UNIT - VI

INSTRUMENTS

Definition:

The instruments which are used to measure electrical quantities are called Electrical Instruments

Example:

- Ammeter
- Voltmeter
- Energy meter

CLASSIFICATION OF INSTRUMENTS:

Electrical instruments are divided into two categories they are:

1. Absolute instruments

2. Secondary instruments

Absolute instruments:

Gives the quantity to be measured in term of constants of instrument and its deflection.

Example: Tangent Galvanometer

Secondary instruments:

Determine the electrical quantity to be measured directly in terms of deflection

CLASSIFICATION OF SECONDARY INSTRUMENTS

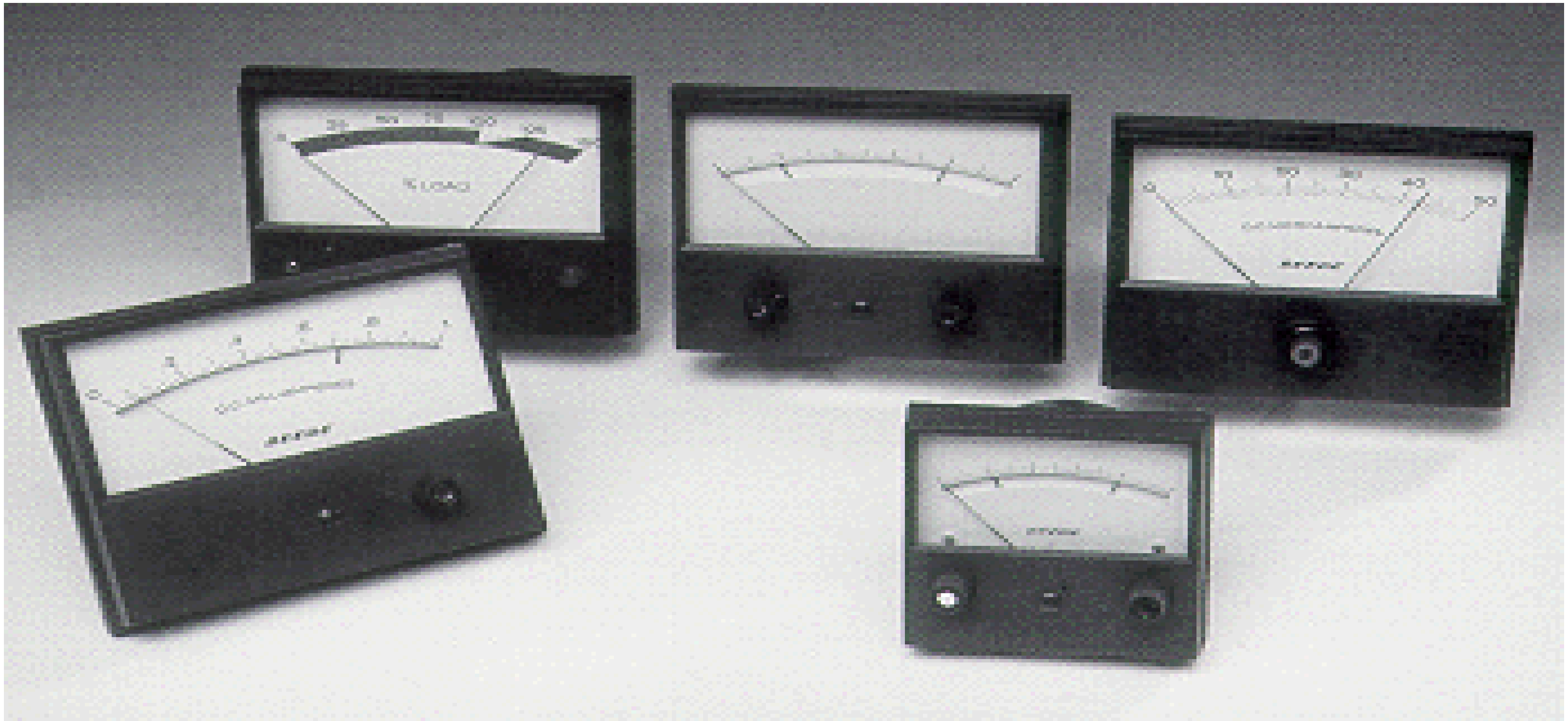
Secondary instruments can be classified into 3 types

1. Indicating instruments
2. Integrating instruments
3. Recording instruments

Indicating Instruments:

It indicates the magnitude of an electrical quantity at the time when it is being measured. The indications are given by a pointer moving over a scale.

Example: Ammeter, Voltmeter, watt meter



Integrating Instruments:

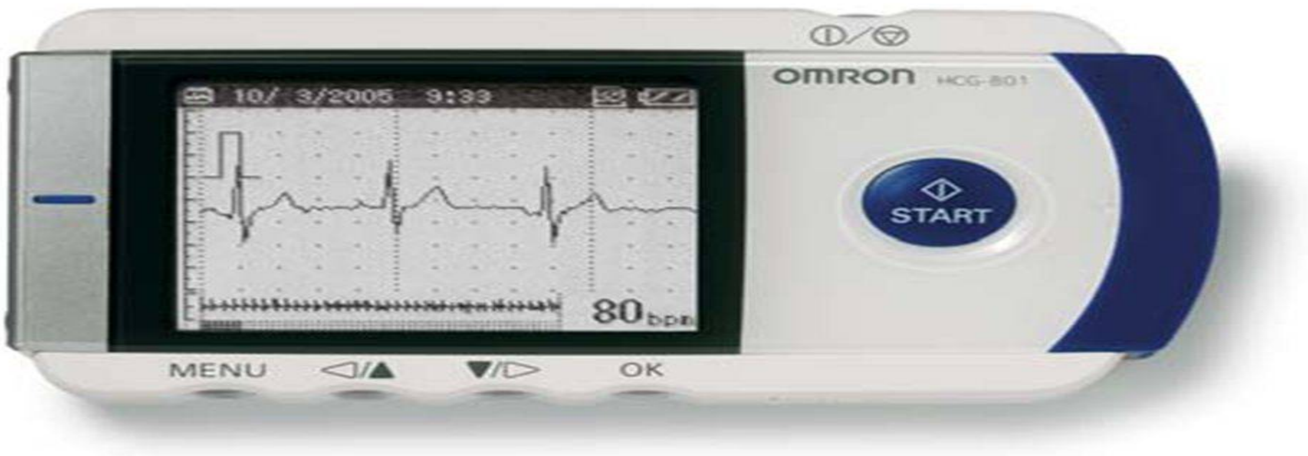
Add up the electrical quantity and measure in a given period of time.

