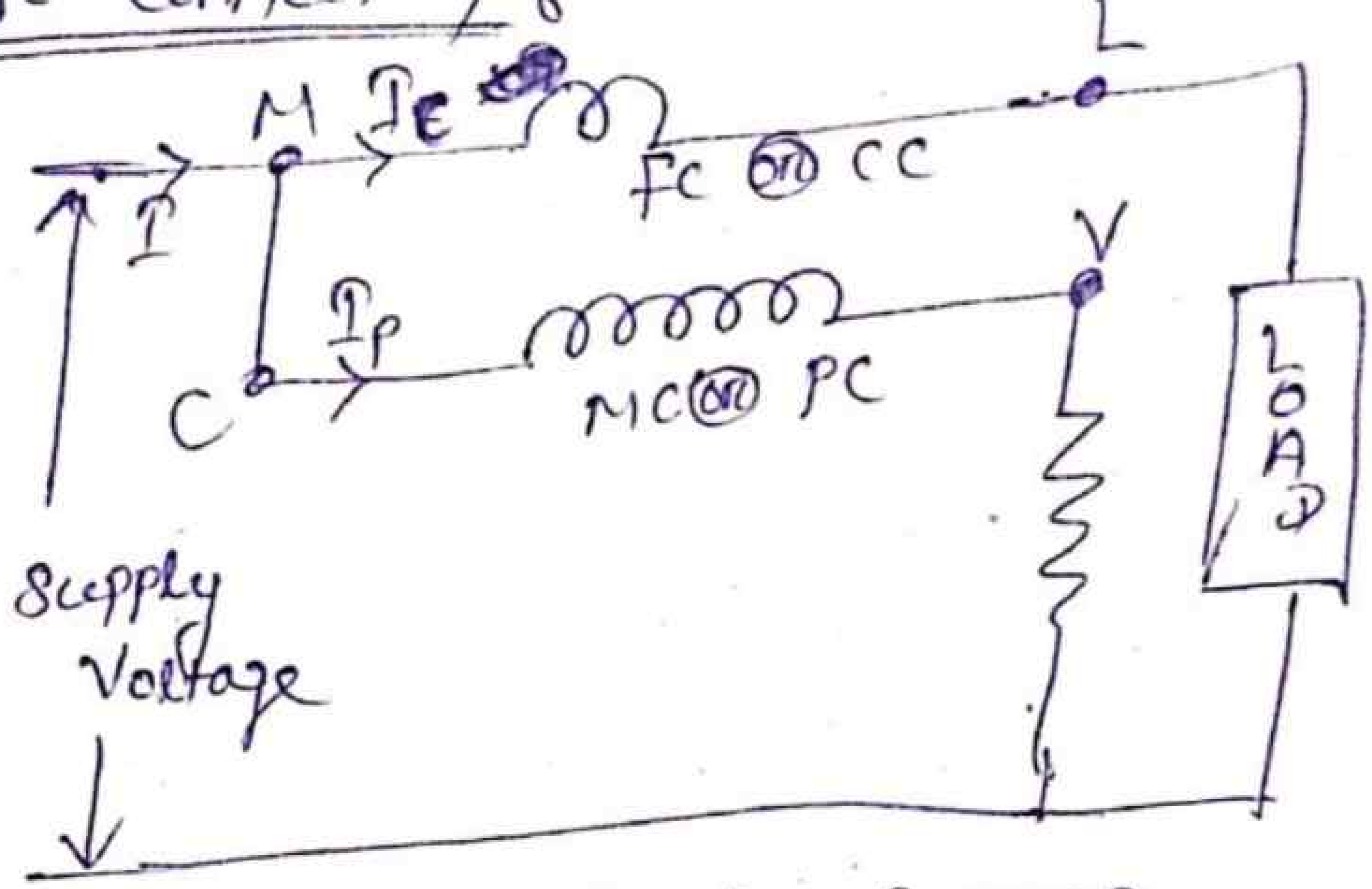
(or) it has ~~alternate~~ opposite effect of inductance.

To avoid this error capacitance value is adjusted to suitable value.

(III) Error due to connection :-

There are two alternating methods of connecting wattmeter

MC connection :-



M → main C → Common
L → Line V → voltage of selectivity.

here in this connection PC is connected on supply side hence 'V' applied to the PC is voltage across the load + voltage drop across the fixed coil.

$V_{pc} = V_L + V_{FC}$

$WMR = I_L \cdot V_L + I_L \cdot V_{FC}$

The power indicated by the instrument = power consumed by the load + power loss in FC.

$$WMR = I_L V_L + I_L \cdot V_{FC}$$

$$I_L \cdot I_L R_{FC}$$

$$= I_L^2 R_{FC}$$

$$\doteq I_c^2 R_{FC}$$

From this eqn we can say that wattmeter absorbs more power than power absorbs by the load. The excessive power is treated as error, i.e.

