Electrical & Electronic Measuring Instruments

- **Module 1** - CO1 - Identify different types of electrical measuring instruments and their operation.

Electrical & Electronic Measuring Instruments

Electrical & Electronic Measuring Instruments

- What you mean by a **measuring instrument**?

→Measuring instrument determines the value of quantity to be measured.

- Electrical measuring instrument measures electrical quantity such as voltage, current, resistance, power, energy etc.
- Examples are Voltmeter, ammeter, ohmmeter, wattmeter, energymeter etc.

Methods of measurement

- **Direct Method of Measurement** - In this method of measurement, the unknown quantity is directly compared with the standard quantity.
- The result of the quantity is expressed in number. It is the most common method of measuring the physical quantities like length, temperature, pressure, etc.
- Example: The physical balance directly measures the weight of the matter. Also measuring the length of a paper or cloth using scale.

Methods of measurement

- **Indirect Method of Measurement** - The direct measurement gives the inaccurate results in most of the cases. Hence, the direct method is rarely preferred for measurement.
- In indirect method of measurement, the physical parameters of the quantity are measured by the direct method, and then the numerical value of the quantity is determined by the mathematical relationship.
- Example: The length, breadth and height of the substance is measured by the direct method and then by the help of the given relation the weight of the substance is known. Weight Length x Breadth x Height x Density

Classification of Instruments

1. Absolute Instruments
2. Secondary Instruments

Absolute Instruments

- Absolute instrument (primary instruments) determines the magnitude of the quantity to be measured in terms of the instrument parameter.
- They are rarely used. Working with absolute instruments for routine work is time consuming.
- They are mainly used for the calibration of secondary instruments.
- Eg: Tangent galvanometer which gives the measured current in terms of the tangent of the deflected angle, the radius, and the number of turns of the galvanometer , Rayleigh’s current balance

Secondary Instruments

- Secondary instruments determine the value of the quantity directly. (No analytical calculation is required).
- They have to be calibrated initially by comparing with an absolute instrument or with a standard secondary instrument.
- Most of the measuring instruments which are used, generally are of secondary type measuring instrument.

Eg: ammeter, voltmeter etc

Calibration

- Calibration is the comparison between a known measurement (Standard) and the measurement of calibrating instrument.
- Accuracy of standard instrument should be very high.
- A graph is drawn between the standard value and measured value to check the accuracy of the measuring instrument. This curve is known as calibration curve.
- Why calibration→ After manufacturing of measuring instruments, calibration is required to check their accuracy. Also, the accuracy of measuring instruments degrade over time due to wear and tear. Calibration improves the accuracy of the measurement. (hence less error).

Classification of Instruments

- Analog and Digital instruments

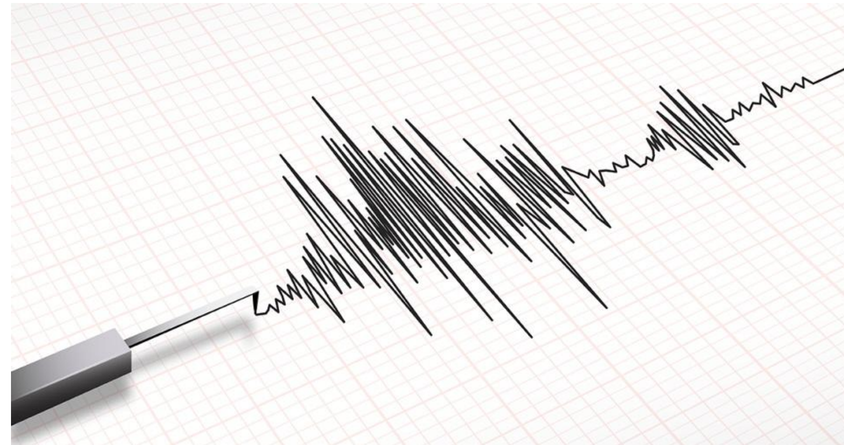
Analog instrument	Digital Instrument
In analog instruments, physical variable of interest is in the form of continuous or stepless variations.	In digital instruments, physical variables are represented by digital quantities.
The output varies in continuous fashion as quantity is measured, having infinite values in a given range.	The output varies in discrete step and thus give finite values in a given range.
Examples are speedometer of automobile, fuel gauge, voltmeter, ammeter, wrist watch, thermometer etc.	Examples are odometers, digital ammeter and voltmeters.
The information form is as the position of pointer on dial / scale.	The information form is as a number.
The best possible accuracy is 0.25%.	The best possible accuracy is +0.005% or better
Moving parts are involved in analog instrument.	There are no moving parts in digital instrument.

Classification of Instruments

1. Indicating Instruments :

- Indicating instruments are those which indicate the magnitude of an electrical quantity at the time when it is being measured.
- Their indications are given by a pointer moving over calibrated dial.
- Ammeters, voltmeters are examples of indicating instruments.. Eg: Ammeter, Voltmeter, Wattmeter

2. Recording Instruments :



- Recording instruments are used in such situations where measurements are used for future reference or computational work.
- The common examples recording instruments are thermoscope , ECG machine, etc.
- The recording instrument records the measured value on graph paper or in a digital recording system.

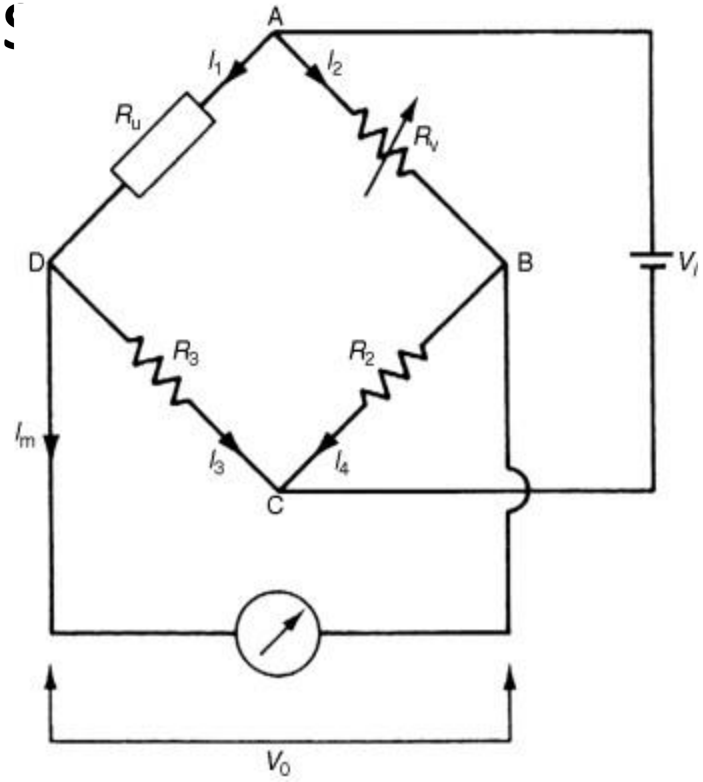
3. Integrating Instruments :

- These instruments record the consumption of the total quantity of electricity, energy, etc. during a particular period of time.
- These instruments give reading for a specific period of time but no indication of reading for a particular instant of time.
- Example: Ampere-hour meter, Household energy meter, kilovolt ampere-hour meter.

Classification of Instruments

1. Null Type Instruments:

- An instrument in which zero or null indication determines the magnitude of measured quantity such type of instrument is called a null type instrument.
- It uses a null detector which indicating the null condition when the measured quantity and the opposite quantity are same.
- Such type of instrument has high accuracy and also it is very sensitive.



- Examples of null type instruments include:
- Wheatstone Bridge: Measures electrical resistance.
- Potentiometer: Measures voltage or potential difference.
- Null type galvanometer: Measures electrical current.

Classification of Instruments

2. Deflection Type Instruments:

- Deflection type instruments work on the principle of measuring the unknown quantity by observing the deflection or movement of a physical indicator in response to that quantity.
- The measured quantity causes a deflection in the instrument, and its value is determined by reading the position of the indicator against a calibrated scale.

- Examples of deflection type instruments include:
- Analog Voltmeter: Measures voltage by deflecting a needle on a scale.
- Analog Ammeter: Measures current by deflecting a needle on a scale.
- Analog Galvanometer: Measures electrical current by detecting the angular deflection of a coil in a magnetic field.

Essential Torques in Measuring Instruments

Essential torques provided in the moving system of Electrical Instruments are:

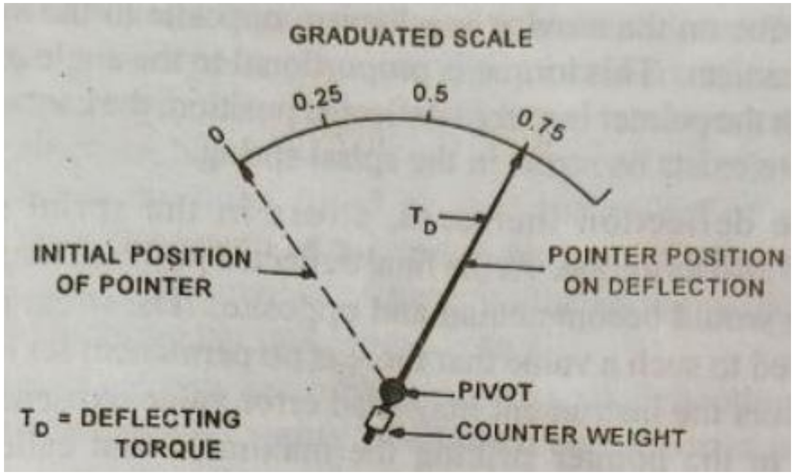
1. Deflecting torque

2. Controlling torque

3. Damping torque

I. Deflecting Torque

- The deflecting force is the force required for moving the pointer from rest on the scale.



- The current (or voltage) under measurement is utilized to produce the deflecting force.

- There are various **effects of current** *which are utilized for producing **deflecting force** in the instrument*

Some important & popular effects of current are:

1. Magnetic Effect
2. Electrodynamic Effect
3. Electrostatic Effect
4. Induction Effect
5. Thermal effect

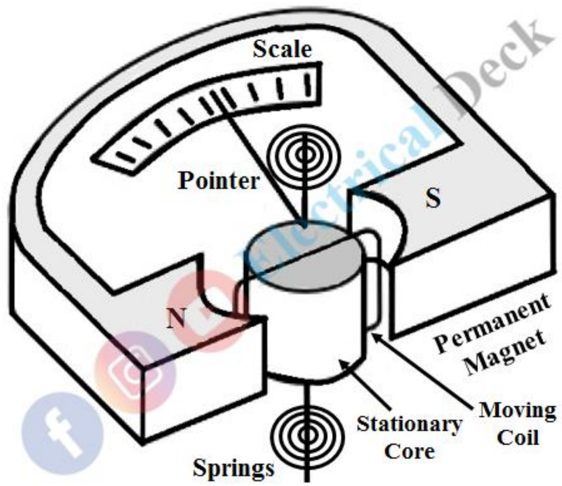
Magnetic Effect

When a current flows through the conductor, a magnetic field is produced in the wire.

This is called magnetic effect of current.

