EXPERIMENT

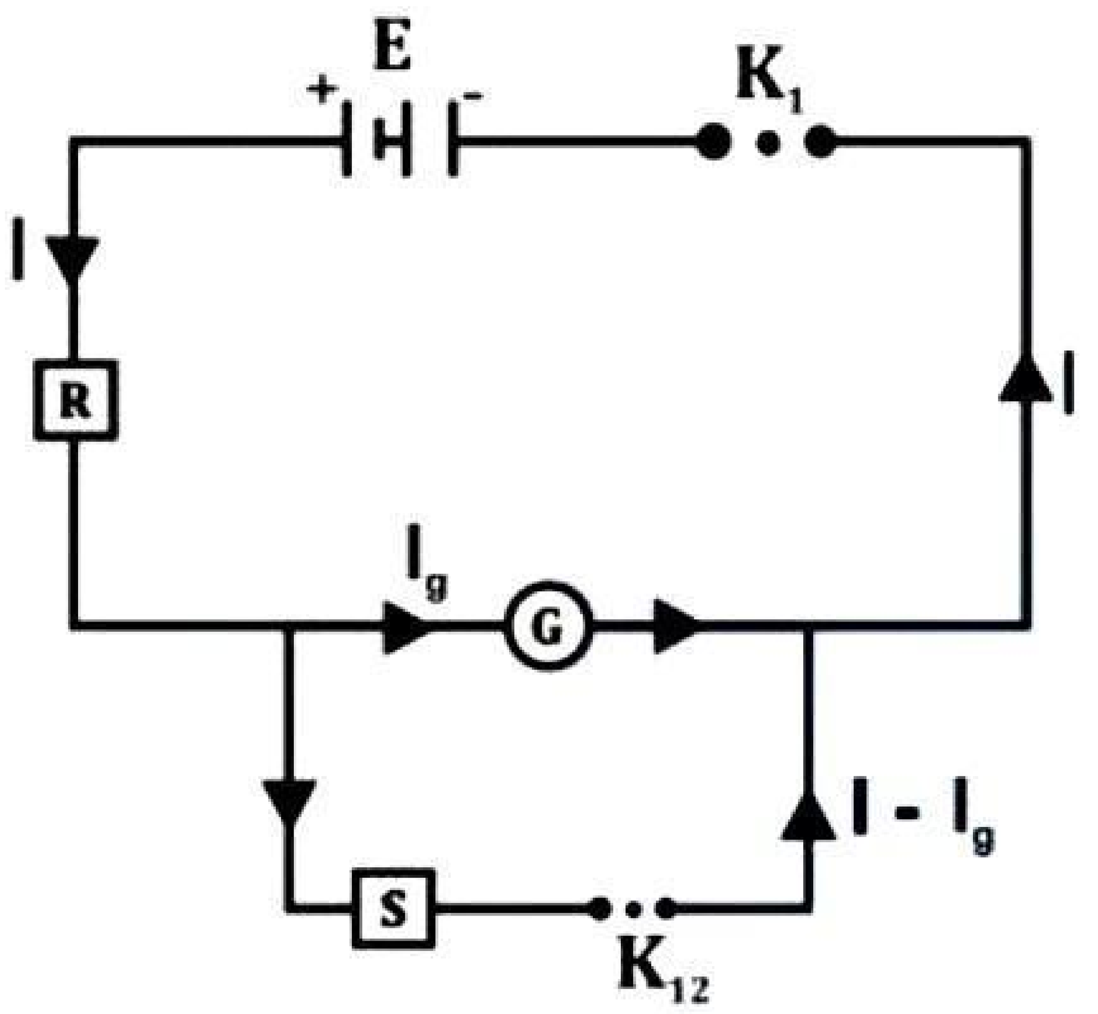
AIM

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

MATERIAL REQUIRED

A galvanometer (pivoted type), a battery (lead accumulator), a high resistance box ($0 - 1000\Omega$), a low resistance box ($0 - 200\ \Omega$), two one-way keys, connecting wires and sandpaper screw gauge, metre scale, rheostat, ammeter.