$error = I_L \cdot V_{FC} = I_L^2 R_{FC} = I_c^2 R_{FC}$

here the error is due to moving coil absorbs in excess voltage than load voltage. The excess voltage is required by F.C.

(4) Error due to mutual inductance :-

Error cause due to mutual inductance betn PC & CC. This error is quite low at power frequency but increases as frequency increases.

To comensate this PC and CC are so arranged that they have zero position of mutual inductance

(5) Error due to Eddy current :-

The eddy currents are induced in the metallic parts of the instruments this creates its own magnetic field. this affects the main ~~current~~ magnetic field which causes error in instrument.

To compensate this metallic part may be reduced (or) shielded or strandard conductor should be used in ~~CC~~ CC.

(6) Error due to Stray magnetic field :-

we already know that dynamometer type wattmeter has weak operating field therefore it is ~~aff~~ easily affected by stray magnetic field. which affects main magnetic field.

TO compensate this instrument should be shielded.

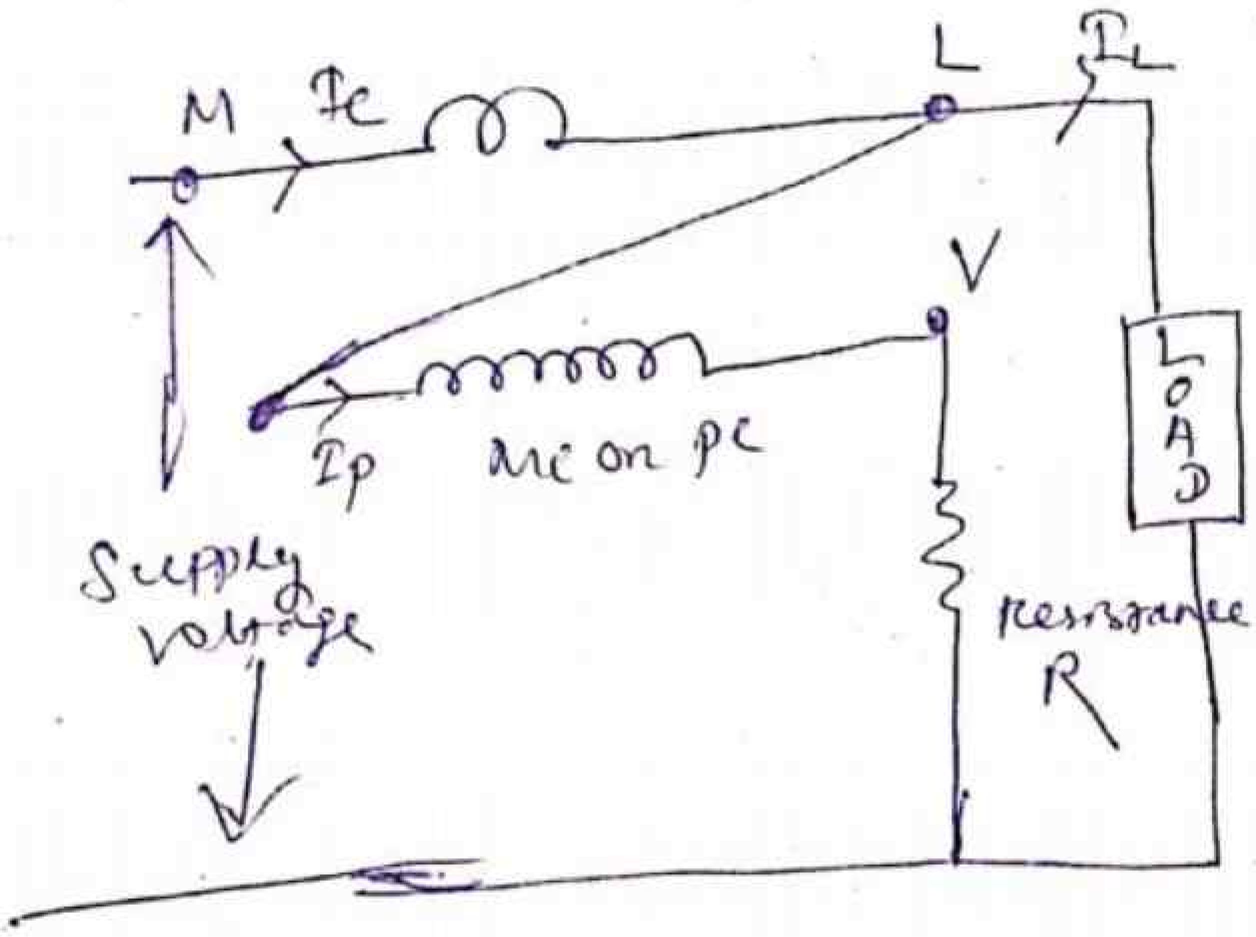
(7) Temperature error :-

The variation of temp will change the resistance of PC coil and stiffiness of Spring.