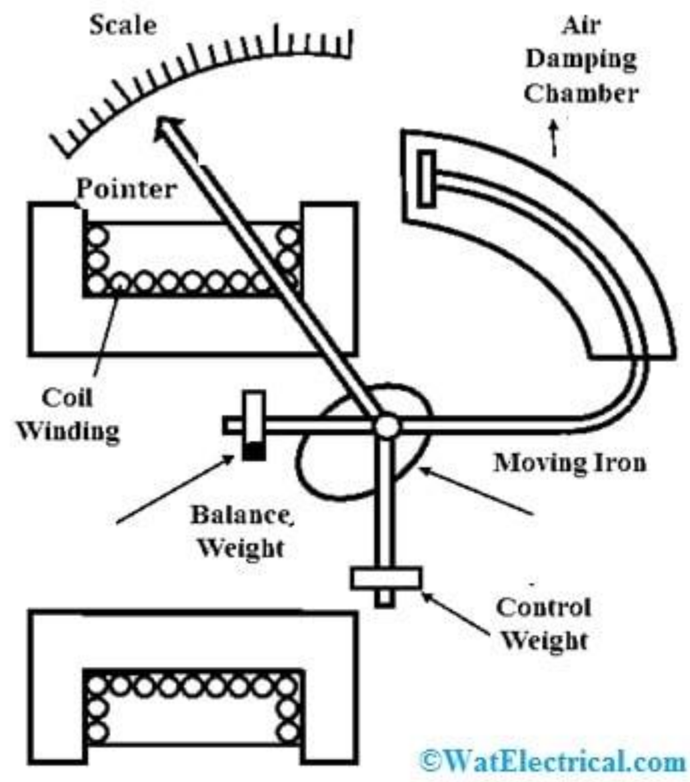
a) If a current carrying conductor is kept in between the poles of permanent magnet, then there will be a force of attraction or repulsion between wire and magnet.

If we made the wire in form of coil and placing it on the spindle as well as attaching a pointer to it, then it will give deflection on the scale on passage of current through the coil.



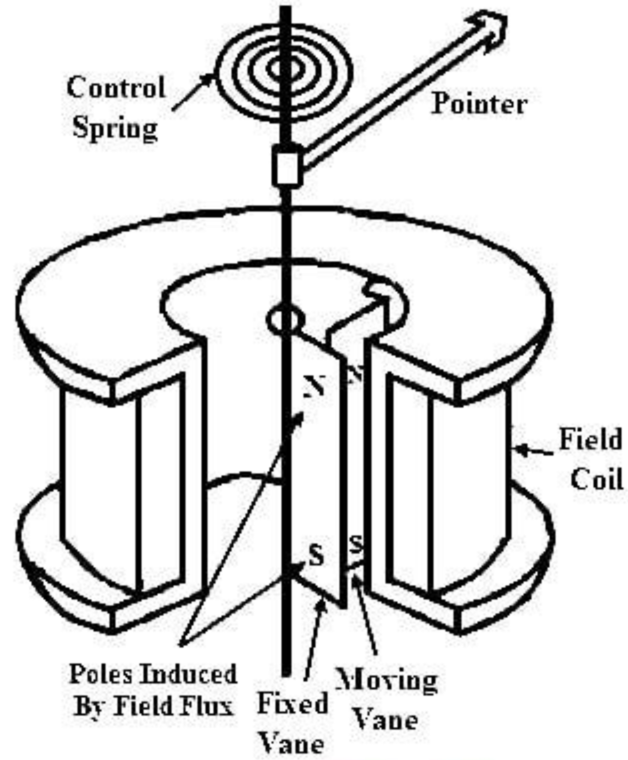
This principle is used in **Permanent Magnet Moving Coil (PMMC) Instruments.**

b) If a piece of soft iron is brought near the current carrying coil, then soft iron piece will be attracted by the coil. Attaching a pointer to the soft iron piece will give reading on the scale.

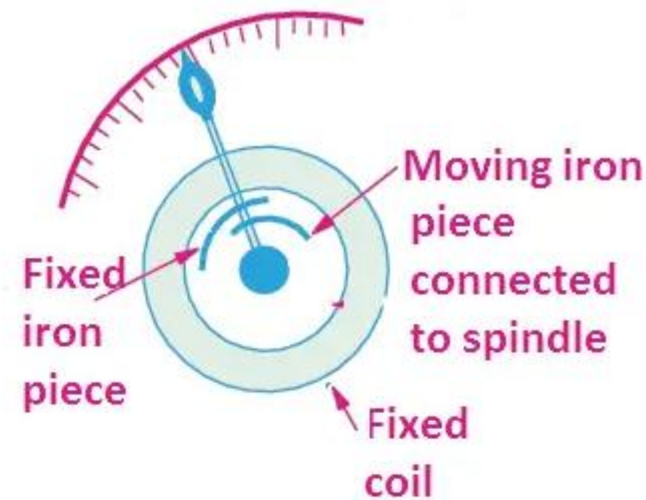


This principle is used in **Attraction type Moving Iron Instruments.**

c) If two soft iron pieces is placed near the coil, then there will be the force of repulsion between them. One iron piece is stationary while other is movable. Pointer is attached to the moving piece.



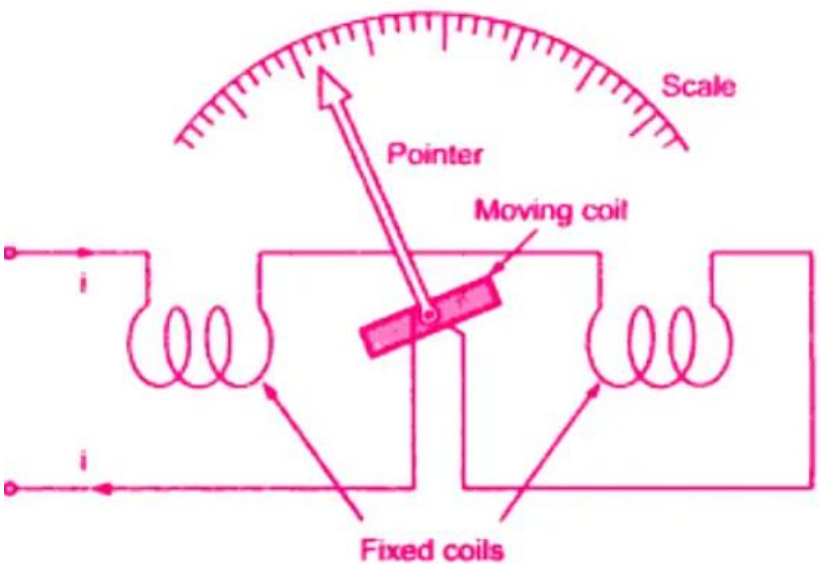
This arrangement gives the **Repulsion type Moving Iron Instrument.**



Repusion type instrument

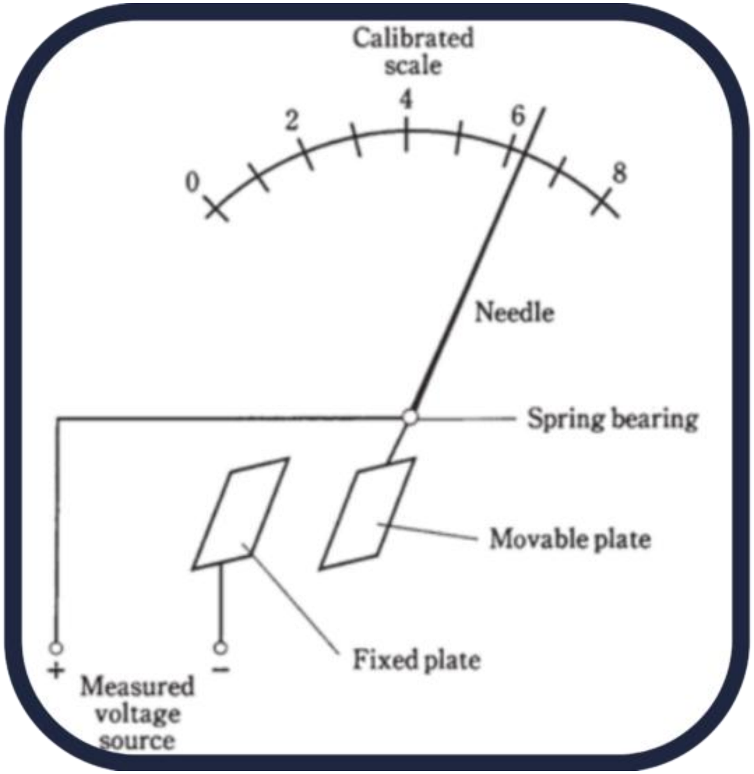
Electrodynamic Effect

- If two current carrying coils are taken, they will produce unlike pole near each other and thus there will be a force of attraction between them.
- One coil is fixed and other is free to move.
- Pointer is attached to the moving coil.
  Such instruments are called Electrodynamic Instruments.
- Generally wattmeter are constructed using this effect.



Electrostatic Effect

- Electrostatic force exists between two charged plates.
- One plate is fixed ,while other is movable and pointer is attached with the moving one.
- Note that only Voltmeters can be made by using this effect. Such voltmeter are called Electrostatic Voltmeter.



Induction Effect

- If a disc is placed in between the poles of an electromagnet , an emf is induced and hence an Eddy current is produced in the disc.
- As per Fleming's left hand rule, force will be exerted on the disc due to the interaction of eddy current and magnetic field of electromagnet. It makes the disc to rotate. A pointer is attached to the disc .
- This effect is utilized in ***energymeter.***
- Instruments using this effect cannot be used to measure dc quantities.

Thermal Effect

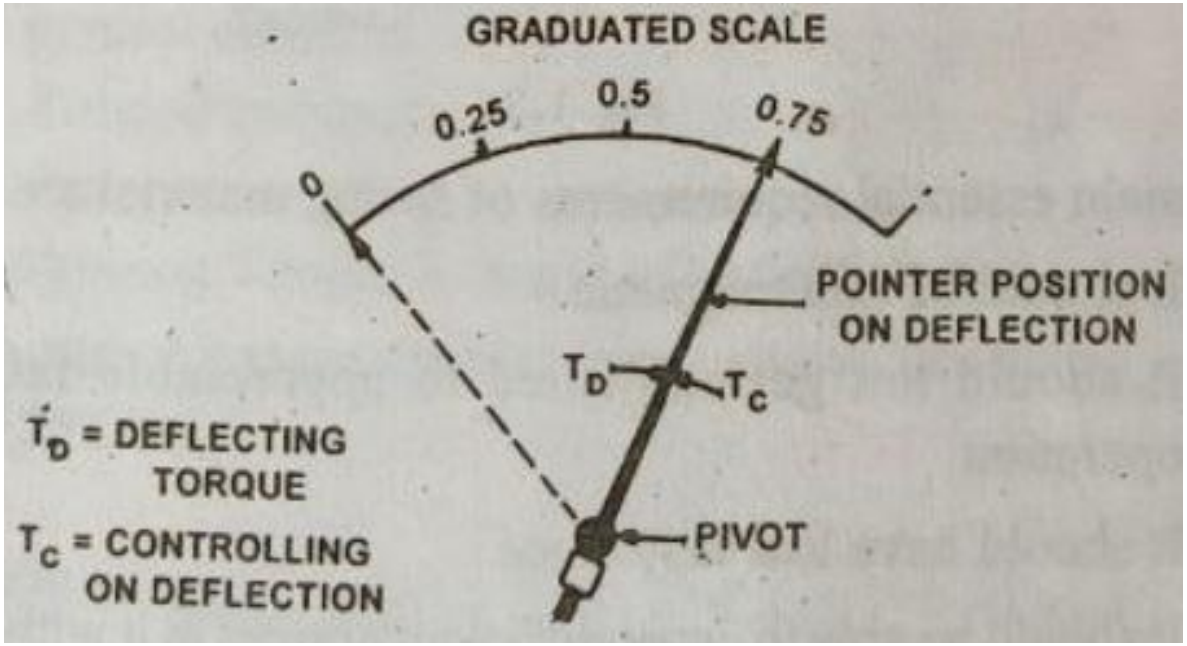
- If the current to be measured is passed through the coil, then heat is produced in the wire.
- As the wire heats up, it undergoes thermal expansion. The wire's length increases due to the higher temperature. This expansion can lead to mechanical stress in the wire.
- This stress causes the wire to change its shape, and this change in shape generates a torque and hence the deflection.
- Hot wire instrument is an example.

