Measurements and Instruments

Analog Instruments

Digital Instruments

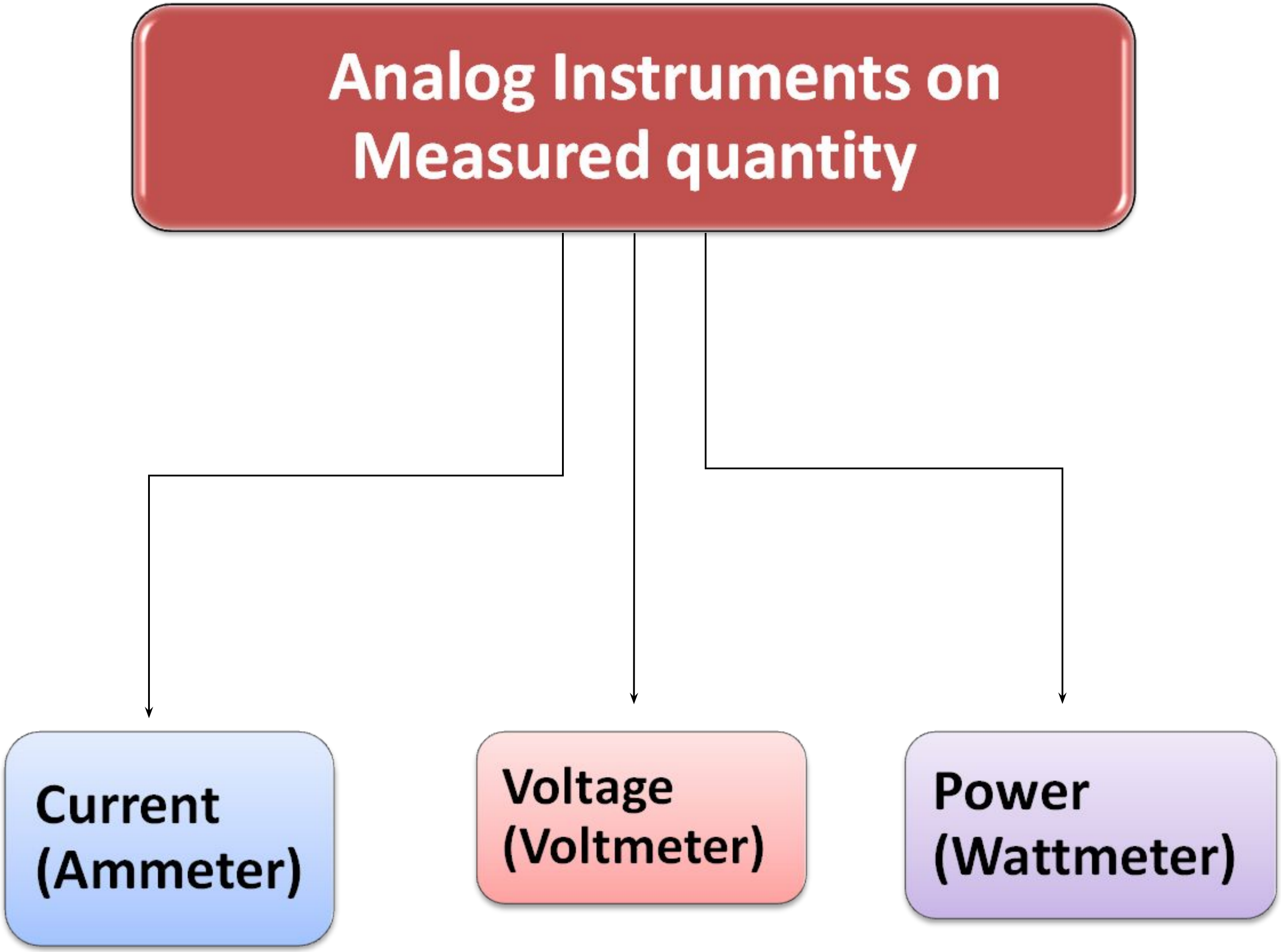
- Analog instrument is the one in which the output or display is a continuous function of time. i.e. infinite no. of values within the range.