To compensate this pc should be made up of alloy of Cu and Mn.

Date - 27/02/20

L-C Connection :-



In this connection the current coil is on supply side therefore it carries pc current + Load current, hence the wattmeter reads the power consume in the load + loss in pressure coil,

$$WMR = I_c \cdot V_{pc}$$

$$= (I_L + I_p) \cdot V_{pc}$$

$$= V_{pc} \cdot I_L + V_{pc} \cdot I_p$$

$$= V_L \cdot I_L + V_{pc} \cdot I_p$$

here, the current coil carries excess current than the current absorbs by the load. this current is for pressure coil. hence the error arrises. here the error is $V_{pc} \cdot I_p$.

LPF type wattmeter (Low power factor)

This wattmeter is used for measurement of power with low power factor because in ordinary dinamometer type wattmeter can't measure power with LPF. due to some reason.

(i) The deflecting in moving system is small.
(ii) In low power factor even when CC and PC are fully excited.

(ii) Error is introduced because of inductance of PC will be large at LPF.

There are some special features incorporated in ordinary dianometer type wattmeter to make it LPF wattmeter.

(i) PC current :- The PC ckt is design to have low value of resistance so that current flowing through it increases by which Td increase.

(ii) Compensation for PC current :- The power being measured in LPF ckt is small and current is high on account of LPF.

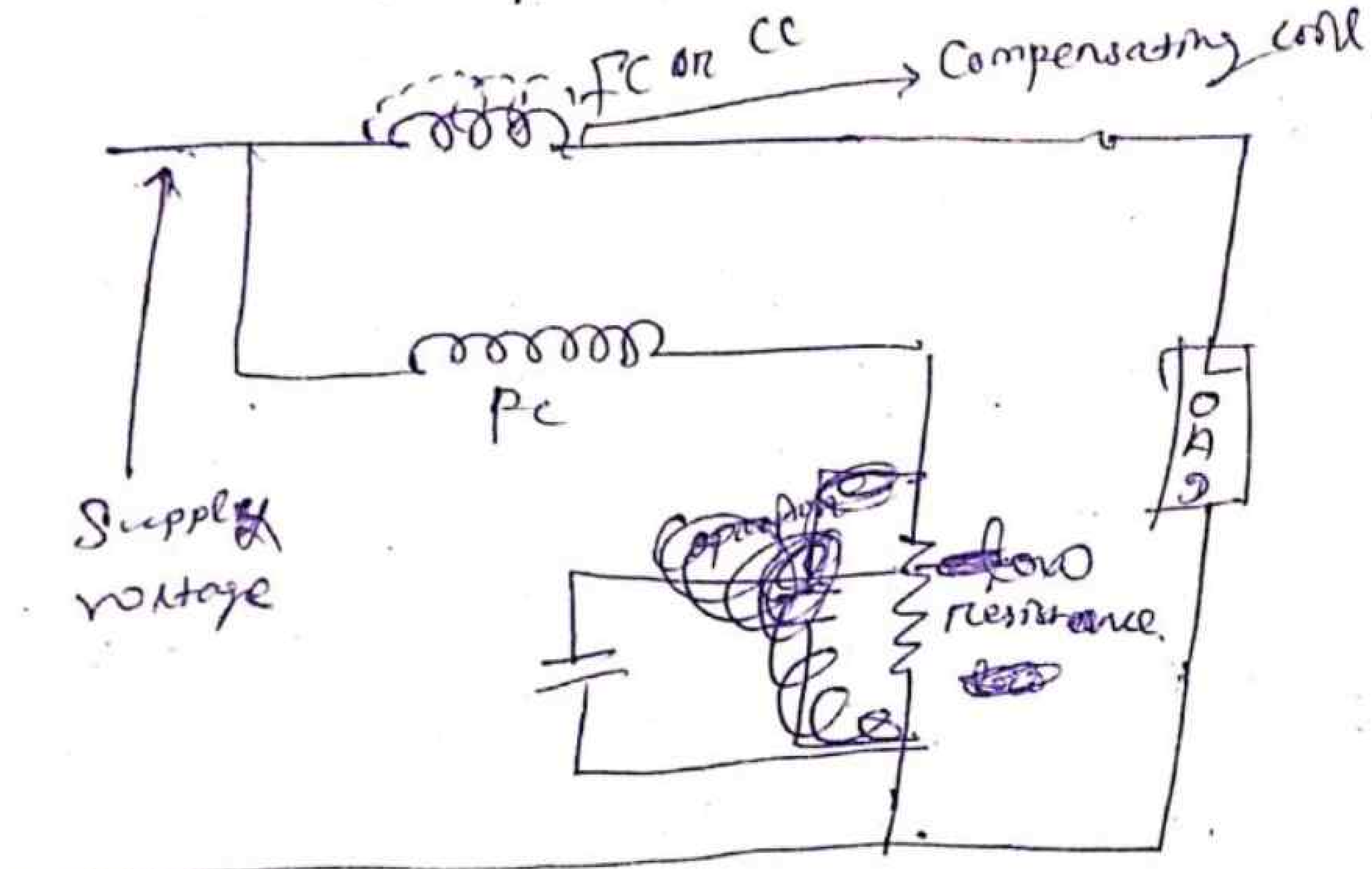
This error arises in both the connection so we have to compensate it.