II. Controlling Torque

WHAT IS CONTROLLING TORQUE?

- This controlling torque opposes the deflecting torque.
- The deflection of the pointer will be indefinite and pointer will go on moving, if there is no controlling torque.
- Pointer will be at rest when controlling torque becomes equal to deflecting torque.

- Controlling torque acts in the opposite direction to the deflecting torque.
- In the absence of controlling torque, the pointer once deflected, would not return to zero position on the removal of the current.



There are two methods of providing controlling torque in the instrument.

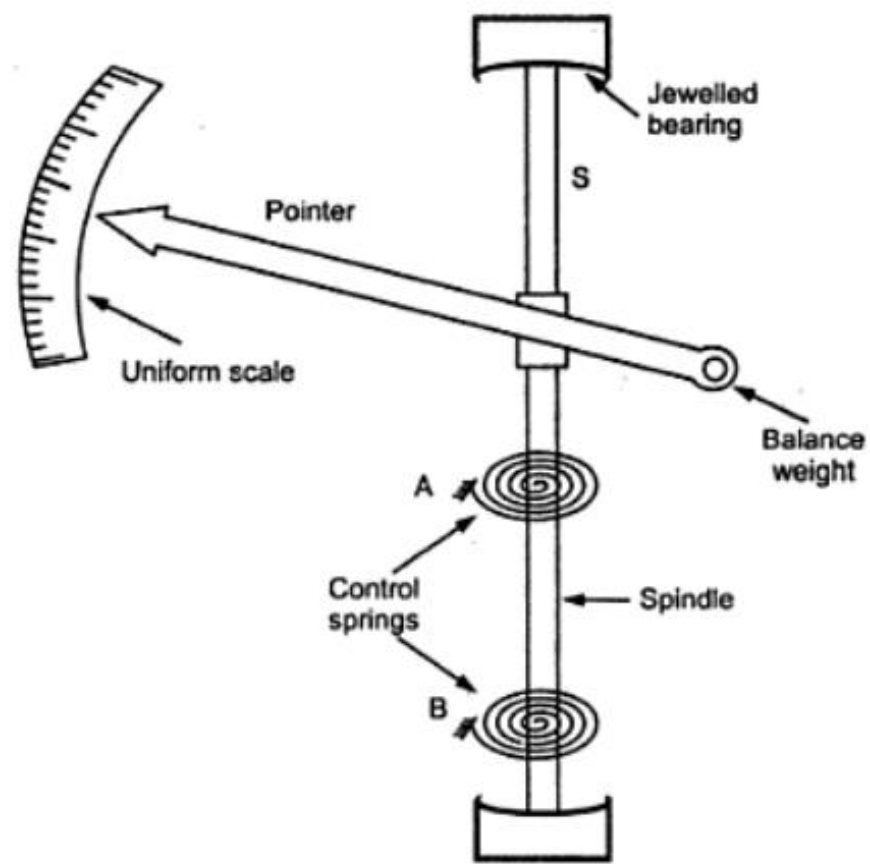
1. Spring Control. (common)

2. Gravity Control. (rare)

1.SPRING CONTROL

- In this method, two springs made up of **phosphor bronze** are used.
- One spring is placed above while other spring is placed below the spindle of the instrument.
- One end of each spring is attached to the spindle and its other end is attached to the fixed part of the instrument.

Arrangement for Spring Control Method.

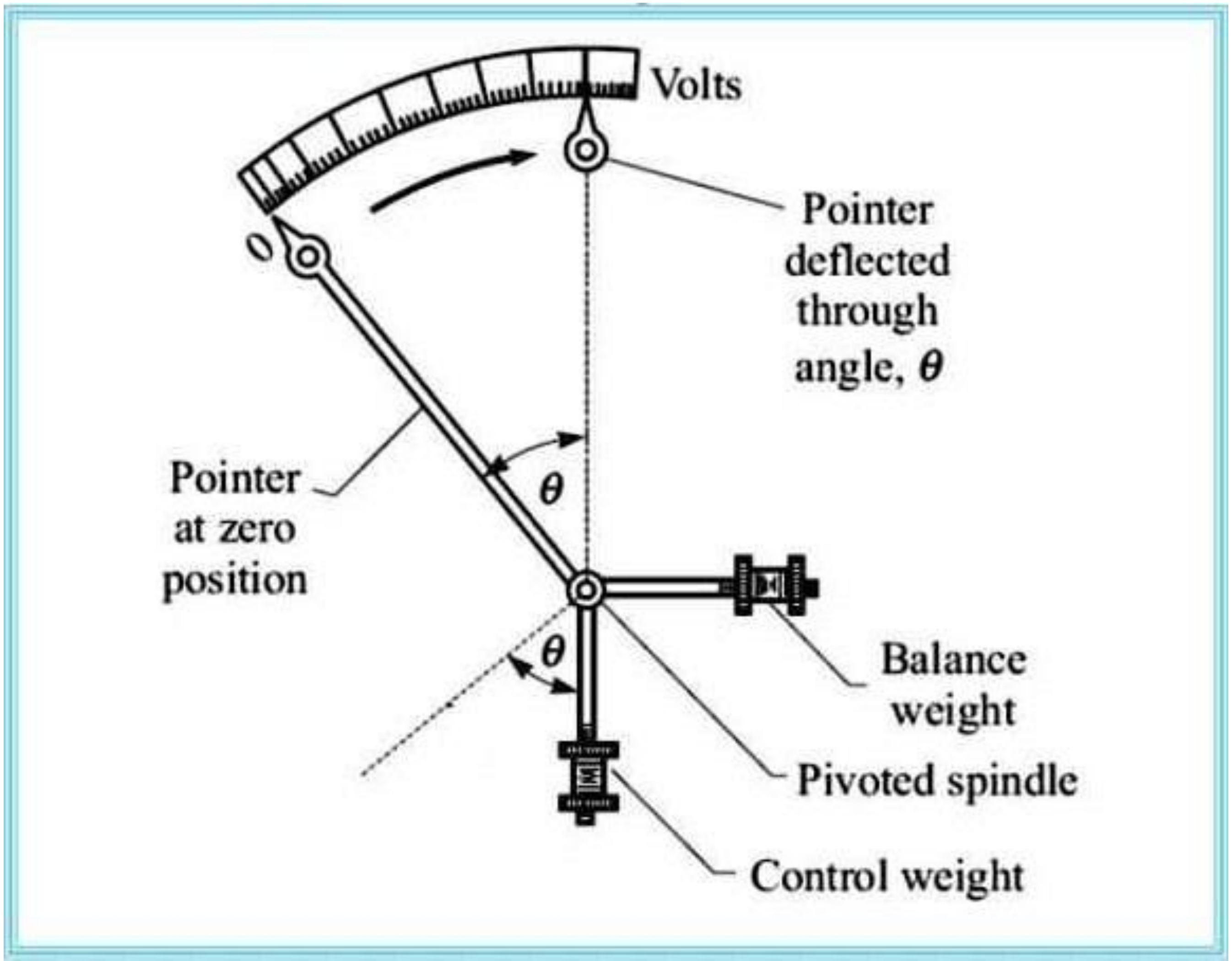


- When the instrument is not in use, the springs are in their natural conditions and the controlling torque is zero.
- When the instrument is used to measure any electrical quantity then a deflecting torque is produced, and then pointer moves and the spring gets twisted.
- This twist produces the controlling torque.
- The twist goes on increasing with the increase in the deflection of pointer and so does the controlling torque.
- Position comes when the deflecting torque becomes equal to the controlling torque and pointer stops.

$$T_c \propto \theta$$

2. GRAVITY CONTROL METHOD

- In this method, natural downward pull due to gravity is employed.
- A small weight "W" is attached to the moving system


Volts
Pointer deflected through angle, θ
Pointer at zero position
θ
θ
Balance weight
Pivoted spindle
Control weight

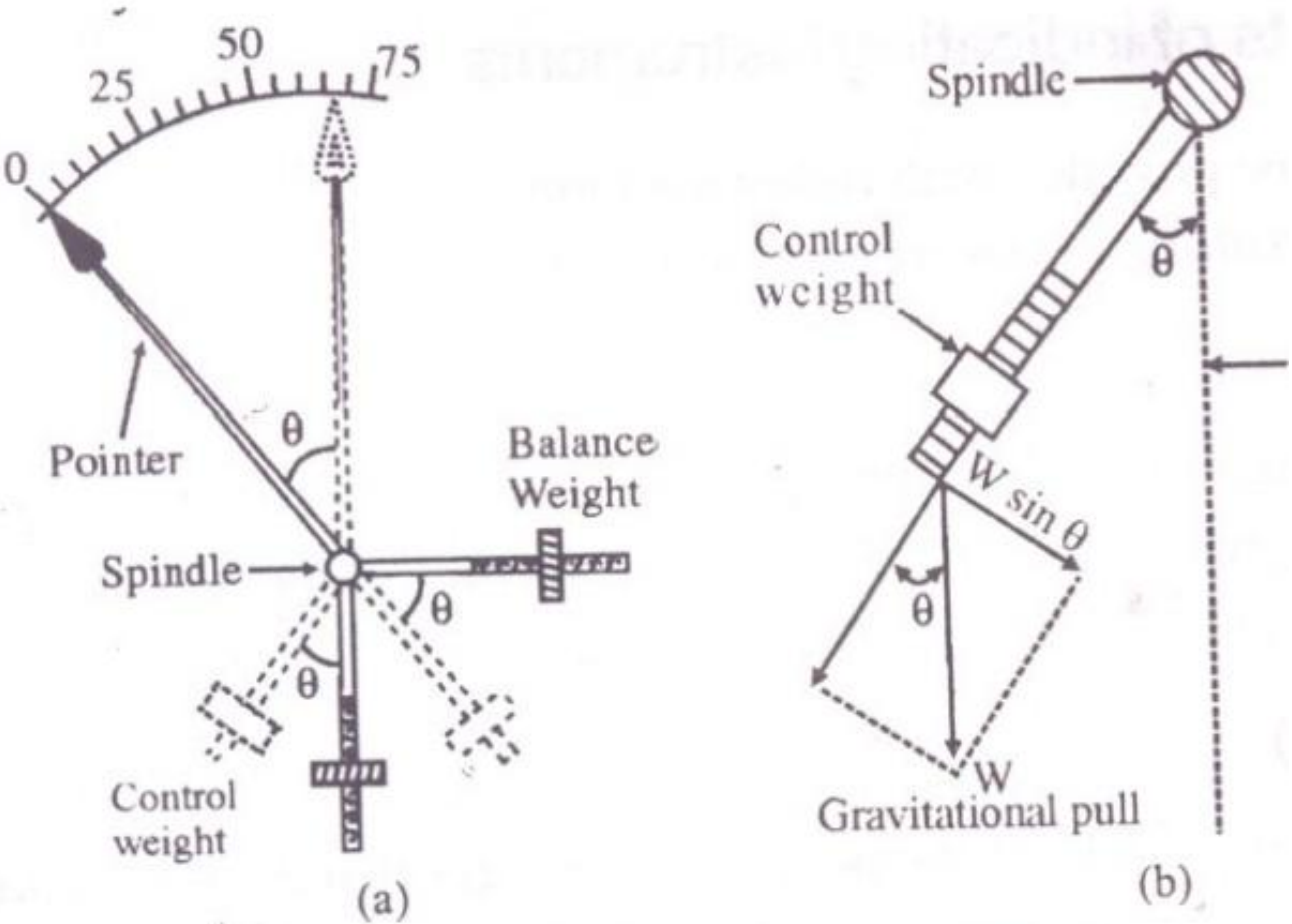


Fig.4.2 Gravity Control Method.

