LECTURE

on

ELECTRICAL MEASUREMENT & MEASURING INSTRUMENTS

CONTENTS

Essential requirement of indicating instruments

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1. Deflecting torque
2. Controlling torque
3. Damping torque or restoring torque

Deflecting Torque

- Deflecting torque causes the moving system and pointer of the instrument to move from its zero position. Production of deflecting torque depends upon the type of indicating instrument and its principle of operation

Controlling Torque

- Controlling torque limits the movement of pointer and ensures that the magnitude of deflection is unique and is always same for the given value of electrical quantity to be measured.

Two methods of controlling Torque

- i. Spring Control method
- ii Gravity control method

Spring Control method

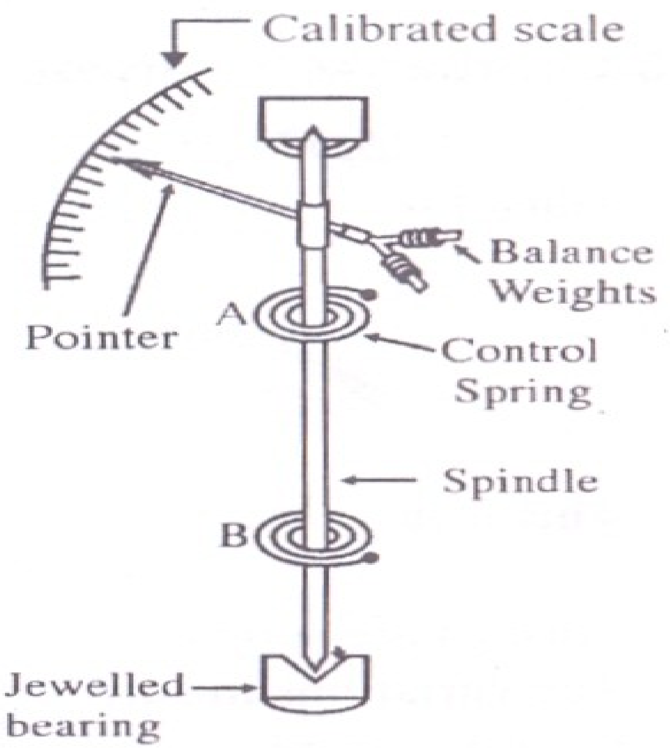


Fig.4.1 Spring control method

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

Working of Spring Control Method

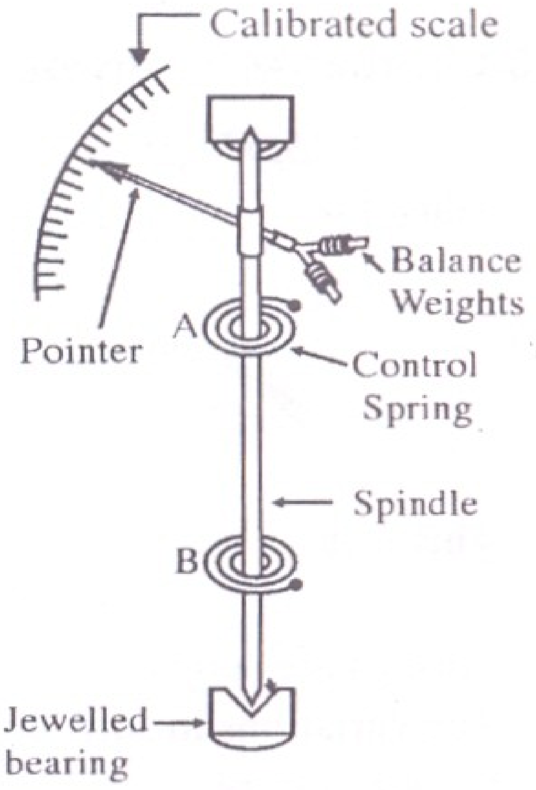