Example: Energy meters

Recording Instruments:

Gives a continuous record of the variations of the magnitude of an electrical quantity to being measured.

Ex: ECG (Electro cardiogram)



Basic Principle of Indicating Instruments

Magnetic effect: Used in ammeters, voltmeters, watt-meters, integrating meters etc.

Thermal effect: Used in ammeters and voltmeters.

Chemical effect: Used in dc ampere hour meters.

Electrostatic effect: Used in voltmeters.

Electromagnetic induction effect: Used in ac ammeters, voltmeters, watt meters and integrating meters

ESSENTIALS OF INDICATING INSTRUMENTS

1. Deflecting or operating torque

2. Controlling or restoring torque

3. Damping torque

Deflecting or operating torque:

- It is produced by utilizing one of the electrical effects such as magnetic, Thermal, chemical, Electrostatic and electromagnetic induction etc...
- Deflection torque causes the moving system to move from 'zero' position, when the instrument is connected in the circuit to measure electrical quantity.
- It is denoted by T_d.

Controlling or Restoring torque:

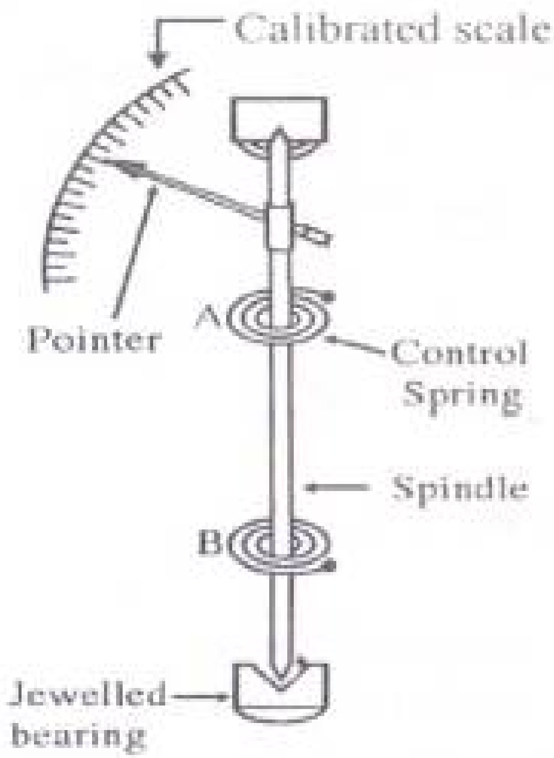
- The deflection of the moving system is indefinite if there is no controlling torque.
- This torque opposes the deflecting torque and increases with the deflection of the moving System.
- The pointer is brought to rest when these two torques are equal.
- Under the influence of controlling torque the pointer will return to its zero position.
- It is denoted by T**c.**

Controlling torque is obtained in indicating instrument by two ways

1. Spring Control

2. Gravity control

Spring Control:



Spring control method

1. Two phosphor bronze hair springs of spiral shapes are attached to the spindle of the moving system of the instrument.

2. They are wound in opposite direction

3. Pointer is attached to the spindle of the moving system

1. When the moving system deflected, one spring gets wounded and the other one gets unwounded. This results in controlling torque whose magnitude is directly proportional to angle of deflection.

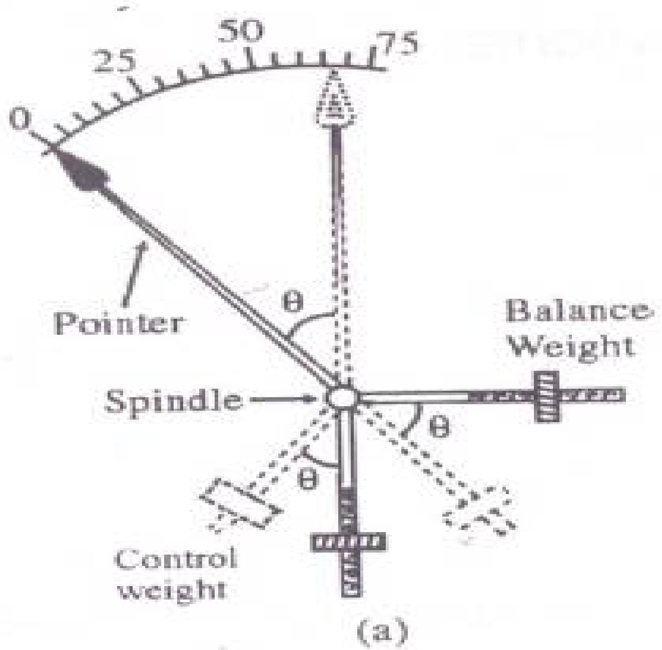
2. Td is directly proportional to current I and Tc is directly proportional to deflection angle, at final steady state Td = Tc, deflection is directly proportional to current, hence scale is linear

$$T_d \, \alpha \, I$$

$$T_c \, \alpha \, \theta.$$

In the final deflected position: $T_d = T_c$. Hence $\theta \, \alpha \, I$.

