## 4. Experimental Objectives

1) Understand the basic structure and usage of a micro-amp galvanometer;
2) Learn how to extend the measurement range of a galvanometer and understand the principle of constructing a multimeter;
3) Learn the calibration method of a electric meter.

## 5. Precautions

1) Do not place magnetic objects near the DC micro-ampere galvanometer;
2) Do not directly connect the DC power supply to the DC micro-ampere galvanometer;
3) Check the wiring is correct and the resistance of the multi-turn potentiometer is at the maximum before turn on the power supply.

## 6. Experimental Procedures

1) Construct a DC ammeter of range $0 \sim 1mA$ using a micro-amp meter of range $0 \sim 100\mu A$ (internal resistance about $1.7K\Omega$)

a) Measure the internal resistance of the micro-ampere meter.

Connect the circuit according to Figure 3 and Figure 4 respectively to measure the internal resistance using the half deflection method and the substitution method. Where the power supply is $E = 5V$, $R_1$ is a multi-turn potentiometer of $33K\Omega$, $R_2 = 43K\Omega$, $R_0$ is a resistance box. Use the standard ammeter on the panel the "monitoring meter" by setting it to the side "uA".

b) Substitute $R_g$ into formula (5) to calculate the shunt resistance $R_p$.

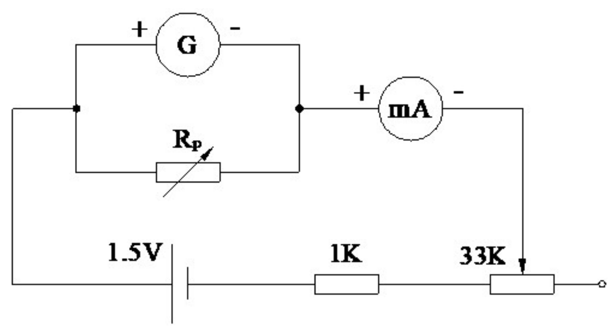



Figure 8 Experimental circuit for calibrating DC ammeter

c) Calibrate the constructed DC ammeter.

Connect the circuit according to Figure 8. In Figure 8, a resistance box is used as $R_p$. The power supply is $E = 1.5V$. Adjust the current with a $33K\Omega$ multi-turn potentiometer, and use the standard ammeter with range $0 \sim 1.999mA$ for calibration.

d) Calibrate the zero point of the meter.

Adjust the pointer to zero with the zero adjustment screw of the meter.

e) Calibrate full scale.

Turn on the $1.5V$ power, adjust the multi-turn potentiometer to set the standard milliampere to $1mA$. Check whether the micro-ammeter reaches full scale. If not, carefully adjust the resistance box $R_p$ till exact full scale is achieved.

f) Determine the grade of the constructed meter.

Adjust the multi-turn potentiometer to reduce the current reading on the micro-amp meter with a constant step size $\Delta I$ till $I = 0$. At each step, write down both the readings on the micro-amp meter and the standard ammeter. Then increase the current reading on the micro-amp meter with a constant step size $\Delta I$ till $I = 1mA$, and write down both meter's readings at each step. Average the two calibration results and draw the calibration curve. Finally, determine the grade of the constructed ammeter according to the calibration curve.

2) Construct a DC voltmeter of range $0 \sim 1V$ using a micro-amp meter of range $0 \sim 100\mu A$ (internal resistance about $1.7K\Omega$)

Substitute the known $R_g$ (measured in previous experiment) of microampere meter into equation (7) to calculate the dividing resistance $R_s$.

Connect the calibration circuit as shown in Figure 9. A resistor box is used as $R_s$, and the power supply is $E = 1.5V$.

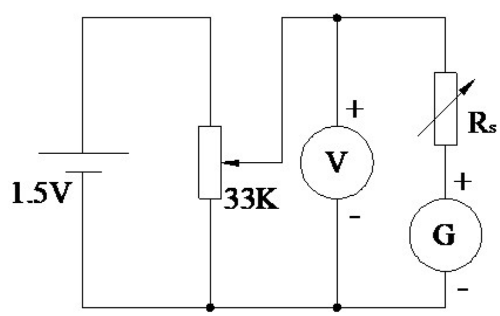



Figure 9 Circuit for calibrating DC voltmeter

Refer to the previous experiment to calibrate the constructed DC ammeter, make calibration curve, and determine the grade of the constructed voltmeter.

**7. An example of data recording and processing**

Note: Following data are for reference only, not the criteria for apparatus performance:

The current range of the galvanometer to be modified is $100\mu A$. The internal resistance is measured as $1.72K\Omega$ by the half-deflection method and $1.73K\Omega$ by the substitution method. The substitution method was used in following experiments.

