R. C. Patel College of Engineering & Polytechnic, Shirpur

Department of Electrical Engineering

Name of Subject: **- Electrical & Electronic Measurement (EEM)**

Course Code: **- 313334**

Scheme:- **EE-3K**

Semester**:- Third**

Unit No. 01- Fundamentals of Measurement

CO1 - Apply the basics of measurement to the measuring instruments.

Unit	Title	COs	Learning hours	R Level	U Level	A Level	Total Marks
I	Fundamentals of Measurement	CO1	7	2	4	4	**10**

THEORY SYLLABUS CONTENT

Fundamentals of Measurement

1.1 Measurement: Definition, need and significance.
1.2 Static and dynamic characteristics of measuring instruments.
1.3 Types of errors in measurement and compensation.
1.4 Classification of Instruments.
1.5 Deflecting, controlling and damping torque.
1.6 Calibration: Need, significance and general procedure.
1.7 Construction and working principle of Permanent magnet moving coil (PMMC) and Permanent magnet moving iron (PMMI) meter.
1.8 Range Extension of ammeter and voltmeter- a) Shunt and multiplier (for DC), b) CT and PT (for AC)
1.9 Classification of resistance: Low, Medium and High.

Subject Incharge
Mr. N. S. Borse

Unit - I

Fundamentals of Measurement

(10 Marks)

* **Measurement :-**

Def" ⇒ Measurement is a process by which an unknown quantity is compared with predefined standard value with significant units.

or The process of conversion of physical parameters into meaningful number is called as "Measurement."

* **Significance of Measurement (Necessity) :**

→ It provide a common standard which understood worldwide.
→ It reduces error and wastage.
→ Different quantities can be compared easily.
→ The standard use for comparison purpose must be accurately defined
→ Standard should be commonly accepted
→ Measurent help in achieving goals & and make correct decision.

* **Need :**

1) Accuracy in work
2) helps in design & Manufacturing
3) ensure safe operation
4) helps to maintain product quality & standards in industries
5)

* Static & dynamic characteristics:

Static characteristics ⇒ the characteristics which does not change w.r.t. time.

ex. Accuracy, precision etc.

Dynamic characteristics ⇒ the characteristics which changes rapidly w.r.t. time.

e.x. Transient response, steady-state response, speed of response, periodic response.

Static characteristics:

1) Accuracy: It is closeness betn true value and measured value.
conformity to truth
closeness with true value

ex. Actual value = 9 A
Measured value = 9.01 A
→ Higher the accuracy, lower the error.

2) precision: precision is a measures of consistency or repeatability of the measurement.
It is also known as the degree of exactness for which an instrument is designed. It is also known as degree of exactness.
Precise instrument may not be accurate, but an accurate instrument has to be precise.

ex. Actual value = 100 V
Measured value = 105 V, 105.1 V, 104.9 V
given instrument is precise but not accurate

3) Repeatability: It is defined as the closeness among a number of consecutive measurement of the o/p for same i/p under same operating conditions (temp, Press)
→ Same person measures same thing again & again using same instrument and same conditions
ex. one student measure 5 times.

4) Reproducibility: It is defined as the closeness among a number of repeated measurement of the o/p for same value of i/p under different operating conditions.

→ Different persons or different instrument measure the same thing under changed conditions.

→ ex. 5 student measure a same thing.

5) Linearity: An instrument is liner, if it's output is linearly proportional to input.

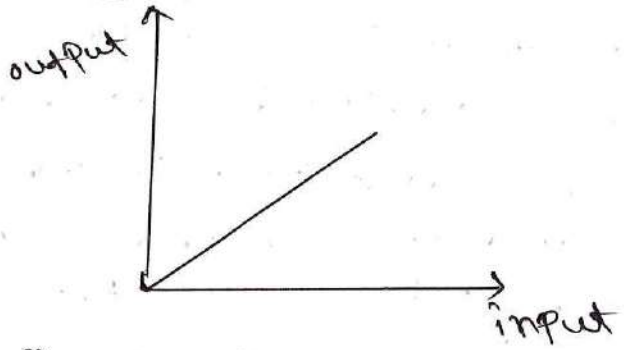


fig: linearity of instrument

when incremental change in the input, output are constant over the specified range.

6) Sensitivity: It is defined as, the ratio of change in output to the change in input.

sensitivity is the smallest change in value of a measured variable to which an instrument responds.

$$\text{sensitivity} = \frac{\text{change in output signal}}{\text{change in input signal}}$$

7) Drift: It is the gradual variation in the output over the period of time, that is independent to change in input condition.

