Investigating Characteristics of Sensitive Galvanometer by Isogonic Method and SPSS

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ABSTRACT: By making use of isogonic method and combining with SPSS, this paper attempts to measure the sensitivity and internal resistance of a sensitive galvanometer, evaluate experimental data and its uncertainty with confidence probability of 95%. This paper introduces experimental circuit and principle, and gets reliable and reasonable results.
KEYWORD: Isogonic Method; Sensitive Galvanometer; SPSS; Sensitivity; Internal Resistance; Uncertainty

1 INTRODUCTION

Sensitive galvanometer is a kind of magnetoelectric ammeter with a high sensitivity. It can be used to measure micro current, low voltage, or used as a galvanometer directly. Investigating the characteristics of sensitive galvanometer is an important experiment of college physics [3]. According to reference [1], [4], [7] we know that, isogonic method is much better than half deviation method when measuring sensitivity and internal resistance of a sensitive galvanometer. So the isogonic method is used in this paper. In addition, uncertainty estimation (confidence probability of 95%) is used to evaluate experimental data. Further more, by use of the curve estimation function of SPSS [6], error caused by instrument or human factors is reduced significantly.

2 EXPERIMENTAL CIRCUIT AND CALIBRATION

The experimental device is demonstrated in Figure1; it mainly includes a sensitive galvanometer, a regulated power supply, two resistance boxes, a standard resistor, a voltmeter, a rheostat and two switches (one of the two switches is a reversing switch).

The experimental device is shown in Figure 2. There are two voltage dividers in the circuit. The first voltage divider is formed by rheostat R_0, which can change the voltage U from 0 to E. The voltage U is indicated by a voltmeter. The second voltage divider consists of standard resistor R_1 and resistance box R_2. If $R_1 << R_2$, voltage U_1 across R_1 will be very small.

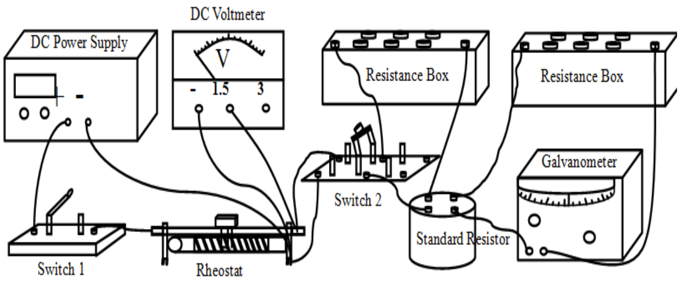

Figure 1. Experimental device

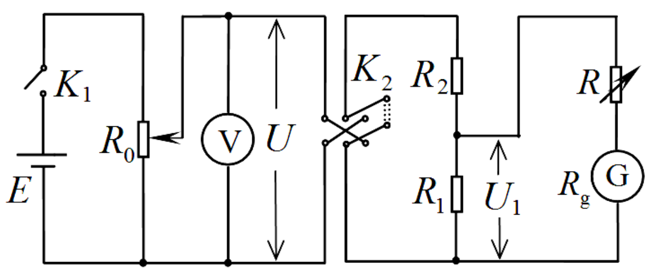

Figure 2.Experimental circuit

With K_1, K_2 open; calibrate the cursor of sensitive galvanometer coinciding with the zero point of the ruler. Fix $R_1 = 1\Omega$ and $R_2 = 32k\Omega$, select cursor deflection number $N = 40div$.

3 EXPERIMENTAL PRINCIPLES

3.1 *Measurement Principle*

In Figure 2, the equivalent resistance of R_1 and $(R+R_g)$ is

$$R_1' = \frac{R_1(R+R_g)}{R_1+R+R_g} \tag{1}$$

Voltage U_1 across R_1 and $(R+R_g)$ is

$$U_1 = I_g(R+R_g) = U\frac{R_1'}{R_1'+R_2} \tag{2}$$

If $R_1 << R_2$, thus $R_1' << R_2$, equation (2) can be simplified as

$$I_g(R+R_g) \approx U\frac{R_1'}{R_2} \tag{3}$$

Substitute equation (1) into equation (3) gives

$$R+R_1 = \frac{R_1}{R_2 I_g}U - R_g \tag{4}$$

The sensitivity [9] is defined as

$$S = \frac{N}{I_g} \tag{5}$$

From equation (4) and equation (5) we get

$$R+R_1 = S\frac{R_1}{R_2 N}U - R_g \tag{6}$$

Let $Z = \frac{R_1}{R_2 N}U$ and $W = R + R_1$, then equation (6) can be simplified as

$$W = SZ - R_g \tag{7}$$

For convenience, we call Z as comprehensive quantity, and call W as resistance composite quantity.

