CHAPTER 15
ELECTRICAL MEASURING INSTRUMENTS

THE MOVING COIL GALVANOMETER:

The moving coil galvanometer is a basic electrical instrument. It is used for the detection or measurement of small currents.

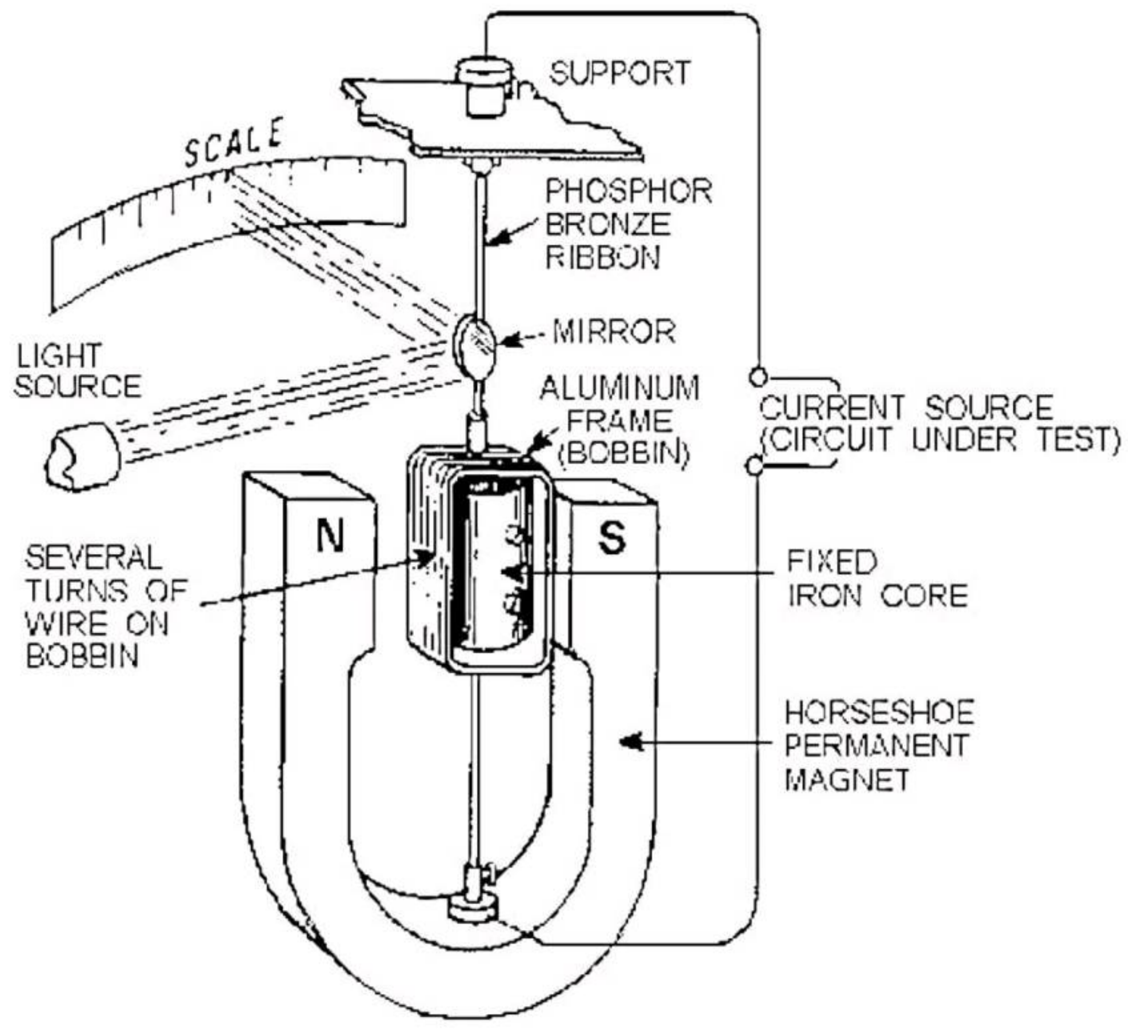
PRINCIPAL:

When a current flow in a rectangular coil placed in a magnetic field it experiences a magnetic torque due to which it rotates through an angle pro0portinoal to the current flowing through it.

CONSTRUCTION:

The essential parts of a moving coil galvanometer are.

1) A U shaped permanent magnet with cylindrical concave pole piece.
2) A flat coil of thin enamel insulated wire (usually rectangular).
3) A soft iron cylinder
4) A pointer or mirror
5) A scale or lamp and scale arrangement.
6) Spring or spiral.



