重庆大学-辛辛那提大学联合学院

学生实验报告

CQU-UC Joint Co-op Institute (JCI)
Student Experiment Report

实验课程名称 Experiment Course Name 大学物理实验（I）

开课实验室（学院）Laboratory (School) JCI

学院 School CQU-UC 年级专业班 Student Group 18ME01

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学年 Academic Year 2019 学期 Semester Spring

成绩 Grade	
教师签名 Signature of Instructor	

批改说明 Marking instructions:

指导老师请用红色水笔批改，在扣分处标明所扣分数并给出相应理由，在封面的平时成绩处注明成绩。

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开课学院、实验室 Academic School/ Laboratory CQU-UC

实验时间 Date of Experiment 2019 年 Year 03 月 Month 26 日 Day

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实验目的 Description/Instruction:

Multimeter, also known as multiplexing meter, multimeter, triple meter, multimeter and so on, is an indispensable measuring instrument for power electronics and other departments. Generally, the main purpose is to measure voltage, current and resistance. Multimeter can be divided into pointer multimeter and digital multimeter according to display mode. It is a multi-function and multi-range measuring instrument. Generally, the multimeter can measure DC current, DC voltage, AC current, AC voltage, resistance and audio electric equality. Some can also measure AC current, capacitance, inductance and some semiconductor parameters (such as beta). This experiment requires us to understand the structure of the magnetoelectricity meter and the significance of its main symbols, to learn one (or two) methods of measuring the internal resistance of the meter head, and to preliminarily understand the basic principles of the three-use meter and design it.

Experiment 1: Measurement of the Internal Resistance of Watch Head and Design of Three-purpose Meter

原理和设计 Principle and Design:

1. Composition of multimeter

There are many functions of multimeter, but there are three main ones: current measurement, voltage measurement and resistance measurement. The three-meter made in this experiment is the design and assembly of a three-purpose meter (DC ammeter, DC voltmeter and Ohmmeter) with microammeter as display.

It is easy to design these three functions separately, as shown in Fig. 1(a)~(c).

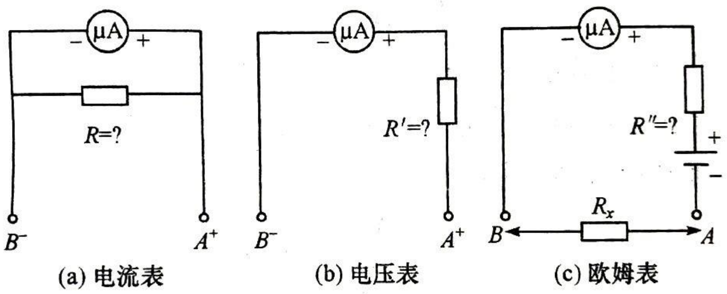

Figure 1: Principle Diagram of Separate Meter Design

As can be seen from Fig. 1, the design of DC galvanometer is to calculate the value of shunt resistance R; the design of DC voltmeter is to calculate the value of series resistance R'; the ohmmeter is a DC voltmeter plus a DC power supply. When the ohmmeter connects A and B to a resistance R_X, the head pointer deflection is used to measure the value of resistance R_X to be measured.

2. Measurement of the Internal Resistance of the Meter Head

In order to design and make the three-purpose meter correctly, there are many methods to measure the internal resistance of the meter head accurately. The commonly used methods are half-value method and substitution method. The circuit is shown in figs. 2 and 3.