Gravity control:



Gravity Control Method.

$$T_d \propto I$$

$$T_c \propto \sin\theta$$

$$I \propto \sin\theta$$

1. In gravity control method, a small weight is attached to the spindle of the moving system. Due to the gravitational pull, a control torque (acting in opposite direction to the deflecting torque) is produced whenever the pointer tends to move away from its initial position.

2. In this case, Td is directly proportional to current I and Tc is directly proportional to sine of the deflection angle, since Td = Tc, sine of the deflection is directly proportional to current, hence scale is non linear i.e. cramped scale.

Advantages

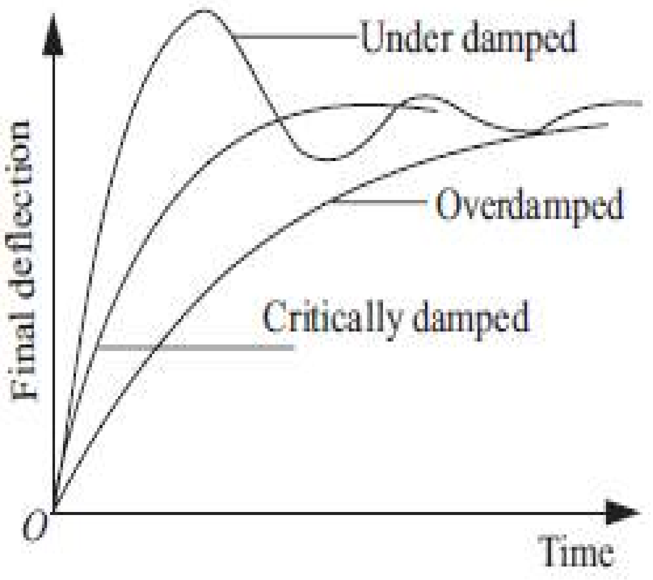
1. It is cheap and not affected by temperature variations.
2. It does not deteriorate with time.
3. It is not subject to fatigue.

Disadvantages

1. Since the controlling torque is proportional to the sine of the angle of deflection, the scale is not uniformly divided but cramped at its lower end.
2. It is not suitable for use in portable instruments (in which spring control is always preferred).
3. Gravity control instruments must be used in vertical position so that the control weight may operate and also must be leveled otherwise they will give zero error.

DAMPING TORQUE:

- Damping torque minimizes the oscillations of the pointer about the final steady state deflection and makes it steady.. In the absence of this torque, pointer continues oscillating to its final position after reaching to its final position.
- Depending on the magnitude of damping, it can be classified as Under damped, over damped and critically damped.



Over damped: Pointer moves slowly to final steady state value.
Critically damped: pointer reaches its final steady state position rapidly and smoothly.
Under damped: Pointer oscillates a lot before it reaches final steady state position.

DAMPING METHODS:

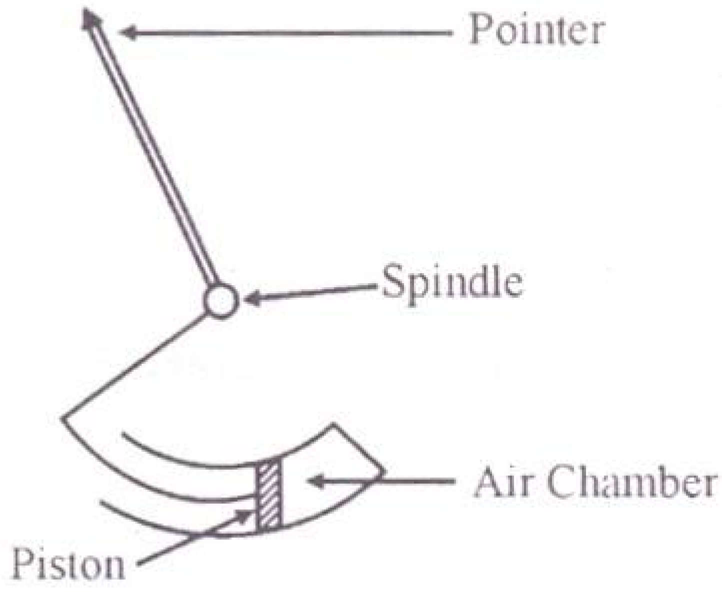
The damping torque is produced by the following methods:

1. Air Friction Damping

2. Fluid Friction Damping

3. Eddy Current Damping

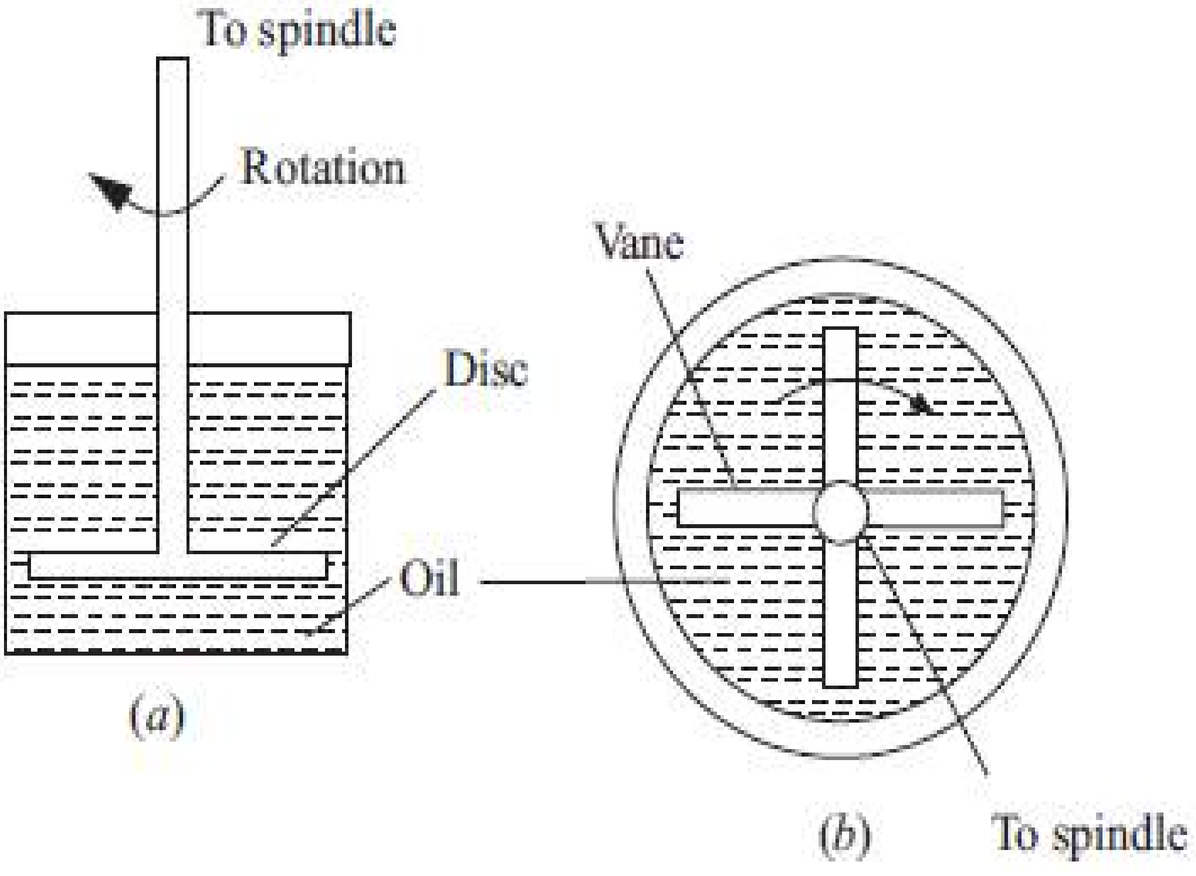
Air Friction Damping:



(a)

- A light aluminum frame is attached to the moving system. This piston moves in an air chamber (cylinder) closed at one end.
- When the pointer oscillates in clockwise direction, the piston goes inside and the cylinder gets compressed. The air pushes the piston upwards and the pointer tends to move in anticlockwise direction.
- If the pointer oscillates in anticlockwise direction the piston moves away and the pressure of the air inside cylinder gets reduced. The external pressure is more than that of the internal pressure. Therefore the piston moves down wards. The pointer tends to move in clock wise direction.

Fluid Friction Damping:

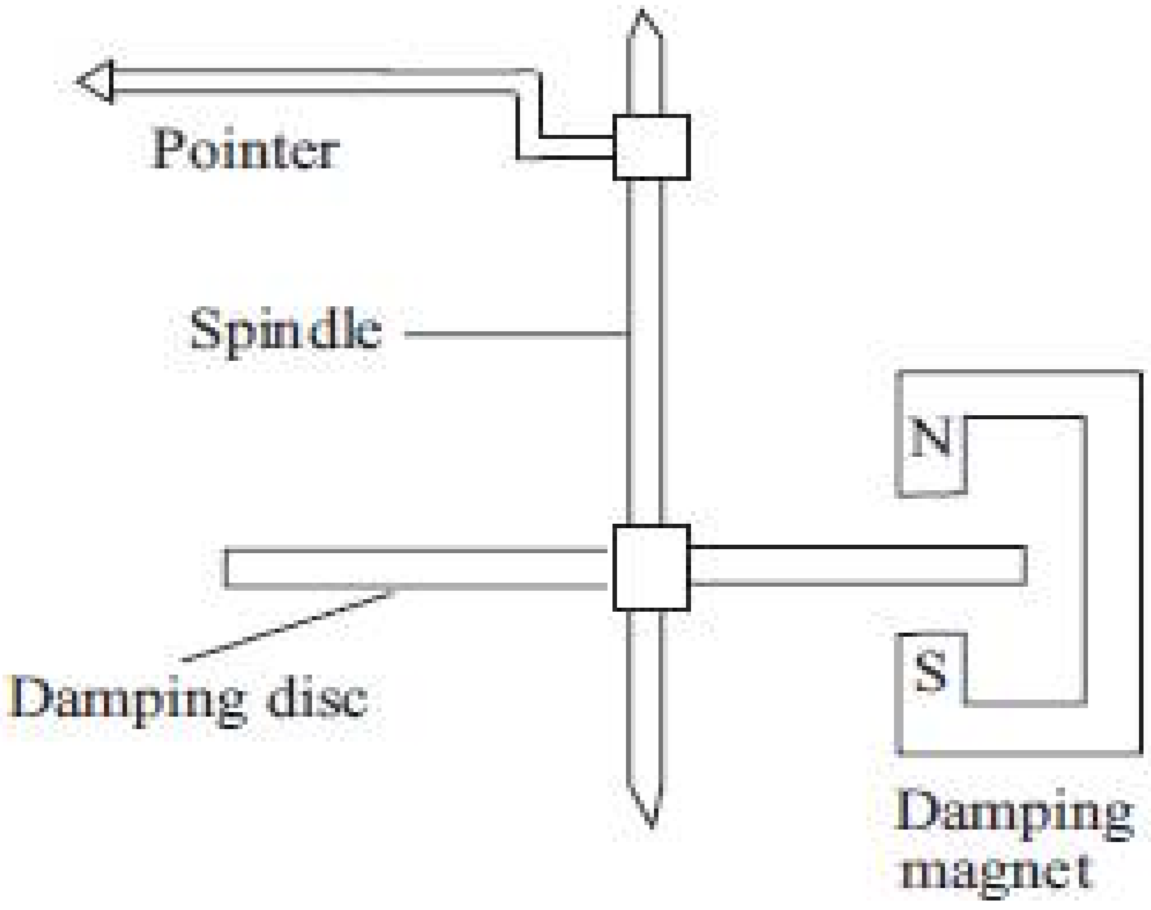


- This form of damping is similar to air friction damping.
- The action is the same as in the air friction damping.
- Mineral oil is used in place of air and as the viscosity of oil is greater, the damping force is also much greater.
- The vane attached to the spindle is arranged to move in the damping oil.
- It is rarely used in commercial type instruments.

Disadvantages:

1. The instruments with this type of damping must be kept always in a vertical position.
2. It is difficult to keep the instrument clean due to leakage of oil.
3. It is not suitable for portable instruments.

Eddy Current Damping:



- An aluminum frame or damping disc is mounted on the spindle and free to rotate in the magnetic field provided by damping magnets.
- Since damping disc is rotating with spindle, emf is induced in the disc according to faradays law of electromagnetic induction.
- Since disc is a closed circuit, eddy current in the form of concentric circles will be induced in the damping disc.
- Interaction between this eddy current and magnetic field develops a force on the damping disc which opposes the movement of sheet.
- And thus provides damping of the oscillations of the pointer.

TYPES OF INSTRUMENTS:

1. Moving Coil Type Meters

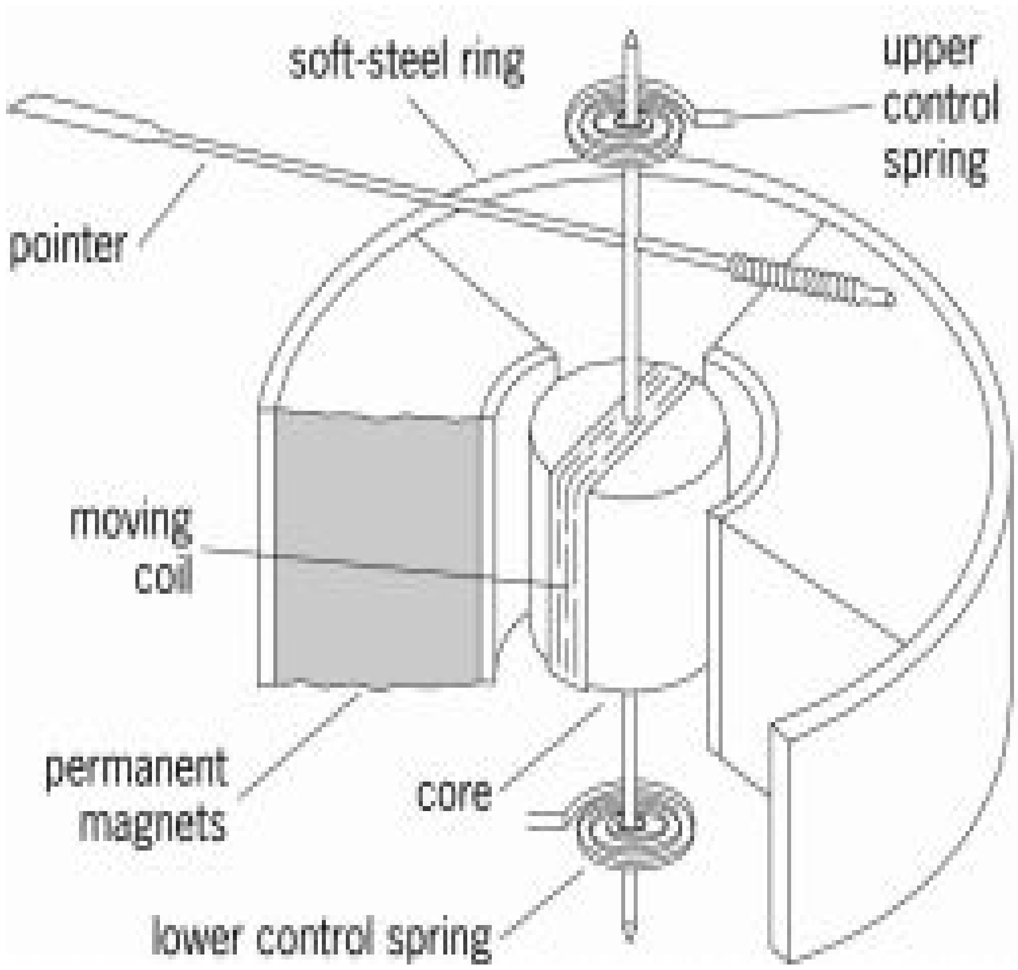
   a) Permanent Magnet type(PMMC)