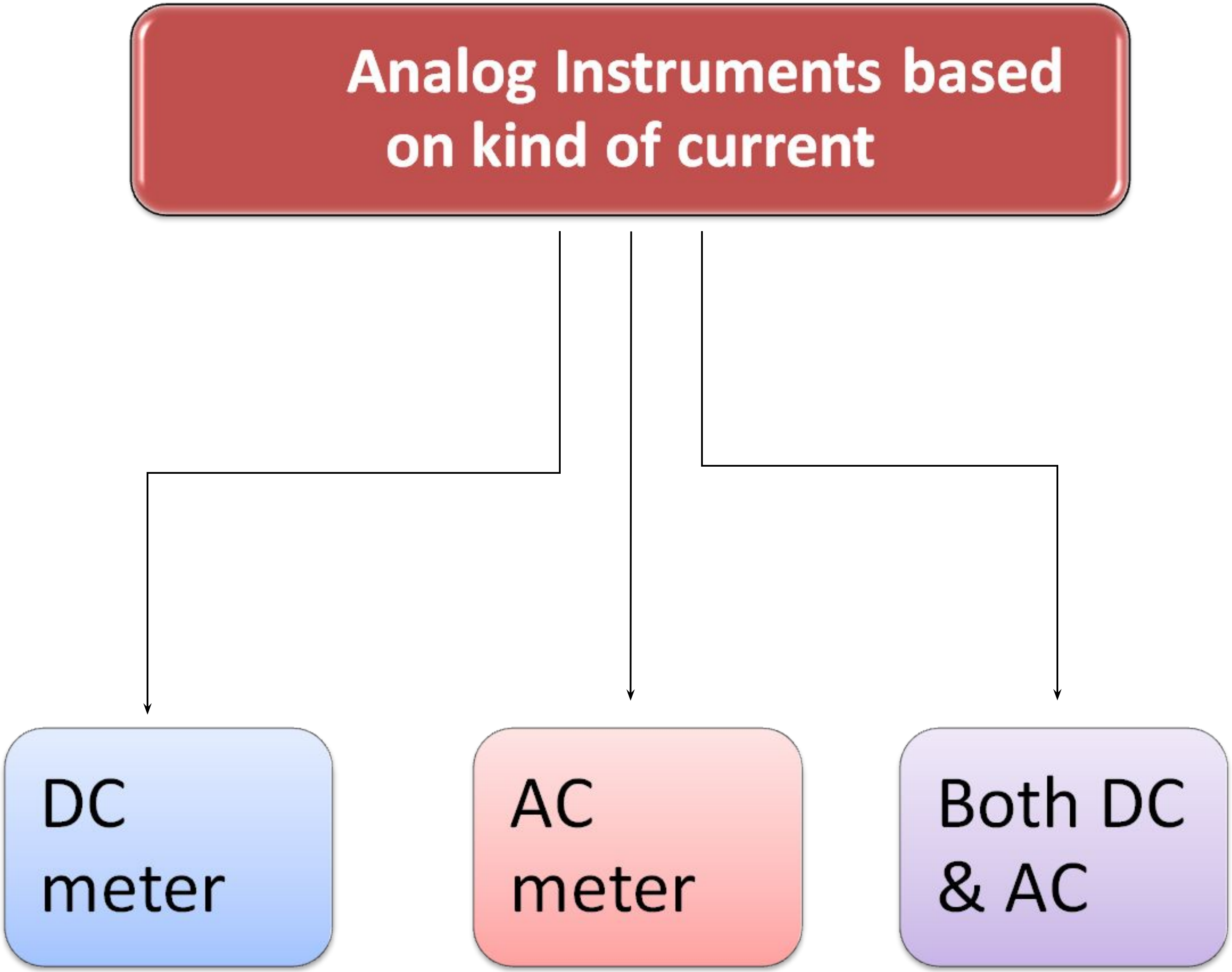
- Digital instrument has an output in discrete steps. i.e. finite no. of value within range.

Classification of Analog Instruments

According to:

- Quantity to be measured.
- Kind of current to be measured (AC/DC/both).
- Display the output.
- Principle of operation.


Analog Instruments on Measured quantity
Current (Ammeter)
Voltage (Voltmeter)
Power (Wattmeter)


Analog Instruments based on kind of current
DC meter
AC meter
Both DC & AC

Principle of Operation

- Magnetic Effect
- Thermal Effect
- Electrostatic Effect
- Induction Effect
- Hall Effect

Essential Requirements of an instrument

Deflecting system

Controlling system

Damping system

Deflecting system

- The deflecting torque has to overcome the following torque-components presents:

(i) Torque due to the inertia of the moving system

(ii) Controlling torque

(iii) Damping torque

(iv) Frictional (coulomb) torque

Controlling System

The controlling torque developed in an instrument has two functions:

(*a*) It limits the movement of the moving system and ensures that the magnitude of the deflections always remains the same for a given value of the quantity to be measured.

(*b*) It brings back the moving system to its zero position where the quantity being measured is removed or made zero.

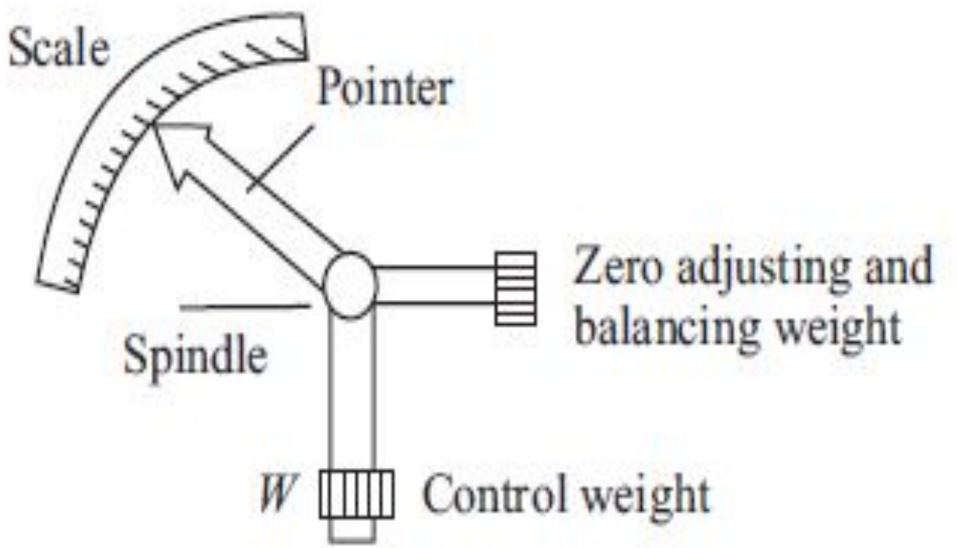
- Controlling force equal and opposite to the deflecting force at final steady position.