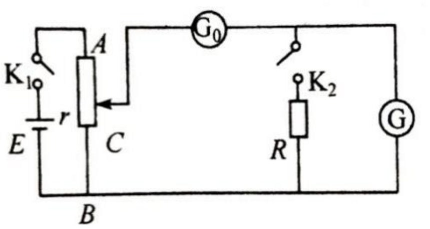

Figure 2: Half value method

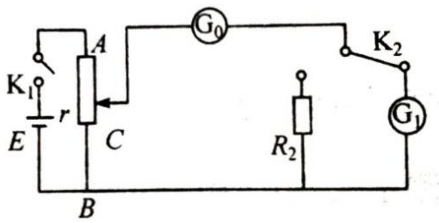

Figure 3: Substitution method

The circuit of measuring the internal resistance of the meter head by half-value method is shown in Fig. 2, in which $G_0$is the meter head to be measured (100 mu A), and G is the meter head to be measured. It is a monitoring ammeter (0-150 mu A), R is a sliding resistance, R is a resistor box, E is a DC regulated power supply closing switch K_1, disconnecting K_2, G_0 and G are series loops. At this time, the sliding resistor, sliding head C gradually moves to point A (increasing the output voltage), making G fullness (or a fixed value). Obviously, the current flowing through G and G_0 is equal, and after recording their readings, closing K_2, the resistance of the whole circuit at this time. The reading of G_0 and G meters will not be equal, and the size of sliding resistance will be adjusted, keep the original value of G_0's reading unchanged, and adjust the size of resistance box R so that the reading of G is half of the original value. At this time, the current flowing through resistance box R is equal to the current flowing through meter head G, and the value of resistance box R is equal to R_g.

As shown in Fig. 3, the circuit of measuring the internal resistance of the meter head by substitution method is shown by reversing the switch K_2 to one end, then closing K_1, adjusting the position of C point to make G fullness (or a certain value). At this time, record the reading of G_0, then reverse the reading of K_2 to two ends (first adjusting R, making R about 5000Ω), and then adjust the value of R to keep the original value of Go unchanged. At this time, the reading of resistance box R = Rg.

3. Basic Errors and Correction of Meters

Any meter measurement will produce errors, which are usually expressed by absolute errors, relative errors and maximum reference errors (also known as basic errors of meters).

The absolute error of alcohol is the difference between the electric value Ai and the measured actual value K_2 (given by the standard meter with higher accuracy level), i.e. Δ_i=A_i-A_0; the relative error is the ratio of absolute error to A_0, usually expressed in percentage.

Reference error η is the ratio of absolute error to ammeter limit A_m, i.e.

$$\eta = \frac{\Delta_i}{A_m} \times 100\% \quad (1.1)$$

Because the absolute errors of each point on the ammeter are not very different, the citation errors of each point are also somewhat different, but their differences are small. The relative errors of each point vary greatly because of the great changes in the measured values. Therefore, the citation errors are more advantageous than the relative errors in expressing the accuracy grade of the ammeter, that is, the citation errors are more advantageous than the relative errors, i.e.

$$K = \frac{\Delta_{max}}{A_m} \times 100\% \quad (1.2)$$

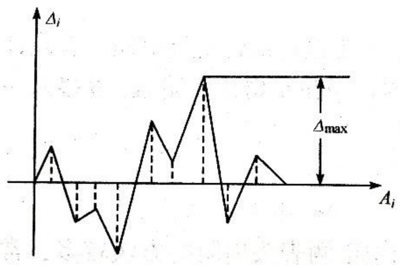

Figure 4: Calibration curve

After modification or long-term use, the ammeter must be corrected. The method is to measure a certain current or voltage at the same time with a standard meter with higher accuracy. If the calibration value of the ammeter is A_i and the corresponding value of the standard meter is A_0, then the absolute error of each calibration is Δ_i=A_i-A_0. The maximum absolute error Δ_{max} is found out, and the calibration of the ammeter to be calibrated can be calculated by using formula accuracy level K.

If A_i is the abscissa and Δ_i is the ordinate, electricity can be drawn. The calibration curve of the table is connected by a straight line between the two calibration points. The whole figure is polygonal, as shown in Fig. 4.

实验器材 List of instruments and materials:

100μA meter head, DC ammeter, resistance box, sliding resistor, DC regulated power supply, two single-pole switch (or single-pole double-throw switch) , a number of wires.

实验步骤 Implementation:

1. Measuring the internal resistance of the meter head

The resistance of the meter head is measured by half-value method. The wiring is shown in Fig. 2. First disconnect K_2, close K, adjust sliding rheostat r to make G full, record the reading of G_0 and G, then close K_2, adjust the resistance of resistance box R, and at the same time adjust the size of R to keep the original value of Go, while the reading of G is half of the original value, at this time R = Rg :

Note: The current that the head can pass is very small. Therefore, when adjusting r, the sliding head C should be placed at the lowest output voltage (sliding head C should be placed at the B end), and then increase slowly, so that the current can not exceed the rated value, let alone reverse current.

