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LEARNING THROUGH MISTAKES: AN INQUIRY BASED EXPERIMENT

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ABSTRACT

A new experiment was theoretically developed to find the internal resistance (G) of a moving coil galvanometer. The value of G was experimentally found out using this new proposed method. To verify this value of G, it was also measured with other conventional methods. These values did not match. An inquiry in the proposed experiment helped to identify an unaccounted mistake. The experiment was repeated with the same theory but by modifying the experimental set up. The modification verified the value of G. This manuscript reports as to how learning through mistakes is useful to develop and refine procedural understanding of experiments. The advantages that make inquiry-based learning more effective, is also discussed here.

Keywords:
moving coil galvanometer, internal resistance, OPAMP

I. Introduction

Physics and mathematics are the pillars of engineering. So together, these subjects allow engineers to innovate and solve complex challenges. The laboratory and workshop work in science and technology has a special significance. Just to verify a scientific principle in a conventional way as directed by the laboratory manual or by the teacher, should not be the only aim of laboratory work. In fact, the laboratory practice should deeply focus on the "hands-on to minds-on" [1] aspect as it links the practical activities with the understanding of scientific / technical concepts, thereby developing deeper intellectual skills. It also helps in analysing, understanding the underlying scientific ideas and if needed modify and innovate the ideas.

A moving coil galvanometer (MCG) is a very useful device used in physics / electrical engineering laboratories as it is a fundamental instrument used to measure electric currents of small magnitude. The MCG has an inherent internal resistance (G) and its value has to be taken into account while designing current and voltage measuring devices. There are various methods to experimentally find G like half scale deflection [2], Carey Fosters bridge method [3], etc. The other parameters of a MCG like damping constant, current sensitivity, figure of merit, etc. are also measured using some well documented experiments [2-4].

This manuscript reports development of a new method to find G of MCG. However, it was observed that the value of G using this method and the one measured with other conventional methods did not match. A detailed inquiry of the theory as well as the experimental procedure, helped to locate the problem. To fix the error, the experiment was repeated with the construction of a voltage source using OPAMP. The result of this new method agreed well with the conventional methods.

Committing a mistake inadvertently in an experiment is quite a common phenomenon. It's always challenging to identify an error with 'Socratic questioning' [5] and incredibly valuable in teaching-learning process. It is essential to identify and fix an error / mistake for nurturing meaningful learning experiences, developing deeper understanding of the subject, strengthening experimental- problem solving skills and developing scientific thinking.

II. Method

This section involves the following steps.

2.1 Theory of this new method:

Consider a moving coil galvanometer (MCG) with internal resistance G in series with a regulated voltage supply $+V$ and an external current limiting variable resistance R (using resistance box), as shown in Fig. 1. If I is the current flowing in the circuit, then using Kirchoff's law we have:

$V= I (G +R)$ (1)

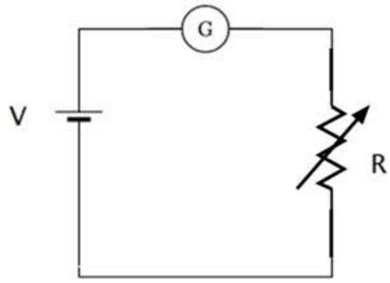

Fig. 1: MCG in series with a power supply and a current limiting (variable) resistance

The deflection (θ) in the MCG is directly proportional to the current I, or $\theta = k\,I$, where k is a constant.

Thus, $I = \theta / k$

Putting this term in equation (1), $V\,k = \theta\,(R + G)$ (2)

As V is constant, $V\,k$ is a new constant c.

Therefore, $1/\theta = (R/c) + (G/c)$ is obtained by rearranging Eqn. (2).

This is a straight-line equation when a graph is plotted between $1/\theta$ versus R with slope $1/c$ and intercept is G/c.

Therefore, G = intercept × 1 / slope (3)

is the required value of resistance (G) of galvanometer.

2.2 Verification

To verify the experimental validity of the method described above, it was decided to find the value of G with conventional methods also, like using the Carey Fosters bridge and half scale deflection methods. It was found out to be 45.2 Ω and 45.6 Ω respectively. However, G when experimentally measured using the circuit shown in Fig. 1 and Eqn. 3. and it was found out to be 5 kΩ. It shows that the value of G didn't match with the value calculated using the proposed new method.

2.3 The inquiry

Staring from Eqn. 1 to Eqn. 3, even though mathematically the theory was correct, there was a mismatch in this experimentally calculated value of G. This initiated an 'inquiry as a part of learning' about the contribution made by some spurious resistance in Eqn.1. The only factor that could interfere was the resistance contributed by readymade DC regulated +5V (using IC LM7805) power supply. It was used without much thought about the magnitude of its internal resistance. These spurious resistances might be from the neon lamp used in power supply, current limiting resistances, etc.

2.4 The solution

Aligning with the practical activities (hands-on) with concepts (minds-on) as a basic theme of science and technical education, the experiment was repeated by replacing it with a power supply which has practically a zero- output resistance.

The use of OPAMP as an inverting amplifier, non-inverting amplifier, integrator, buffer amplifier, etc. is well known. An ideal OPAMP has infinite input resistance and zero output resistance. The open loop-output impedance of OPAMP IC - TL084 at 1MHz is about 100 Ω and decreases with decrease in frequency and is almost zero for DC voltages [6, 7]. TL084 is a FET based OPAMP. Thus, practically the output resistance of OPAMP is negligibly small.