- At the zero position of the pointer, the control weight **W** is in the vertical position and therefore no controlling torque is produced
- under the action of the deflecting force, the pointer moves from its zero position.
- As shown in the figure, as pointer moves weight will also move.
- But due to gravity, the control weight would try to come back to its original vertical position and hence produces the necessary controlling torque.

$$T_c \propto \sin\theta$$

Comparison

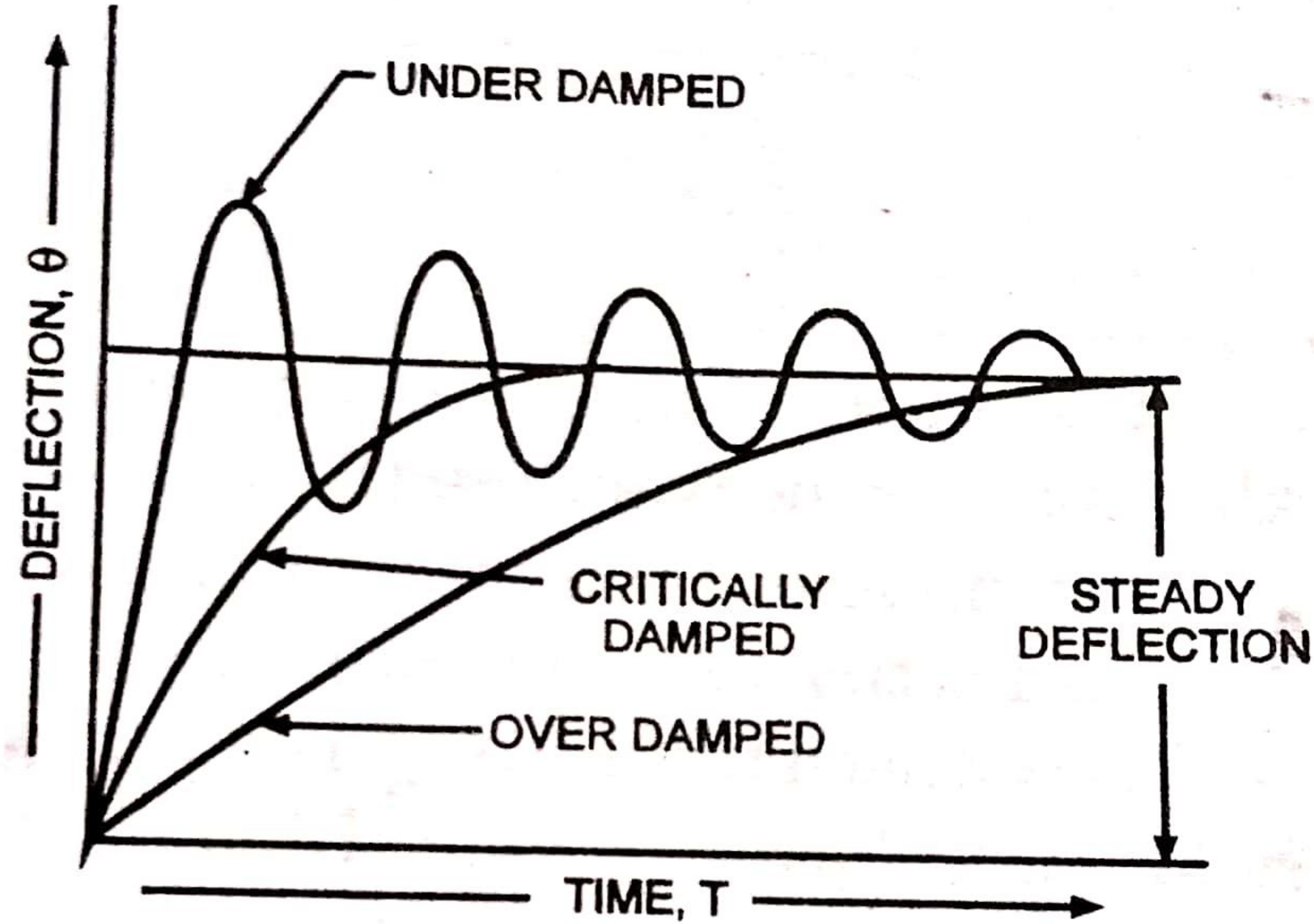
	Spring control	Gravity control
Control torque	T_c α θ	T_c α sinθ
Scale	Uniform	Cramped at the beginning and at the end
Mounting	Any position	Vertical only
Cost	Costly	Cheap

III. Damping Torque

- Damping force in any electrical instrument is necessary because it brings the pointer at rest quickly.

- In the absence of damping force, due to inertia of the moving system, the pointer will oscillate about its final position for some time before coming to rest.

- Absence or improper damping in any instrument makes the process of measurement from the instrument slow.


UNDER DAMPED
DEFLECTION, θ
CRITICALLY
DAMPED
STEADY
DEFLECTION
OVER DAMPED
TIME, T

- The degree of damping is adjusted in such a way that it makes the pointer to deflect to the final position without overshooting the final value.
- Such type of damping is known as critical damping.
- In practice the results are obtained when the damping is slightly less than critical value.
- Increase in damping above the limit is called over damping which will make the instrument slow

METHODS OF PRODUCING DAMPING FORCE/TORQUE

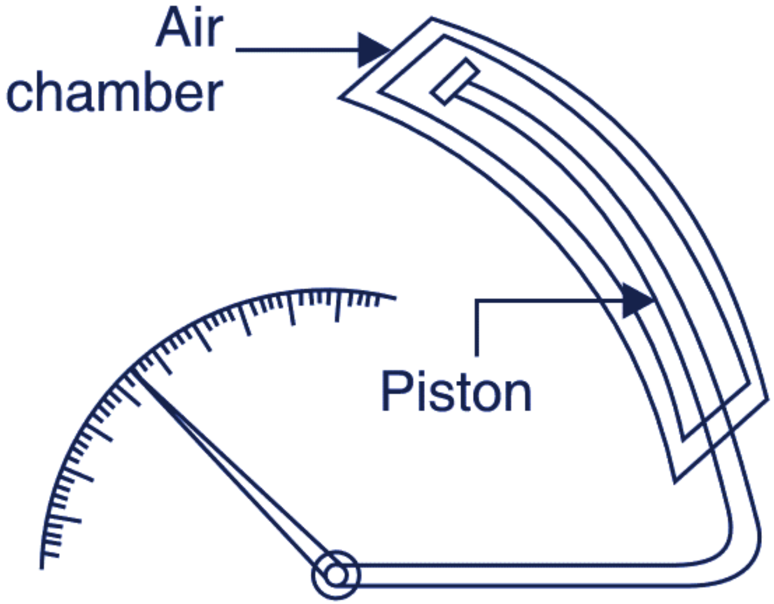
1. **Air friction damping**

2. **Fluid Friction damping**

3. **Eddy current damping**

Air friction damping

- It consists of a piston attached to the moving system of instrument.
- This piston is placed in a chamber which is closed at one end.
- The cushioning action of the air on the piston damps out any tendency of the pointer to oscillate about the final deflected position


Air
chamber
Piston

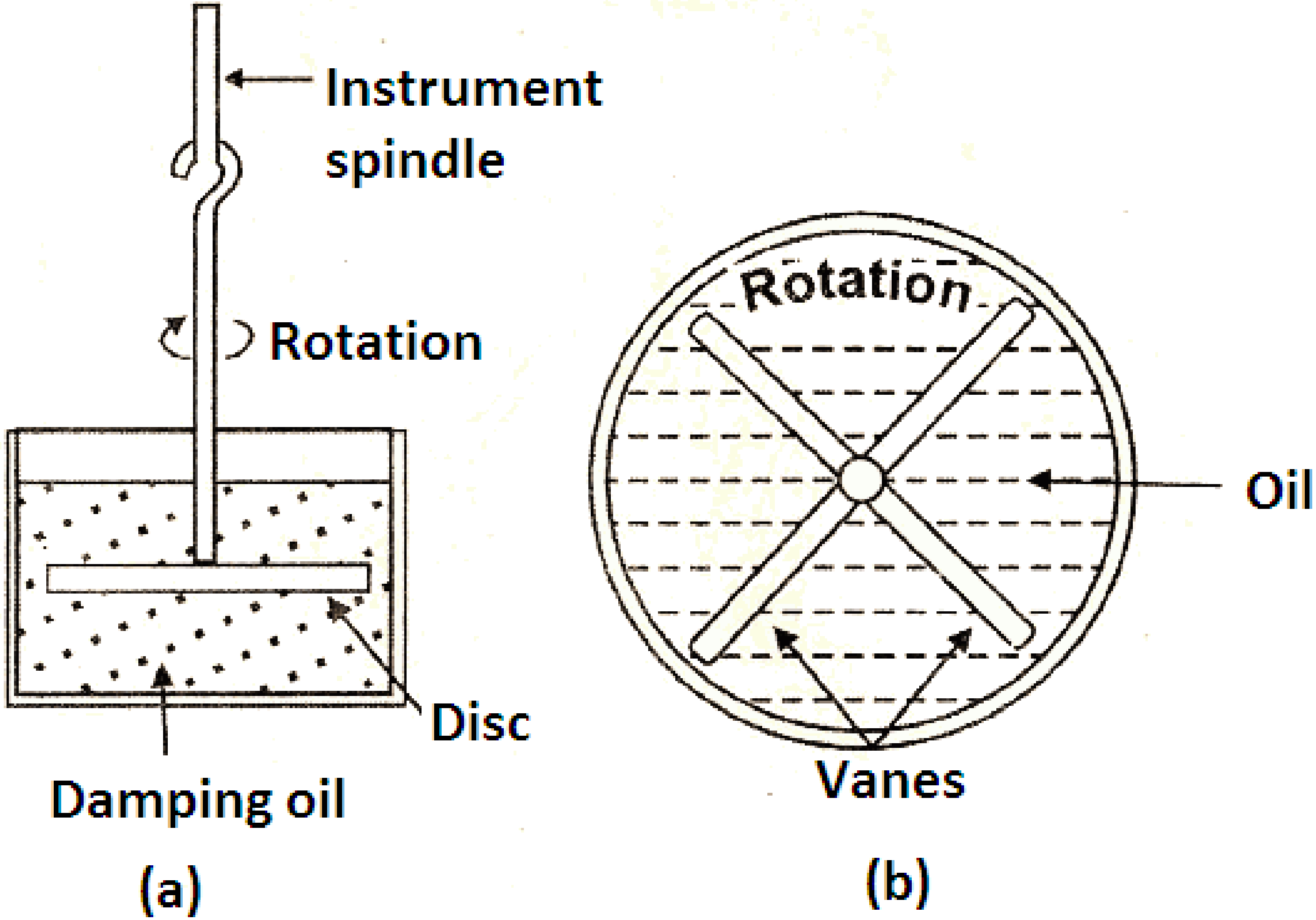

Air Chamber
Piston
Pointer
Spindle

Fluid Friction damping

- It is similar to the air friction .
- In this method, disc attached to the spindle of the moving system is kept immersed in a pot containing oil of high viscosity.
- As the pointer moves, the friction between the oil and disc opposes the motion of the pointer and thus necessary damping is provided.