Fig.4.1 Spring control method

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

Gravity Control Method

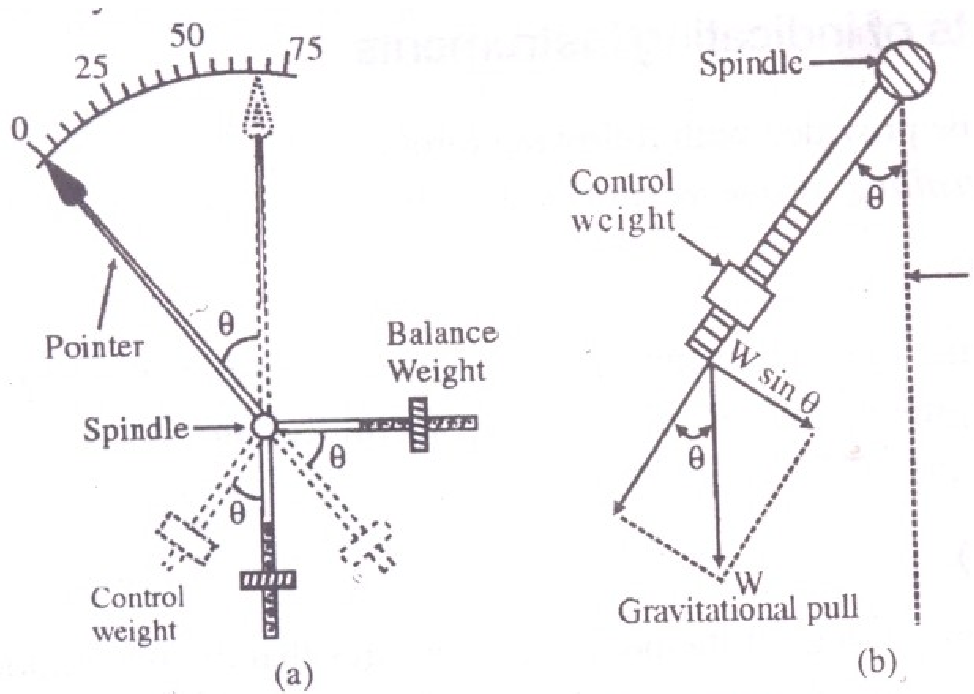


Fig.4.2 Gravity Control Method.

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.

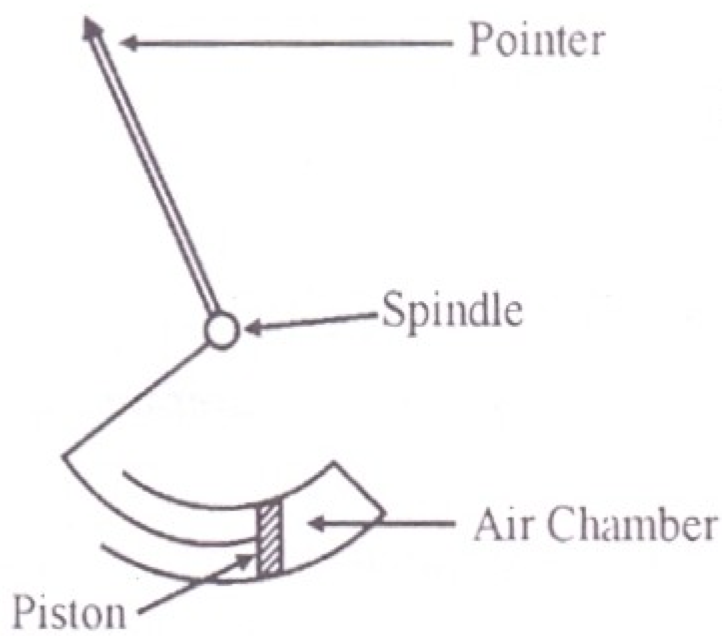
Damping torque

- 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 underdamped, overdamped and critcal damp

Damping Methods

- 1. Air Friction Damping
- 2. 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. At the time of oscillation of the moving system or pointer about its final steady state, if the piston is moving into the chamber, the trapped air gets compressed and the pressure opposes the motion of the piston (and therefore the moving system or pointer). Similarly, if the piston is moving out of the chamber, the pressure in the closed chamber falls and becomes less than air pressure on the outer part of the piston. Motion is thus again opposed. Oscillations are damped.

