Principles of Physics II (PHY112)

Lab

Experiment no: 4

Name of the experiment: Determination of the resistance of a galvanometer by half deflection method

Theory

In this experiment we are going to find out the resistance of a galvanometer by passing currents through it and observing the deflections, caused by the currents, of its pointer. See Figure 1. The resistance of a galvanometer is the resistance of a coil of wire wound over a rectangular frame kept in a magnetic field inside the galvanometer. When a current passes through the coil, the coil experiences a magnetic force and gets deflected. A pointer connected with the coil can rotate along a circular scale.

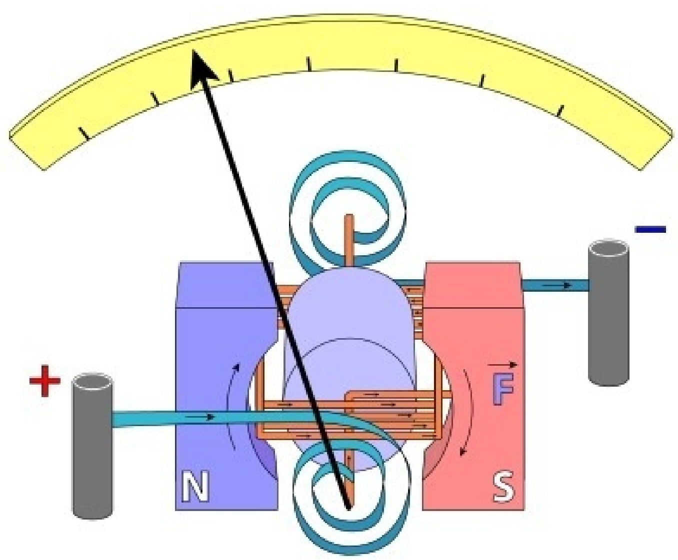


Figure 1: Galvanometer (courtesy: wikimedia.org)

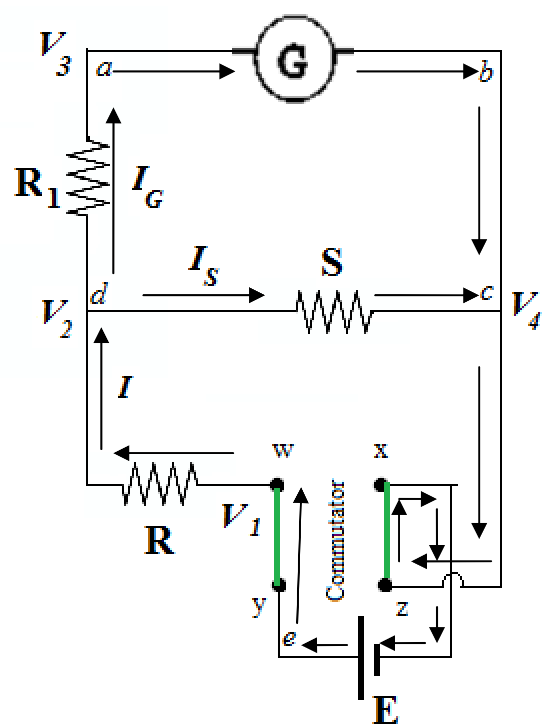


Figure 2: The circuit diagram for the experiment

The circuit is constructed according to the diagram shown in Figure 2. The galvanometer of resistance G is connected in series combination with a resistance box of resistance R_1. This G & R_1 series combination is connected in parallel combination with a shunt box of resistance S. The (R_1, G, S) component is connected with another resistance box of resistance R in series combination. The whole set of resistors is connected with two diagonally opposite connecting points of a commutator. Another two connecting points of the commutator are connected with a DC voltage source of emf E. By using the commutator we can change the direction of the flow of current. In Figure 2, (w, y) and (z, x) are connected. A current I is generated from the positive terminal of E. It gets divided into I_S and I_G. I_S passes through the shunt box and I_G passes through the R_1 and the galvanometer. Both of the flows later combine to become I again which reaches the negative terminal of the DC voltage source. V_1, V_2, V_3 and V_4 are the electric potential of the four nodes of the circuit as shown in Figure 2.