- Due to greater viscosity of oil, the damping is much effective than air friction.

- However, oil damping is not much used because of several disadvantages such as **leaking of oil, keeping instrument in vertical position, not portable etc.**

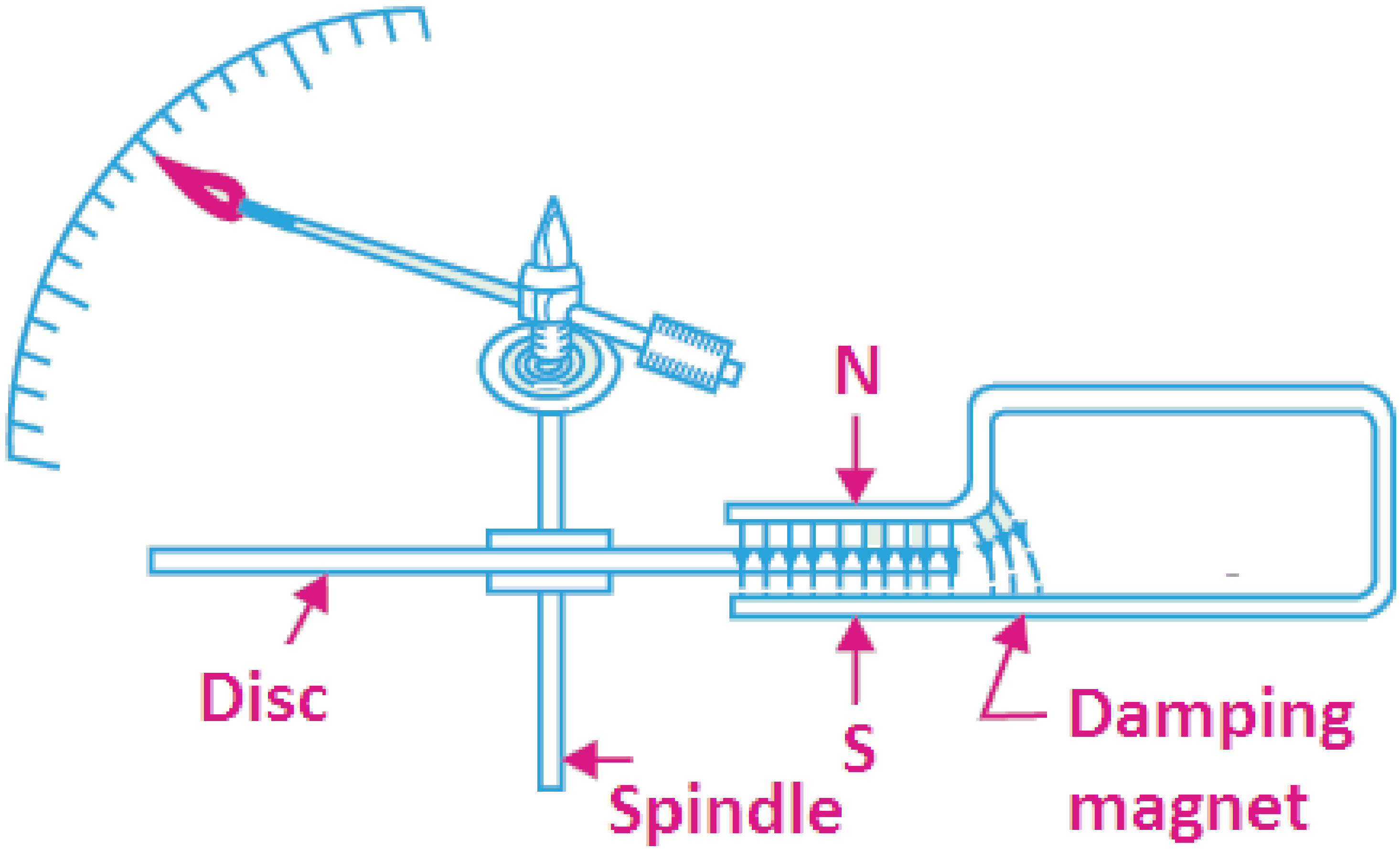


Fluid friction damping

Eddy Current damping

- This form of damping is the most efficient of the three.
- A thin aluminum or copper disc is attached to the spindle allowed to move between the poles of a permanent magnet.
- As the pointer moves, the disc cuts across the magnetic field and eddy currents are induced in the disc.

- These eddy currents react with the field of the magnet to produce a damping force which opposes the motion according to Lenz’s Law.
- Eddy current damping is commonly used


N
Disc
S
Damping
magnet
Spindle

PMMC (Permanent Magnet Moving Coil) instrument

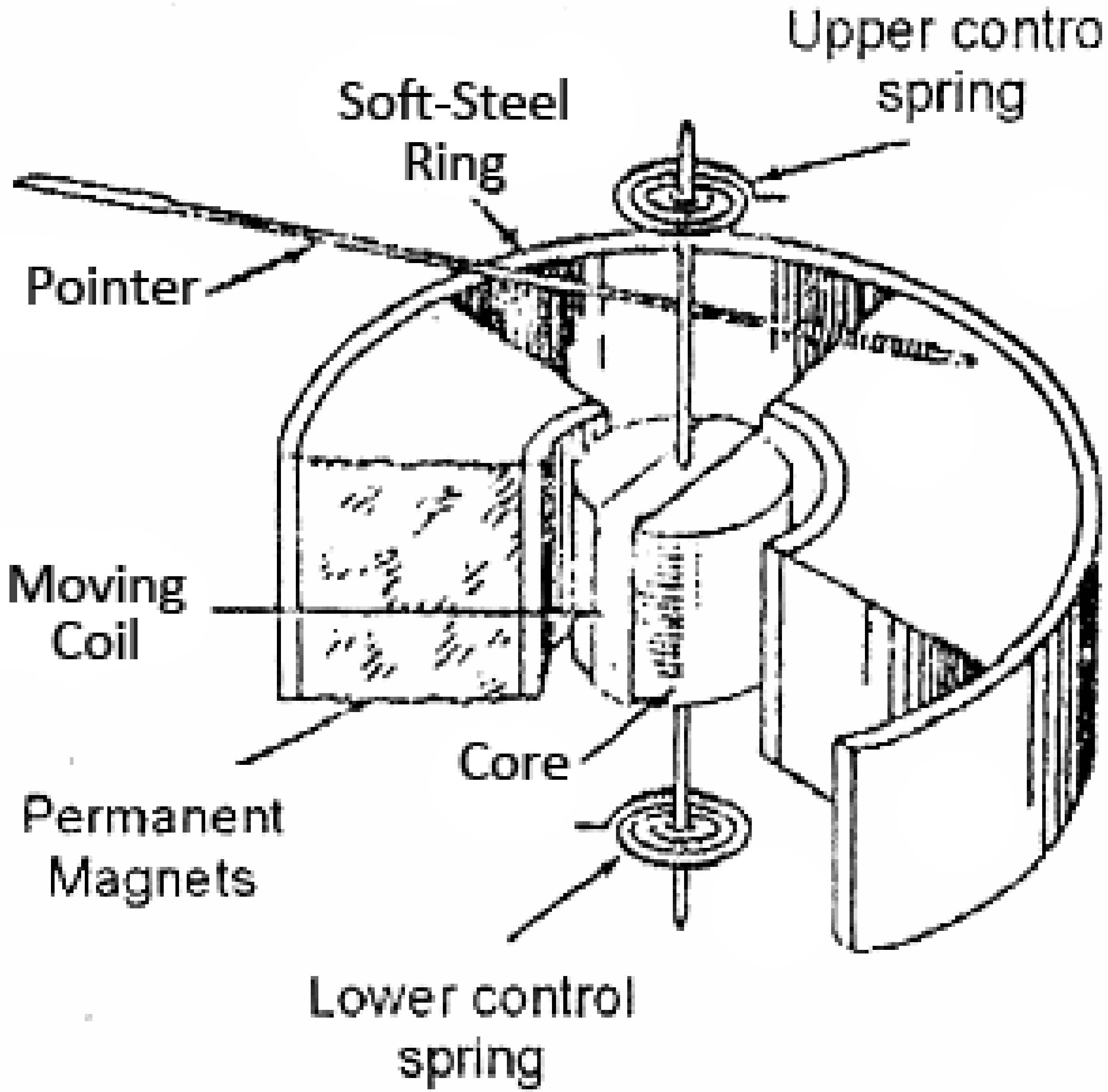
- The PMMC instrument working is similar to the motor working.
- These instruments use permanent magnets to create the stationary magnetic field in the coils.
- Then it is used with the moving coil that is connected to the electric source for generating deflection torque according to the Fleming left-hand rule theory.
- Whenever a current carrying conductor is located within a magnetic field, then it experiences a force that is perpendicular to the current & the field. Based on the rule of “Fleming left hand”.