It is commanly caused by internal temperature change and component instability.

This undisirable change is occurs because of the aging of components / parts.

8) Dead Zone: Range of input reading when their is no change in output.

→ Dead zone is the maximum value of the quantity under measurement to which the instru doesn't respond.

→ Dead zone occurs because of friction & inertia.

9) Span: The algebric difference between upper & lower range value of the instrument.

10) Range: The region between the limit, within which an instrument is design to operate for measuring, a physical quantity is called range of instrument.

11) Resolution: If input to an instrument is varied slowly the output does not change at all until a certain increment is exceeded, this increment is called resolution.

* Types of Error in Measurement:

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

Their are three types of error in the instrument.

1) Gross Error - Due to human Mistake e.g. temp 23.4°c

2) systematic Error - a) Instrumental Error
e.g. Manufacturing Default Misuse, loading effect.

b) Environmental Error
e.g. Humidity, Dust, Dirt vibration, electrostatic field

c) observation error
eg parallex effect.

3) Random Error - other than gross error & systematic error.

⇒ Sources of error - poor design parts, lack of Knowledge to operate instru. change in process parameters Poor maintenance, design limitations, error due to operator.

Compensation of Error in Measurement:

1) Gross error – take care while reading & recording the data
   - take at least three readings for finilizing the value.
2) Instrumental error – use calibrated instrument
   - avoid loading effect of meter
3) Environmental error – use instrument in controlled conditions of pressure, temp, humidity
   - Provide electrostatic & magnetic shield to avoid electrical & magnetic effect.
4) observation error – use modern instruments having digital display.
   - use mirror on display to avoid error
5) Random error – This error are due to unknown causes. This error are normally very small, hence no need to compensate.

* Classification of Instrument:

Instrument are classified as Indicating, Recording Integriting. Analog instrument, digital instrument, electrical instrument and Mechanical instrument.

Parameter	Analog Instru.	Digital Instru.
1) Working Principle	The instru. that display analog signal is called analog instru.	The instru. that display digital signal is called digital instru.
2) Accuracy	Less Accuracy	High Accuracy
3) Power Required	Does not required any Power supply	It required external Power supply
4) cost	less cost	More expensive
5) Portability	Easily port or move	Does not easily port
6) Error	observational error	Free from obs. error
7) Example	Ammeter, voltmeter	Multimeter, Energy Meter

1) Electrical Instrument: The instrument which is used for measurement of any electrical quantity i.e. current, voltage, power is called electrical instru
e.x. Ammeter, Voltmeter, wattmeter, eneegy meter etc

2) Mechanical Instrument: The instrument use for measurement of any mechanical quantity, i.e. diameter, length etc is called mechanical instrument.
ex. Vernier caliper, pressure gauge etc.

* Types of Torque: (Force)
There are three types of torque
1) Deflecting Torque (T_d)
2) Controlling Torque (T_c)
   a) Spring control
   b) Gravity control
3) Damping Torque (T_{damp})
   a) air friction damping
   b) Fluid friction damping
   c) Eddy current damping.

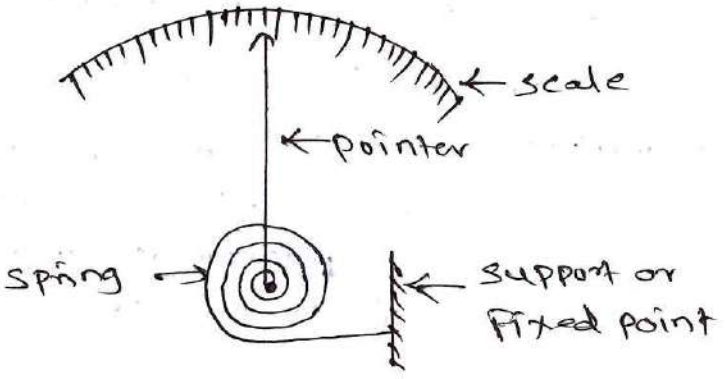
1) Deflecting Torque: The deflecting torque moves the pointer on a scale. This torque is proportional to quantity under measurement ($T_d \propto I$)
It is produced by using effect of electric current such as magnetic effect, Heating effect, chemical effect.
The torque which is responsible for deflection of pointer.

2) Controlling Torque (T_c): The function of the controlling torque is

a) To stop the pointer at correct position ($T_d = T_c$)

b) To bring the pointer back to the zero position, when quantity is zero.