Eddy current damping

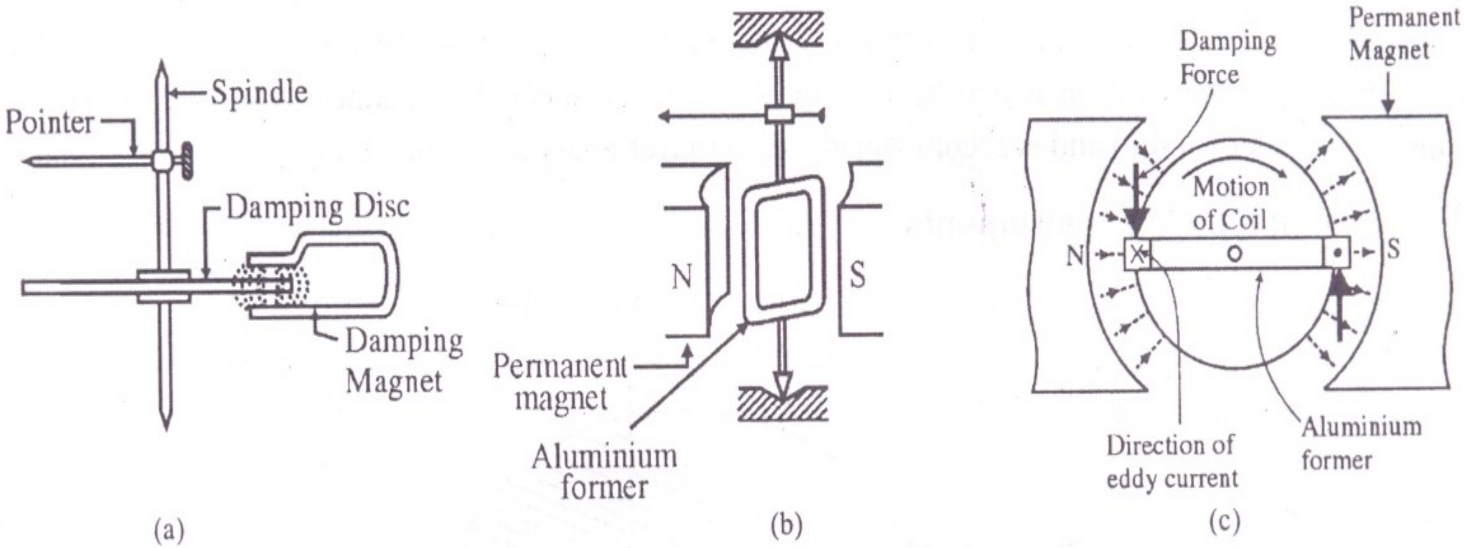


Fig.4.6 Eddy Current Damping.