Because the internal resistance of the meter head has a great influence on the assembly of the three-purpose meter, another method is suggested to measure the internal resistance of the meter head. Finally, the satisfactory value or average value is taken as the design value.

2. When referring to the reference circuit diagram of the second experiment (Fig. 6) and the related circuit for design and design, we should understand the circuit diagram; understand the main performance of the table head provided by the laboratory (internal resistance, limit, etc.); and then calculate each R value one by one.
3. Comparing with the insertion board of the three-meter, the position of each element, the function of changing shape and the layout of the line diagram are preliminarily understood.
4. Write the design report.

Experiment 2：Measurement of the Internal Resistance of Watch Head and Design of Three-purpose Meter

原理和设计 Principle and Design:

The three-meter is mainly composed of a magnetoelectricity measuring mechanism (i.e. the meter head) and a measuring circuit controlled by a switch. In fact, according to the principle of refitting the meter, a meter head is connected with various measuring circuits to form a multi-range ammeter, a voltmeter and an ohmmeter.

The requirements of the three-purpose meter we designed and assembled are: DC current 3-bar, DC voltage 3-bar and Ohm table 1-bar. The reference circuit is shown in Fig. 5.

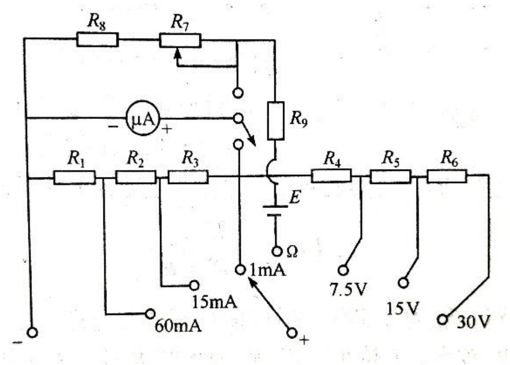

Figure 5: Reference schematic diagram of three-meter

1. The design of DC current

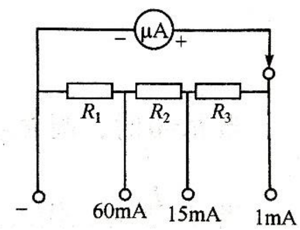

Figure 6: DC ammeter circuit

The range of the meter head in Fig. 5 is 100μA. Now the range of the meter head is extended to 1mA,1.5mA and 60mA. The circuits related to these three limits are extracted from the figure. As shown in Fig. 6, for the current meter design with the limit of 60mA, we have changed the circuit to the circuit shown in Fig. 7. The current through the meter head is full range. For current I_0, the current passing through R is 0.06-I_0, therefore

$$I_0(R_3+R_2+R_g)=(0.06-I_0)R_1 \quad (1.3)$$

For the ammeter design with a limit of 15mA, it is similar to the circuit diagram shown in Fig. 8. The following equations can be obtained:

$$I_0 R_g = (0.01 - I_0)(R_1 + R_2 + R_3) \quad (1.4)$$

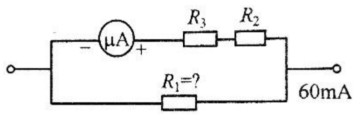

Figure 7: Limit 60μA Amperometer Circuit

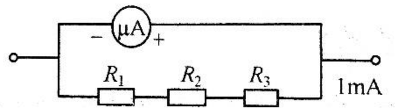

Figure 8: Limit 60mA Amperometer Circuit

For the limit of 15mA, the following equations can also be listed:

$$I_0(R_g + R_3) = (0.015 - I_0)(R_1 + R_2) \quad (1.5)$$

When the above three equations are combined, the values of R_1, R_2, R_3 can be obtained.

2. Design of DC Voltage Shield

R_1, R_2, R_3 have been calculated, so the dotted wire frame can be regarded as the internal resistance of an equivalent meter head, because the total current of the equivalent meter head is 1mA. Thus, according to the extended voltage range, the values of R_4, R_5 and R_6 can be calculated respectively.

实验器材 List of instruments and materials:

100μA meter head, DC ammeter, DC voltmeter, resistance box, DC regulated power supply, nine-hole plug-in board, various conductors, etc.