- The pointer shows final steady state deflection when controlling Torque (T_c) = Deflecting Torque (T_d)
- The magnitude of the controlling torque is directly proportional to the deflection of the pointer and acts in opposite direction to the deflecting torque. ($T_c \propto \theta$)
- Controlling torque is produced by two methods.
  a) Spring control method: This method is commonly used in indicating instrument.
  - It uses one or two spiral hair springs made up of phosphor bronze is attached to the spindle of the meter.
  - one end of spring is attached to spindle and other end is attached to fixed point on the instru.



Advantages:

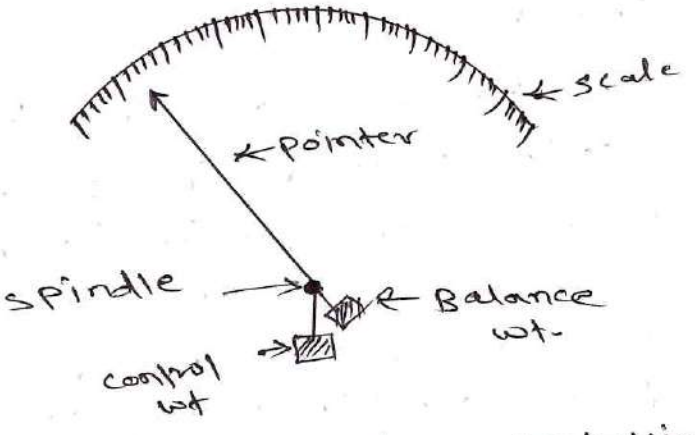
1) spring control is easy to apply.
2) cost is less
3) Adjustment of controlling torque is easy
4) Maintenance is easy
5) It can used in Horizontal & vertical positin
6) High torque to weight ratio.

disadvantages:

1) Change in temp affect the spring length.
2) Accidental stress in the spring may damage them.
3) If spring is stretched beyond it's limit it may loose it's elastic property.

b) Gravity control Method:

- It uses gravity force to produce controlling torque.
- control weight & balance wt. are attached to the spindle



$T \propto \sin\theta$

- control weight produce controlling torque into gravity.
- Balance wt. is used to balance the weight of the pointer.

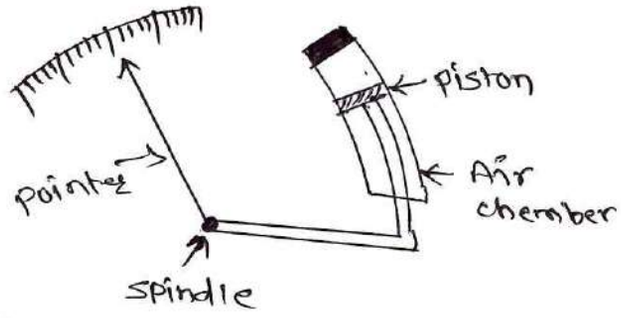
Advantages: 1) No effect of temperature
2) cost is less cumpared to spring control
3) Adjustment can be done easily
4) longer life.

Disadvantages: 1) It can not be used in Horizontal
2) due to control wt, increase the overall wt of instrument.
3) low torque to wt. ratio
4) scale is non-uniform
5) Maintenance is complicated.

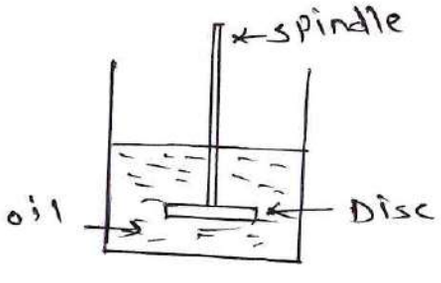
3) Damping Torque (T_{damp}):

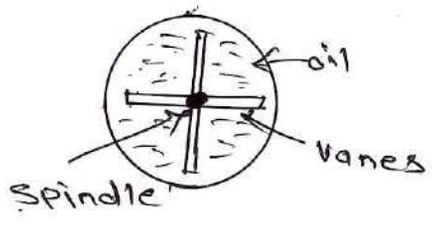
- When pointer deflect, due to Movement of inertia the moving system oscillates around the final position before it take steady state.
- Unless the pointer becomes stationary we can not take reading of the meter.
- The damping torque reduces the time of oscillation of the pointer.
- The damping can be provided by
  a) Air friction b) Fluid friction c) Eddy cln

a) Air friction damping: It uses compressed air pressure to produce damping torque.
- The high pressure air opposed the motion of spindle.