In the experiment, close K_1, K_2, slide rheostat to make the voltage U change from 0.6V to 1.5V gradually (take voltage step to be 0.1V). For each voltage, adjust resistance R until the cursor deflection equals to N (40div), now record R as R_q; then reverse K_2, keep U unchanged and adjust R until the cursor deflection equals to N (40div) again, record R as R_h. The mean resistance is $R = (R_q + R_h)/2$.

Apply curve estimation function of SPSS to the data; it is easy to find the relationship between the comprehensive quantity Z and resistance composite quantity W, and calculate the sensitivity and internal resistance of the sensitive galvanometer.

3.2 *Uncertainty Analysis of Sensitivity*

For a direct measurement quantity k, its uncertainty can be divided into class A and class B. The standard deviation [5] of a series data is

$$u_{(\bar{k})} = \sqrt{\frac{\sum_{i=1}^{n}(k_i-\bar{k})^2}{n(n-1)}} \tag{8}$$

In class A, if the data is 10 or more, the uncertainty of k obey t distribution, when $p = 0.95$, $t_p = 2.26$ thus

$$u_{A(\bar{k})} = 2.26u_{(\bar{k})} \tag{9}$$

$\bar{k}$ in equations (8) and (9) stands for $\bar{R}$, $\bar{U}$, $\bar{R}_1$ or $\bar{R}_2$ respectively.

In class B, the instrument limit error Δ is subject to uniform distribution $C = \sqrt{3}$,
when $p = 0.95$, $k_p = 1.96$, then

$$u_{B(k)} = 1.96\frac{\Delta_k}{\sqrt{3}} \tag{10}$$

where k stands for $\bar{R}$, $\bar{U}$, $\bar{R}_1$ or $\bar{R}_2$ respectively.

The uncertainty of a direct measurement quantity k is

$$u_{(k)} = \sqrt{u^2_{A(\bar{k})} + u^2_{B(k)}} \tag{11}$$

For indirect measurement quantity $y = f(k_1, k_2, ..., k_i, ...k_m)$, the standard uncertainty [2] is

$$u_{c(y)} = \sqrt{\sum_{i=1}^{n}\left(\frac{\partial y}{\partial k}\right)^2 u^2_{(k_i)}} \tag{12}$$

The relative uncertainty is

$$u_{r(y)} = \sqrt{\sum_{i=1}^{n}\left(\frac{\partial(\ln y)}{\partial k_i}\right)^2 u^2_{(k_i)}} \tag{13}$$

Consider equation (8), (13), the relative uncertainty of the sensitivity is

$$u_{r(s_i)} = \sqrt{\left(\frac{u_{(W)}}{W}\right)^2 + \left(\frac{u(z)}{z}\right)^2} \tag{14}$$

4 EXPERIMENTAL DATA PROCESSING

4.1 *Measured Data and Processing*

Table 1. Parameters of sensitive galvanometer Ac15/6

Internal resistance[Ω]	Critical external resistance[10^2Ω]	Sensitivity [10^8div/A]	Damp time [s]
38	4	4	4

Table 2. Relationship between *U* and *R*

i / Group	*U*[V]	R_q[Ω]	R_h[Ω]	*R*[Ω]
1	0.598	149.50	148.10	148.80
2	0.704	183.80	180.60	182.20
3	0.797	214.50	212.10	213.30
4	0.900	246.50	243.90	245.20
5	0.999	279.70	275.80	277.75
6	1.102	310.20	307.20	308.70
7	1.199	338.60	341.80	340.20
8	1.302	374.40	369.30	371.85
9	1.401	402.60	402.20	402.40
10	1.500	435.20	431.00	433.10

where $R=(R_q+R_h)/2$, $R_1=1\Omega$, $R_2=32.00\mathrm{k}\Omega$, $N=40\mathrm{div}$ and $\Delta_R=0.1\Omega$.

Table 3. Relationship between W and Z

i /group	W [10^2Ω]	Z [10^{-6} V/div]
1	1.4980	0.4671875
2	1.8320	0.5500000
3	2.1430	0.6226563
4	2.4620	0.7031250
5	2.7875	0.7804688
6	3.0970	0.8609375
7	3.4120	0.9367188
8	3.7285	1.0171875
9	4.0340	1.0945313
10	4.3410	1.1718750

4.2 *Using SPSS Software to Analyze the Calibration Curve*

Put experimental data in Table 3 into SPSS software, taking Z as variable and W as dependent variable. By use of the function of curve estimated of SPSS, we have the calibration curve equation

$$W=4.035275236\times10^8 Z-37.731730 91 \quad (15)$$

The calibration curve is shown in Figure 3.