FUNCTION OF THE PARTS:

1) The U shaped magnet having concave pole pieces produces radial magnetic field.
2) The sot iron cylinder helps in keeping the field stronger and radial.
3) The rectangular coil suspended between the pole pieces rotates when current passes through it.
4) The mirror or pointer shown deflection produced in the coil.
5) The scale gives the quantity of deflection.
6) The suspension strip and spring or spiral produces restoring torque. They bring the coil block to its initial position when current stops flowing. One end of the strip and one end of the spiral spring radial magnetic field spring also acts as current lead.

All the parts are connected according to the figure 1.

WORKING:

When a current passes through the galvanometer coil it experiences a magnetic deflecting torque which tends to rotate it form a twist in the suspension strip. The twist in the strip produces an elastic restoring torque. The coil rotates until the elastic restoring torque due to the strip does not equal and cancel the deflection magnetic torque and then it attains equilibrium and stops rotating any further. In this case,

Deflecting torque = restoring torque.

$$\text{Deflecting torque} = BINA \cos \propto$$

$$\text{And restoring torque} = c\,\theta$$

$$BINA \cos \propto = C\theta$$

$$I = \left(\frac{C}{BAN\ Cos\alpha}\right)\theta$$

Since the field is radial $\propto = 0$ and $\cos \theta = 1$

$$I = \left(\frac{C}{BAN}\right)\theta$$

Where B = strength of the magnetic field, I = current in the coil, A = area of the coil,
N = number of turns in the coil, θ = Angle of twist of the suspension strip
C = torque per unit twist of the suspension strip for equilibrium.

$$I \propto \theta$$

In pivoted type:

Or Weston galvanometer by a strip is pivoted between two jeweled bearings. The restoring torque is provided by two hair springs one on either side of the coil and cutting in the opposite sense. The two ends of the coil are connected one to each spring. The hair spring thus also serve as current leads to the coil. A light alumunium pointer is fixed to the coil which moves over a calibrated circular scale with equal divisions which measure the deflection directly.

Current sensitivity of a galvanometer:

The current sensitivity of a galvanometer defined as the current in microphones required to produce deflection of 1 division i.e 1mm on a scale placed at a distance of 1m from the mirror of the galvanometer. A galvanometer is said to be sensitive of a small current produces large deflection in it.

Factors on which sensitivity depends:

Sensitivity of a galvanometer depends upon $\frac{C}{BAN}$ to make galvanometer sensitive C should be small or BAN should be large.

(1)C can be made small by making suspension wire thin and large but it makes suspension wire weak or galvanometer large.
2) A can be increased by making large frame but it makes the coil heavy.
3) N can be increased by increasing number of turns but it makes the coil heavy.
4) B can be increased by using strong magnet. This method is adopted to make galvanometer more sensitive.

THE AMMETER:

Ammeter is an instrument which is used for measuring electric current.

Conversion galvanometer into ammeter:

A galvanometer can measure small current and its scale is calibrated for the current. For the measurement of large current a by pass resistance called a shunt of appropriate. Small value is connected in parallel with galvanometer coil. This resistance allows the large excess current through it self while a function of the current passes though the galvanometer coil. The scale of the instruments is so calibrated that it can measure current directly.

Derivation:

Consider a galvanometer G whose resistance is R_g and which gives full scale deflection when current I_g flows through it. To convert this galvanometer I to an ammeter which an measure a maximum current I a shunt R_s of appropriate small resistance should be connected in parallel with galvanometer such that the current I_g must flow through the galvanometer coil as shown in the figure. The potential difference V_g across the galvanometer is given by $V_g = I_g R_g$ the potential differences V_s across the shunt is given by,