(iii) Compensation for inductance of PC :-

This error is caused by PC inductance. This is compensated by connecting a capacitor across a part of series resistance in PC ckt.

Small control torque

LPF wattmeter are design small control torque so that they can give full scale deflection for power factor as low as 0.1.



here the compensating coil is connected in series with the PC. It is made as nearly as possible identical and coincident with ~~series~~ current coil.

It is so connected that, it opposes the field of current coil. hence the resultant field is due to the load current.

Induction type watt meter

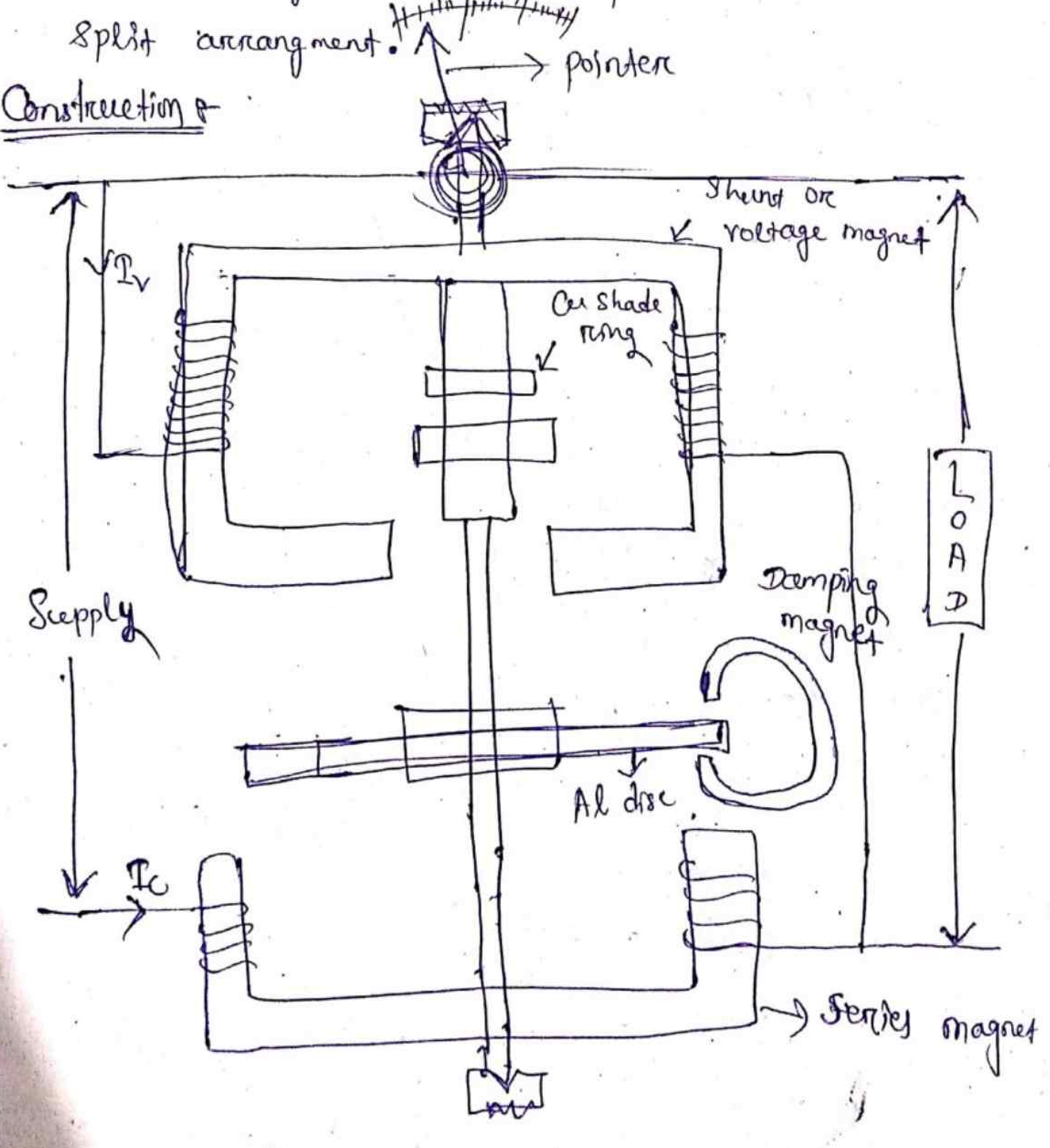
Date- 27/2/20

The induction type watt meter is used to measure ac power only.