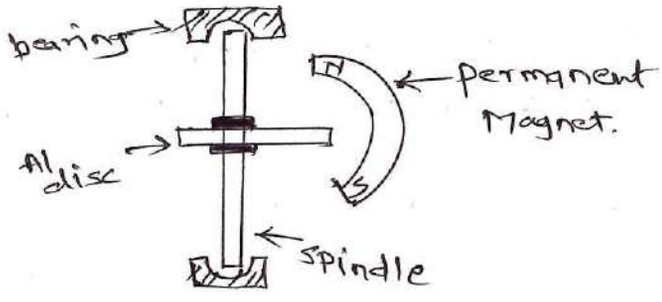
b) Fluid friction damping: High viscosity oil is used to produce damping torque.
- Vanes are attached to spindle & it is immersed in container carrying oil.
- This instrument operate in vertical position only.





c) Eddy current damping:

- lenz law is used to produce damping torque
- permanent magnet (c-shaped) is placed around a rotating disc.
- flux of permanent magnet is cut by disc, emf is induced in it.
- According to lenz law, this emf oppose basic cause of producing it, i.e. oppose the rotation.

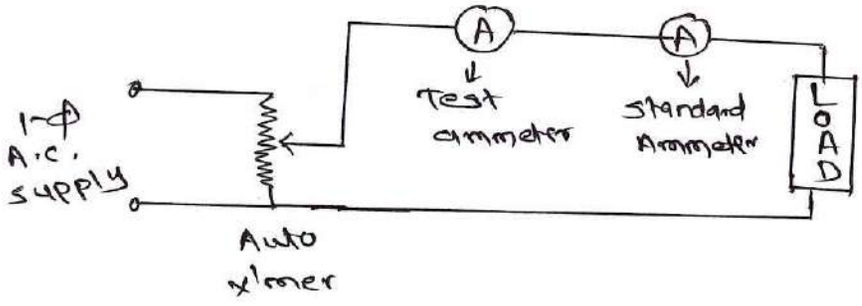


* Calibration: calibration is a process of estimating the value of quantity by comparing that quantity with a standard quantity.

Need: calibration of all instruments is important to check the instrument against a known standard to determine the error and accuracy.

significance: 1) To minimize the error in instrument
2) To make sure about standard of instrument.
3) due to calibration, instrument gives correct reading.

procedure: If a meter is to be calibrated to find its accuracy & error is comparison with standard instrument.
Then both test instrument & standard instrument are connected in same circuit, take various reading of both and compared to find error



$$\% \text{ Error} = \frac{\text{Measured value} - \text{True value}}{\text{True value}} \times 100$$

Only measure D.C. quantity (I & V)
Uniform scale.

* Permanent Magnet Moving coil (PMMC):

Construction: 1) It consist of rectangular coil wound on aluminium frame.

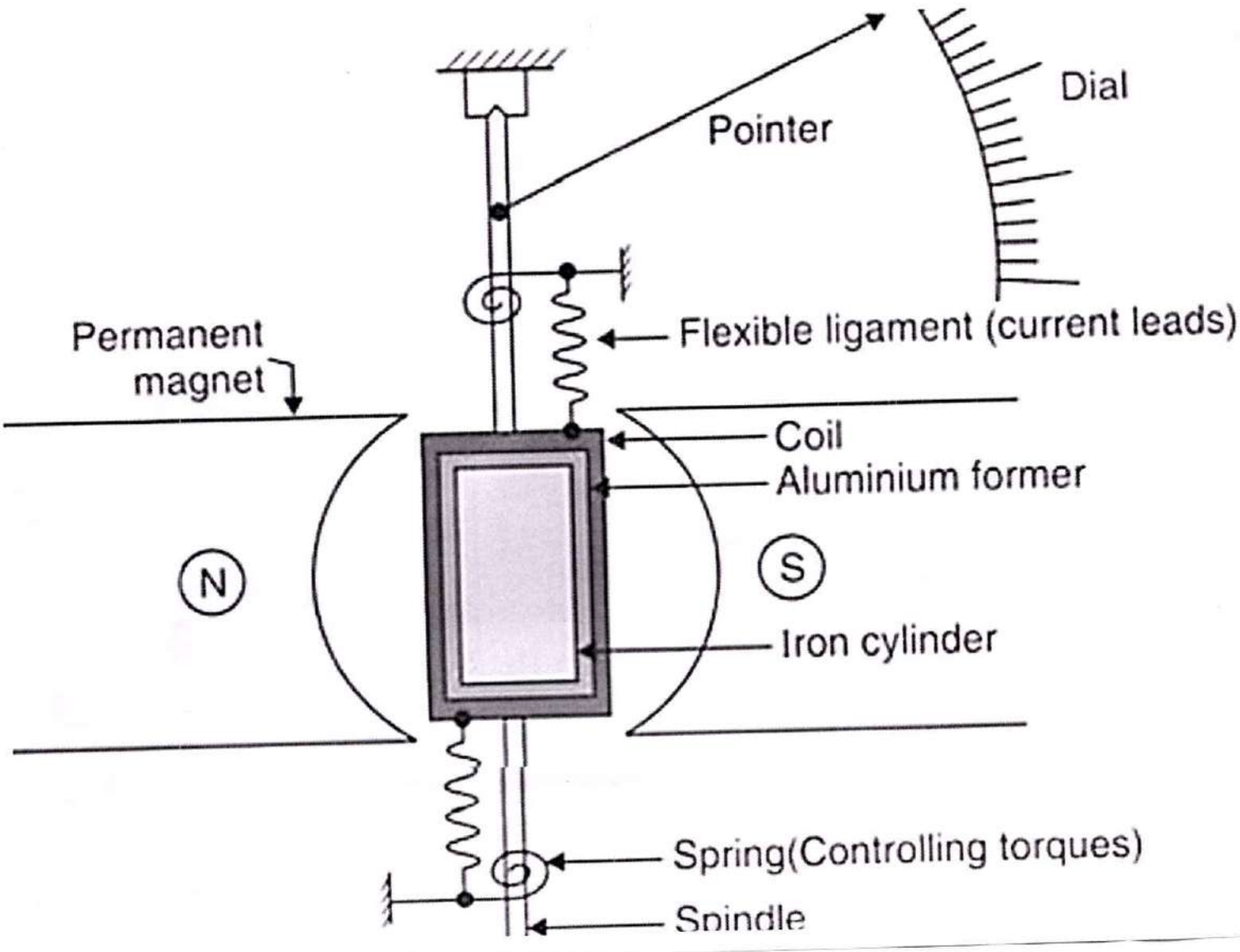
2) The coil is attach on spindle which is rest in bearing.