$$V_s = I_s R_s = (I - I_g) R_s$$

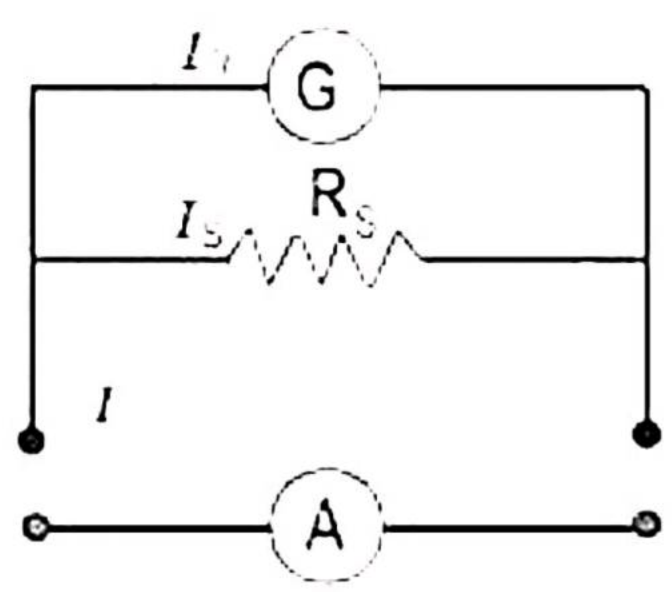
Where $I_s = I - I_g$ current though the shunt.

As R_g and R_s are connected in parallel to each other therefore potential difference across them will be equal

$$V_s = V_g$$

$$(I - I_g) R_s = I_g R_g$$

$$R_s = \left(\frac{I_g}{I - I_g}\right) R_g$$



This expression is called expression for shunt resistance is required for conversion of galvanometer into I range of an ammeter.

THE VOLTMETER:

Voltmeter is an instrument which is used for measuring potential difference the terminals of loads in a circuit.

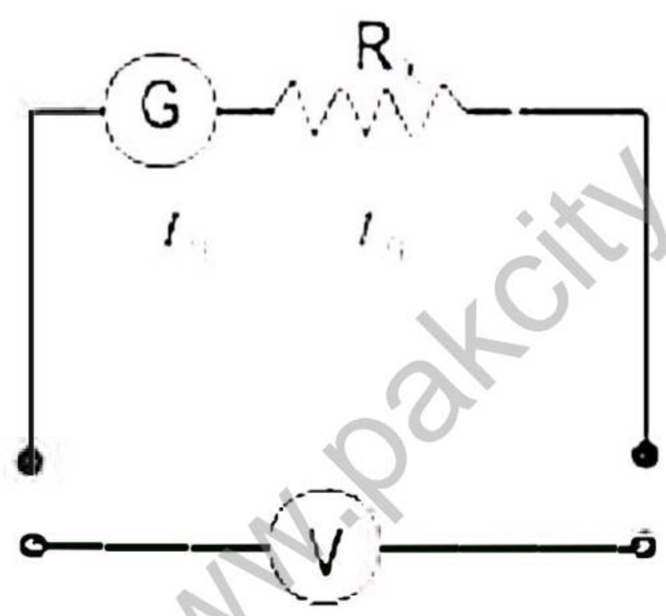
Conversion of galvanometer into voltmeter:

A galvanometer can be used for measuring a very small potential difference if its scale is calibrated for voltage for the measurement of large potential difference a high resistance of the order of kilo ohms is connected in series with it. This resistance is commonly known as multiplier resistance and denoted by R_x.

Derivation:

Consider a galvanometer G whose resistance is R_g and which deflects full scale for the current I_g. To convert this galvanometer in to a voltmeter measuring a potential difference of range 'V' a high resistance R_x must be connected in series with galvanometer such that for the potential difference V applied between the ends of the above combination the current I_g must flow through the galvanometer as shown in the figure. Now the total resistance between the terminals a and c is $(R_x + R_g)$.

By Ohms law,



$$V_{ac} = V_{ab} + V_{bc}$$

$$V = I_g R_x + I_g R_g$$

$$R_x = \frac{V}{I_g} - R_g$$

Voltmeter is always connected in parallel with the circuit.

WHEATSTONE BRIDGE:

It is a circuit which is used to find unknown resistance. If four resistance R_1, R_2, R_3 and R_4 are connected end to end in order to form a closed mash ABCDA, and between two pairs of alternate points A and C, B and D a battery of output voltage V_{AC} is connected through a key K_1 and a sensitive galvanometer G is connected through another key K_2 respectively the circuit so formed is called Wheatstone bridge as shown in figure.

BALANCED WHEAT-STONE BRIDGE

When 'K_1'is connected, no current passes through the galvanometer because K_2 is disconnected. When 'K_1' and 'K_2' are switched ON and no current flows through the galvanometer, the condition of bridge is called "Balanced condition". It is possible only when the potential difference between the terminals of galvanometer is zero or potential of point 'B' = potential of point 'D' i.e.

$$V_B = V_D$$

EXPRESSION FOR BALANCED BRIDGE

FROM FIGURE:

- R_1 & R_2 are connected in series. Reason: (only one path for the flow of current)
- R_3 & R_4 are connected in series.
- R_1 & R_3 are connected in parallel. Reason: (two paths for the flow of current)

* R_2 & R_4 are connected in parallel.