Principle :-

The principle of operation of induction wattmeter is same as that of induction ammeter & voltmeter however, it differs from induction ammeter & voltmeter in so far that separate two coils are used to produce the rotating flux in place of one coil with phase split arrangment.

Construction :-



It consists of two laminated electromagnet. one is called shunt magnet is connected across the supply & carries current ~~Protected~~ Proportional to applied voltage this coil of this magnet is made highly inductive so that the current in it lags behind the supply voltage by an angle 90°.

→ The other magnet is called series magnet which is connected in series with supply & carries load current.
The coil of this magnet is made highly non-inductive.

→ A thin Aluminium disc is mounted on the spindle is placed betn two magnet so that it cuts fluxes of both the magnets.
The pointer is attached to the spindle which moves over the calibrated scale.

Control system:-

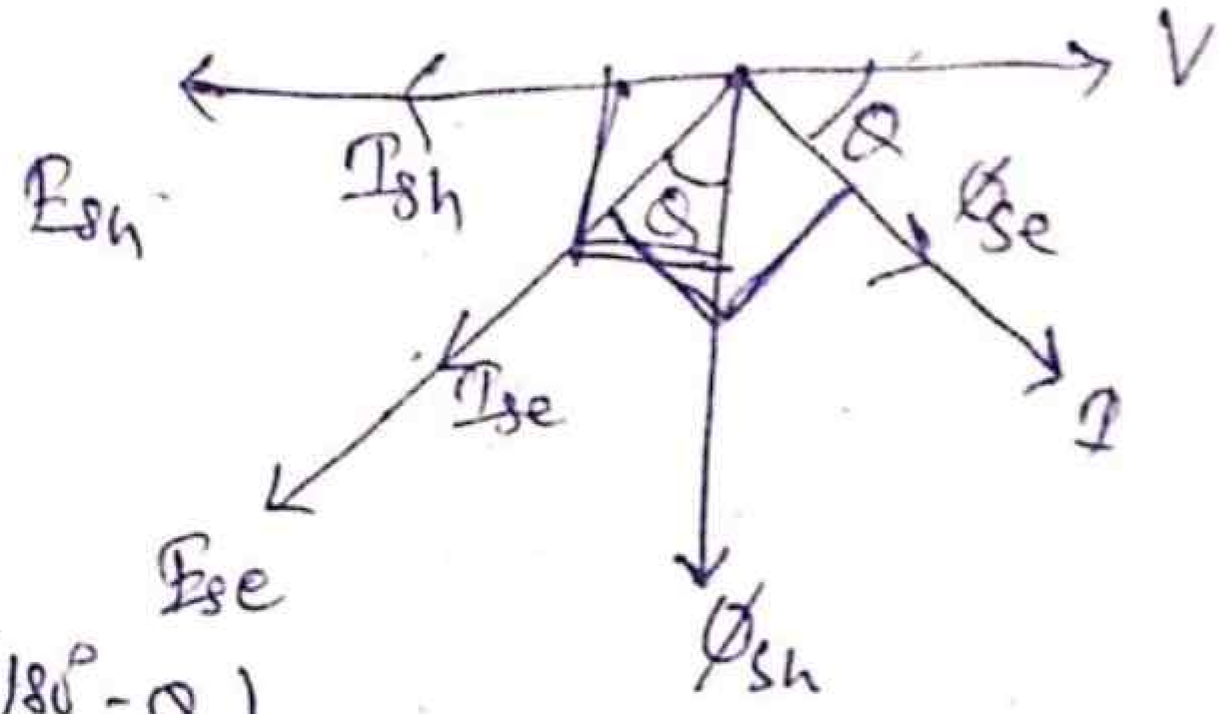
Spring control mechanism is used here.

Damping system:-

C shaped braking magnet is used here.

Working:-

When the wattmeter is connected to measure a.c power, the shunt magnet carries current propotional to supply voltage i.e. ($I_{sh} \propto V$) & series magnet carries the load current ($I_{sh} \propto I$). Due to this two fluxes ϕ_{sh} & ϕ_{se} are created & two eddy currents are developed these are I_{esh} & I_{ese}. The interaction betn eddy currents & opposite fluxes produce the deflecting torque on the disc.



