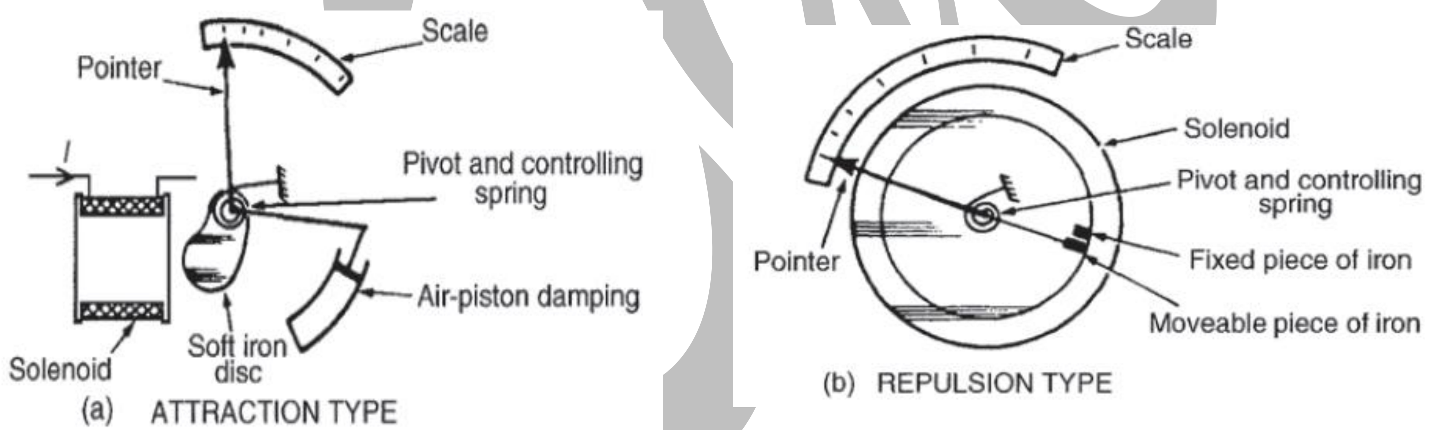
UNIT- 4th - Measuring Instruments

Construction and basic operation principle of moving iron instruments

Moving-iron instruments are generally used to measure alternating voltages and currents. In moving iron Instruments the movable system consists of one or more pieces of specially-shaped soft iron, which are so pivoted as to be acted upon by the magnetic field produced by the current in coil.
There are two general types of moving-iron instruments namely:
1. Attraction (or single-iron) type .
2. Repulsion (or double iron) type

Different components of a moving-iron instrument

Moving element: a small piece of soft iron in the form of a vane or rod.
Coil: to produce the magnetic field due to current flowing through it and also to magnetize the iron pieces.
In repulsion type, a fixed vane or rod is also used and magnetized with the same polarity.
Control torque is provided by spring or weight (gravity).
Damping torque is normally pneumatic, the damping device consisting of an air chamber and a moving vane attached to the instrument spindle.
Deflecting torque produces a movement on an aluminum pointer over a graduated scale.



In an **attraction type of moving-iron instrument** when current flows in the solenoid, a pivoted soft iron disc is attracted towards the solenoid and the movement causes a pointer to move across a scale.
In **the repulsion type moving-iron instrument** two pieces of iron are placed inside the solenoid, one being fixed, and the other attached to the spindle carrying the pointer. When current passes through the solenoid, the two pieces of iron are magnetized in the same direction and therefore repel each other. The pointer thus moves across the scale. The force moving the pointer is, in each type, proportional to I^2 and because of this the direction of current does not matter. The moving-iron instrument can be used on d.c. or a.c.; the scale, however, is non-linear.

Measurement of Electric Voltage and Current

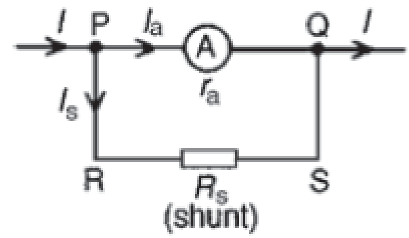
- Moving iron instruments are used as Voltmeter and Ammeter only.
- Both can work on AC as well as on DC.

Construction & operation Voltmeter & Ammeter

A voltmeter, which measures p.d., has a high resistance (ideally infinite) and must be connected in parallel with the part of the circuit whose p.d. is required. There is no difference between the basic instrument used to measure current and voltage since both use a milliammeter as their basic part. This is a sensitive instrument which gives f.s.d. for currents of only a few milliamperes.