Verily, $V_1 - V_4 = E$ (1)

According to Ohm's law we can write that,

$V_1 - V_2 = I R$ (2)

$V_2 - V_4 = I_S S$ (3)

$V_2 - V_3 = I_G R_1$ (4)

$V_3 - V_4 = I_G G$ (5)

If we sum up the voltage differences across different components of the closed loop *e*-*d*-*a*-*b*-*c*-*e* we get

$(V_1 - V_2) + (V_2 - V_3) + (V_3 - V_4) + (V_4 - V_1) = 0$ [Confirming Kirchhoff's loop-voltage rule]

$\Rightarrow IR + I_G R_1 + I_G G + (-E) = 0$ [Using equations (2), (4), (5) and (1)]

$$\Rightarrow E = IR + I_G(R_1 + G) \quad (6)$$

Again, if we sum up the voltage differences across different components of the closed loop *a*-*b*-*c*-*d*-*a* we get,

$(V_2 - V_3) + (V_3 - V_4) + (V_4 - V_2) = 0$ [Kirchhoff's loop-voltage rule]

$$\Rightarrow I_G R_1 + I_G G + (-I_S S) = 0$$

$$\Rightarrow I_S S = I_G(R_1 + G)$$

$$\Rightarrow \frac{I_S}{I_G} = \frac{(R_1 + G)}{S}$$

$$\Rightarrow \frac{I_S}{I_G} + 1 = \frac{(R_1 + G)}{S} + 1$$

$$\Rightarrow \frac{I_S + I_G}{I_G} = \frac{I}{I_G} = \frac{(R_1 + G + S)}{S}$$

[According to Kirchhoff's current rule: $I_S + I_G = I$]

$$\Rightarrow I = \frac{(R_1 + G + S)}{S} I_G \quad (7)$$

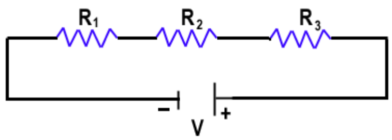
By using the result of equation (7) in equation (6) we get,

$$E = \frac{(R_1 + G + S)}{S} I_G R + I_G (R_1 + G) = \frac{(R_1 + G + S)R + S(R_1 + G)}{S} I_G$$

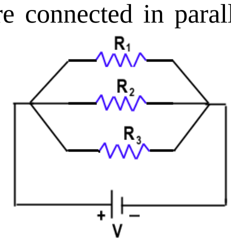
$$\Rightarrow I_G = \frac{SE}{(R_1 + G + S)R + S(R_1 + G)} \tag{8}$$

I have shown this equation (8) from the very elementary Ohm's law. Those who know the following rules can find out the expression for galvanometer current I_G in a much quicker way.

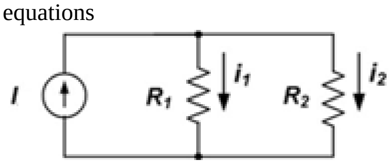
- If R_1, R_2, R_3, ..., R_n resistances are connected in series combination then equivalent resistance is given by $R_{equivalent} = \sum_{i=1}^{n} R_i$



- If R_1, R_2, R_3, ..., R_n resistances are connected in parallel combination then equivalent resistance is given by $\frac{1}{R_{equivalent}} = \sum_{i=1}^{n} \frac{1}{R_i}$



- When a current, I gets divided into two flows: i_1 and i_2 that pass through two resistors of resistances R_1 and R_2 which are in parallel combination then the currents passing through the resistors are given by the following equations



$$i_1 = \frac{R_2}{R_1 + R_2} I \text{ and } i_2 = \frac{R_1}{R_1 + R_2} I$$

Find out the equivalent resistance of the circuit of Figure 2. Then, work out the current, I in terms of the resistances and emf of the voltage source. Finally, find out I_G using the current division rule.

We know that the deflection angle of the galvanometer's pointer θ is proportional to the current passing through the galvanometer, I_G.

$$\theta \propto I_G \Rightarrow \theta = \frac{1}{k} I_G \Rightarrow I_G = k\theta \tag{9}$$

Here, k is the galvanometer constant.

In this experiment initially the resistance R_1 is kept 0. Then the current passing through the galvanometer is $\frac{SE}{(GR+SR+SG)}$ (according to equation (8)) which causes the deflection of angle α (say).

Then according to equation (9)

$$\frac{SE}{(GR+SR+SG)} = k\alpha \tag{10}$$

Then on a trial and error basis the value of R_1 is chosen in such a way that angle of deflection gets reduced down to the half of the previous value (when R_1 was 0). Therefore, we can write for this value of R_1,

$$\frac{SE}{(R_1+G+S)R+S(R_1+G)} = \frac{k\alpha}{2} \tag{11}$$

By dividing the equation (10) by the equation (11) we get,

$$\frac{(R_1+G+S)R+S(R_1+G)}{(GR+SR+SG)} = 2$$

$$\Rightarrow \frac{(GR+SR+SG)+RR_1+SR_1}{(GR+SR+SG)} = 2$$

$$\Rightarrow 1+\frac{RR_1+SR_1}{(GR+SR+SG)} = 2$$

The shunt box's resistance S is much smaller than R and G. Therefore, we can neglect the terms containing S in the above mentioned equation which eventually shows that

$$R_1 \approx G \tag{12}$$

Finally, we conclude that the value of R_1 for which the galvanometer's deflection is reduced down to the half of its deflection when $R_1 = 0$, is approximately equal to the galvanometer's resistance. This statement holds when the shunt box's resistance is much smaller than the resistances of the galvanometer and the resistance box which is connected in series combination with the cell.