DIAGRAM



Resistance of galvanometer

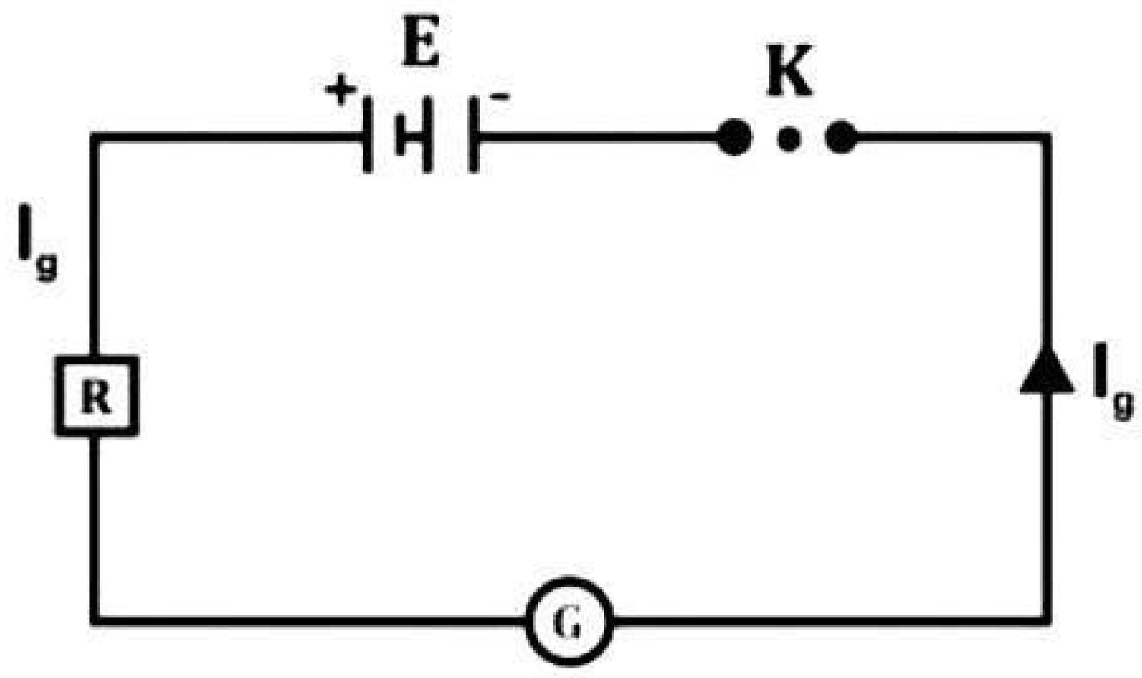


Figure of merit

THEORY

The galvanometer functions as a highly sensitive apparatus designed for the detection of extremely low currents. Its operation relies on the concept that when an electric current passes through a coil situated in a uniform magnetic field, the coil experiences torque. A pointer attached to the coil determines its deflection as it moves along a scale. In the case of a moving coil galvanometer with a linear scale, the current (I_g) flowing through it is determined by closing the key K_1, expressed as:

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

Where, E is the cell's electromotive force, R is the circuit resistance, and G is the galvanometer resistance. The deflection (θ) exhibited by the galvanometer due to the current flow (I_g) is proportional, as denoted by $I_g \propto \theta$, or equivalently $I_g = k\theta$, with the relationship,

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

Upon closing the key K_2 and adjusting the resistance (S) so that the deflection is halved $\left(\frac{\theta}{2}\right)$, the current through the galvanometer (I_g') is proportional to $\frac{\theta}{2}$, expressed as:

$$I'_g = k\frac{\theta}{2}$$

Applying the principle of shunt, $I'_g = I\left(\frac{S}{G+S}\right)$, leads to the relationship,

$$I\left(\frac{S}{G+S}\right) = k\frac{\theta}{2} \qquad \text{.....................(ii)}$$

Where, I represents the current in the main circuit. Given that G and S are in parallel, the equivalent resistance R′ is expressed as,

$$\frac{1}{R'} = \frac{1}{G} + \frac{1}{S} = \frac{G+S}{GS}$$

Or,
$$R' = \frac{GS}{G+S}$$

Consequently, the total circuit resistance $= R + R' = R + \frac{GS}{G+S}$

The current in the main circuit is determined by,

$$I = \frac{E}{R+R'} = \frac{E}{R + \frac{GS}{G+S}}$$

By substituting this I into equation (ii), we derive,

$$\frac{E}{R + \frac{GS}{G+S}} \times \left(\frac{S}{S+G}\right) = k\frac{\theta}{2}$$

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

Upon dividing equation (i) by (iii), the result is,

$$\frac{R(G+S)+GS}{(R+G)S} = 2$$

Or,
$$RG + RS + GS = 2RS + 2GS$$

Or,
$$G(R-S) = RS$$

Or,
$$G = \frac{RS}{R-S} \qquad \text{.....................(iv)}$$

Equation (iv) reveals the galvanometer resistance G of the galvanometer coil. The figure of merit k for the galvanometer is defined as the current flowing through the galvanometer per unit division deflection. By substituting $\theta = n$ into equation (i), the figure of merit is expressed as,

$$\boxed{k = \frac{E}{n(R+G)}} \qquad \text{.....................(v)}$$

Here, (n) represents the galvanometer deflection in divisions. The inverse of the figure of merit of a galvanometer serves as a measure of its sensitivity.

