Galvanometer, Ammeter & Voltmeter

Galvanometer

A galvanometer is a device (instrument) used for detecting feeble electric voltage, currents in a circuit. It has a coil pivoted (or suspended) between concave pole faces of a strong laminated horse shoe magnet. When an electric current passes through the coil it deflects. Its deflection is noted by attaching a pointer to the coil (or by using a lamp and scale arrangement). The deflection is proportional to the current passed. The galvanometer coil has a moderate resistance (about 100 ohms) and the galvanometer itself has a small current carrying capacity (1 mA).

Moving coil (pointer type) Galvanometer

(a) Construction: (Refer Section 2.13).
(b) Theory: Let,

Area of galvanometer coil $= A$

Number of turns in coil $= N$

Current through coil $= I$

Magnetic flux density of the radial magnetic field of galvanometer magnet $= B$

Then,

Deflecting torque $\tau_{def} = NAIB$

Let,

Restoring torque per unit twist of control spring $= K$

Angle of twist (deflection) $= \theta$, then

Restoring torque, $\tau_{rest} = K\theta$

At equilibrium, $\tau_{def} = \tau_{rest}$

$$NAIB = K\theta$$

or

$$I = \left(\frac{K}{NAB}\right)\theta \quad \text{or} \quad I = G\theta$$

where G = K/NAB and is called galvanometer constant. Knowing G and observing θ, I can be calculated.
(c) Figure of merit: If is defined as the current required to produce unit deflection in the galvanometer. It is represented by the symbol k.

$$k = \frac{I}{\theta}$$

$$k = \frac{I}{\theta} = \frac{K}{NAB} = G \text{ galvanometer constant}$$

(d) Current sensitivity: Deflection produced due to flow of unit current in its coil, is called current sensitivity of the galvanometer. It is represented by the symbol S_I

From relation, $$I = \frac{K}{NAB}\theta$$

$$S_I = \frac{\theta}{I} = \frac{NAB}{K}$$

(e) Voltage sensitivity: Deflection produced due to current produced by unit potential difference between ends of the galvanometer coil, is called voltage sensitivity of the galvanometer. It is represented by the symbol S_V.

For coil of resistance R, $$I = \frac{V}{R}$$

Hence, $$\frac{V}{R} = \frac{K}{NAB}\theta$$

$$S_V = \frac{\theta}{V} = \frac{NAB}{KR} = \frac{S_I}{R}$$

Ammeter (ampere meter)

An ammeter is a device (instrument) used for measuring large electric currents in ‘ circuits. For this purpose, it is put in series with the circuit in which the current is to be measured.
For accurate measurement, an ammeter must have following two properties:

1. A very small resistance (zero in ideal case).
2. A very large current carrying capacity.

It is done by connecting low resistance in parallel with the coil of the galvanometer. This parallel low resistance is called shunt. The shunt reduces the overall resistance of the ammeter and increases its current carrying capacity.

Voltmeter

A voltmeter is a device (instrument) used for measuring electric potential difference between two points in a circuit. For this purpose, it is put in parallel with that branch of circuit, at the ends of which the potential difference is to be measured.
For accurate measurements a voltmeter must have following two properties:

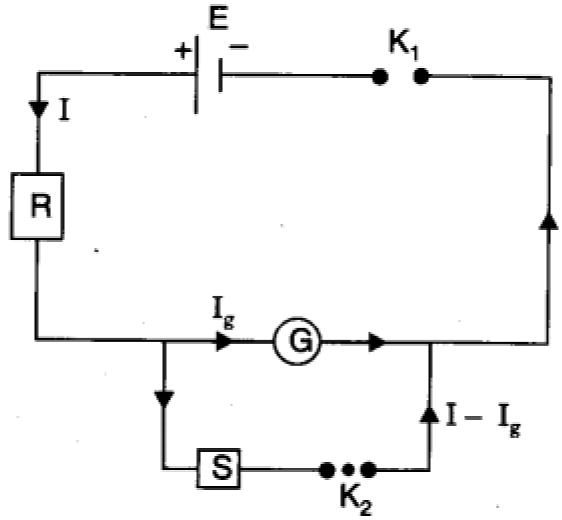
1. A very large resistance (infinite in ideal case).

2. A very small current carrying capacity.

It is done by connecting a high resistance in series with the coil of the galvanometer. The series high resistance increases the overall resistance of the voltmeter and reduces its current carrying capacity.

Resistance of a galvanometer by half deflection method

The connections for finding the resistance of a galvanometer by half deflection method are shown in When key K_1 is closed and K_2 open, then current flowing through the galvanometer is given by



Resistance of galvanometer by half deflection method.

$$I = \frac{E}{R+G} = k\theta \quad ...(1)$$

($\because$ current $\propto$ deflection in galvanometer)

where E is the E.M.F. of the cell, R is resistance from the resistance box, G is the galvanometer resistance and 0 is the deflection in galvanometer for current I, k is proportionality constant (called figure of merit).