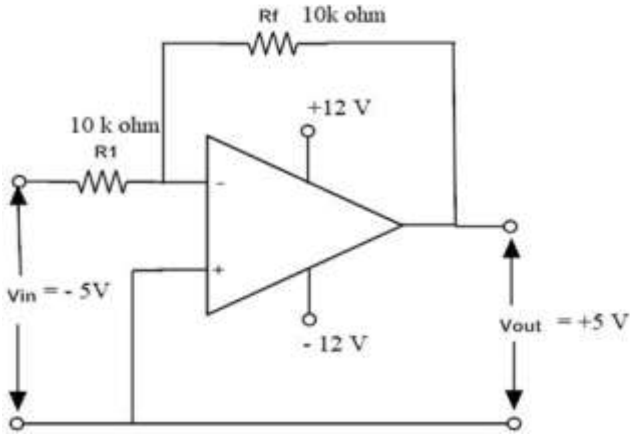

Fig. 2: OPAMP as an inverting amplifier using TL084

Basically, the circuit shown in Fig. 2, is a non-inverting amplifier with unity gain and (practically) zero output resistance. The output voltage of this inverting amplifier was $V_o = +5$ V, when input voltage supplied was -5 V (using IC7905). This +5 V was now used as a voltage source in Fig. 1, so as to eliminate the interference of resistance of power supply. Thus the output voltage of an OPAMP, as an inverting amplifier was used as a power supply (V in Eqn. 1), shown by a bold rectangle in Fig.3.

The complete experiment was then repeated with the circuit shown in Fig.3. The variation of the deflection θ with respect to the change in resistance R is given in Table 1 and graphically shown in Fig. 4, as $1 / \theta$ versus R.

From the graph slope and intercept were found out to be 1.7×10^{-4} $div^{-1}\Omega^{-1}$ and 0.8×10^{-2} div. Using Eqn. 3, G was found to be 44.8 Ω, which agrees well with the one using conventional methods (45.2 Ω or 45.6 Ω).

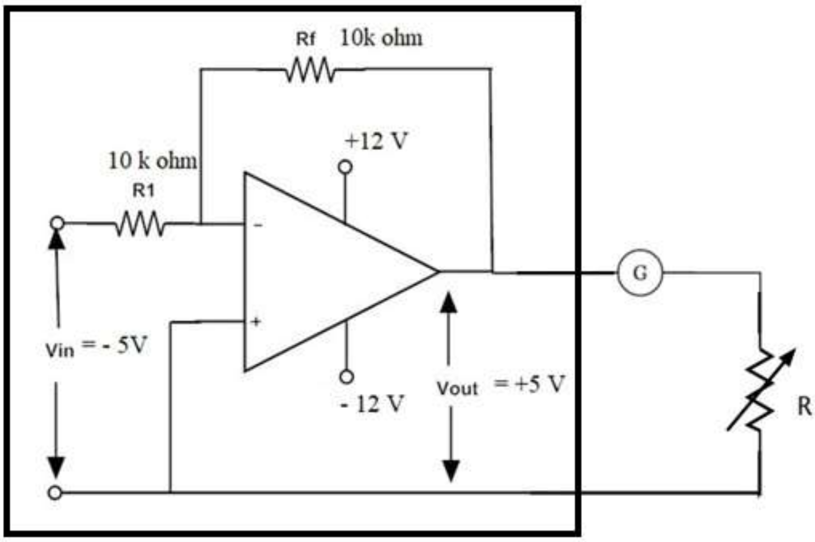

Fig. 3: Voltage source using OPAMP as an inverting amplifier

θ / divisions	*R* / Ω
50	62
46	71
40	89
36	106
30	138
26	169

20	232
16	302

Table 1: Variation of deflection (*θ*) with respect to change in resistance (*R*)

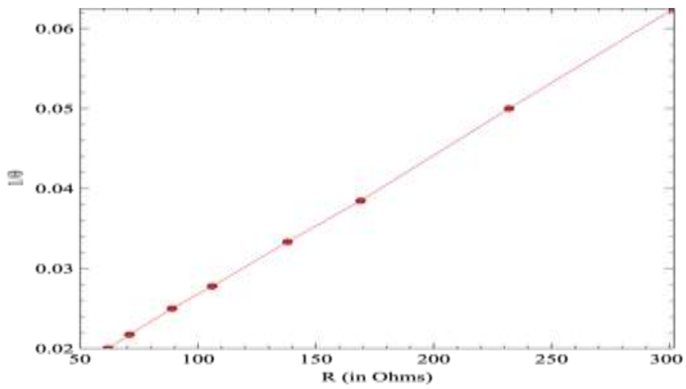

Fig. 4: Variation of 1/*θ* with resistance *R*

III CONCLUSION

Inquiry-based experiments have many advantages that make learning more engaging and effective. The thought process of reasoning through the evaluation of experimental evidence, solving a problem or coming to a correct conceptual understanding is achieved by embracing mistake as a part of learning. In this experiment, (1) a new experimental method to calculate the internal resistance of a MCG was developed, (2) this experiment also helped to understand how the resistance of a power supply interferes with the results and why it should be practically zero, (3) The use of OPAMP as a voltage source with (practically) zero output resistance was also demonstrated through this experiment.

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