V = supply voltage

$T_1 = K\, I_{ese}\, \phi_{sh} \cos Q$

$T_2 = K\, I_{esh}\, \phi_{se} \cos(180^\circ - Q)$

$$T_d = T_1 - T_2$$

$$= K\, I_{ese}\, \phi_{sh} \cos Q - K\, I_{esh}\, \phi_{se} \cos(180 - Q)$$

$$= K\left[I_{ese}\, \phi_{sh} \cos Q + I_{esh}\, \phi_{se} \cos Q\right]$$

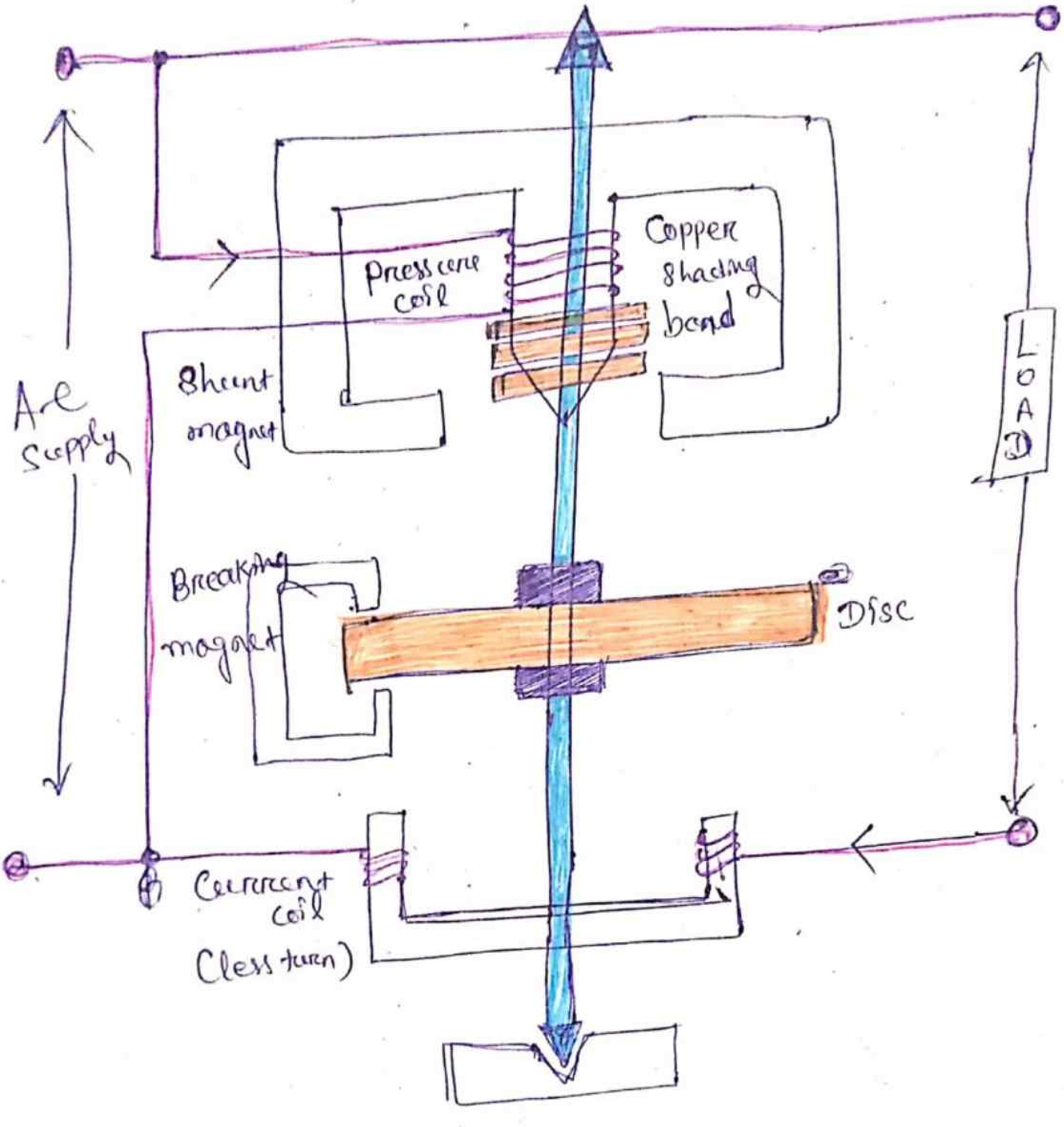
$$= K\left[K_1\, IV \cos Q + K_2\, VI \cos Q\right]$$

$$= K\, VI \cos Q \cdot [K_1 + K_2]$$

$$T_d \propto VI \cos Q$$

Date- 29/2/20

Induction type Energy meter



Errors :-

In single phase induction type energy meter the errors may be caused by driving system or breaking s/s. The driving s/s may cause error due to incorrect magnitude of fluxes, incorrect phase angles (Produced by improper lag adjustment, abnormal frequency, variation in resistance with temp etc.).

and lack of symmetry in magnetic ckt, which makes the meters to creep.

(ii) Incorrect magnitude of fluxes are produced by abnormal values of current, voltage or frequency or variation in coil resistance.