Let current I_1 flows through R_1 & R_2 and I_2 through R_3 & R_4.
When bridge is balanced,
Therefore,

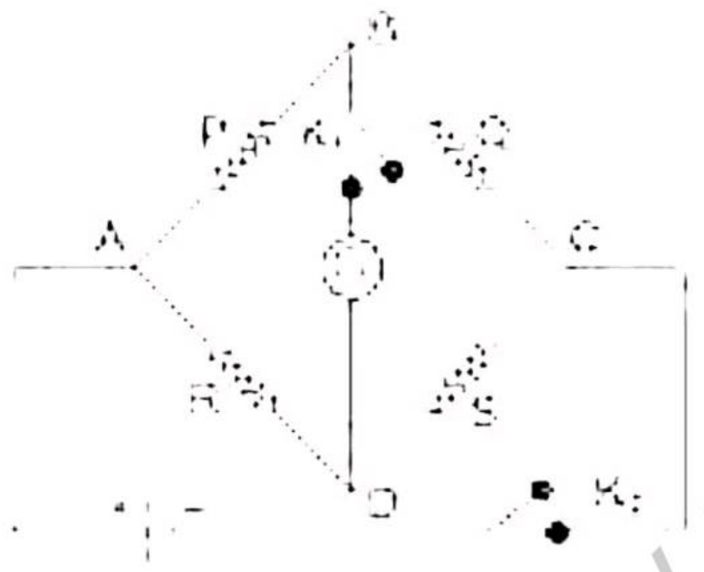
$$V_{AB} = V_{AD}$$
$$IR_1 = I_2R_3 \text{-------------(i)}$$

Similarly,

$$V_{BC} = V_{CD}$$

$$I_1R_2 = I_2R_4 \text{-----------(ii)}$$

Dividing equation (i) by equation (ii)



$$\frac{I_1R_1}{I_1R_2} = \frac{I_2R_3}{I_2R_4}$$

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

APPLICATIONS OF WHEATSTONE BRIDGE
A number of resistance measuring devices have been devised on the principle of Wheatstone bridge. For example:

* Meter bridge * Post office box * Potentiometer * Carey Foster's bridge * Callendar bridge
* Griffith's bridge

METRE BRIDGE:
The meter bridge also called slide- wire bridge is an instrument based on Wheatstone principle it consists of a long this copper strip bent twice at right angles two small portions are cut off from it near the bends to provide the gaps across which two resistances a known one and an unknown may be connected each of the three pieces of the strip is provided with binding screws a uniform wire (of magnesium or constantan) one meter long and of fairly high resistance is stretched alongside a meter scale connected to the ends of the strips.

POST OFFICE BOX (P. O BOX)
Post office box is an instrument which is based on Wheatstone principle it was first introduced for finding resistance of telegraph wires and for fault finding work in the post and telegraph office that why it is called "post office box" it is more compact and easier op use

THE OHMMETER:
Ohmmeter is a device used for the measurement of resistance it consists of a sensitive galvanometer "G" adjustable resistor "R" and a torch cell "E" connected in series between two terminals A and B as shown if fig the unknown resistance "X" to be measured is connected between the terminals A and B
The resistance "R" is so chosen that when the terminals A and B are short circuited (i.e. x= O) the galvanometer gives full scale deflection and when no connection is made between A and B (i.e. x= O) value of "X" between zero deflection for the value of "X" between zero and ∞ the deflection is small or large depending on the value of X the scale of the galvanometer is first calibrated with diffe3rent known values of

X and then the circuit serves as an Ohmmeter to measure any unknown resistance approximately the scale of the Ohmmeter is however is not linear.

POTENTIOMETER:

Potentiometer is a device for measuring the potential difference (or voltage) between two points of a circuit or the E. M. F of a current source it consists of a uniform wire stretched on a wooden board along a meter scale

THE AVO-METER:

An AVO-meter is an apparatus which is used to measure current voltage and resistance in other words it is an ammeter, voltmeter and ohmmeter it can measure direct as well as alternating voltage and currents. It consists of a galvanometer with different scale graduated in such way the all three quantities can be measured A selector –cum-range switch is provided it has its own battery a rectifier is also included in the instruments to convert A. C into D. C before they passes through the galvanometer.