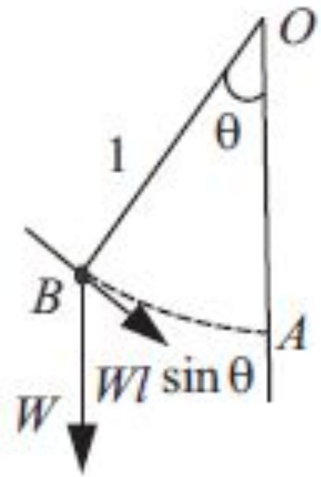
- Types of controlling force:

  (i) Gravity control

  (ii) Spring control

Gravity control

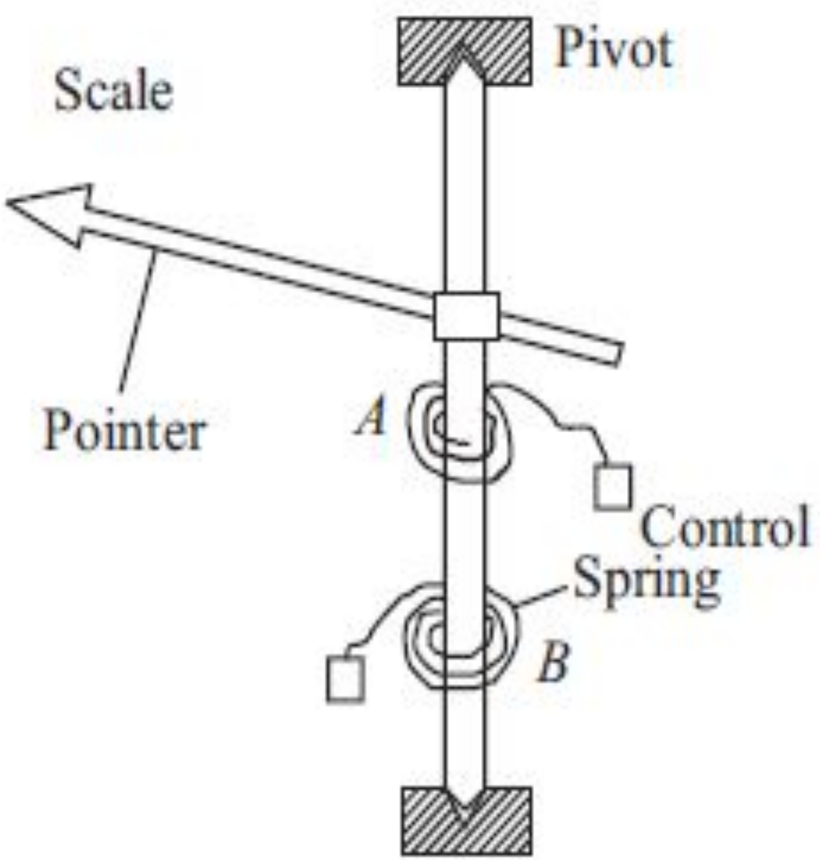




$$T_c = Wl \sin\theta = k_g \sin\theta$$

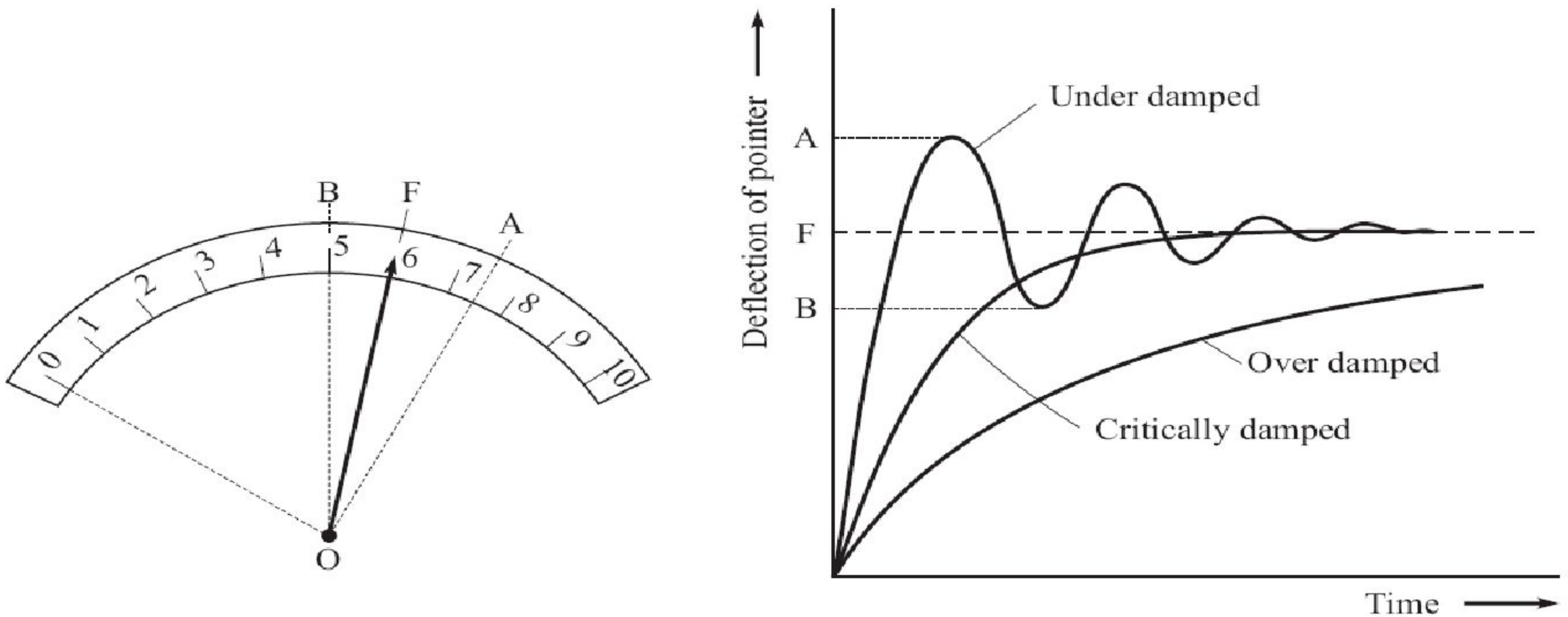
- At rest, w is vertical and no torque
- When pointer deflects, w moves in opposite direction .
- But due to gravity, w tries to come to its initial position which produces opposing torque.
- Opposing torque ------> Controlling torque.

Spring Control