3) The sides of coil place in the air gap bet^n two poles of permanent magnet.

4) The soft iron piece is used to reduce air gap & it makes the magnetic field uniform.

5) Two spiral springs are attached to the spindle they produce controlling torque.

6) Pointer is attach to the spindle with balance wt.



Working principle: When current carrying conductor placed in magnetic field, force is exerted on conductor. This force tends to move the coil in space.

$$\text{Force} = NBIL$$

where F = force on moving coil
N = Number of turns of coil
B = Magnetic flux density
I = current flowing thro coil
L = length of conductor.

The direction of force on moving coil is given by Flemings left hand rule.

Working: current carrying conductor placed in magnetic field force is exerted on that conductor.

$F \propto NBIL$, N, B, L are constant

Hence deflecting torque $\propto$ I (current)

- The controlling torque is produced by spring

∴ controlling torque (T_c) $\propto \theta$

where θ = deflection of pointer in degree

as $T_d = T_c$ pointer becomes stationary.

- Eddy current damping produces a damping torque. Eddy current induced in aluminium frame of moving coil.

Advantages: 1) Deflection is proportional to current ($T_d \propto I$)

2) scale is uniform

3) High accuracy due to high torque to wt. ratio

4) High sensitivity.

5) used to measure high current & voltage.

6) Power consumption is very low.

7) Effective eddy clm damping

Disadvantages: 1) Suitable for DC measurement only.
2) The direction of force depends on direction of current
3) cost is higher
4) affected by external magnetic field.

* Moving Iron (MI) instrument:

It measures AC & DC current and voltage.
There are two types of MI instrument.
a) Attraction type
b) Repulsion type