Ammeter

- Instrument used to measure current in the circuit.
- Always connected in series with the circuit and carries the current to be measured.
- This current flowing through the coil produces the desired deflecting torque.
- It should have low resistance as it is to be connected in series.



(a)

When an ammeter is required to measure currents of larger magnitude, a proportion of the current is diverted through a low value resistance connected in parallel with the meter. Such a diverting resistor is called a shunt.

$V_{PQ} = V_{RS}$. Hence $I_a r_a = I_S R_S$. Thus the value of the shunt,

$$R_S = \frac{I_a r_a}{I_S} \text{ ohms}$$

Voltmeter

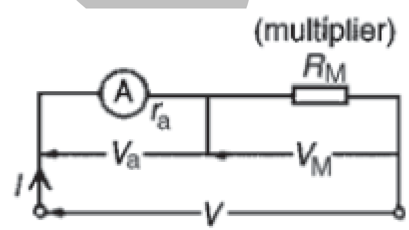
- Instrument used to measure voltage between two points in a circuit.
- Always connected in parallel.
- Current flowing through the operating coil of the meter produces deflecting torque.
- It should have high resistance. Thus a high resistance of order of kilo ohms is connected in series with the coil of the instrument

The milliammeter is converted into a voltmeter by connecting a high value resistance (called a multiplier) in series with it as shown in Fig.(b).

$V = V_a + V_M = Ir_a + IR_M$

Thus the value of the multiplier,

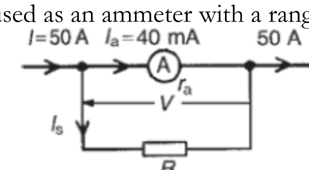
$$R_M = \frac{V - Ir_a}{I} \text{ ohms}$$



(b)

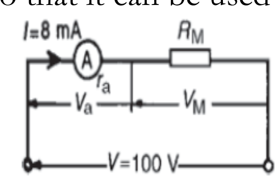
Q. 1) A moving-coil instrument gives a f.s.d. when the current is 40mA and its resistance is 25Ω . Calculate the value of the shunt to be connected in parallel with the meter to enable it to be used as an ammeter for measuring currents up to 50A

Answer & Hint :- Thus for the moving-coil instrument to be used as an ammeter with a range 0–50A, a resistance of value **20.02mΩ** needs to be connected in parallel with the instrument.



Q. 2) A moving-coil instrument having a resistance of 10Ω, gives a f.s.d. when the current is 8mA. Calculate the value of the multiplier to be connected in series with the instrument so that it can be used as a voltmeter for measuring p.d.s. up to 100V.

Answer & Hint :- 12.49 kΩ



Type of instrument	Moving-coil	Moving-iron
Suitable for measuring	Direct current and voltage	Direct and alternating currents and voltage (reading in rms value)
Scale	Linear	Non-linear
Method of control	Hairsprings	Hairsprings
Method of damping	Eddy current	Air
Frequency limits	–	20–200 Hz
Advantages	1 Linear scale 2 High sensitivity 3 Well shielded from stray magnetic fields 4 Low power consumption	1 Robust construction 2 Relatively cheap 3 Measures dc and ac 4 In frequency range 20–100 Hz reads rms correctly regardless of supply wave-form
Disadvantages	1 Only suitable for dc 2 More expensive than moving iron type 3 Easily damaged	1 Non-linear scale 2 Affected by stray magnetic fields 3 Hysteresis errors in dc circuits 4 Liable to temperature errors 5 Due to the inductance of the solenoid, readings can be affected by variation of frequency

D'Arsonval Galvanometer

D'Arsonval Galvanometer is one of the most used permanent magnet moving coil (PMMC) type instrument which indicates the magnitude of current flowing in the coil.

D'Arsonval movement principle :

An action caused by electromagnetic deflection, using a coil of wire and a magnetized field. When current passes through the coil, a needle is deflected. Whenever electrons flow through a conductor, a magnetic field proportional to the current is created. This effect is useful for measuring current and is employed in many practical meters. Since most of the meters in use have D'Arsonval movements, which operate because of the magnetic effect. The basic dc meter movement is known as the D'Arsonval meter movement because it was first employed by the French scientist, D'Arsonval, in making electrical measurement.

