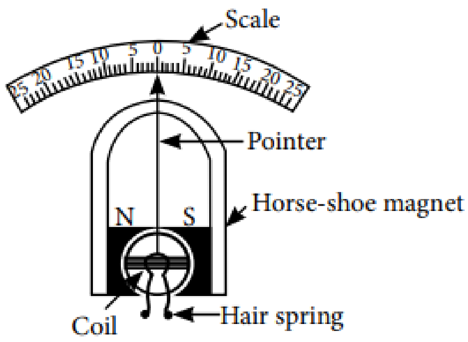
Experiment - 12 : Resistance and figure of merit of a galvanometer by half-deflection method.

A galvanometer is device (instrument) used for detecting feeble electric currents in circuits.

Moving Coil Galvanometer

In laboratory we commonly use a pivoted coil pointer type moving coil galvanometer, called Weston galvanometer (See figure below).

It consists of a high, laminated, horse-shoe magnet with concave pole faces to provide a radial magnetic field. A coil of thin insulated copper wire wrapped over a copper frame is mounted on two jewelled pivots symmetrically between the pole faces. The motion of the coil is controlled by two attached hair springs, one above and the other below the coil. These hair springs also serve as lead and make contact with two terminals (binding screws) provided at the top of the bakelite frame. An aluminium pointer is attached perpendicular to the coil. The free end of the pointer moves over an arc like scale. The scale has zero (0) in the middle and equal number of divisions (25 or 30 divisions, 1 div = 1°) on either side of the central zero. The pointer end stays at zero.



The galvanometer is connected in series in the circuit in which current is to be detected. The current passes through the coil pivoted in the magnetic field. The coil experiences equal, parallel and opposite forces on its arms which form a couple. The couple rotates the coil which makes the pointer move on the scale. The deflection (measured as number of divisions) is proportional to the current passed. The galvanometer is quite sensitive and gives full scale deflection even for a small current (say 1 milli-ampere).

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 τ_{def} = NAIB

Let Restoring torque per unit twist of control spring = c

Angle of twist (deflection) = θ, then

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

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

$$NAIB = c\theta,\ I = \left(\frac{c}{NAB}\right)\theta \text{ or } I = K\theta$$

where $K = \dfrac{c}{NAB}$ and is called galvanometer constant.

Knowing K and observing θ, I can be calculated.

Current Sensitivity

Deflection produced due to flow of unit current in its coil, is called current sensitivity of the galvanometer. Its symbol is S_I .

From relation, $I = \dfrac{c}{NAB}\theta;\ S_I = \dfrac{\theta}{I} = \dfrac{NAB}{c}$

Voltage Sensitivity

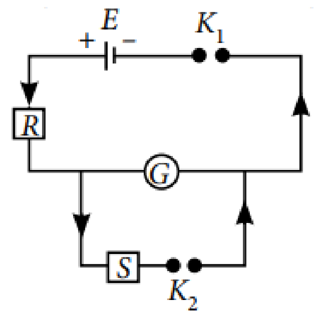
Deflection produced due to current produced by unit potential difference between ends of the galvanometer coil, is called voltage sensitivity of the galvanometer. Its symbol is S_V.

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

Hence, $\dfrac{V}{R} = \dfrac{c}{NAB}\theta;\ S_V = \dfrac{\theta}{V} = \dfrac{NAB}{cR} = \dfrac{S_I}{R}$

Resistance of Galvanometer

The connections for finding the resistance of a galvanometer by half deflection method are shown in figure. 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.

$$I = \frac{E}{R+G} = k\theta \qquad \ldots(\text{i})$$

(current ∝ 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 θ is the deflection in galvanometer for current I, k is proportionality constant (called figure of merit).