Apparatus

Zero centered galvanometer, commutator, two resistance boxes, a shunt box, wires and a DC voltage source.

Procedure

1) Construct the circuit as shown in the Figure 2.
2) From the resistance box of resistance R, pluck the plug of $200\,\Omega$. R = 200 Ω now. From the shunt box, pluck the plug of 0.5 Ω resistance. S = 0.5 Ω now. Make $R_1=0$ by putting all the plugs in the resistance box of resistance R_1. In the commutator connect the (w, y) and (x, z) terminals separately.
3) Observe the deflection of the galvanometer's pointer and note down it.
4) Keeping the resistance R and S constant, adjust the value of R_1 until the deflection is reduced down to the half of the previous deflection. Record this value of R_1which is approximately equal to the value of the galvanometer resistance G.
5) Reverse the current by connecting (w, x) and (y, z) terminals of the commutator separately. Repeat steps 3 and 4.
6) Keeping R = $200\,\Omega$ repeat step 2 to 5 for S = 0.4, $0.3\,\Omega$.
7) Repeat step 2 to 5 for $R=300\,\Omega$
8) Work out the average of the values of G.

Read carefully and follow the following instructions:

- **Please READ the theory carefully, TAKE printout of the 'Questions on Theory' and ANSWER the questions in the specified space BEFORE you go to the lab class.**

- **To get full marks for the 'Questions on Theory' portion, you must answer ALL of these questions CORRECTLY and with PROPER UNDERSTANDING, BEFORE you go to the lab class. However, to ATTEND the lab class you are REQUIRED to answer AT LEAST the questions with asterisk mark.**

- **Write down your NAME, ID, THEORY SECTION, GROUP, DATE, EXPERIMENT NO AND NAME OF THE EXPERIMENT on the top of the first paper.**

- **If you face difficulties to understand the theory, please meet us BEFORE the lab class. However, you must read the theory first.**

- **DO NOT PLAGIARIZE. Plagiarism will bring ZERO marks in this WHOLE EXPERIMENT. Be sure that you have understood the questions and the answers what you have written, and all of these are your own works. You WILL BE asked questions on these tasks in the class. If you plagiarize for more than once, WHOLE lab marks will be ZERO.**

- **After entering the class, please submit this portion before you start the experiment.**

Name: _______________________ ID: _______________ Sec: ___ Group: __ Date: ___________

Experiment no: ___

Name of the Experiment: ____

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Questions on theory (all diagrams should be drawn by using a pencil and a scale)

*1) What is resistance of the galvanometer? [0.25]

Ans:

*2) Draw the circuit diagram for this experiment. [0.25]

Ans:

*3) Derive an expression for the current passing through the galvanometer as a function of the resistances of the shunt box, two resistance boxes and the emf of the voltage source, i.e., equation (8). [2]

Ans:

*4) Show that, the value of R_1 for which the galvanometer's deflection is reduced down to the half of the deflection when $R_1 = 0$, is approximately equal to the galvanometer's resistance. [2]

Ans:

5) For a certain value of shunt-resistance, *S* and a certain value of *R*, when R_1 is set to 0 then the deflection of the galvanometer is shown in Figure A.