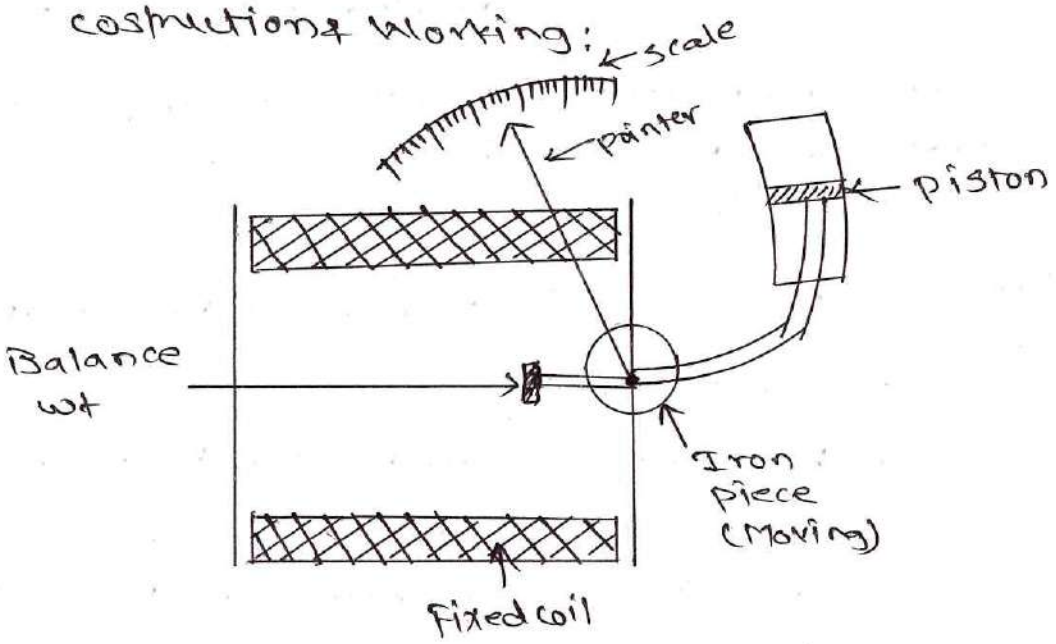
MI measure both AC & DC
Non-uniform scale.

a) Attraction type MI instrument:

Working principle: Magnetic attraction
when an iron piece is kept near magnetic field, it gets attracted towards the magnetic field.

current is to be measure is pass through fixed coil, coil is act as electromagnet in attraction type meter, this electromagnet attract the iron piece producing the deflecting torque.

Construction & Working:



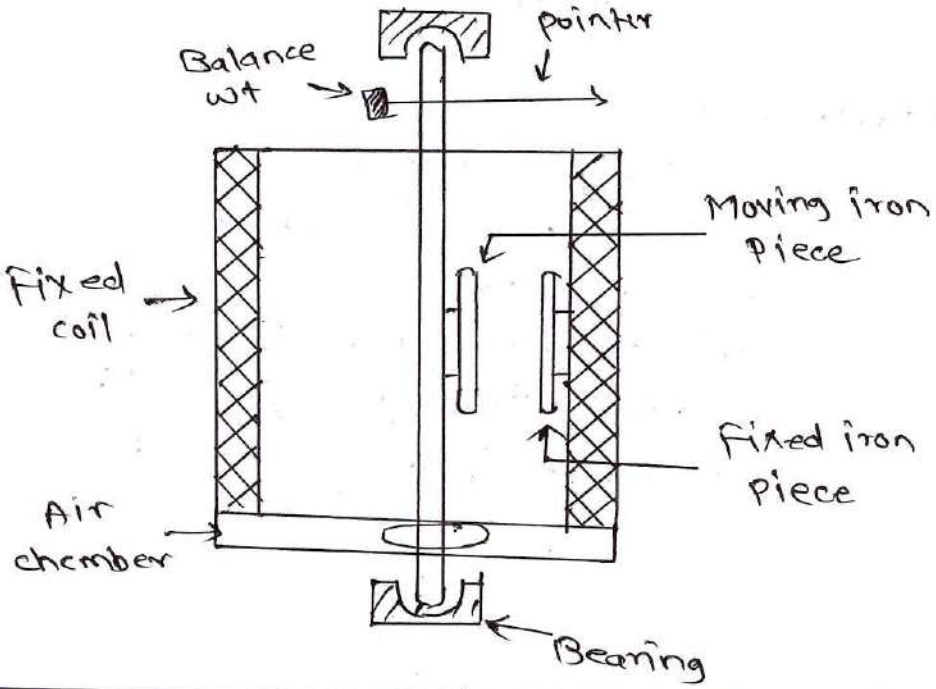
1) In attraction type meter small iron piece is attach to the spindle.
2) Fixed coil is placed near the spindle,
3) current is pass through the fixed coil, will act as a electromagnet producing magnetic field & attracted to the moving iron piece.
4) The deflecting torque is directly proportional to the square of current ($T_d \propto I^2$)
5) Hence the scale is non-uniform
6) Controlling torque produced by gravity or spring control.
7) generally air friction damping is used

b) Repulsion type MI instrument :

Working principle: When two iron pieces are magnetized with same polarity, a repulsive force act on them and moving iron deflected.

Construction & Working :

1) A hollow circular coil is used and one of the iron piece is attach inside the hollow coil
2) other iron piece is attach to the spindle.



3) The c/n is to be measure, is pass through the fixed coil, coil produces the magnetic field.