This type of meter movement is a current measuring device which is used in the ammeter, voltmeter, and ohmmeter. Basically, both the ammeter and the voltmeter are current measuring instruments, the principal difference being the method in which they are connected in a circuit. While an ohmmeter is also basically a current measuring instrument, it differs from the ammeter and voltmeter in that it provides its own source of power and contains other auxiliary circuits.

Construction :-

This instrument is very commonly used in various methods of resistance measurement and also in d.c. potentiometer work.

Different parts of D'Arsonval galvanometer

1) Moving coil:

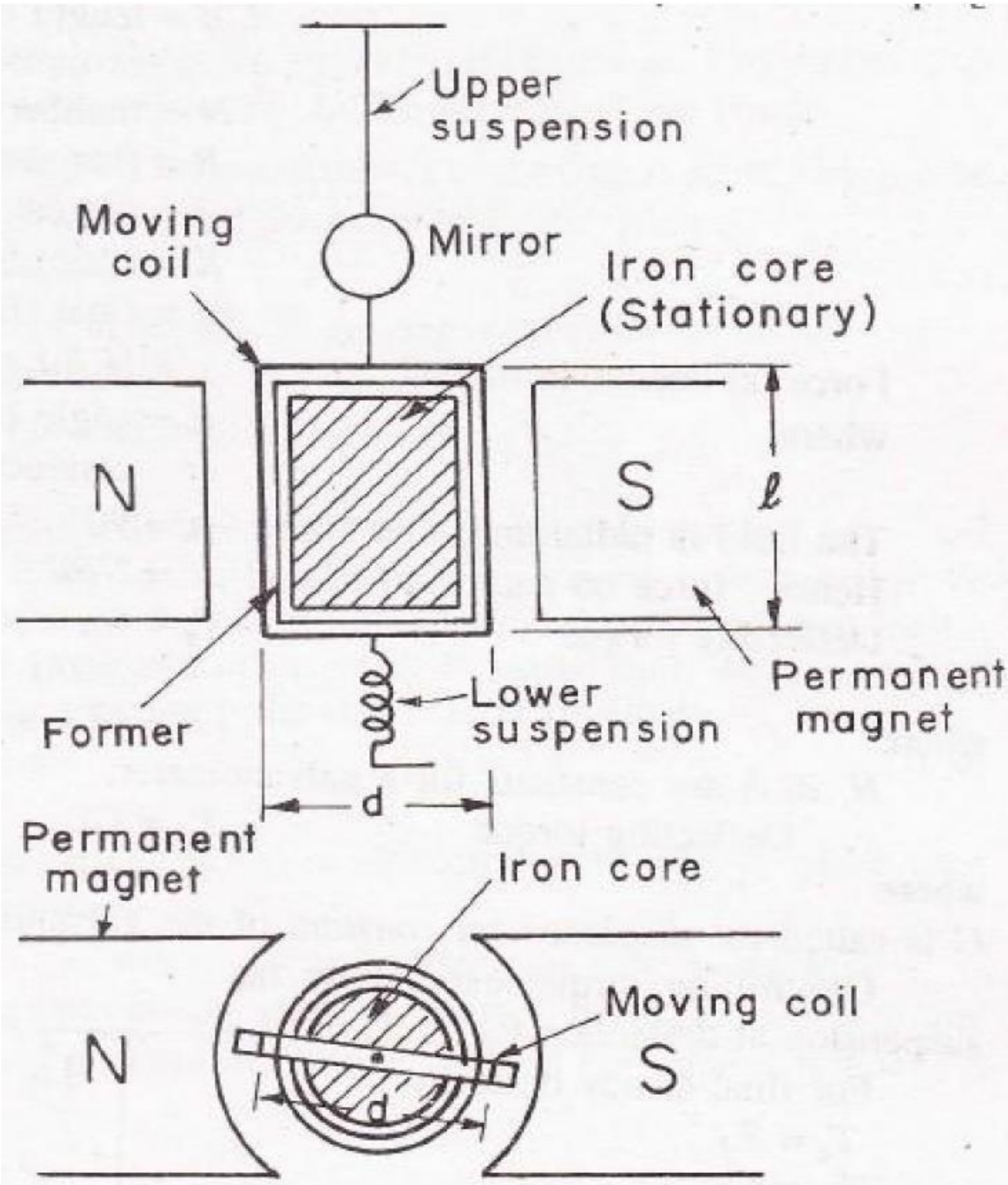
It is the current carrying element. It is either rectangular or circular in shape and consists of number of turns of fine wire. This coil is suspended so that it is free to turn about its vertical axis of symmetry. It is arranged in a uniform, radial, horizontal magnetic field in the air gap between pole pieces of a permanent magnet and iron core. The iron core is spherical in shape if the coil is circular but is cylindrical if the coil is rectangular. The iron core is used to provide a flux path of low reluctance and therefore to provide strong magnetic field for the coil to move in. this increases the deflecting torque and hence the sensitivity of the galvanometer. The length of air gap is about 1.5mm. In some galvanometers the iron core is omitted resulting in of decreased value of flux density and the coil is made narrower to decrease the air gap. Such a galvanometer is less sensitive, but its moment of inertia is smaller on account of its reduced radius and consequently a short periodic time.