Eddy current damping

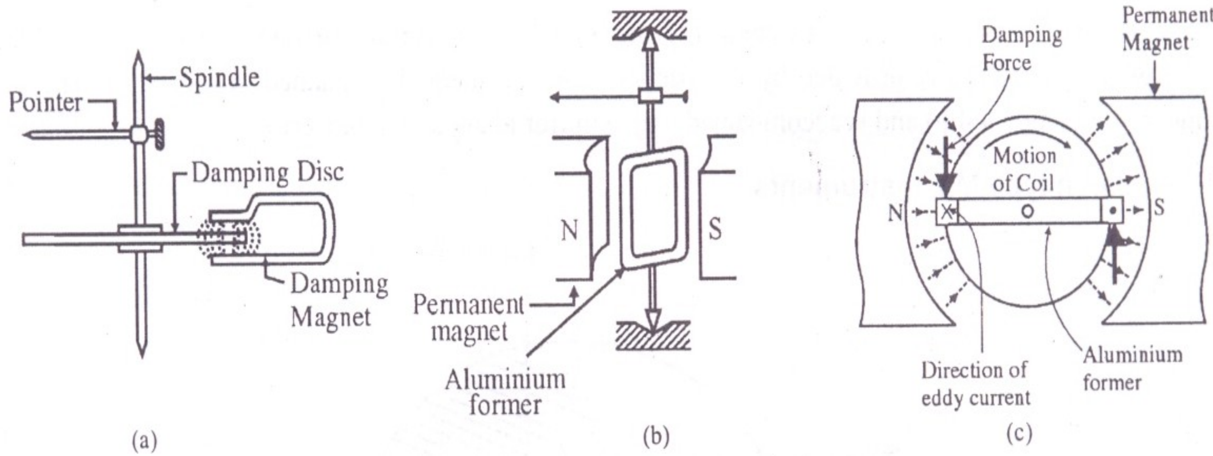


Fig.4.6 Eddy Current Damping.

- **Construction & Working**

1. 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.

Moving Iron Instruments

Construction

1. Instrument consists of a stationary coil in which the current to be measured is passed.
2. A piece of un-magnetized soft iron which is of oval shape is mounted rigidly on the spindle. This soft iron piece is free to move about the spindle and along with the spindle.

Working

1. 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.
2. Control torque is provided either by control springs or by gravity control method
3. Damping is provided by air friction damping
4. The scale is non-linear. Mirror is provided to avoid parallax error.

Attraction type M. I. Instruments

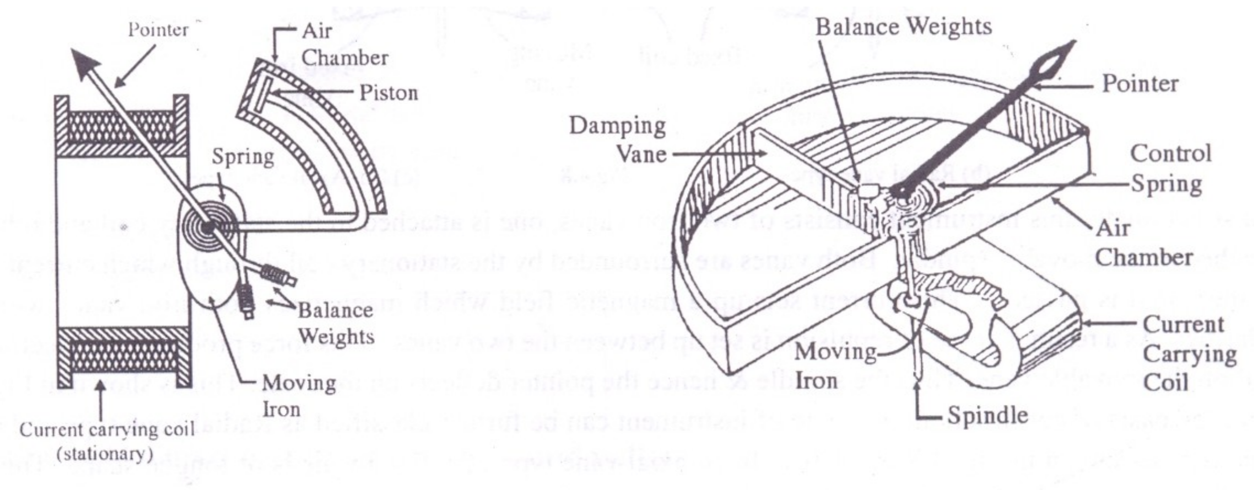
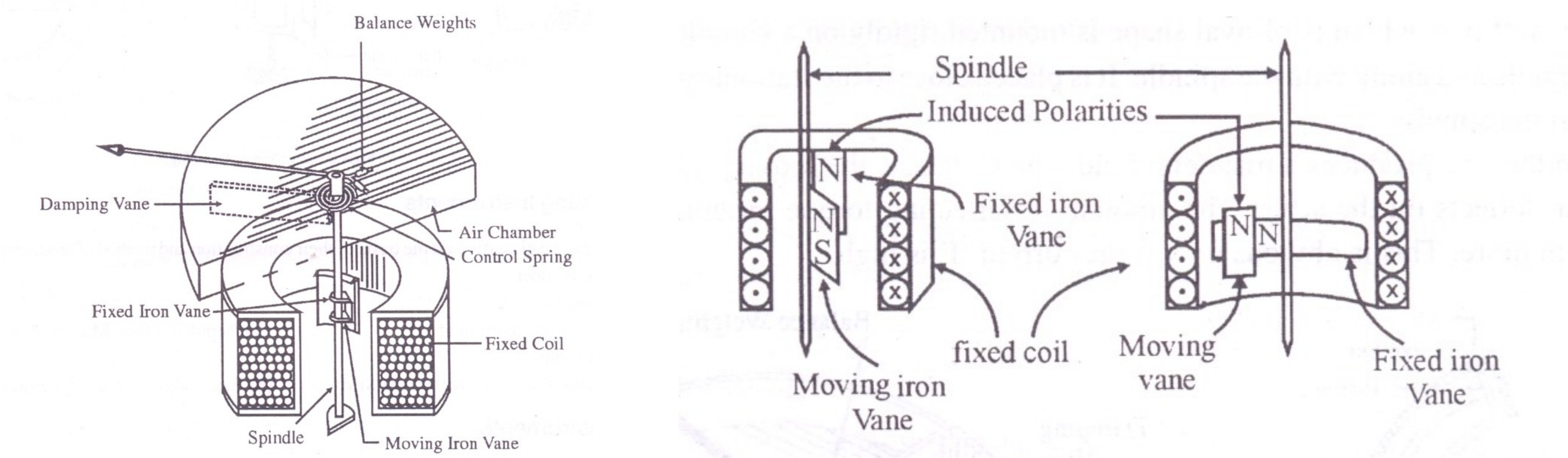