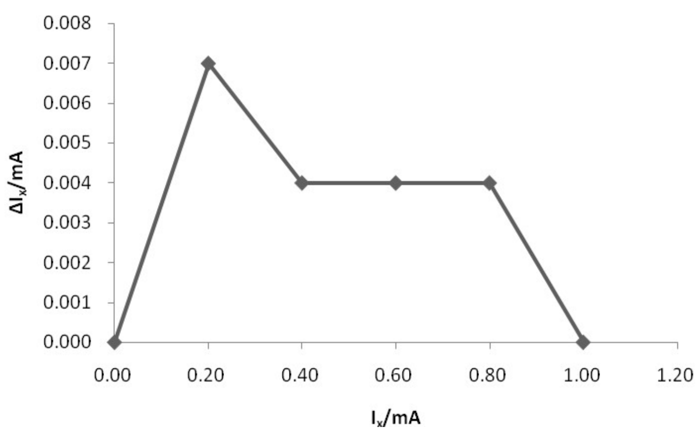
**1) Construct a DC ammeter with measurement range 0 ~ 1 mA**

The parallel resistance is calculated as $R_p = \frac{I_g R_g}{I - I_g} = \frac{0.0001 \times 1730}{0.001 - 0.0001} = 192\Omega$.

The experiment result is $R_p = 190\Omega$. The error is about 1%.
Table 1 Calibration data of the modified DC ammeter

Table 1 Data of the constructed ammeter after calibration

| Scale of Galvanometer | 0 | 2.0 | 4.0 | 6.0 | 8.0 | 10.0 |
|---|---|---|---|---|---|---|
| Reading of Constructed Ammeter $I_{x1} / mA$ | 0 | 0.20 | 0.40 | 0.60 | 0.80 | 1.00 |
| Reading of Standard Ammeter $I_{01} / mA$ | 0 | 0.207 | 0.404 | 0.604 | 0.804 | 1.000 |
| $\Delta I_x = I_0 - I_x / mA$ | 0 | 0.007 | 0.004 | 0.004 | 0.004 | 0 |




Calibration curve of the constructed DC ammeter

The maximum error of the constructed ammeter is $\frac{0.007}{1} \times 100\% = 0.7\%$. Since $0.5 < 0.7 < 1.0$, the accuracy grade of the constructed meter is 1.0.

**2) Construct a DC voltmeter with measurement range 0 ~ 1 V**

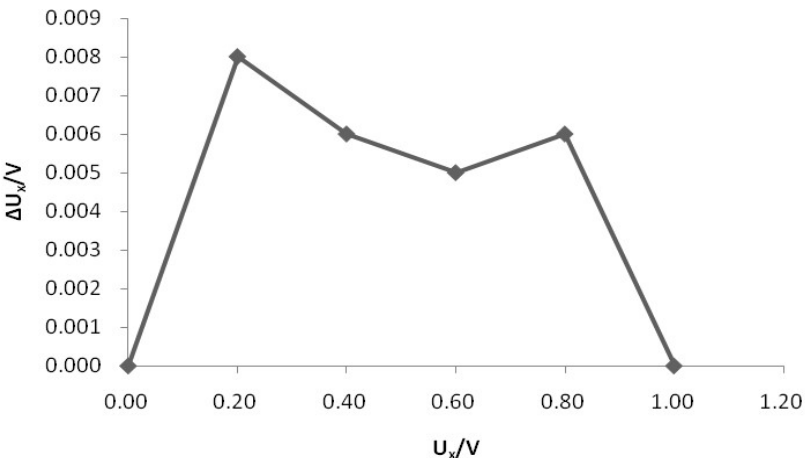
The serial resistance is calculated as $R_s = \frac{U}{I_g} - R_g = \frac{1}{0.0001} - 1730 = 8270\Omega$.

The experiment result is $R_s = 8500\Omega$. The error is about 2.8%.
Table 2 Calibration data of the modified DC ammeter

Table 2 Data of the constructed voltmeter after calibration

| Scale of Galvanometer | 0 | 2.0 | 4.0 | 6.0 | 8.0 | 10.0 |
|---|---|---|---|---|---|---|
| Reading of Constructed Voltmeter $U_{x1} / V$ | 0 | 0.20 | 0.40 | 0.60 | 0.80 | 1.00 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Reading of Standard Voltmeter $U_{01}/V$ | 0 | 0.208 | 0.406 | 0.605 | 0.806 | 1.000 |
| $\Delta U_x = U_0 - U_x / V$ | 0 | 0.008 | 0.006 | 0.005 | 0.006 | 0 |




Calibration curve of the constructed DC ammeter

The maximum error of the constructed ammeter is $\frac{0.008}{1}\times 100\% = 0.8\%$. Since $0.5 < 0.8 < 1.0$, the accuracy grade of the constructed meter is 1.0.