When key Kg is also closed and the value of shunt resistance S is so adjusted that deflection in the galvanometer becomes θ/2 then resistance of the parallel combination of G and S is GS/G+S and current in the circuit is

$$I' = \frac{E}{R + \frac{GS}{G+S}} = \frac{E(G+S)}{R(G+S)+GS} \qquad ...(2)$$

Of this current I', a fraction $\frac{S}{G+S}$ flows through the galvanometer given by

$$I_1' = \frac{I'S}{G+S} = \frac{ES}{R(G+S)+GS} = k\,\frac{\theta}{2}$$

or

$$\frac{2ES}{R(G+S)+GS} = k\theta \qquad ...(3)$$

Comparing Eqs. (1) and (3), $\frac{E}{R+G} = \frac{2ES}{R(G+S)+GS}$ ...(4)

By solving Eq. (4), we can find $\boxed{G = \frac{RS}{R-S}}$ ...(5)

Figure of merit of a galvanometer

It is defined as the current required to produce a deflection of one division in the scale of galvanometer. It is represented by the symbol k. (It is reciprocal of current sensitivity). When current I produces a deflection 0 in the galvanometer, then figure of merit is given by using Eq. (1),

by using Eq. (1),

$$k = \frac{I}{\theta} = \frac{E}{(R+G)\theta}$$

or

$$\boxed{k = \frac{E}{(R+G)\theta}}$$

If n is the number of divisions in the galvanometer scale, then current required to produce full scale deflection is given by $I_g = nk$.

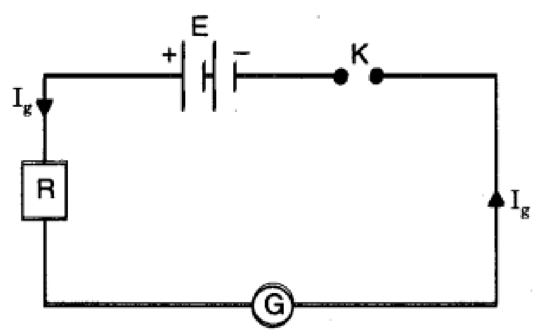
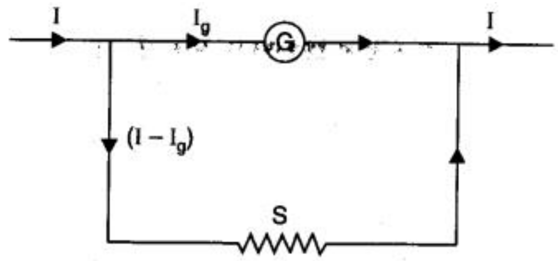


Figure of merit of a galvanometer.

Conversion of a galvanometer into an ammeter

A galvanometer can detect only small currents.

For measuring large currents (to convert into ammeter), a small resistance called shunt resistance (S) is connected in parallel across the galvanometer. Out of total current I only a small current I_g flows through the galvanometer for full scale deflection and remaining $I-I_g$by passes through the shunt S. Since G and S are parallel to each other therefore, potential difference across both is same.



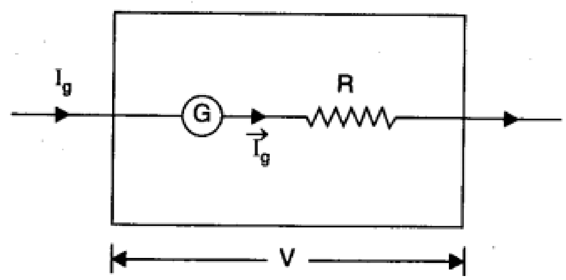
Shunt resistance.

$\therefore \qquad I_g \cdot G = (I - I_g) \cdot S$

or $\qquad \boxed{S = \dfrac{I_g \cdot G}{(I - I_g)}} \qquad \left[\text{If } I = nI_g, S = \dfrac{G}{n-1}\right]$

Conversion of a galvanometer into a voltmeter

(a) Introduction: A voltmeter is a high resistance galvanometer, used for measuring the potential difference between two points of an electric circuit. It is always connected in parallel with those two points. The resistance of a galvanometer is made very large so that its measuring range increases and when connected in parallel to a circuit, it draws a feeble current and does not change the magnitude of current flowing in the main circuit. Hence to convert a galvanometer into a voltmeter a suitable high resistance is connected in series with the galvanometer, as resistance of a galvanometer, is very low.



Series resistance.

(*b*) ***Conversion.*** Let G be the resistance of a galvanometer and I_g be the current required to produce full scale deflection. If the galvanometer is to be converted into a voltmeter of range $0 - V$ volts ($V > I_g \cdot G$), we must connect a high resistance R in series with it such that

$$V = I_g (R + G) \text{ or } R + G = \frac{V}{I_g}$$

$\therefore$ Value of high resistance $\boxed{R = \dfrac{V}{I_g} - G} \qquad$ [If $\quad V = nV_g = n(I_g G), R = (n-1)\, G.$]