Fig.4.7 Attraction Type M.I. Instrument.

- **Construction**
  1. This instrument consists of stationary coil in which current I that is to be measured is passed
  2. 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.
  3. A pointer is fixed on the spindle.

Repulsion type M. I. Instruments

Repulsion type M. I. Instruments

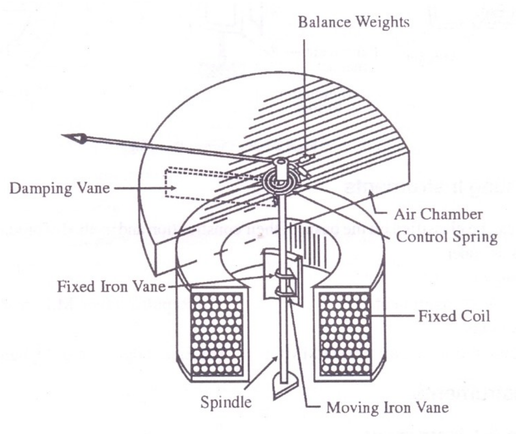


(b) Radial vane type Fig.4.8 (c) Co–Axial vane type

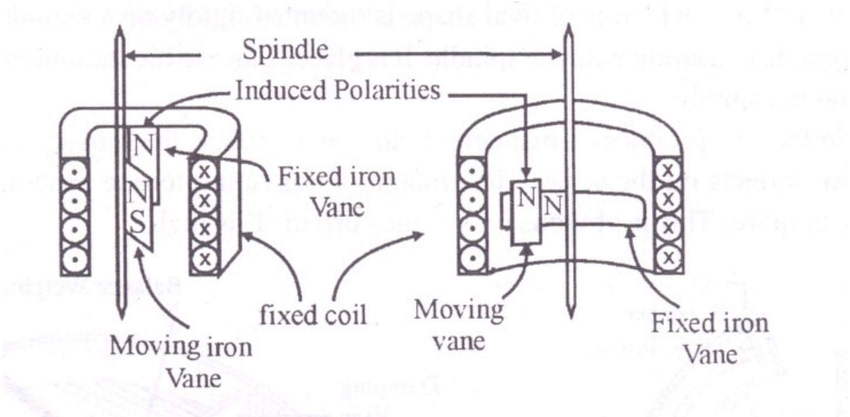
Construction

- 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.

