EXPERIMENT 6

AIM

To determine the resistance of a galvanometer by half-deflection method and to find its figure of merit.

APPARATUS AND MATERIAL REQUIRED

A moving coil galvanometer, a battery or a battery eliminator (0 - 6 V), one resistance box ($R_{BOX\ 1}$) of range 0 - 10 kΩ, one resistance box ($R_{BOX\ 2}$) of range 0 - 200 Ω, two one way keys, voltmeter, connecting wires and a piece of sand paper.

PRINCIPLE

Galvanometer

Galvanometer is a sensitive device used to detect very low current. Its working is based on the principle that a coil placed in a uniform magnetic field experiences a torque when an electric current is set up in it. The deflection of the coil is determined by a pointer attached to it, moving on the scale.

When a coil carrying current I is placed in a radial magnetic field, the coil experiences a deflection θ which is related to I as

$$I = k\,\theta \qquad \text{(E 6.1)}$$

where k is a constant of proportionality and is termed as figure of merit of the galvanometer.

The circuit arrangement required for finding the resistance G of the galvanometer by half deflection method is shown in Fig. E 6.1.

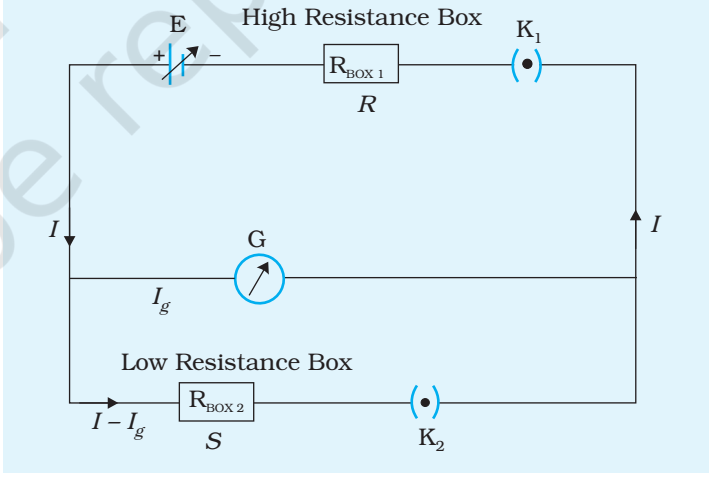

Fig. E 6.1 *Circuit for finding resistance of galvanometer*

When a resistance R is introduced in the circuit, the current I_g flowing through it is given by

(E 6.2)
$$I_g = \frac{E}{R + G}$$

In this case, the key K_2 is kept open. Here E is the emf of battery, G is the resistance of the galvanometer whose resistance is to be determined.

If the current I_g produces a deflection θ in the galvanometer, then from equation (E 6.1) we get

(E 6.3)
$$I_g = k\,\theta$$

Combining equations (E 6.2) and (E 6.3) we get

(E 6.4)
$$\frac{E}{R + G} = k\,\theta$$

On keeping both the keys K_1 and K_2 closed and by adjusting the value of shunt resistance S, the deflection of the galvanometer needle becomes $\frac{1}{2}$ (half). As G and S are in parallel combination and R in series with it, the total resistance of the circuit

(E 6.5)
$$R' = R + \frac{GS}{G + S}$$

The total current, I due to the emf E in the circuit is given by

(E 6.6)
$$I = \frac{E}{R + \dfrac{GS}{G + S}}$$

If I'_g is the current through the galvanometer of resistance G, then

$$G\,I'_g = S\,(I - I'_g)$$

(E 6.7)
or,
$$I'_g = \frac{IS}{G + S}$$

Substituting the value of I from Equation (E 6.6), in equation (E 6.7) the current I'_g is given by

$$\left[I'_g = \frac{IS}{G+S} = \frac{E}{R + \frac{GS}{G+S}} \cdot \frac{S}{G+S} \right]$$

$$I'_g = \frac{ES}{R(G+S)+GS} \qquad \text{(E 6.8)}$$

For galvanometer current I'_g, if the deflection through the galvanometer is reduced to half of its initial value $\left(= \frac{\theta}{2}\right)$ then

$$I'_g = k\left(\frac{\theta}{2}\right) = \frac{ES}{R(G+S)+GS}$$

On dividing Eq. (E 6.2) by Eq. (E 6.8),

$$\frac{I_g}{I'_g} = \frac{E}{R+G} \times \frac{R(G+S)+GS}{ES} = 2$$

or, $R\,(G+S) + GS = 2S\,(R+G)$

$\Rightarrow$ $RG = RS + GS$

$\Rightarrow$ $G\,(R-S) = RS$

or, $G = \frac{RS}{R-S}$ (E 6.9)

By knowing the values of R and S, the galvanometer resistance G can be determined. Normally R is chosen very high (~ 10 kΩ) in comparison to S (~ 100 Ω) for which

$$G \simeq S$$

The figure of merit *(k)* of the galvanometer is defined as the current required for deflecting the pointer by one division. That is

$$k = \frac{I}{\theta} \qquad \text{(E 6.10)}$$

For determining the figure of merit of the galvanometer the key K_2 is opened in the circuit arrangement.