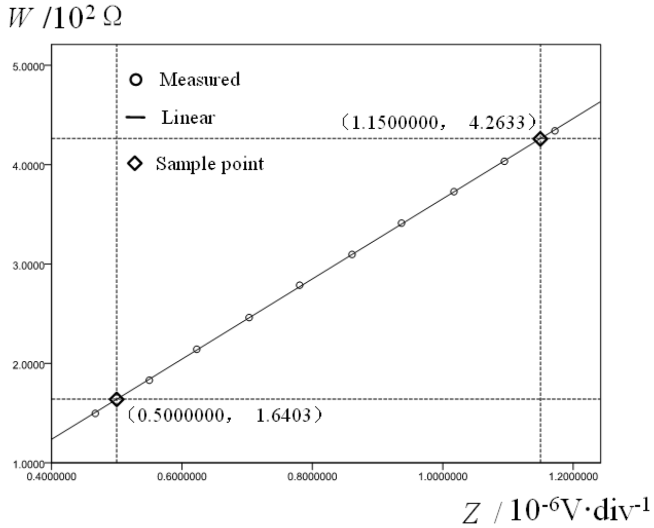

Figure 3.W-Z calibration curve obtained by SPSS

4.3 *Estimation of Uncertainty of Sensitivity*

According to Figure 3, the calibration curve is a straight line. Take two points (Z_1, W_1) and (Z_2, W_2) from the straight line, we have

$$S=\frac{W_2-W_1}{Z_2-Z_1} \quad (16)$$

$$u(_{Z_j})=\frac{u(_{W_j})}{4.035275236\times10^8} \quad (17)$$

By equation (14), (16)

$$u_{r(S)}=\frac{u_{(S)}}{S}=\sqrt{\left(\frac{u_{(W_2-W_1)}}{W_2-W_1}\right)^2+\left(\frac{u_{(Z_2-Z_1)}}{Z_2-Z_1}\right)^2} \quad (18)$$

By Figure 3, combined with equation (16), (17), (18), we list experimental results in Table 4.

Table 4. Experimental results of the sensitive galvanometer

$u_{(W_1)}=u_{(W_2)}$ [Ω]	$u_{(z_1)}=u_{(z_2)}$ [10^{-10} V/div]	S [10^8 div/A]	$u_{r(S)}$
0.16	4.0	4.035±0.035	0.09 %

5 ANALYSIS AND CONCLUSION

From the data in Table 3, by means of curve estimate function of SPSS, we get the calibration equation (15) and calibration curve (Figure 3). The calibration equation (15) is a linear equation, and calibration curve is a straight line. The intercept 37.73 of equation (15) is internal resistance of the sensitive galvanometer, which is very close to the value listed in Table 1. The slope 4.03×10^8div/A of equation (15) is the sensitivity of the sensitive galvanometer, which is in good agreement with 4×10^8div/A , the value listed in Table 1. These show that the experimental results are very accurate.

In order to get linear equation (15), it is very important to choose proper parameters in the circuit. In the experiment, standard resistance is 1Ω, one resistance box is 32kΩ, voltage changes from 0.6V to 1.5V, operating the reversing switch. All these can reduce accidental error and system error, and make the measurement results more reliable and reasonable.

REFERENCES

[1] He Delin. Improvement on method of measuring sensitivity and internal resistance of sensitive galvanometer. *University physics experiment*. Vol.9 No.1: 27-30

[2] Liu Caiming. Estimation and expression of uncertainty in of *University physics experiment*. University physics. Vol.16 (8): 21-2

[3] Qi Jingang & Gao Jiwei. Measurement of internal resistance and current constant of galvanometer. *Journal of Changchun normal university (natural science edition)*. Vol.29 No.6: 27-29

[4] Shen Shizhang. Error analysis in measuring internal resistance of sensitive galvanometer. *Physics experiment*. Vol.4 No.2: 63-53

[5] Song Wenfu & Zhu Li. Estimation and expression of uncertainty. *University physics experiment*. Vol.17 No.1:69-71

[6] Song Zhigang. 2008. *SPSS 16.0 Guide to data analysis*. Telecommunications Press

[7] Xu Shunsong. Reseach on characteristics of galvanometer. *University physics*.Vol.23 No.1:44-46

[8] Yang Shuwu & Zhao Lizhu. 2007. *General Physics experiment 2(Electromagnetism, version 4)*. Beijing: Advanced education press.