(iii) The breaking s/s may cause error due to change in break magnet strength, change in disc resistance (OR) abnormal friction of moving parts.

(b) Compensation and adjustment :-

(1) for low lagging power factor

We know that the meter will reads correctly at any power factor only when ϕ_{sh} lags supply voltage by 90°, but because the meter potential coil is not purely inductive hence the lagging angle is less than 90°. however PC flux can be made to lag supply voltage exactly 90°, by introducing a magnetic shunt ckt that allows the ϕ_{sh} to by pass the gap in which the disc is located. The required mmf is obtained from lag coil located on the central limb of the shunt magnet close to the disc gap so that it may link with the flux that cuts the disc.

For proper adjustment coe shading band is connected the central line of shunt magnet.

ii) For friction or light load :-

Despite every care in the design the pivot bearing which forms a lower bearing for the spindle when simple clip pin type of bearing at the top of the spindle frictional error are liable to be serious specially at light load. So in order to ensure a meter response to very light load small compensating torque particularly independent of load on the meter to overcome the friction of bearing and registering mechanism.

This is usually attend by placing a small shading loop also termed as load plate in the air gap of shunt magnet. So that it produces a lag in the time phase of part of pressure coil flux.

(iii) For creeping :-

It is the error caused in the energy meter due to rotation of disc without load. ~~a slight~~

A slight torque developed by the light load adjustment may cause the disc to rotate slowly in PC are excited ~~both~~ but with no-load current flowing. this effect is known as creeping and it is prevented cutting two holes or slots in the disc. of the opposite side of spindle..

The disc tends to remain stationary when one of the whole comes under one of the poles of shunt magnet.

In some cases a small piece of iron wire is attached to the edge of the disc.
This adjustment to avoid creeping is called preliminary of light load adjustment.

For full load :-

There may be an error in the resistating and such an error evident when meter is checked as rated voltage and rated current at unity power factor. here the adjustment is carried out either by varying the position of magnetic shunt to control the amount of flux by breaking magnet.
The moment of break magnet is to reduce the speed of rotation of disc. by moving the break magnet with respect to disc. the meter can resistor correctly within the required limit of error.

Frictional errors

Date-3/03/20

Frictional forces at the rotor bearing and registering mechanism caused noticeable error at light loads. at the light loads the torque due to friction acts considerable to the breaking torque on the disc of rotor. since friction torque not proportional to the speed but is roughly constant and can cause considerable error,

Adjustment :-
This error can be reduced by making the ratio of ϕ_{sh} and ϕ_{se} large with the help of shading band.

Temperature error :-
Temperature error due to variation of temp is very small because various effects tends to neutralize one another,
The resistance of disc and characteristics of magnetic ckt and strength of break magnet are affected by changes in temp.

frequency variation :-
The meter is designed to give minimum error at a particular frequency. If the supply frequency changes the reactance of coil changes resulting small error.

Error due to voltage variation :-
This error is very small i.e. (0.2 – 0.3)%
This can be eliminated by the proper design by ~~proper de~~ magnetic ckt. of shunt magnet,

(5) Frequency meter

Frequency meter is two types.

(I) Electrical resonance type.
(II) Mechanical resonance type.

Again electrical resonance ~~type~~ ~~meter~~ is two types.

(i) Ferrodynamic type.
(ii) Electrodynamometer type.