2) Damping:

There is a damping torque present owing to production of eddy currents in the metal former on which the coil is mounted. Damping is also obtained by connecting a low resistance across the galvanometer terminals. Damping torque depends upon the resistance and we can obtain critical damping by adjusting the value of resistance.

3) Suspension:

The coil is supported by a flat ribbon suspension which also carries current to the coil. The other current connection in a sensitive galvanometer is a coiled wire. This is called the lower suspension and has a negligible torque effect. This type of galvanometer must be leveled carefully so that the coil hangs straight and centrally without rubbing the poles or the soft iron cylinder. Some portable galvanometers which do not require exact leveling have " taut suspensions" consisting of straight flat strips kept under tension for at the both top and at the bottom. The upper suspension consists of gold or copper wire of nearly 0.012-5 or 0.02-5 mm diameter rolled into the form of a ribbon. This is not very strong mechanically; so that the galvanometers must he handled carefully without jerks. Sensitive galvanometers are provided with coil clamps to the strain from suspension, while the galvanometer is being moved.

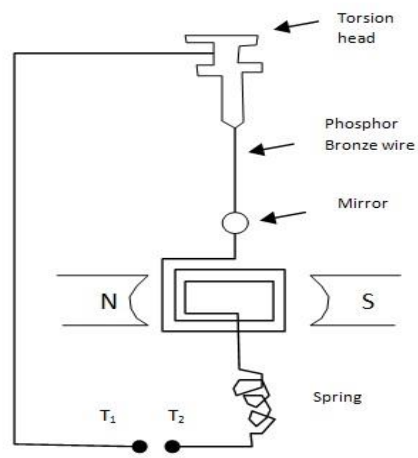


D'Arsonval Galvanometer

4) Indication:
The suspension carries a small mirror upon which a beam of light is cast. The beam of light is reflected on a scale upon which the deflection is measured. This scale is usually about 1 meter away from the instrument, although ½ meter may be used for greater compactness.
5) Zero setting:
A torsion head is provided for adjusting the position of the coil and also for zero setting.

Ballistic Galvanometer:

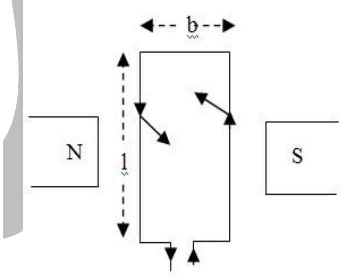
Ballistic galvanometer is an instrument which is invariably used in all DC measurements. Ballistic Galvanometer is used for the measurement of charge or quantity of electricity passes through it.



Principle:- When a current is passed through a coil, suspended freely in a magnetic field, it experiences a
forces in a direction given by Fleming's left hand rule.

Construction:- It consists of a rectangular coil of thin copper wire wound on a non-metallic frame of ivory. It is suspended by means of a phosphor bronze wire between the poles of a powerful horse-shoe magnet. A small circular mirror is attached to the suspension wire. Lower end of the coil is connected to a hair-spring. The upper end of the suspension wire and the lower end of the spring are connected to terminals T_1 and T_2. A cylindrical soft iron core (C) is place symmetrically inside the coil between the magnetic poles which are also made cylindrical in shape. This iron core concentrates the magnetic field and helps in producing radial field. The B.G. is used to measure electric charge. The charge has to pass through the coil as quickly as possible and before the coil stars moving. The coil thus gets an impulse and a throw is registered. To achieve this result, a coil of high moment of inertia is used so that the period of oscillation of the coil is fairly large. The oscillations of the coil are practically undamped.