Repulsion type M. I. Instruments



(a)



(b) Radial vane type Fig.4.8 (c) Co–Axial vane type

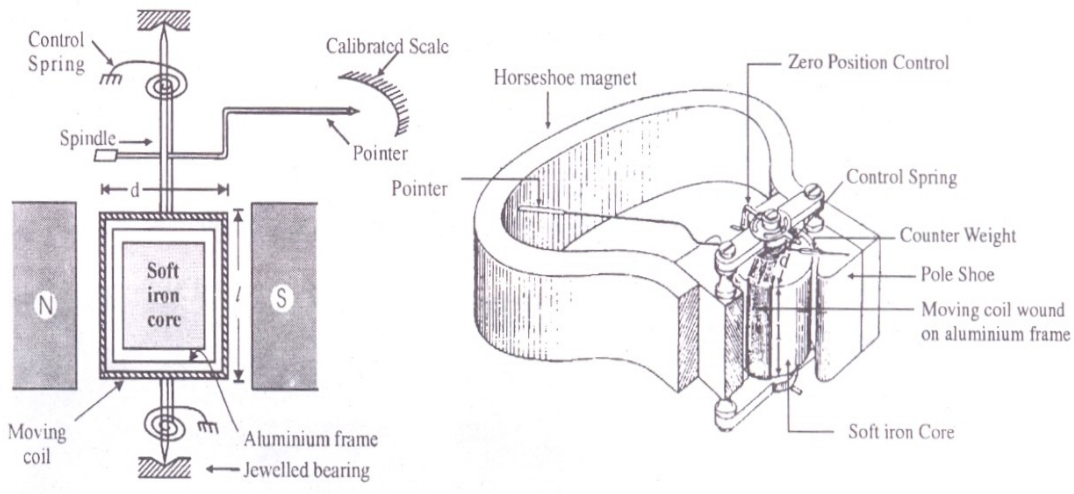
Working

- 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**

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

Permanent Magnet Moving Coil Instruments

Permanent Magnet Moving Coil Instruments



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 in the space within the alluminium frame.
- Two spiral springs are mounted on the spindle to produce control torque. Control spring also serves an additional purpose & acts as control lead.
- Pointer is mounted on spindle. Mirror is provided below the scale to avoid parallax error. The spindle is supported by jeweled bearings.

Permanent Magnet Moving Coil Instruments

Construction

1. It consists of permanent magnet which is stationary.
2. 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.
3. A soft iron core is placed in the in the space within the alluminium frame. This core is stationary and is provided to reduce the reluctance of the magnetic path between two poles of the permanent magnet.
4. Two spiral springs are mounted on the spindle to produce control torque. The control spring also serves an additional purpose and acts as control lead. Pointer is mounted on spindle. Mirror is provided below the scale to avoid parallax error. The spindle is supported by jeweled bearings.

Working

1. The current to be measured is passed through moving coil via control springs.
2. A current carrying moving coil is now in a magnetic field. According to Flemings left hand rule, torque is produced on the coil and coil moves, pointer deflects.
3. Damping torque is provided by eddy current damping method.

- Torque equation- Deflection is proportional to current

Permanent Magnet Moving Coil Instruments

Errors in PMMC Instruments

- Weakening of permanent magnet due to ageing and temperature effects
- Weakening of springs due to ageing and temperature effects
- Change of resistance of moving coil with temperature.

Merits

- Uniform scale for the instrument
- Power consumption is very low
- A single instrument can be used for different current and voltage ranges
- The toque-weight ratio is high gives higher accuracy.