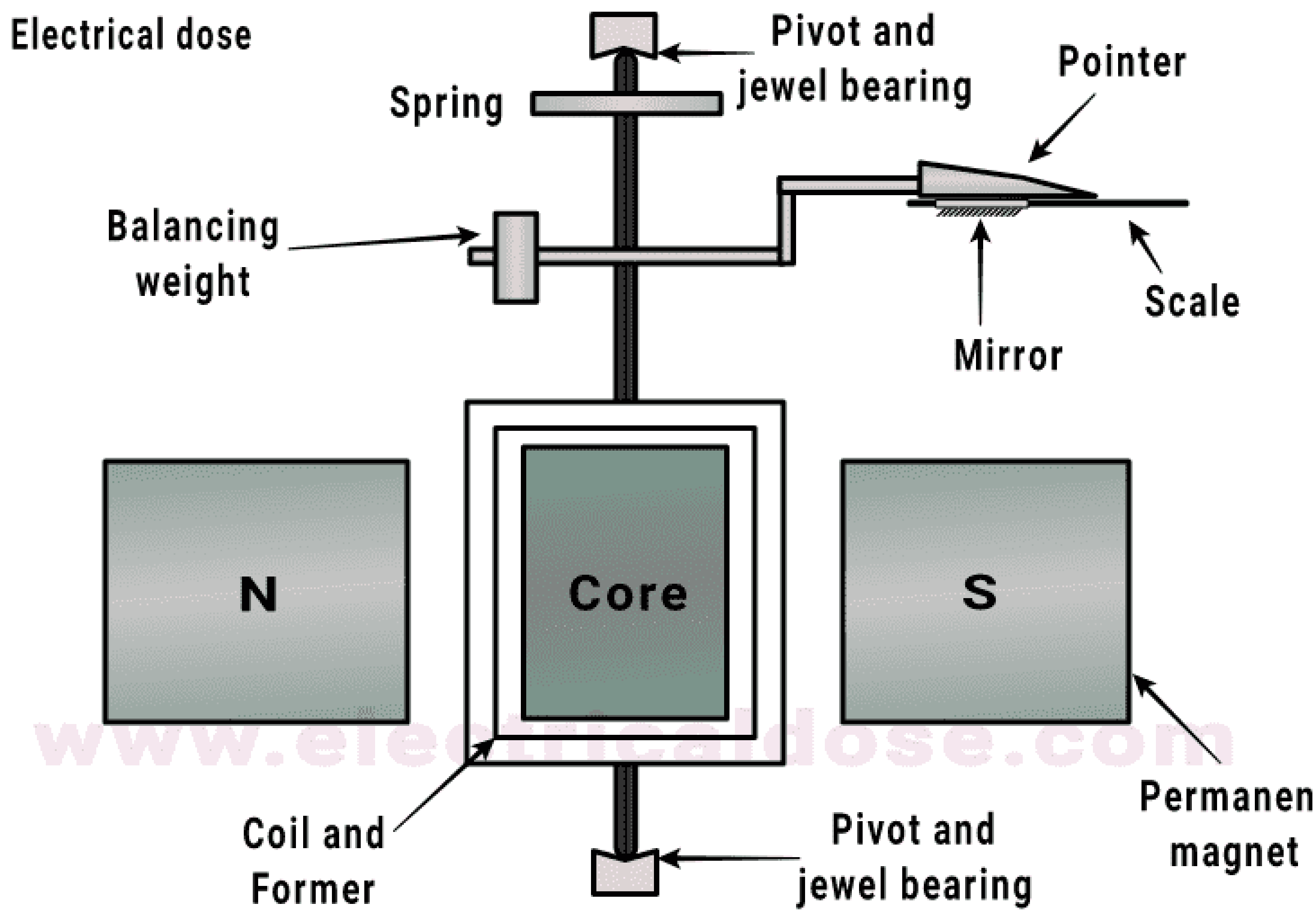
Construction of PMMC Instruments

PMMC Construction

Components

- Magnet System
- Moving System
- Control Spring
- Damping System
- Pointer & Scale


Upper control spring
Soft-Steel Ring
Pointer
Moving Coil
Core
Permanent Magnets
Lower control spring


Electrical dose
Pivot and
jewel bearing
Pointer
Spring
Balancing
weight
Scale
Mirror
N
Core
S
www.electricaldose.com
Coil and
Former
Pivot and
jewel bearing
Permanen
magnet

Magnet System

- The PMMC instrument uses the permanent magnet for creating the magnetic field.
- Magnet materials with high field strength is used.

  Eg: Alnico

Moving System

- Consist of coils wound on a rectangular aluminium frame (former).
- This aluminium frame is placed on a soft iron core to increase the flux linkage.
- The coil is the current carrying part of the instruments which is freely moved between the stationary field of the permanent magnet.

Control Spring

- The controlling torque is provided by two phosphorous bronze flat coiled helical springs. These springs serve as a flexible connection to the coil conductors.
- These springs are arranged among the two jewel bearings. These springs are responsible for producing controlling torque.

Damping

- The damping torque is used for avoiding the oscillations in the final position.
- Eddy current damping is used in PMMC.
- This damping torque is induced because of the movement of the aluminium frame, which is moving between the poles of the permanent magnet.

Pointer and scale

- The pointer is connected to the moving coil.
- The pointer moves on a scale according to the deflection of the coil.
- The pointer is made of lightweight material
- In PMMC, scale is uniform

Working of PMMC

PRINCIPLE:

A current carrying conductor placed in a magnetic field produces torque.

- When PMMC is connected in a circuit, current flows through the coil.
- When current flows through the coil, a magnetic field is produced around the coil.
- This magnetic field interacts with the magnetic field of the permanent magnet and hence deflection torque is produced.
- Thus the pointer attached to the spindle is deflected over the scale.

- The PMMC instruments are used only for the direct current. (DC)
- The alternating current (AC) varies with the time.
- The rapid variation of the current varies the torque of the coil.
- But the moving system (core, coil, spindle and pointer) can not follow the fast reversal of the torque due to inertia. Thus, it cannot be used for AC.

Torque equation

Deflecting Torque, $T_d = NIAB$

N = number of turns of coil.

I = current passing through the coil.

A= area of the coil.

B = flux density.

$$T_d \alpha\, I$$

- Since spring control is used, controlling torque is proportional to the angle of deflection

$$T_c \propto \theta$$

- At final position, $T_d = T_c$

  ➔ $\theta \propto I$

Deflection is proportional to current.

Hence PMMC has uniform scale.

ADVANTAGES OF PMMC INSTRUMENT

- They have low power consumption.
- Such instruments have uniform scale.
- The PMMC instruments have high accuracy because of the high torque weight ratio.
- They have very effective and efficient Eddy current damping.
- Range can be easily extended.
- Can be used to measure both I & V. (for voltage measurement, current flowing through the coil is proportional to the voltage to be measured.)

Disadvantages of PMMC

- These instruments cannot measure AC quantities.
- The cost of these instruments is high as compared to moving iron instruments.

- For current measurement, coil of few turns of thick wire is used ➔ for low resistance ➔ to carry large current.
- For voltage measurement, coil of large number of turns of thin wire is used ➔ for high resistance ➔ to draw small current.

Construction and working of Moving Iron (MI) instruments

Types

- Attraction type moving iron instruments.
- Repulsion type moving iron instruments.

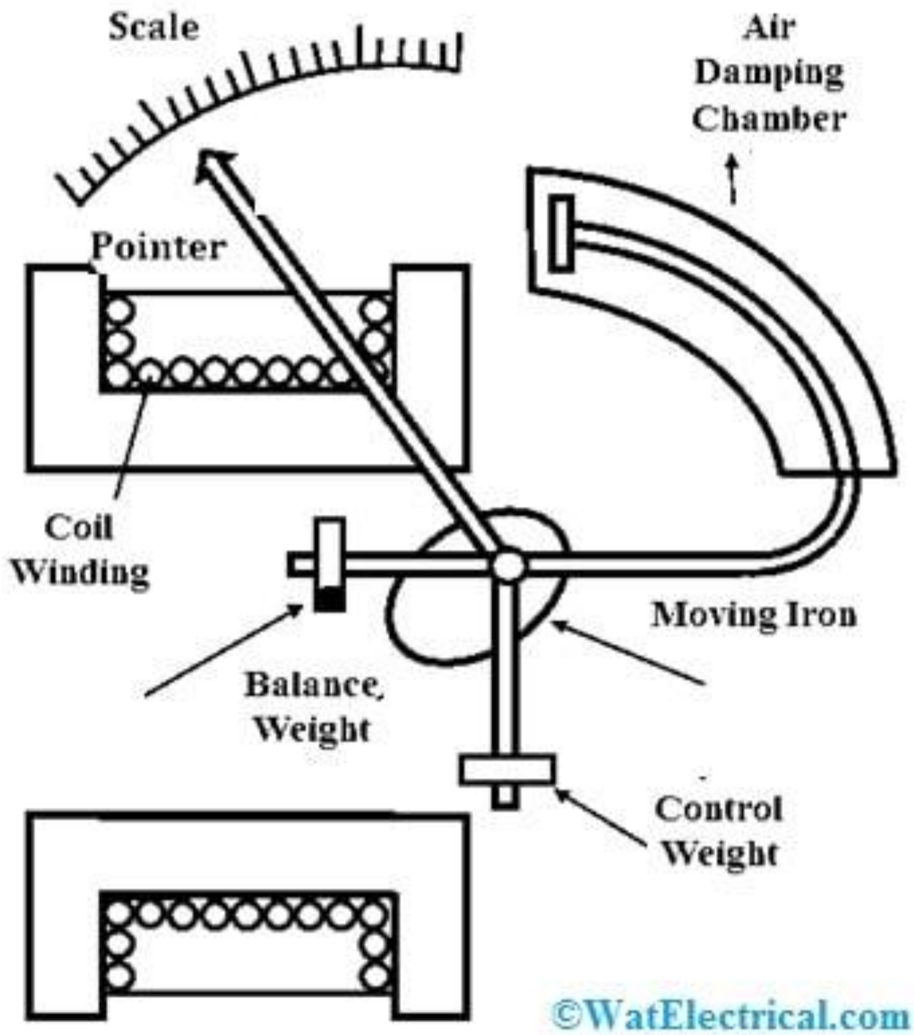
Attraction Type Moving Iron Instrument

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

- This is because the iron tries to occupy a position of minimum reluctance.

- Thus, a force is exerted on the soft iron piece and deflection in the needle takes place.

Construction



- An attraction type moving iron instrument consists of stationary coils.
- An oval shaped soft iron piece is connected to the spindle to which a pointer is attached.
- Controlling torque can be provided by gravity or spring.
- Damping torque is provided by air friction damping. (Eddy current damping is not possible in MI instruments).

Deflecting torque ,$T_d \alpha\, I^2$

- since the deflection toque is proportional to the square of the current, change in the direction of current will not change the direction of deflection torque.
- Hence, the direction of deflecting torque remains unchanged.
- **Thus *attraction type moving iron instruments* can be used on AC as well as on DC systems. It measures RMS value of AC.**

Controlling torque, $T_c \alpha \theta$ (for spring control)

At final position, $T_d = T_c$

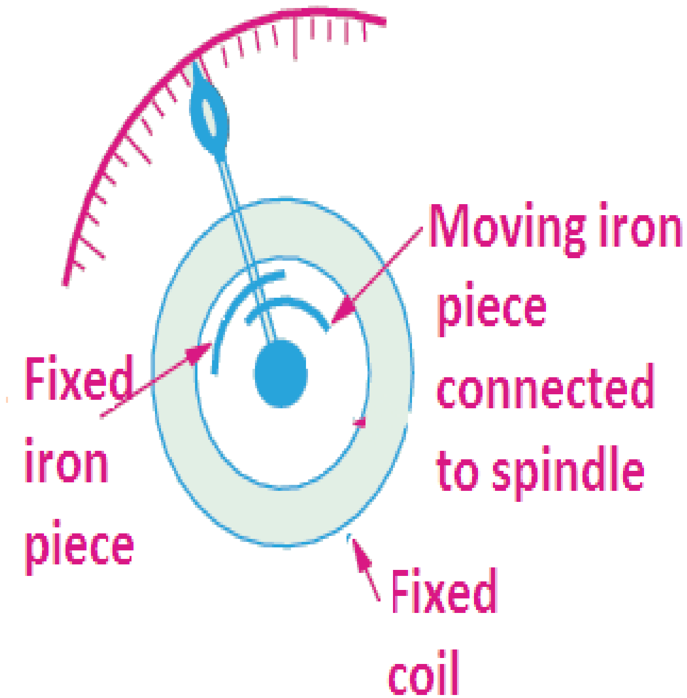
➔ $\theta \alpha I^2$

Since deflection θ is proportional to the square of current flowing through the coil, the scale of MI instrument is non-uniform, being crowded in the beginning.