4) Both the iron pieces are placed in the same magnetic field, it having same polarity.

5) deflecting torque is produced due to the force of repulsion between same polaries iron pieces.

6) The force of repulsion is directly proportional to the square of current ($T_d \propto I^2$), hence the scale is non-uniform.

7) controlling torque is provided by spring and damping torque is provided by air friction damping.

Advantages: 1) It can measure both Ac & DC quantity
2) simple construction
3) chiper in cost
4) High torque to wt. ration, hence high accuracy
5) can be operate in vertical & Horizontal position

Disadvantages: 1) The scale is non-uniform
2) Sensitivity is less as $T_d \propto I^2$
3) affected due to external mag. field

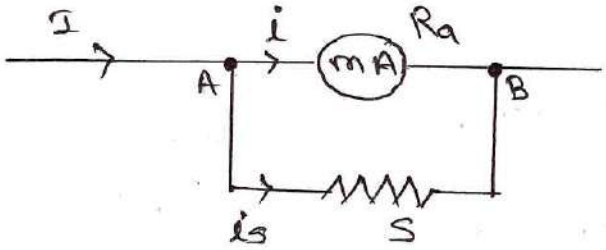
* Material used:
1) coil - copper
2) Iron piece - soft iron
3) spindle - steel
4) spring - phosphor bronze
5) controlling wt - steel / iron
6) Balance wt - steel / iron

MC Instrument	MI instrument
1) It measure only DC.	1) It measure AC & DC.
2) It having uniform scale	2) It having non-uniform scale
3) More sensitivity	3) Less sensitivity.
4) High cost	4) chipper in cost
5) Torque to weight ratio is more	5) less as compared to MC
6) Eddy current damping is used	6) Air friction damping is used
7) Spring control are used	7) Spring control or gravity control are used
8) Symbol 	8) Symbol 
9) deflection $\propto I$	9) deflection $\propto I^2$
10) Moving - coil stationary - Magnet	10) Moving - Iron piece stationary - coil

(11th Resi)

* Range Extension of Ammeter using shunt:

1) The range of ammeter can be extended by using resistance known as shunt.
2) This method can be used for AC & DC ammeter.
3) Low value resistance connected in parallel with coil of meter.
4)



let I = total current to be measured
i = current capacity of meter
Ra = resistance of ammeter (internal)
S = resistance of shunt
is = current through shunt resistance

Apply KCL at node A

$$I = i + i_s \quad \text{---} \quad (1)$$

as meter & shunt are parallel, voltage drop is same

$$i \cdot R_a = i_s \cdot S$$

$$S = \frac{i \cdot R_a}{i_s} \quad \text{---} \quad (2)$$

put value of is in eqn no. 2

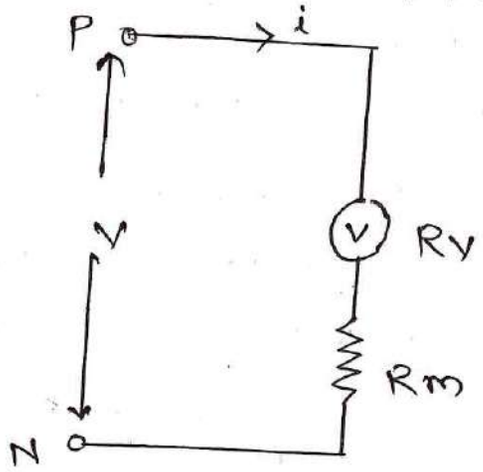
$$\boxed{S = \frac{i\,R_a}{I - i}} \quad \text{or} \quad \boxed{S = \frac{i}{I - i} \cdot R_a}$$

* problems on shunt.

(series resi)

* Range Extention of Voltmeter using Multiplier:

1) This method can be used for extension of DC & AC voltmeter.
2) Multiplier is the high resistance which connected in series with the coil of meter.

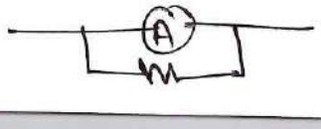


where, V - range of voltmeter
R_v - resistance of voltmeter
R_m - multiplier resistance
i - c/n flowing thro meter
V - total voltage measured.