Demerits

- This instrument can be used only on DC supply
- The cost of the instrument is more than M.I. Instruments

Electrodynamic Instruments

Electrodynamic Instruments

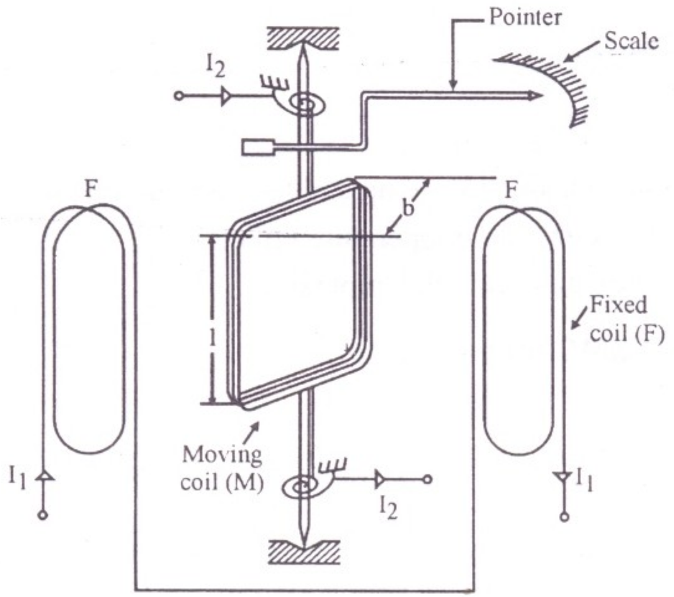


Fig. 4.10 Electrodynamic Instrument

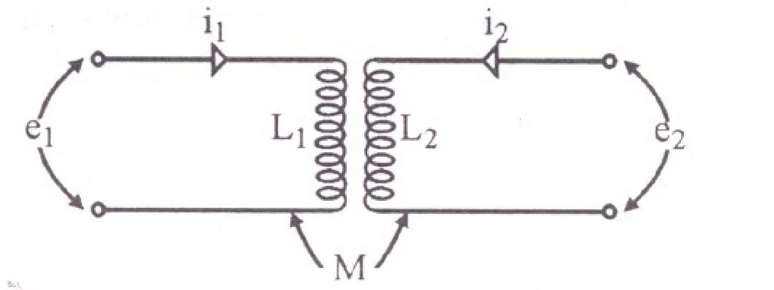


Fig.4.11 Equivalent circuit of the electrodynamic instrument.

Construction

- Stationary part consists of two fixed coils connected in series as shown in fig. so that they carry same current.
- The moving system consists of a coil mounted on the spindle which is free to rotate in the space between the two fixed coils. The coil is made up of thin copper wire and is air cored to avoid hysterisis.
- Control torque provided by two spiral springs. They also act as connecting leads for the moving coil. Pointer is mounted on the spindle.
- Mirror is provided to avoid parallax error.
- Damping is provided by air friction damping.

Electrodynamic Instruments

Working

- Current to be measured is passed through two stationary coils which are connected in series, forms magnetic field.
- Current to be measured is also passed through moving coil via control springs. Now current carrying moving coil is placed in magnetic field. According to Flemings left hand rule, force is experienced on the moving coil, gives deflection of the pointer.
- Torque

  $T_d \propto i_1 \times i_2$

  i1- current flowing through fixed coil,

  i2 - current flowing through moving coil

Electrodynamic Instruments

Merits

- It can be used on a.c as well as d.c.
- It can be used as ammeter voltmeter and wattmeter
- it is also called as dynamometer instruments