- A and B attached to the moving system.
- One end—>spindle
- Other end---> fixed point.
- Initially---> no compression in the springs so no torque.
- When pointer moves---> one spring is unwound while the other gets twisted.
- Resultant twist---> controlling torque

Damping System



(*a*) The deflection of the pointer on the scale.

(*b*) The deflection versus time curves.

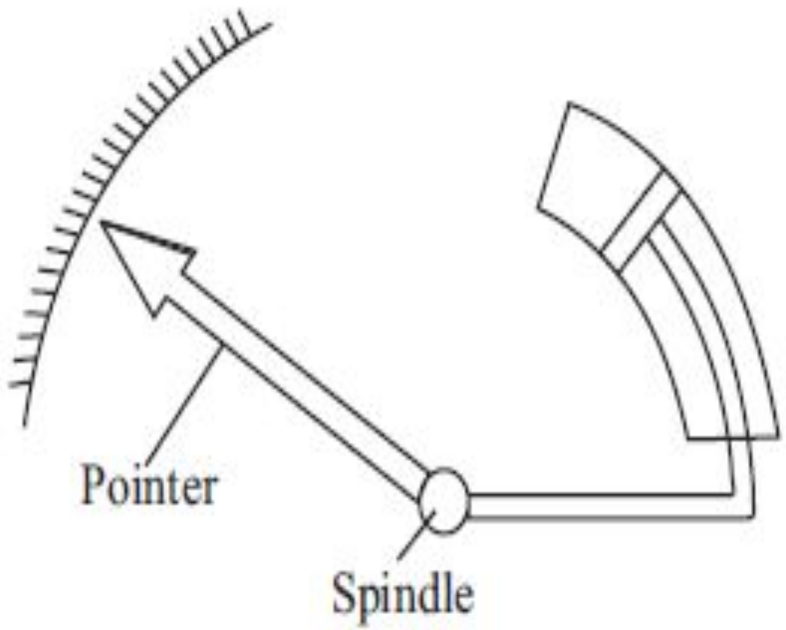
The damping torque is proportional to the speed of rotation of the moving system