Theory. (i) Consider a rectangular coil of N turns placed in a uniform magnetic field of magnetic induction B. Lel l be the length of the coil and b its breadth. Area of the coil = A = lb.



When a current i passes through the coil, torque on the coil is $\tau = NiBA$. … (1)

If the current passes for a short interval dt, the angular impulse produced in the coil is

$$\tau\, dt = NiBA\, dt \quad \dots (2)$$

If the current passes for t seconds, the total angular impulse given to the coil is

$$\int \tau\, dt = NBA \int i\, dt = NBAq \quad \dots (3)$$

Here $\int I\, dt = q$ = total charge passing through the galvanometer coil.

Let I be the moment of inertia of the coil about the axis of suspension and ω its angular velocity. Then, Change in angular momentum of the coil = Iω … (4)

$$\therefore \quad I\omega = NBAq. \quad \dots (5)$$

(ii) The kinetic energy of the moving system $1/2\, I\omega^2$ is used in twisting the suspension wire through an angle θ. Let c be the restore torque per unit twist of the suspension wire. Then,

Work done in twisting the suspension wire by an angle $\theta = 1/2 c\theta^2$

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Work done is twisting the suspension wire by an angle $\theta = 1/2 c\theta^2$

$$\therefore 1/2 I\, I\omega^2 = 1/2 c\, \theta^2 \text{ or } I\omega^2 = c\theta^2 \quad \dots (6)$$

(iii) The period of oscillation of the coil is

$$T = 2\pi \sqrt{(1/c)} \text{ or } T^2 = 4\pi^2 I/c \quad (7)$$

∴ Multiplying Eqs. (6) and (7), $I^2 \omega^2 = c^2T^2\theta^2 / 4\pi^2$

$$\text{Or } I\omega = cT\theta / 2\pi \quad \dots (8)$$

Equating (5) and (8), $NBAq = cT\theta / 2\pi$

$$\text{Or } q = (T/2\pi)\,(c/NBA)\,\theta \quad \dots (9)$$

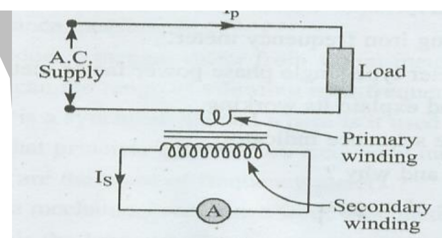
This gives the relation between the charge flowing and the ballistic throw θ of the galvanometer. $q \propto \theta$.
$(T/2\pi)\,(c/NBA)$ is called the ballistic reduction factor (K).

$$\therefore q = K\,\theta$$

Vibration Galvanometer:-
Vibration galvanometer are the D'Arsonval type i.e. PMMC type having a moving coil suspended between the pieces of permanent magnet. When an alternating current is passed through the moving coil, an alternating deflecting torque is produced which makes the coil vibrate with a frequency equal to the frequency of current passing through it. The damping is very small in this Galvanometer.
Construction:-
The moving coil consists of fine bronze or platinum silver wire. This wire passed over a small pulley at the top and it is pulled tight by a spring attached to the pulley. The tension of spring can be adjusted by turning a milled head attached to the spring. The loop of wire is stretched over two ivory bridge pieces , the distances between these pieces is adjustable. When the moving coil vibrates due to passage of AC, the reflected beam from the mirror throws a band of light upon a scale provided for the purpose.
Tuning:-
Tuning means adjustment of the frequency of natural system so that it is equal to the frequency of current passing through the coil.
Use:-
Vibration Galvanometer are suitable for use at low power audio frequency . Most common application is as a null indicating instrument in AC bridge circuits and current comparators.

Instrument transformers are high accuracy class electrical devices used to isolate or transform voltage or current levels. The most common usage of instrument transformers is to operate instruments or metering from high voltage or high current circuits, safely isolating secondary control circuitry from the high voltages or currents. The primary winding of the transformer is connected to the high voltage or high current circuit, and the meter or relay is connected to the secondary circuit. Instrument transformers may also be used as an isolation transformer so that secondary quantities may be used in phase shifting without affecting other primary connected devices

Measurement of current as Current Transformer (CT)
The primary winding is so connected that the current to be measured passes through it and the secondary is connected to the ammeter .
The function of CT is to step down the current.



Measurement of voltage by Potential Transformer (PT)
The primary winding is connected to the voltage side to be measured and secondary to the voltmeter.
The function of PT is to steps down the voltage to the level of voltmeter.