When key K_2 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

$$I' = \frac{E}{R+\frac{GS}{G+S}} = \frac{E(G+S)}{R(G+S)+GS} \qquad \ldots(\text{ii})$$

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 $$\frac{2ES}{R(G+S)+GS} = k\theta \qquad \ldots(\text{iii})$$

Comparing Eqs. (i) and (iii),

$$\frac{E}{R+G} = \frac{2ES}{R(G+S)+GS} \qquad \ldots(\text{iv})$$

By solving eq. (iv), we can find $G = \frac{RS}{R-S}$

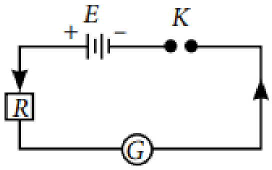
Figure of Merit of a Galvanometer

It is defined as the current required to produce a deflection of one division in the scale of galvanometer. Its symbol is k. (It is reciprocal of current sensitivity).

When current I produces a deflection θ in the galvanometer, then figure of merit is given by using Eq. (i),

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

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



MCQs Corner

Experiment – 12

51. The scale of a galvanometer of resistance 100 Ω contains 25 divisions. It gives a deflection of 1 division on passing a current of 4×10^{-4} A. The resistance in ohm to be added to it, so that it may become a voltmeter of range 2.5 V is

(a) 100 (b) 150 (c) 250 (d) 300

52. A galvanometer, having a resistance of 50 Ω, gives a full-scale deflection for a current of 0.05 A. The length in metre of a resistance wire of area of cross-section 2.97×10^{2} cm^2 that can be used to convert the galvanometer into an ammeter which can read a maximum of 5 A current is (specific resistance of wire = 5×10^{-7} Ω m)

(a) 8 (b) 6 (c) 3 (d) 1.5

53. A moving coil galvanometer has 150 equal divisions. Its current sensitivity is 10 divisions per milliampere and voltage sensitivity is 2 divisions per millivolt. In order that each divisions reads 1 V, the resistance in ohms needed to be connected in series with the coil will be

(a) 99995 (b) 9995 (c) 10^3 (d) 10^5

54. A microammeter has a resistance of 100 Ω and a full-scale range of 50 μA. It can be used as a voltmeter or as a higher range ammeter provided a resistance is added to it. Pick the correct range and resistance combination(s).

(a) 50 V range with 10 kΩ resistance in series

(b) 10 V range with 200 kΩ resistance in series

(c) 5 A range with 1 Ω resistance in parallel

(d) 10 mA range with 1 Ω resistance in parallel

Answer Key

51. (b) 52. (c) 53. (b) 54. (c)

Hints & Explanation

51. **(b) :** For full scale deflection, $I_g = nk$

$\therefore \quad I_g = 25 \times (4 \times 10^{-4}) = 10^{-2}$ A

Now $R = \dfrac{V}{I_g} - G = \dfrac{2.5}{10^{-2}} - 100 = 250 - 100 = 150\ \Omega$

52. **(c) :** We know that $(I - I_g)S = I_gG$

$\therefore\ I = \dfrac{(G+S)}{S} I_g$

Therefore, $5 = \dfrac{50+R}{R} \times 0.05$ or $R = \dfrac{2.5}{4.95}\ \Omega$

Further $R = \rho\left(\dfrac{l}{A}\right)$ or $l = \dfrac{AR}{\rho}$

or $l = \dfrac{(2.97\times10^{-6})\times(2.5)}{(5\times10^{-7)}\times4.95} = 3$ m

53. **(b) :** We know that $R = \dfrac{V}{I_g} - G$

G = galvanometer resistance $= \dfrac{V_{\max}}{I_{\max}} = 5\ \Omega$

$\dfrac{V}{I_g} = 10000,\ \therefore\ R = 10000 - 5 = 9995\Omega$

54. **(c) :** We know that $I_g = V/(R + G)$

For a, $50 \times 10^{-6} = 50/(R + 100)$

$\therefore \quad R = (10^6 - 100)\Omega$

For b,

$50 \times 10^{-6} = 10/(R + 100),\ \therefore\ R = 200 \times 10^3\ \Omega$

Further $I_g = \{S/(S + G)\}I$

For c,

$50 \times 10^{-6} = \{S/(S + 100)\}\ 5 \times 10^{-3}$

Solving, We get $S = 100/99 \approx 1\ \Omega$.