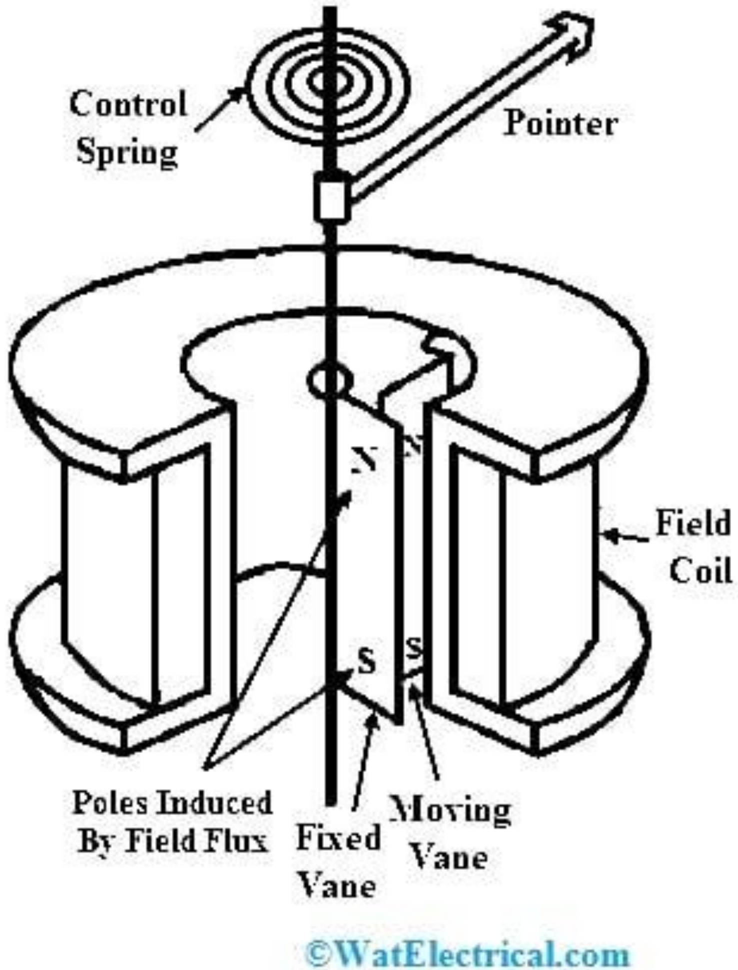
Repulsion type

The basic principle of a *repulsion type moving iron instruments* is that the repulsive forces will act when two similarly magnetized iron pieces, are placed near each other.

Construction



Repusion type instrument



- It consists of a fixed coil which carries the operating current.
- Inside the coil, there are two soft iron pieces placed parallel to each other.
- One soft iron piece is fixed and the other is movable.
- Movable piece is connected to the spindle.
- A pointer is attached to the spindle which gives deflection on the scale.
- The controlling torque can be provided by spring control or gravity control.
- Damping torque is provided by air friction.

Working

- When the instrument is connected in the circuit, the operating current flows through the coil.
- A magnetic field is setup around the coil, this field magnetizes both the pieces similarly i.e. both the pieces attain similar polarities.
- A force of repulsion acts between the two, therefore movable piece moves away from the fixed piece.
- Thus the pointer attached to the spindle deflects over the scale.

- If the current in the coil is reversed, the direction of magnetic field produced by the coil is reversed.
- Though the polarity of the magnetized soft iron pieces is reversed still they are magnetized similarly and repel each other.
- Hence, the direction of deflecting torque remains unchanged.
- **Thus, repulsion type moving iron instrument can be used on DC as well as on AC systems.**

- The moving iron instruments are mainly used for AC measurements.
- They also can measure DC quantities but their **characteristics are inferior to that of permanent moving coil instruments.**
- Therefore, for DC measurements permanent moving coil instruments are preferred and used.

Advantages of Moving Iron Instruments

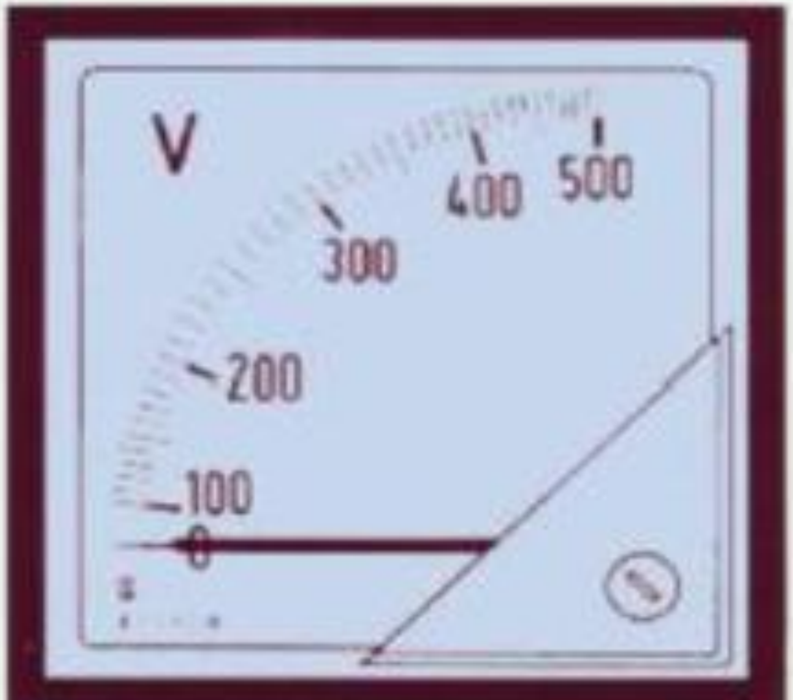
- The moving iron instruments are cheap, robust and simple in construction.
- These instruments can be used for both AC and DC.
- These instruments are reasonably accurate. (But accuracy is less than that of PMMC).
- The moving iron instruments have high operating torque.
- These instruments can withstand momentarily overloads.

Disadvantages

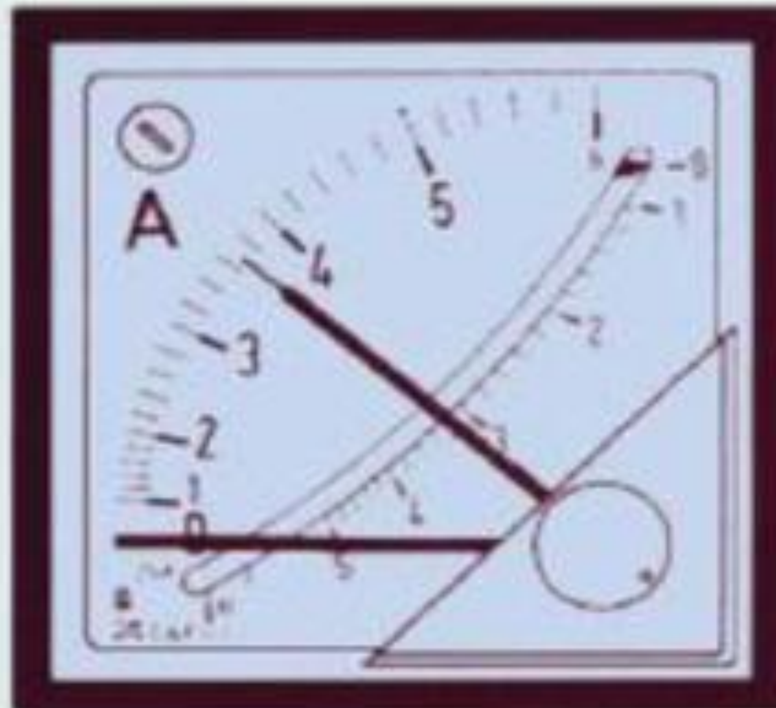
- The moving iron instruments have non-uniform scale.
- These instruments are not very sensitive compared to PMMC.
- Power consumption is high in the moving iron instruments.
- Errors are introduced due to change in frequency. (Instruments are designed for a particular frequency).

Comparison of PMMC and MI

No	PMMC	MI
1	Coil moves in the magnetic field.	Coil is fixed. Soft iron moves in the magnetic field.
2	Deflection torque is proportional to the current.	Deflection torque is proportional to the square of the current.
3	Eddy current damping is used.	Air friction damping is used.
4	Spring control	Spring or Gravity control.
5	Scale is uniform.	Scale is non-uniform
6	Low power consumption.	High compared to PMMC.
7	Costly	Cheap.
8	Only for DC	For DC and AC
9	Highly sensitive	Less sensitive compared to PMMC.
10	High accuracy	Accuracy is OK, but less than PMMC.



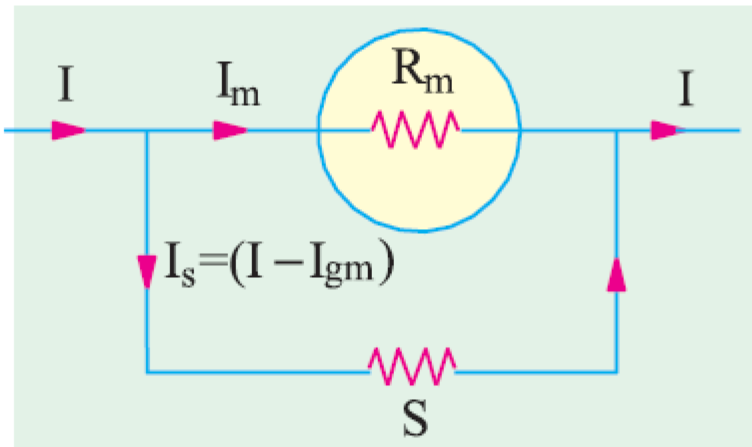
Moving iron voltmeter



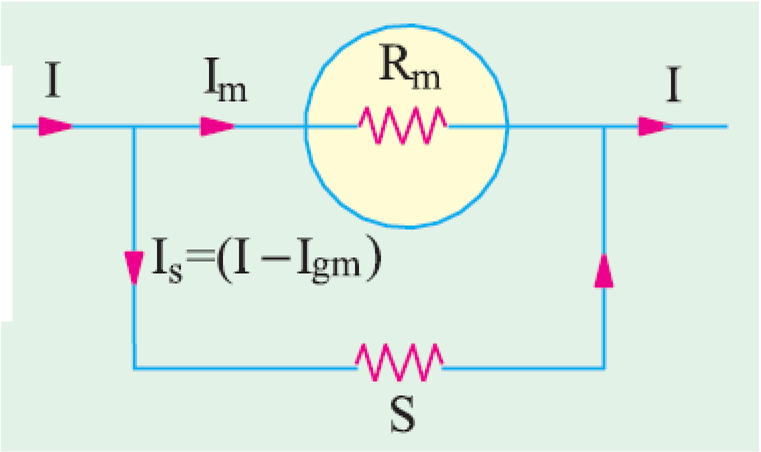
Moving iron ammeter

Extension of Range of MC instruments

- ***(i) As Ammeter***
- When such an instrument is used as an ammeter, its range can be extended with the help of a **low resistance shunt**.
- This shunt provides a bypath for extra current because it is connected *in parallel with instrument.*
- *These shunted instruments can be made to* record currents many times greater than their normal full-scale deflection currents.
- The ratio of maximum current (with shunt) to the full-scale deflection current (without shunt) is known as the 'multiplying power' or 'multiplying factor' of the shunt.



Extension of Range of MC instruments



R_m = instrument resistance
S = shunt resistance
I_m = full-scale deflection current of the instrument
I = line current to be measured

$$\therefore \quad I_m \times R_m = S\,I_s = S\,(I - I_m)$$

$$\therefore\ S = \frac{I_m R_m}{(I - I_m)}\ ;\ \text{Also}\ \frac{I}{I_m} = \left(1 + \frac{R_m}{S}\right)$$

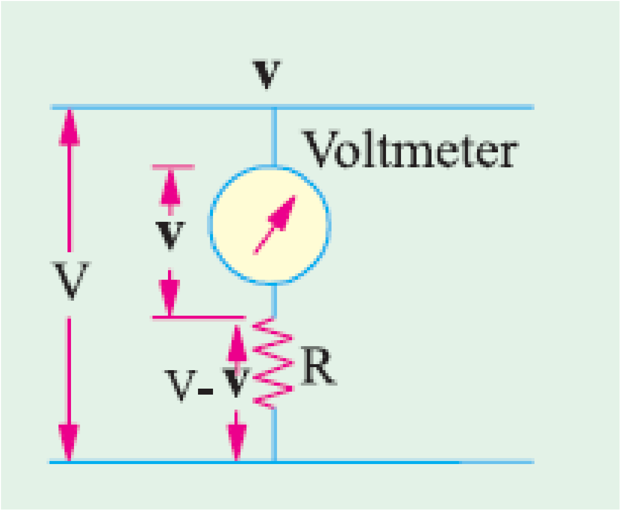
$$\therefore \qquad \text{multiplying power} = \left(1 + \frac{R_m}{S}\right)$$

- lower the value of shunt resistance, greater its multiplying power.