Demerits

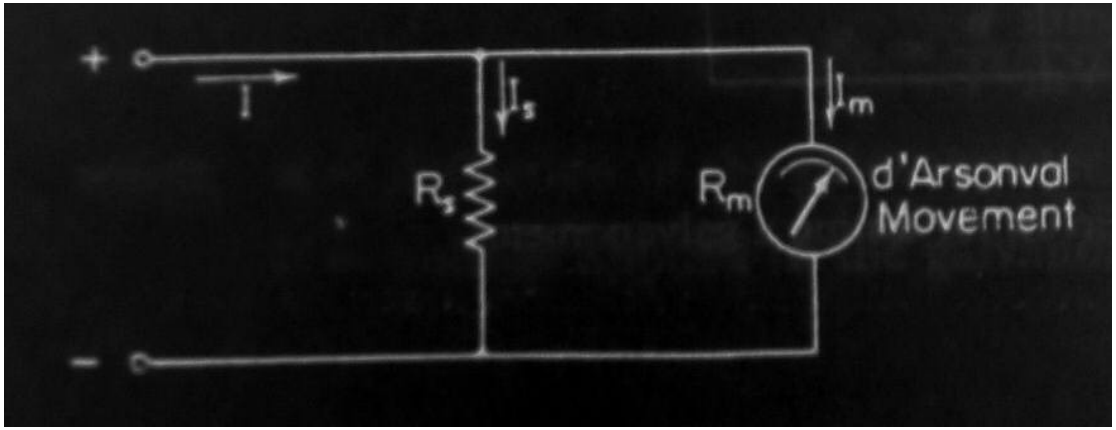
- Low torque to weight ratio
- More expensive
- Weak magnetic field
- Scale is non-uniform

Electrodynamic Instruments

Electrodynamic instruments as voltmeter, ammeter and wattmeter

- When used as an ammeter, the fixed coils are made up of thick conductors to carry the load current. But since it is not possible with moving coil, it is shunted (connected in parallel) with suitable resistor
- When used as an voltmeter, all coils are made from less cross section conductor. To increase instruments impedance. To increase the instruments impedence, a heavy resistor is connected in series with them
- When used as an wattmeter, fixed coils are used as current coil and moving coil as pressure coil. Constructionally, fixed coils are made up of thick copper wire and moving coil with thin conductors

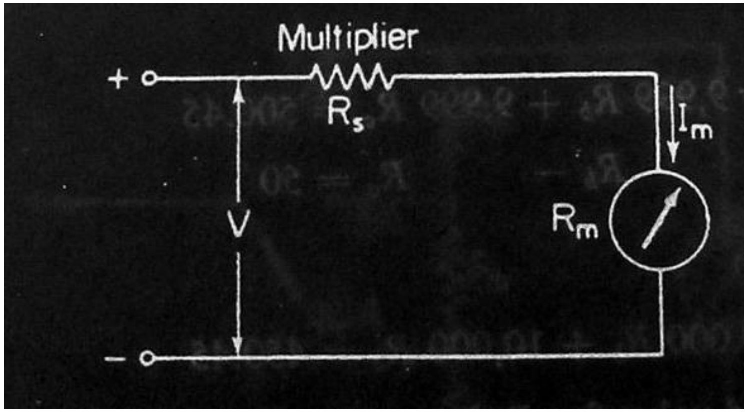
DC Ammeters
Shunt Resistor



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

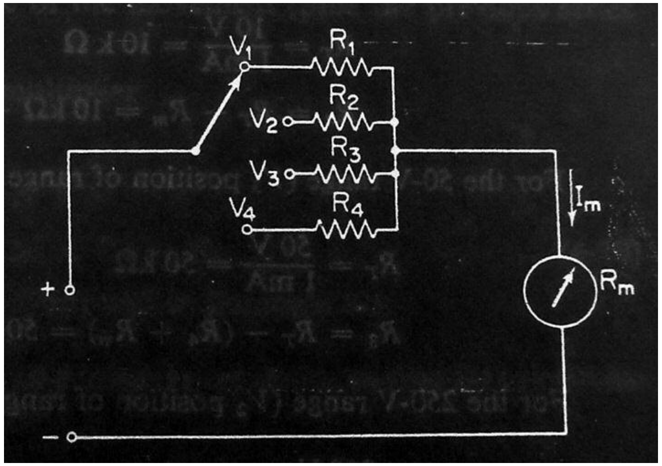
DC Voltmeters

- Basic dc voltmeter circuit --→



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

- Multirange voltmeter ---------→



- Voltmeter sensitivity :

$$S = \frac{1}{I_{fsd}} \frac{\Omega}{V}$$

THE END