$$T_v = k_v \frac{d\theta}{dt}$$

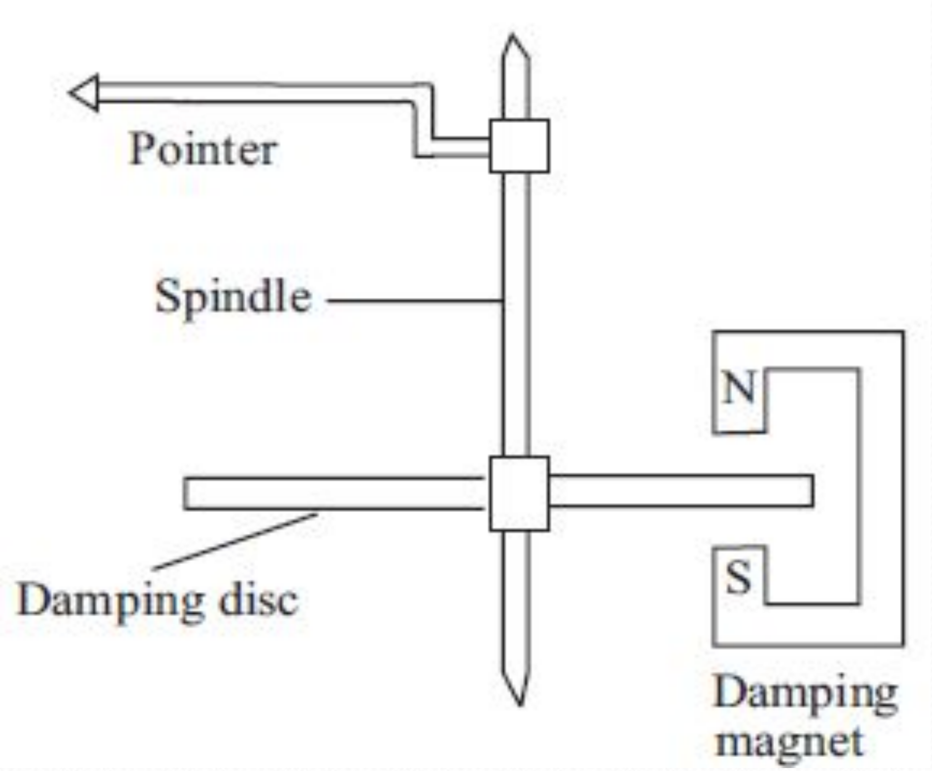
- The remedy lies in providing a suitable **damping torque.**
- If **over-damped**, the time-delay in taking the reading becomes unnecessarily long.
- If **under damped**, the oscillations of the pointer would not be killed completely.
- Thus, the damping torque should be just sufficient to kill the oscillation without increasing the delay-time.
- This condition is said to be ***critically damped*** or '***dead beat***'.

Air Friction Damping

Air frictional force opposing the motion



Eddy Current Damping



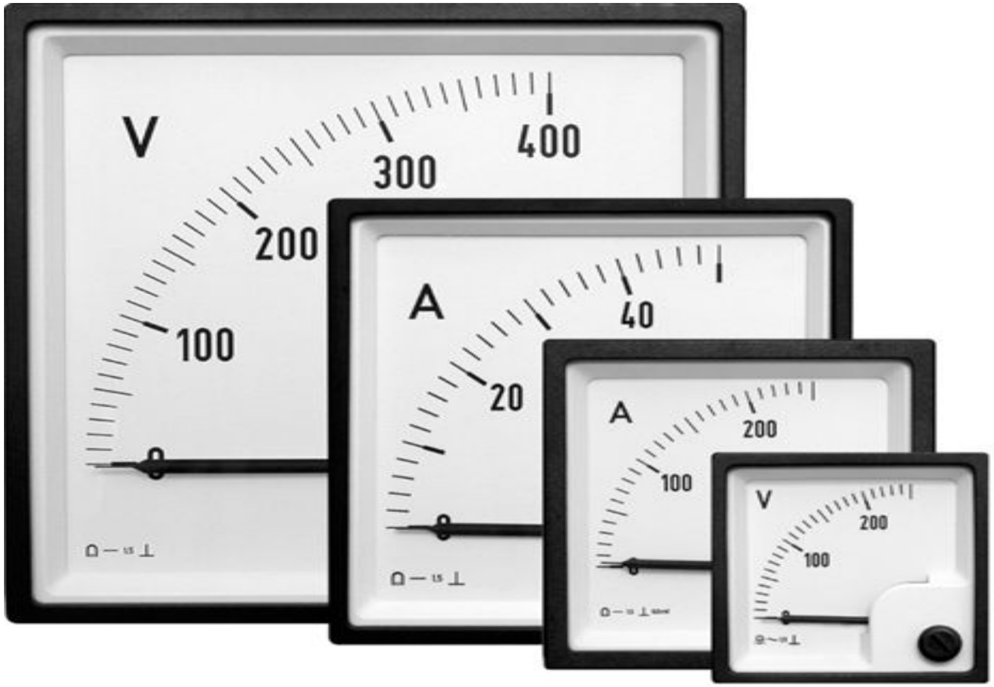
Types of Indicating Instruments

- Moving coil Instruments
- Moving iron Instruments
- Dynamometer Instruments
- Induction Instruments