实验步骤 Implementation:

1. Change the 100 μA meter head into three-purpose meter with the following specifications
   DC current: 1mA, 15mA, 60mA.
   DC voltage: 7.5V, 15V, 30V.
   Ohmmeter: the central resistance is 12kΩ.
   The resistance value of R_1~R_9 can be calculated by referring to relevant circuits.
   Note: The internal resistance of the watch head should be measured accurately.
2. Choose the resistance that meets the above calculation (generally found on the plugboard). If it is not suitable, it can be adjusted by a variable resistance (i.e. potentiometer) to the required resistance value.
3. Refer to Fig. 5.6.5, insert the components and the lead wire of the watch head into the nine-hole junction board, connect the circuit
4. Check the DC current and DC voltage block, and design the circuit itself.

When checking, 5 points are checked by integer scale (each range needs to be checked). The integer readings are selected by the calibration table and the corresponding readings of the standard table are read out.

5. Calculate the accuracy level of the assembly meter (2 blocks of current and voltage) and
6. Check the effect of zero-setting resistance.
7. Take the resistance box as the standard, check the resistance value of the ohmmeter center and whether it meets the design requirements (percentage error).
8. Discuss and evaluate your design and fabrication work.

实验结果和数据处理 Results and Data processing:

Results:

Designaion of Multimeter Data Recording Form			
Internal Resistance of AmmeterΩ (Ω)	Half Value Method	Replacement Method	Measured by Multimeter
	2180	**2190**	**2150**
$I_{改}$ （mA）	1	15	60
$I_{标}$ （mA）	0.88	14.7	60.6
ΔI （mA）	**0.12**	**0.3**	**0.6**
$V_{改}$ （V）	**7.5**	**15**	**30**
$V_{标}$ （V）	7.43	14.93	29.91
ΔV （V）	0.07	0.07	0.09

Form: Experiment Data

Calculation of Data:

1. According to the data:

$I_0(R_3 + R_2 + R_g) = (0.06 - I_0)R_1$

$I_0 R_g = (0.01 - I_0)(R_1 + R_2 + R_3)$

$I_0(R_g + R_3) = (0.015 - I_0)(R_1 + R_2)$

We can get $R_1 = 4.26k\Omega$ $R_2 = 12.8k\Omega$ $R_3 = 238\Omega$

2. According to part of the schematic diagram of the ammeter:

$(R_1 + R_2 + R_3)(0.001) + R_4(0.001) = 7.5$ $\rightarrow R_4 = 7.30\ k\Omega$

$(R_1 + R_2 + R_3)(0.001) + R_4(0.001) + R_5(0.001) = 15$ $\rightarrow R_5 = 7.50\ k\Omega$

$(R_1 + R_2 + R_3)(0.001) + R_4(0.001) + R_5(0.001) + R_6(0.001) = 30$ $\rightarrow R_6 = 15\ k\Omega$

3. $K_{\mathrm{I}} = \frac{\Delta \mathrm{I}_{max}}{A_m} \times 100\% \approx 133\%$

$K_{\mathrm{V}} = \frac{\Delta \mathrm{V}_{max}}{A_m} \times 100\% \approx 166\%$

实验讨论 Discussions:

1. Why the error of I and V are 133% and 166%?

After modification or long-term use, the ammeter must be corrected. The method is to measure a certain current or voltage at the same time with a standard meter with higher accuracy. If the calibration value of the ammeter is A_i and the corresponding value of the standard meter is A_0, then the absolute error of each calibration is Δ_i=A_i-A_0. The maximum absolute error Δ_{max} is found out, and the calibration of the ammeter to be calibrated can be calculated by using formula accuracy level K.

2. How to make Ohm Zero?

When the two pens are short connected, Ohm's law shows that the full bias of the ammeter can be achieved by adjusting the sliding rheostat, that is, the pointer refers to the full bias current scale of the ammeter, that is, the zero ohm scale. That is, when the two pens are short connected, the state indicated by the meter pointer should be full bias current and zero ohmic resistance. Otherwise, adjusting the rheostat makes the ammeter pointer point to the full bias current scale, that is, the zero ohm scale, that is, to complete the ohmic zero adjustment.