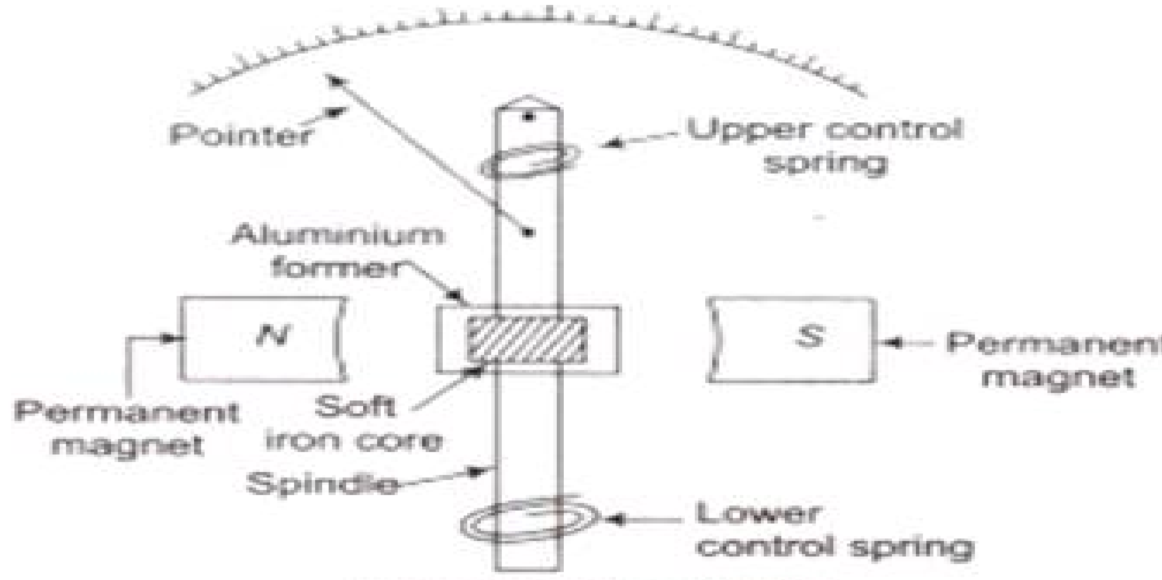
2. Moving Iron Type Meters

   a) Attraction type
   b) Repulsion type

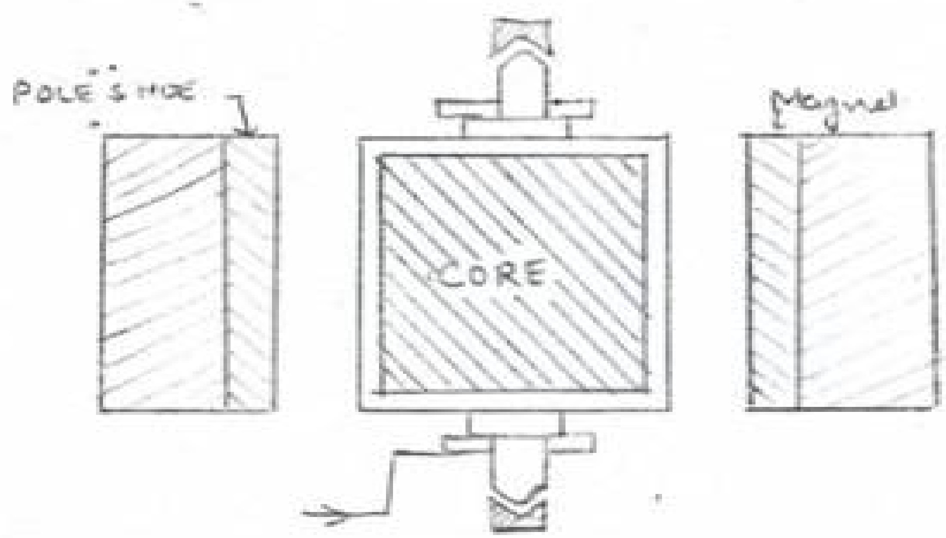
PERMANENT MAGNET MOVING COIL(PMMC)

- These instruments are used either as ammeters or voltmeters and are suitable for d.c work only.
- PMMC instruments work on the principle that, when a current carrying conductor is placed in a magnetic field, a mechanical force acts on the conductor.





Instrument for PMMC



Construction:

- It consists of permanent magnet which is stationary.
- Moving system consists of a spindle attached to a rectangular aluminum frame.
- A coil made up of thin copper wire is wound over the frame. The current to be measured is passed through this coil.
- A soft iron core is placed in the space within the aluminum frame.
- The two springs will provide the controlling torque.
- The damping torque is provided by eddy currents induced in the aluminum former as the coil moves from one position to another position.

Working:

- When the instrument is connected in the circuit to measure current or voltage, the operating current flows through the coil.
- Since the current carrying coil is placed in the magnetic field of the permanent magnet, a mechanical torque acts on it.
- As a result of this torque, the pointer attached to the moving system moves in clockwise direction over the graduated scale to indicate the value of current or voltage being measured.

Let B = flux density, Wb/m^2
l = length or depth of coil, m
b = breadth of the coil.
N = no. of turns of the coil.

If a current of 'I' Amperes flows in the coil, then the force acting on each coil side is given by,

Force on each coil side, $F = BIlN$ Newtons.

Deflecting torque, T_d = Force × perpendicular distance

$= (BIlN) \times b$

$T_d = BINA$ Newton metre

Where, $A = l \times b$, the area of the coil in m^2

Thus, $T_d \, \alpha \, I$

The instrument is spring controlled so that, $T_c \, \alpha \, \theta$

The pointer will comes to rest at a position, where $T_d = T_c$

Therefore, $\theta \, \alpha \, I$

Advantages:-

a) Uniform scale.i.e, evenly divided scale.

b) Very effective eddy current damping.

c) High efficiency.

d) Require little power for their operation.

e) Very accurate and reliable.

Disadvantages:-

a) Cannot be used for AC measurements.

b) More expensive (about 50%) than the moving iron instruments because of their accurate design.

c) Some errors are caused due to variations (with time or temperature) either in the strength of permanent magnet or in the control spring.