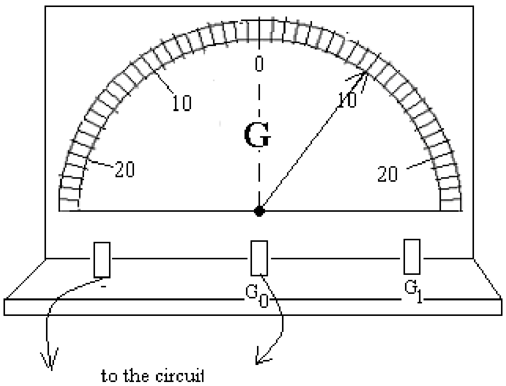
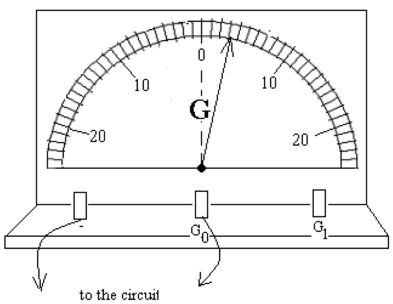
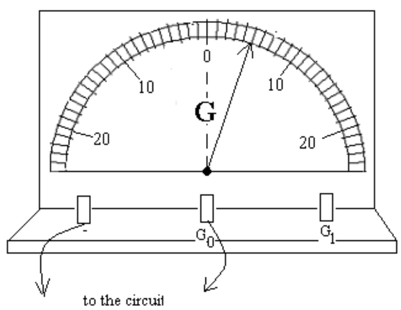


Figure A: Deflection when $R_1 = 0$

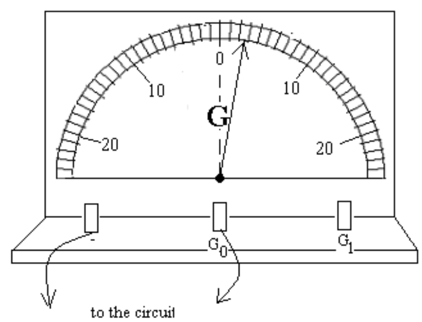
By keeping *S* and *R* fixed the deflections of the galvanometer for different values of R_1 are shown in the following figures.



when $R_1 = 6\ \Omega$



when $R_1 = 3\ \Omega$



when $R_1 = 9\ \Omega$

What is the internal resistance of the galvanometer? [0.5]

Ans:

- **Draw the data table(s) and write down the variables to be measured shown below (in the 'Data' section), using pencil and ruler BEFORE you go to the lab class.**

- **Write down your NAME and ID on the top of the page.**
- **This part should be separated from your Answers of "Questions on Theory" part.**
- **Keep it with yourself after coming to the lab.**

Data

Table: Data for determining the resistance of a galvanometer

No. of observation	R (Ω)	S (Ω)	Flow of current	Deflection when $R_1=0$ (θ_0)	$R_1(\neq 0)$ (Ω)	Deflection when $R_1 \neq 0$ (θ)	$G \approx R_1 / \left(\frac{\theta_0}{\theta} - 1\right)$ (Ω)	Mean G (Ω)

- **READ the PROCEDURE carefully and perform the experiment by YOURSELVES. If you need help to understand any specific point draw attention of the instructors.**
- **DO NOT PLAGIARIZE data from other group and/or DO NOT hand in your data to other group. It will bring ZERO mark in this experiment. Repetition of such activities will bring zero mark for the whole lab.**
- **Perform calculations by following the PROCEDURE . Show every step in the Calculations section.**
- **Write down the final result(s)**

Calculations

Results:

- **TAKE printout of the ‘Questions for Discussions’ BEFORE you go to the lab class. Keep this printout with you during the experiment. ANSWER the questions in the specified space AFTER you have performed the experiment.**
- **Attach Data, Calculations, Results and the Answers of ‘Questions for Discussions’ parts to your previously submitted Answers of ‘Questions on Theory’ part to make the whole lab report.**
- **Finally, submit the lab report before you leave the lab.**

Name: ___________________________ ID: __________________

Questions for Discussions

1) Is the method applicable for a galvanometer of any resistance? How do you find the resistance of a galvanometer when its resistance is very small? [0.5]

Ans:

2) Will you prefer a low or high resistance of a shunt? [0.5]

Ans:

3) If for a particular value of the resistance R_1 the deflection of the galvanometer's pointer drops down to one-n'th of its deflection when R_1 was zero, then what is the galvanometer's resistance? [0.5]

Ans:

4) In your experiment the galvanometer which you have used, the angle of deflection of its pointer is directly proportional to the current passing throw its coil. However, there are some galvanometers called ‘sine galvanometers’ and ‘tangent galvanometers’, where the trigonometric sine or tangent of the angle of deflection respectively, is proportional to the current passing through them. How will you perform your experiment with anyone of these galvanometers? [0.5] (You may use additional paper)

Figure 3: A tangent galvanometer (courtesy: Wikimedia.org)

Ans:

NOTE: Some of the figures shown in this lab manual are collected from the internet. They are free from copyright or the copyright holders grant permission to use them.

https://commons.wikimedia.org/wiki/File:Galvanometer_scheme.png

https://upload.wikimedia.org/wikipedia/commons/4/40/Tangent_galvanometer_Philip-Harris_top1.jpg