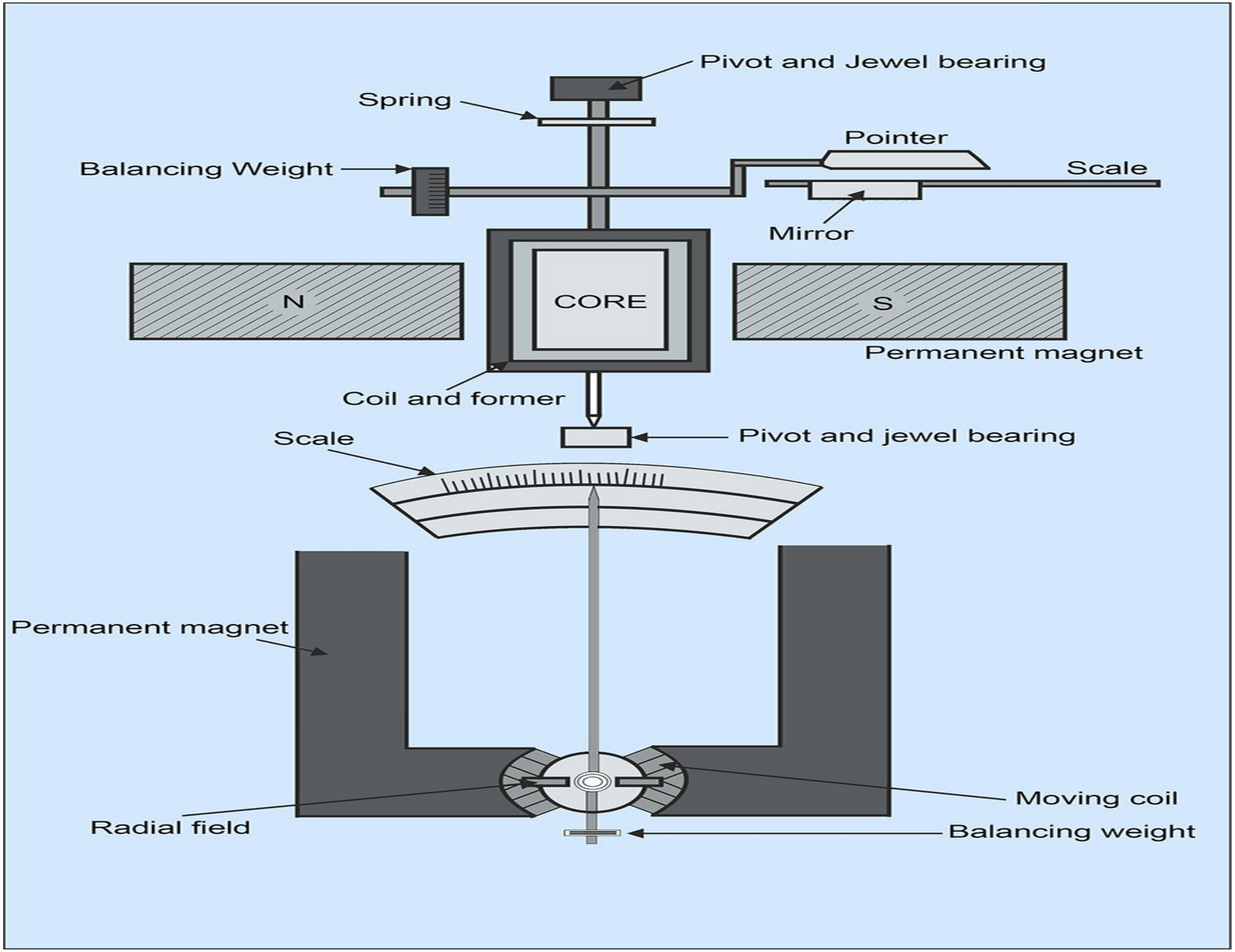
PERMANENT MAGNET MOVING COIL INSTRUMENTS (PMMC)

- Principle :

  When a current carrying conductor is placed in a magnetic field it experiences a mechanical force.
- Force is proportional to current



PMMC



Pivot and Jewel bearing
Spring
Pointer
Balancing Weight
Scale
Mirror
N
CORE
S
Permanent magnet
Coil and former
Scale
Pivot and jewel bearing
Permanent magnet
Moving coil
Radial field
Balancing weight

TORQUE EQUATION

- Since the force *F=NIBL* , (F=NBIL sin α, α=90)
- is directly proportional to the current *I* and to the flux density B in the air gap,
- the net defecting torque= F*d
- T_d= NBILd
- T_d =NBIA, Where A = area of the coil=Ld,
- The controlling torque of the spiral springs,
- In the final steady position,

$$t_d = kI$$

$$\tau_c = c\theta$$

$$\tau_c = \tau_d \quad \text{or} \quad c\theta = kI \quad \rightarrow \quad \theta = \frac{k}{c} I$$

- The deflection is proportional to the current and hence the scale is uniformly divided

Advantages of MC instrument

- The PMMC consumes less power and has great accuracy.
- It has a uniform scale.
- The PMMC has a high torque to weight ratio.
- It can be modified as ammeter or voltmeter with suitable resistance.
- It has efficient damping characteristics and is not affected by stray magnetic field.
- It produces no losses due to hysteresis.

Disadvantage of MC instrument

- The moving coil instrument can only be used on D.C supply as the reversal of current produces a reversal of torque on the coil.
- It's costly as compared to moving coil iron instruments.
- It may show an error due to loss of magnetism of permanent magnet.