Applications:-

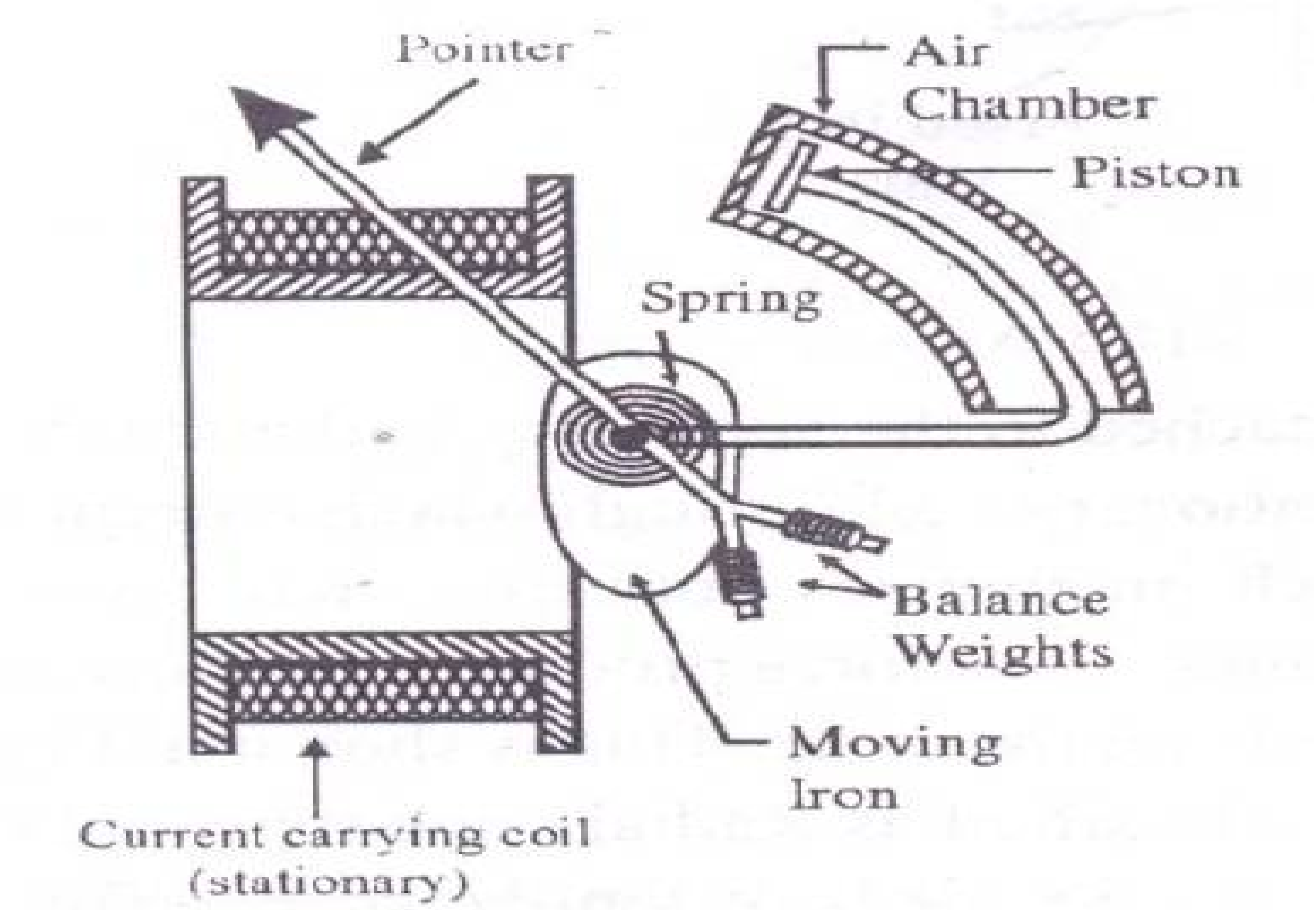
a) In the measurement of direct currents and voltages.

b) In d.c galvanometers to detect small currents.

c) In Ballistic galvanometers used for measuring changes of magnetic flux linkages

MOVING IRON INSTRUMENTS

ATTRACTION TYPE: Whenever a soft iron piece is brought near to the magnet , it gets attracted by the magnet.



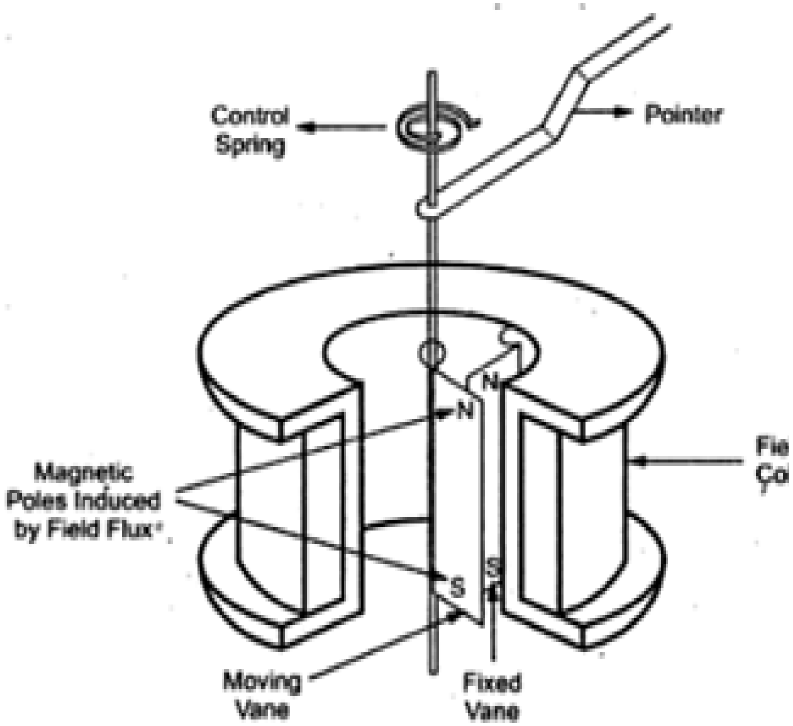
Construction:

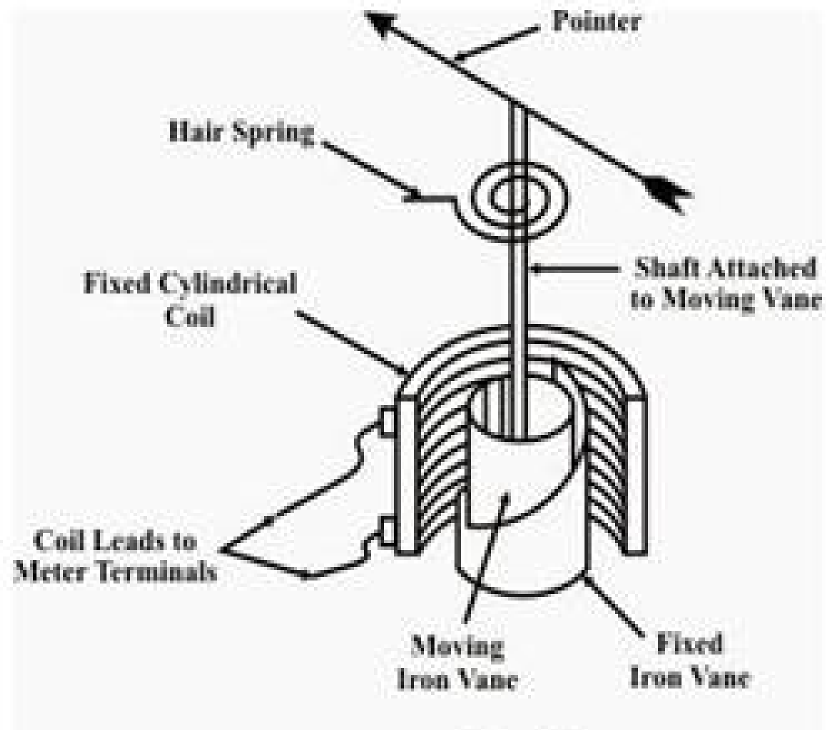
- This instrument consists of stationary coil in which current I that is to be measured is passed.
- A piece of un-magnetised soft iron which is oval in shape is mounted rigidly on the spindle.
- This soft iron piece is free to move about the spindle and along with the spindle. It is placed closer to the stationary coil as shown in fig.
- A pointer is fixed on the spindle.

Working:

- The current to be measured is flowing in the coil, produces a magnetic field.
- Iron piece gets attracted towards centre of the magnetic field and pointer deflects on the scale.
- Control torque is provided by gravity control method.
- Damping is provided by air friction damping.
- The scale is non-linear.

REPULSION TYPE:





Repulsion type.

Construction:

➢This instrument consists of two iron vanes, one is attached to the stationary coil and other one is attached to the movable spindle.

➢Both vanes are surrounded by the stationary coil, current to be measured is passing thorough this coil.

Working:

➢Current to be measured is passing thorough stationary coil produces magnetic field.

➢Both the vanes magnetizes with similar polarities.

➢ As a result a force of repulsion is set up between two vanes.

➢This force produces a deflecting torque on the movable vanes, gives deflection on the scale.

- **General Torque equation of M. I. Instruments**

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

Advantages:

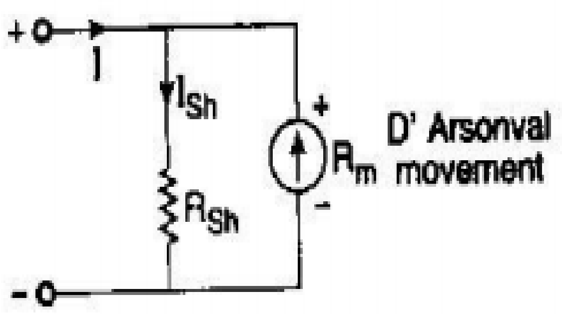
- The instruments are suitable for use in AC and DC circuits.
- The instruments are robust, owing to the simple construction of the moving parts.
- Instrument is low cost compared to moving coil instrument.

Disadvantages:

- The scale is non uniform.
- Power consumption is high at low voltage.

Extension Ranges of meters

Ammeter: Shunts are used for the extension of range of Ammeters



Where, R_m = Internal resistance of coil in Ω
R_{sh} = Resistance of shunt in Ω
$I_m = I_{FS}$ = Full scale deflection current of in Amps
I_{sh} = Shunt current in Amperes
I = Current to be measured in Amperes

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

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

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

$\therefore$ We can write $R_{sh} = {I_m R_m}/{(I - I_m)}$

$$\frac{I}{I_m} - 1 = \frac{R_m}{R_{sh}}$$

$$\frac{I}{I_m} = 1 + \frac{R_m}{R_{sh}}$$

$\dfrac{I}{I_m} = m$ is known as 'multiplying power' of shunt

Resistance of shunt $R_{sh} = {R_m}/{(m-1)}$

Or $R_{sh} = {R_m}/{\left(\dfrac{I}{I_m} - 1\right)}$

Voltmeter:-

For measurement of voltage a series resistor or a multiplier is required for extension of range.

I_m = Deflection current of movement
R_m = Internal resistance of movement
R_s = Multiplier resistance
V = Full range voltage of instrument

$$V = I_m(R_s + R_m)$$

$$R_s = \frac{V - I_m R_m}{I_m} = \frac{V}{I_m} - R_m$$

* For more than 500 V multiplier is mounted outside the case.

$m = V/V_m$ m- Multiplication factor

$m = I_m(R_m+R_s)/ I_m R_m$

$m=R_m+R_s/R_m$

$R_s= (m-1) R_m$