$$V = i.R_v + i.R_m$$
$$= i(R_v + R_m)$$
$$\frac{V}{i} = R_v + R_m$$

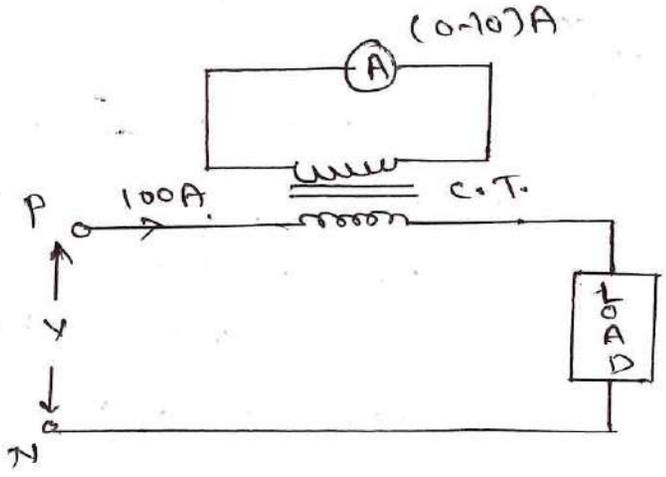
$$\boxed{R_m = \frac{V}{i} - R_v}$$

* problem on Multiplier.

Shunt	Multiplier
1) Used for Ammeter range ext	1) voltmeter range extention
2) $R_{sh} = \frac{I}{I-i} \cdot R_a$	2) $R_m = \frac{V}{i} - R_v$
3) low resi	3) High resi
4) ll el resi	4) Series resi
5) 	5) 

* Range Extension of Ammeter using C.T.:

1) In this method, with the help of current transformer, we can extend the range of low value ammeter.
2) Step-up transformer are use which can decrease the current value in secondary.
3) The low value ammeter is connected in series with secondary of CT transformer.
4) The following fig. shows connection ckt.

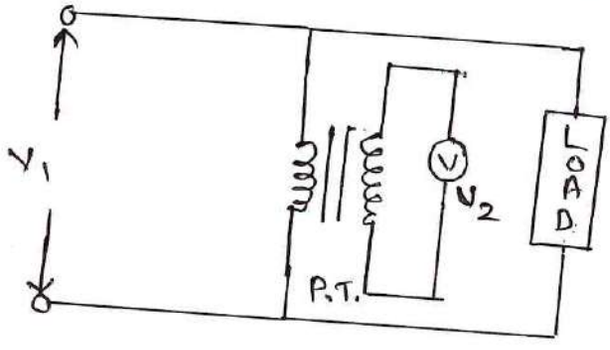


5) The ratio of primary current (I_1) to the secondary current (I_2) is always constant, is called as current ratio.
6) From fig $\frac{I_1}{I_2} = \frac{100}{10} = 10:1$ ratio is const.

* problem on range extension.

* Range Extension of Voltmeter using P.T.:

1) In this method, Potential transformer is used to extend the range of low range voltmeter.
2) Step-down transformer are used which decrease the measured voltage.
3) The primary of P.T. are connected across a terminal whose voltage is to be measured.
4) The low value voltmeter are connected in Parallel with secondary of P.T.
5) The following fig. shows ckt connection.



6) The ratio of primary voltage (V_1) to the secondary voltage (V_2) is always constant.

$$\frac{V_1}{V_2} = \text{constant.}$$

* classification of Resistance:

1) low Resistance: Resistance upto 1Ω is known as low resistance

2) Medium Resistance: Resistance range from 1Ω upto 0.1MΩ is medium resistance.

3) High Resistance: Resistance above 0.1MΩ is High resistance.

18/05/2026

Mr. N. S. Borse
(Subject Teacher)

18.05.2026.

Mr. V. P. Mahajan
HOD, EE

Unit I - Fundamentals of Measurement

Question Bank

Q.1. Define the term calibration and state it's need and purpose for measuring instrument.

Q.2. State the types of error in measuring instru and reasons of occurance & their compensation.

Q.3. Define precision, Accuracy, sensitivity, drift. resolution, repeatability.

Q.4. Problems on shunt & multiplier

Q.5. problems on C.T. & P.T.

Q.6. Explain with sketch, the constution and working principle of Attraction & Repulsion type MI instrument.

Q.7. With neat sketch of PMMC instruments explain it's working briefly. list any four advantages & disadvanteges.

Q.8. Explain the procedure of calibration.

Q.9. State the necessity of extension of Ammeter using shunt.

Q.10. Explain range extention of Ammeter and voltmeter using C.T. & P.T.

Q.11. Desire expression for shunt & Multiplier

Q.12. Explain different torques in measuring instrument.

Q.13. State the difference between analog instrument & digital instrument.

Q.14. State significance of measurement.

Q.15. Compare analog ammeter and voltmeter on the basis of following points.

a) Connection in the circuit
b) Resistance
c) Circuit symbol
d) Extension of range.

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21/5/26
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