Moving-iron instruments

- Moving-iron instruments are generally used to measure alternating voltages and currents.
- It works on the **principle** that the **iron place** near the **magnet attracts towards** it.
- The **force of attraction** depends on the **strength** of the **magnet field** which is depend on magnitude of current flow
- There are two general types of moving-iron instruments namely:
  - **(i) Repulsion** (or double iron) type
  - **(ii) Attraction** (or single-iron) type

Attraction Type Moving Iron Instrument

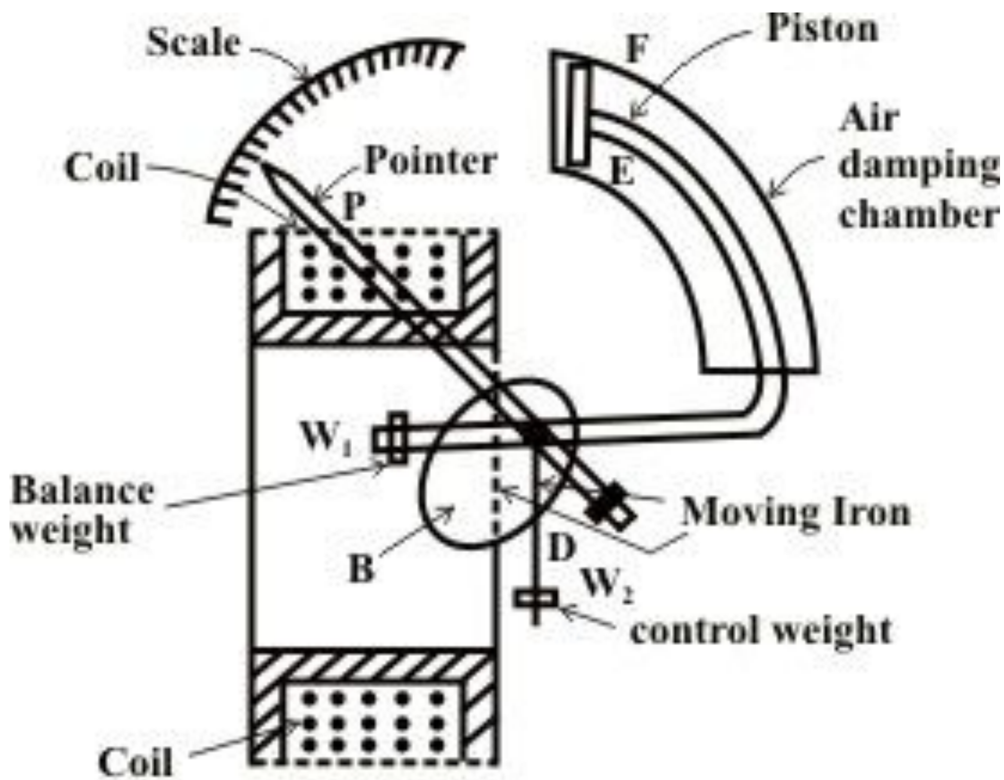


Fig. 42.8: Attraction type

Repulsion Type Moving Iron Instrument

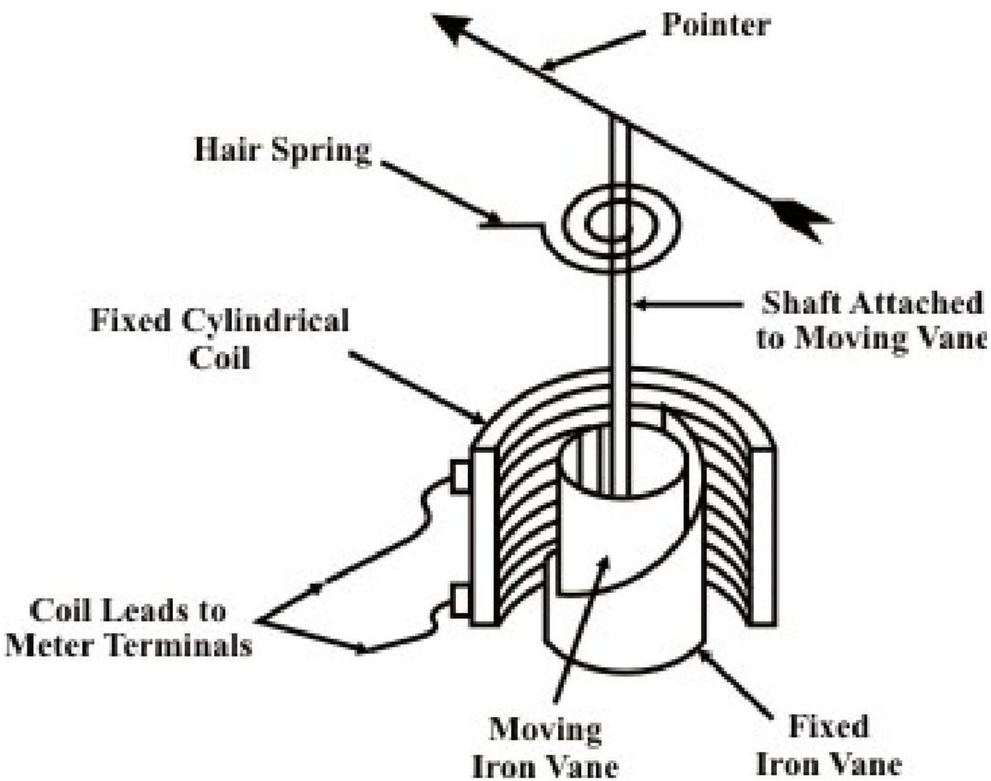
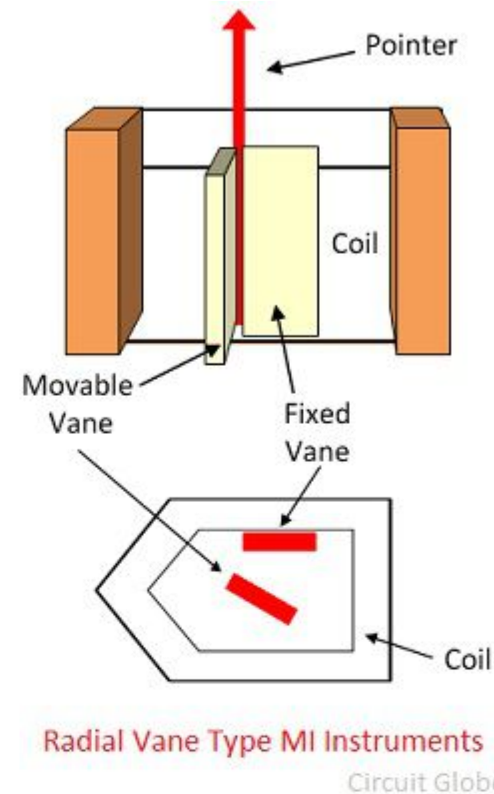