Extension of Range of MC instruments

(ii) As voltmeter

- The range of this instrument when used as a voltmeter can be increased by using a high resistance in series with it. **(Multiplier)**



I_m = full-scale deflection current

R_m = galvanometer resistance

v = $R_m I_m$ = full-scale p.d. across it

V = voltage to be measured

R = series resistance required

Extension of Range of MC instruments

Then it is seen that the voltage drop across R is $V - v$

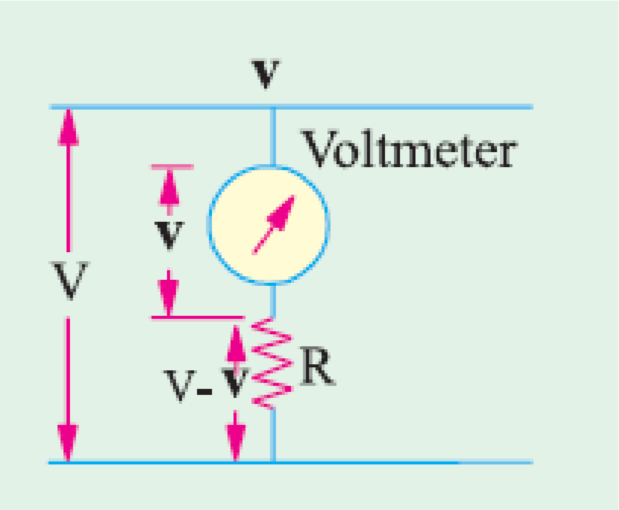
$$\therefore \quad R = \frac{V - v}{I_m} \text{ or } R \cdot I_m = V - v$$

Dividing both sides by v, we get

$$\frac{RI_m}{v} = \frac{V}{v} - 1 \quad \text{or} \quad \frac{R \cdot I_m}{I_m R_m} = \frac{V}{v} - 1$$

$$\therefore \quad \frac{V}{v} = \left(1 + \frac{R}{R_m}\right)$$

$$\therefore \quad \text{voltage multiplication} = \left(1 + \frac{R}{R_m}\right)$$



•Obviously, larger the value of *R, greater the voltage multiplication or range.*

Extension of Range of MC instruments

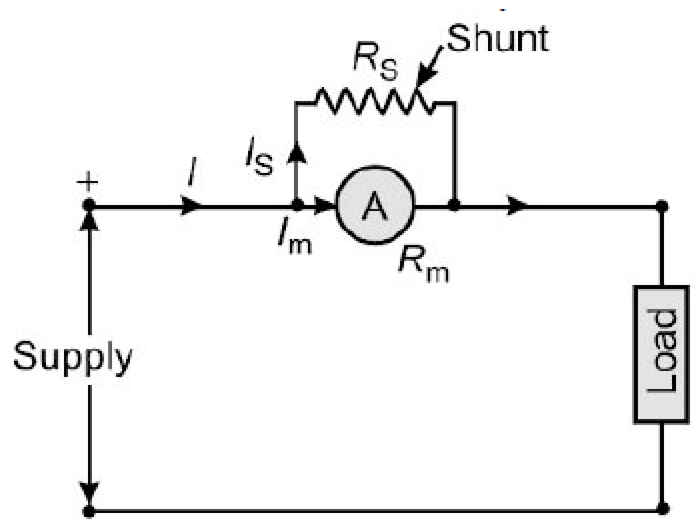
- An ammeter having full scale deflection of 0 to 5~~0~~ 5 A and internal resistance of 2Ω.Find out the value of shunt resistance required to extend the range of meter to 50A.

Hint:

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

$$= 5*4/45$$

$$R_{sh} = 0.22\Omega$$



Extension of Range of MC instruments

Example 10.8. *A moving coil ammeter has a fixed shunt of 0.02 Ω with a coil circuit rtesistance of R = 1 kΩ and need potential difference of 0.5 V across it for full-scale deflection.*

(1) *To what total current does this correspond ?*

(2) *Calculate the value of shunt to give full scale deflection when the total current is 10 A and 75 A.* **(Measurement & Instrumentation Nagpur Univ. 1993)**

Solution. It should be noted that the shunt and the meter coil are in parallel and have a common p.d. of 0.5 V applied across them.

(1) $\therefore I_m = 0.5/1000 = 0.0005$ A; $I_s = 0.5./0.02 = 25$ A

$\therefore$ line current = **25.0005 A**

(2) When total current is 10 A, $I_s = (10 - 0.0005) = 9.9995$ A

$$\therefore \quad S = \frac{I_m R_m}{I_s} = \frac{0.0005 \times 1000}{9.9995} = 0.05\ \Omega$$

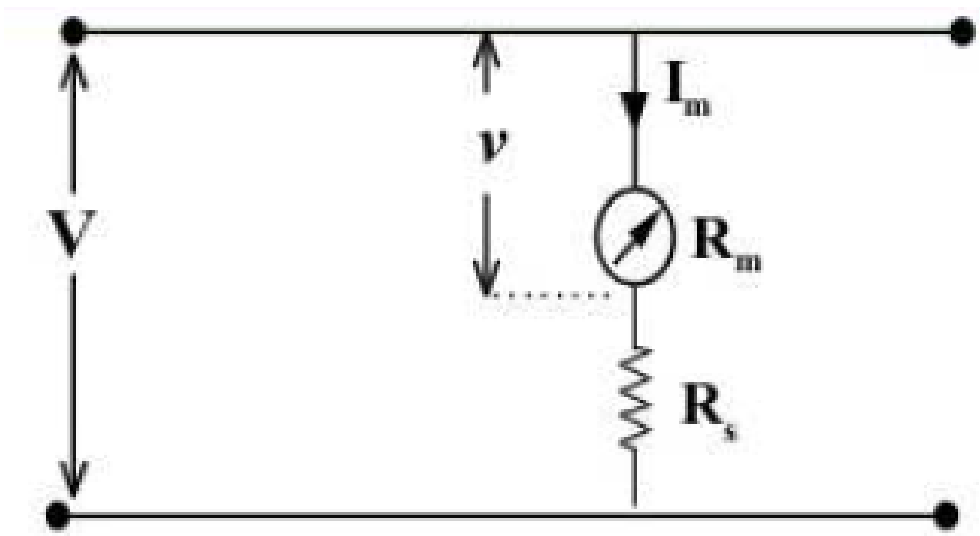
When total current is 75 A, $I_s = (75 - 0.0005) = 74.9995$ A

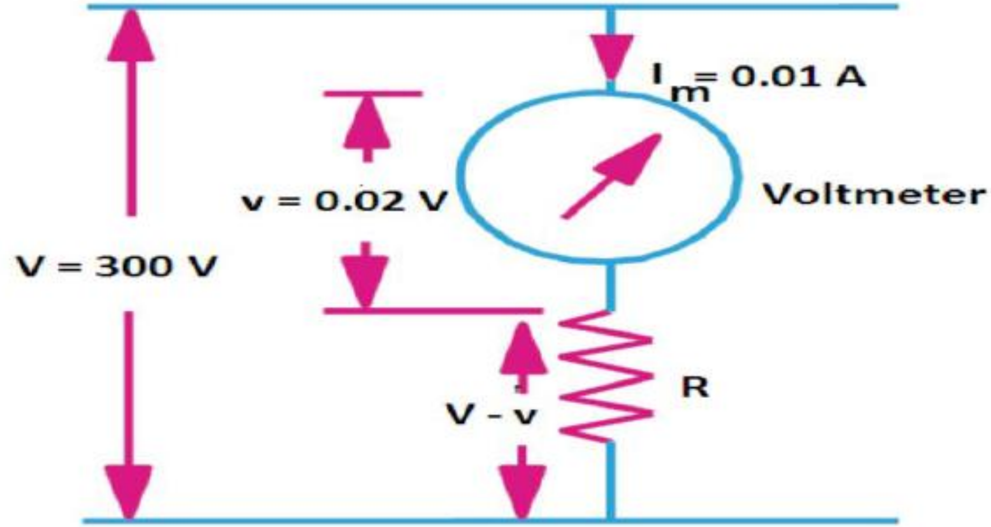
$\therefore \quad S = 0.0005 \times 1000/74.9995 =$ **0.00667 Ω**

Extension of Range of MC instruments

- A moving coil voltmeter reading up to 20 mV has a resistance of 2 ohms. How this instrument can be adopted to read voltage up to 300 volts.

Hint:





- Solution: In this case,
  Voltmeter resistance, $R_m = 2$ ohm
  Full-scale voltage of the voltmeter, $v = R_m I_m = 20$ mV $= 0.02$ V
  Full-scale deflection current, $I_m = v/R_m = 0.02/2 = 0.01$ A
  Voltage to be measured, $V = 300$ V
  Let the series resistance required $= R$
- Then as seen from figure, the voltage drop across R is $V - v$

$R * I_m = V - v$

or $\mathbf{R = (V - v)/I_m}$

or $R = (300 - 0.02)/0.01 = 299.98/0.01 = 29998$ ohms **Ans.**

PROBLEMS

Example 1:- A moving coil ammeter has a full scale deflection of 50 µ Amp and a coil resistance of 1000 Ω. What will be the value of the shunt resistance required for the instrument to be converted to read a full scale reading of 1 Amp.

Solution 1:- Full scale deflection current $I_m = 50 * 10^{-6}\ A$

Instrument resistance $R_m = 1000\ \Omega$

Total current to be measured $I = 1\ A$

Resistance of ammeter shunt required $R_{sh} = \dfrac{R_m}{\dfrac{I}{I_m} - 1} = \dfrac{1000}{\dfrac{1}{50 * 10^{-6}} - 1}$

PROBLEMS

Example 2:- The full scale deflection current of an ammeter is 1 mA and its internal resistance is 100 Ω. If this meter is to have scale deflection at 5 A, what is the value of shunt resistance to be used.

Solution 2:- Full scale deflection current $I_m = 1\ mA = 0.001\ A$

Instrument resistance $R_m = 100\ \Omega$.

Total current to be measured $I = 5\ A$

Resistance of ammeter shunt required $R_{sh} = \dfrac{R_m}{\dfrac{I}{I_m} - 1} = \dfrac{100}{\dfrac{5}{0.01} - 1}$

$R_{sh} = 0.020004\ \Omega$

PROBLEMS

Example 3:- The full scale deflection current of a meter is 1 mA and its internal resistance is 100 Ω. If this meter is to have full-scale deflection when 100 V is measured. What should be the value of series resistance?

Solution 3:- Instrument resistance $R_m = 100\ \Omega$

Full-scale deflection current $I_m = 1\ mA = 1*10^{-3}\ A$

Voltage to be measured $V = 100\ V$

Required series resistance $R_{se} = \dfrac{V}{I_m} - R_m = \dfrac{100}{1*10^{-3}} - 100 = 99{,}900\ \Omega$