Using Eqs. (E 6.2) and (E 6.3) the figure of merit of the galvanometer is given by

$$k = \frac{1}{\theta}\left(\frac{E}{R+G}\right), \qquad \text{(E 6.11)}$$

By knowing the values of E, R, G and θ the figure of merit of the galvanometer can be calculated.

PROCEDURE

1. Clean the connecting wires with sand paper and make neat and tight connections as per the circuit diagram (Fig. E 6.1).
2. From the high resistance box ($R_{BOX\ 1}$) (1-10 kΩ), remove 5 kΩ key and then close the key K_1. Adjust the resistance R from this resistance box to get full scale deflection on the galvanometer dial. Record the values of resistance, R and deflection θ.
3. Insert the key K_2 and keep R fixed. Adjust the value of shunt resistance S to get the deflection in the galvanometer which is exactly half of θ. Note down S. Remove plug K_2 after noting down the value of shunt resistance, S.
4. Take five sets of observations by repeating steps 2 and 3 so that θ is even number of divisions and record the observations for R, S, θ and $\frac{\theta}{2}$ in tabular form.
5. Calculate the galvanometer resistance G and figure of merit k of galvanometer using Eqs. (E 6.9) and (E 6.11) respectively.

OBSERVATIONS

Emf of the battery E = ... V

Number of divisions on full scale of galvanometer = ...

Table E 6.1: Resistance of galvanometer

Sl. No.	High Resistance R (Ω)	Deflection in the galvanometer θ (divisions)	Shunt resistance S (Ω)	Half deflection in the galvanometer $\frac{\theta}{2}$ (divisions)	$G = \frac{R.S}{R-S}$ (Ω)	$k = \frac{E}{R+G}\cdot\frac{1}{\theta}$ A/divisions
1						
2						
--						
5						

CALCULATIONS

Mean value of G (resistance of galvanometer) = ... Ω

Mean value of k (figure of merit of galvanometer) = ... ampere/division.

RESULT

1. Resistance of galvanometer by half deflection method, G = ... Ω
2. Figure of merit of galvanometer, k = ...ampere/division

PRECAUTIONS

1. Key K_1 should be inserted only after high value of R has been taken out from resistance box otherwise galvanometer coil may burn.
2. Adjust R such that deflection in galvanometer is of even division so that $\theta/2$ is more conveniently obtained.
3. Emf of the battery should be constant.
4. Use as high values of R as practically possible. This ensures correct value of G.
5. All the connections and plugs in the resistance box should be tight.

SOURCES OF ERRORS

1. Plugs in the resistance boxes may be loose or they may not be clean.
2. The emf of the battery may not be constant.

DISCUSSION

1. By closing the key K_2 and adjusting the value of resistance in resistance box $R_{BOX\ 2}$, you get the deflection $\theta/2$ in the galvanometer. Then the resistance S equals G, the resistance of galvanometer, because half of the current passing through R is shared by S and half by galvanometer. It is noteworthy that R is so large compared to S or G that opening or closing the key K_2 makes insignificant difference in the current passing through R.
2. We define current sensitivity C of the galvanometer as the deflection produced per unit current. With K_2 open, the current passing through it is

$$C\theta = \frac{E}{R}$$

$$C = \frac{E}{R\theta}$$

3. From eq. E 6.9, $RS = G(R - S)$. Galvanometer resistance G can also be determined from the slope of a graph plotted RS against $(R - S)$ with RS on y-axis and $(R - S)$ on x-axis.

SELF ASSESSMENT

1. How will you use a galvanometer for measuring current?
2. (a) Out of galvanometer, ammeter and voltmeter which has the highest resistance and which has the lowest? Explain.

   (b) Which of the two meters has lower resistance – a milliammeter or a microammeter?
3. What are the factors on which sensitivity of a galvanometer depends?
4. Internal resistance of the cell is taken to be zero. This implies that we have to use a freshly charged accumulator in the experiment or use a good battery eliminator. If the internal resistance is finite, how will it affect the result?
5. Is it possible to find the galvanometer resistance by taking 1/3 deflection ? If so what changes would be required in the formula for calculation of value of G.

SUGGESTED ADDITIONAL EXPERIMENTS/ACTIVITIES

1. Plot a graph between R and $\frac{1}{\theta}$ (R along x- axis). Use the graph to determine G and k.
2. Plot a graph of θ against $\left(\frac{E}{R+G}\right)$ with θ on y-axis and $\left(\frac{E}{R+G}\right)$ on x-axis. How will you determine k from the graph?
3. Use the values of G and k to calculate the value of shunt resistance required to convert the given galvanometer into an ammeter of 0 - 3 A range.
4. Calculate the value of series resistance required to convert the given galvanometer into a voltmeter of 0 – 30 V range.