Fig. 42.7: Repulsion type.



Radial Vane Type MI Instruments

Advantages of the MI Instruments:

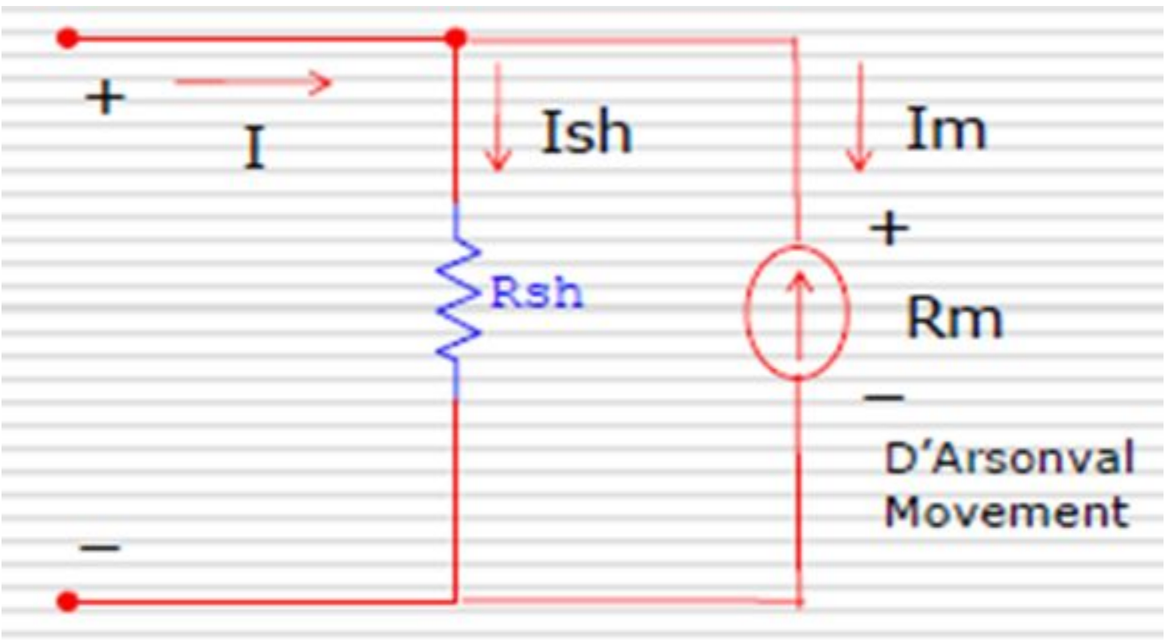
1. Universal use –used for both AC and DC.
2. Less Friction Error – as torque weight ratio is high
3. Cheapness –cheaper than PMMC instrument.

- Robustness – as current carrying part is stationary.

Disadvantages of MI Instruments:

1. Accuracy – not uniform scale, and hence the accurate result is not possible.
2. Errors – because of the hysteresis, frequency and stray magnetic field.
3. Waveform Error – deflection torque is not directly proportional to the square of the current and also the waveforms.
4. Difference between AC and DC calibration – The calibration of the AC and DC are differed.

AMMETER



- The PMMC/MI is used as basic movement system for a ammeter.
- A low value resistor (shunt resistor) is used in DC ammeter to measure large current.

VOLTMETER

- MC/MI is used as a voltmeter by connecting a series resistor R_{se}
- where current remains same but total resistance is extended to extend the scale.