<u>Frequency meter</u>

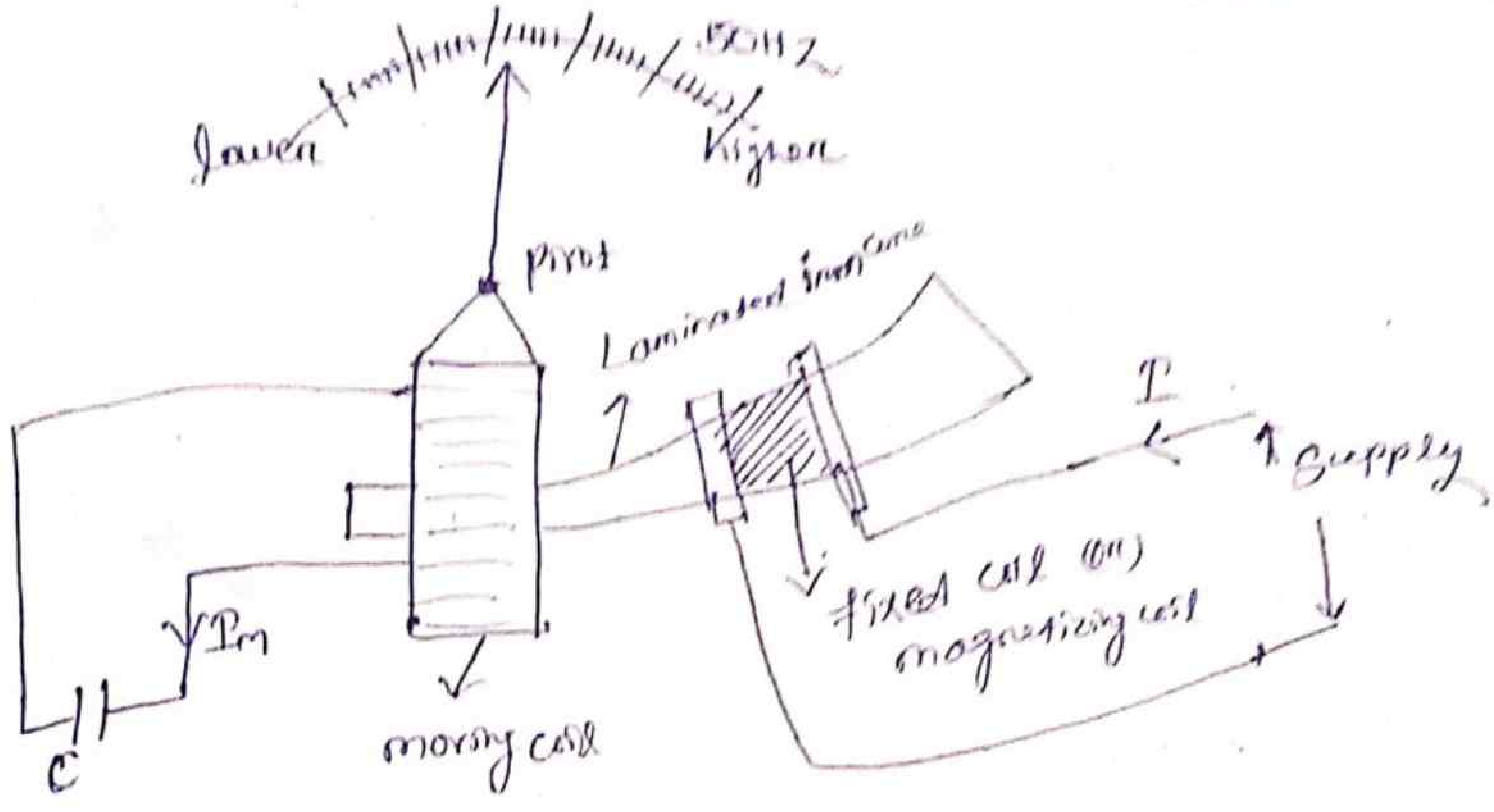
It is the measuring instrument which is used to measure frequency of AC supply.

There are various types of frequency meter present,

(I) electrical resonance type.
(II) mechanical resonance type.
(III) Weston frequency meter
(IV) Ratio meter.
(V) saturable core type frequency meter.

(I) Electrical Resonance type:-

(*) Ferrodynamic type frequency meter:-



It consist of two electromagnet (or) coil. the fixed coil is mounted on one end of the laminated iron core. the supply is given to the fixed coil. The iron core used here is variable cross section and laminated. Its cross sectional area varies gradually over length. It is being maximum over end where fixed coil is mounted and minimum over other end.

A moving coil is pivoted over the iron core. a pointer is attached to the moving coil - the terminals of moving coil are connected to the capacitor of suitable value.

Working principle :-

This instrument is designed in such a way that the pointer movement stops at the occurrence of electrical resonance. electrical resonance can be observed by the condition of $X_L = X_C$.

when the supply is given to the magnetizing coil, current 'I' flows through it and it produces flux ϕ.

This flux is alternating in nature and in phase with I, when it links to the moving coil then emf is induced in the moving coil. 'E' by which a current is flowing in the moving coil. let it is 'I_m'.

In the moving coil a self inductance 'L' is developed. The value of L depends upon the nearness of on position of moving coil on the iron core.

If it is more nearer to the fixed coil 'L' would be more.

The value of capacitor is so chosen that for normal operating frequency (50 Hz) the resonance by default occurs. and the coil is at initial position indicating frequency 50 Hz.

Operation :-

Case-1 - If f > 50 Hz, $X_L > X_C$ with this condition the moving coil rotates in clockwise direction there by pointer graduating starts towards the scale > 50 Hz. In this moment the moving coil is going away from magnetising coil there by 'L' decreases.

with this continuous moment at some position $X_L = X_C$ obtained at that position pointer stops indicating appropriate value of frequency.

Case-2 If $f < 50Hz$ i.e. $X_L < X_C$
In this case moving coil makes deflection in anticlock wise direction with this it reaches nearer to magnetizing coil there by L increases. at some point $X_L = X_C$ occurs and the pointer stops and indicates the frequency.

Case-3 If $f = 50Hz$ i.e. $X_L = X_C$
In this position the deflecting torque of moving coil is zero. hence it remain at its initial position.

Electrodynamometer type frequency meter

Date - 4/2/20

Construction:-