PROCEDURE

1. Set up the circuit according to the diagram provided.
2. Ensure that all plugs in the resistance boxes are securely tightened.
3. Exclude the high resistance from the resistance box and introduce plug key K_1 exclusively.
4. Fine-tune the R value to achieve the maximum deflection, both in numerical terms and within the scale.
5. Record the deflection angle, θ.
6. Introduce key K_2 without altering the R value. Adjust the S value to halve the deflection, i.e., $\frac{\theta}{2}$.
7. Take note of the resistance value, S.
8. Repeat steps 4 to 7 three times to gather varied R values for different S values.
9. Determine the electromotive force (E.M.F) of one of the cells using a voltmeter.

OBSERVATIONS

Table 1:

S. No.	Resistance R	Deflection in the Galvanometer θ	Shunt Resistance S	Half Deflection $\frac{\theta}{2}$	Galvanometer Resistance $G = \frac{RS}{R-S}$
1.					
2.					
3.					
4.					

For the resistance of the galvanometer by half deflection method:

Table 2:

S. No	Number of cells (Battery Eliminator)	e.m.f of the cells or the reading of the battery eliminator E(V)	Resistance from R.B. R (ohm)	Deflection θ (div)	$k = \frac{E}{(R+G)\theta}$
1.					
2.					
3.					
4.					

CALCULATIONS

1. Determine the number of divisions on the galvanometer scale, denoted as $n =$ ________.
2. Subsequently, record this value in column 4 of Table 1.
3. Compute the mean of the G values listed in column 4 of Table 1.
4. Compute the value of k with the formula $k = \frac{E}{(R+G)}$.
5. After the calculation, input this value into column 4 of Table 2.
6. Calculate the mean value of k and document it in column 4 of Table 2.

RESULT

1. The resistance of the given galvanometer by half deflection method = _____ Ω
2. The figure of merit of the galvanometer =_____amp/division.

PRECAUTIONS

1. Make all the connections neat, clean, and tight.
2. The resistance box to be used in series should have very high resistance as compared to the resistance galvanometer and that to be used in parallel should have low resistance.
3. Use a freshly charged battery so that its emf may remain constant throughout the experiment.
4. The deflection in the galvanometer should be large and in an even number of divisions.

SOURCES OF ERROR

1. The emf of the battery may change during the experiment.
2. The calibration of resistance in resistance boxes may not be correct.
3. Plugs in resistance boxes may not be tight and may have contact resistance.

VIVA- VOCE

Q 1. What is a galvanometer?

Ans. A galvanometer is a device used to detect current and its direction of flow.

Q 2. Can a galvanometer be used for measuring current?

Ans. A galvanometer is a very sensitive device. It gives full-scale deflection for a very small current ($\sim 40\mu A$). So, it can be used for measuring currents of the order of μA.

Q 3. What do you do to measure currents of the order of amperes or more?

Ans. We use an ammeter.

Q 4. What is an ammeter?

Ans. An ammeter is a suitably shunted galvanometer, which is made end-zero and calibrated to measure current directly.

Q 5. What type of galvanometer is generally used for making an ammeter?

Ans. Pivoted type moving coil galvanometer.

Q 6. Can a moving coil ammeter be used for measuring ac ?

Ans. No.

Q 7. What is the problem?

Ans. In moving-coil, galvanometer deflection $\theta \propto I$, and in the case of *ac* the average value of current over the whole cycle is zero. Therefore, no deflection is recorded by a moving coil galvanometer.

Q 8. How do we measure *ac* then? Why?

Ans. For direct measurement of *ac* we use a hot wire ammeter. Because on heating effect *ac* and *dc* may be compared, $Q \propto I^2$ and root means the square current is not zero.

Q 9. What method do you employ to find out the resistance of the galvanometer?

Ans. Half deflection method.

Q 10. In this method why do you use a high resistance in series with the galvanometer?

Ans. So that only a low current pass through the galvanometer and is not damaged due to excessive cur rent.

Q 11. What is the reading in the galvanometer when zero resistance is connected across it? Why?

Ans. Zero. Because the entire current flows through the zero-resistance shunt.

Q 12. What is the value of shunt resistance at the beginning of the experiment when galvanometer deflection is θ?

Ans. Infinity.

Q 13. Under what condition is galvanometer resistance equal to shunt resistance?

Ans. When series resistance is so high that shunt resistance may be neglected in comparison to it.

Q 14. What is meant by the figure of merit of a galvanometer?

Ans. It is the amount of current required to produce a deflection of one division.

Q 15. Define the current sensitivity of a galvanometer.

Ans. It is defined as deflection produced by unit current, i.e., $\frac{\theta}{I}$.