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暨南大学本科实验报告专用纸

课程名称 Physics Experiment 成绩评定 ______

实验项目名称 The Wheatstone Bridge 指导教师 Zhang

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实验时间 2022 年 10 月 10 日 上 午～__月__日 __午 温度__℃湿度____

OBJECTIVE:

1. To understand the principle of measuring resistance using a Wheatstone Bridge.
2. To measure the unknown resistances using the self-built and portable Wheatstone Bridge respectively.

THEORY:

The most accurate and rapid method of measuring resistances of widely different values is by means of the Wheatstone bridge. It was invented in 1843 by the English scientist Charles Wheatstone. The purpose of this experiment is to learn to how to build up a Wheatstone Bridge. by yourself and how to use the bridge to measure the resistance of two or more resistors with it, and you will use portable bridge to measure the same resistors, then compare the values.

A Wheatstone bridge is a circuit consisting of four resistors arranged as shown in Fig. 1. It is used for finding the value of an unknown resistance by comparing it with a known one. Three known resistances are connected with the unknown resistance, a galvanometer, and a dry cell as shown in Fig. 1.

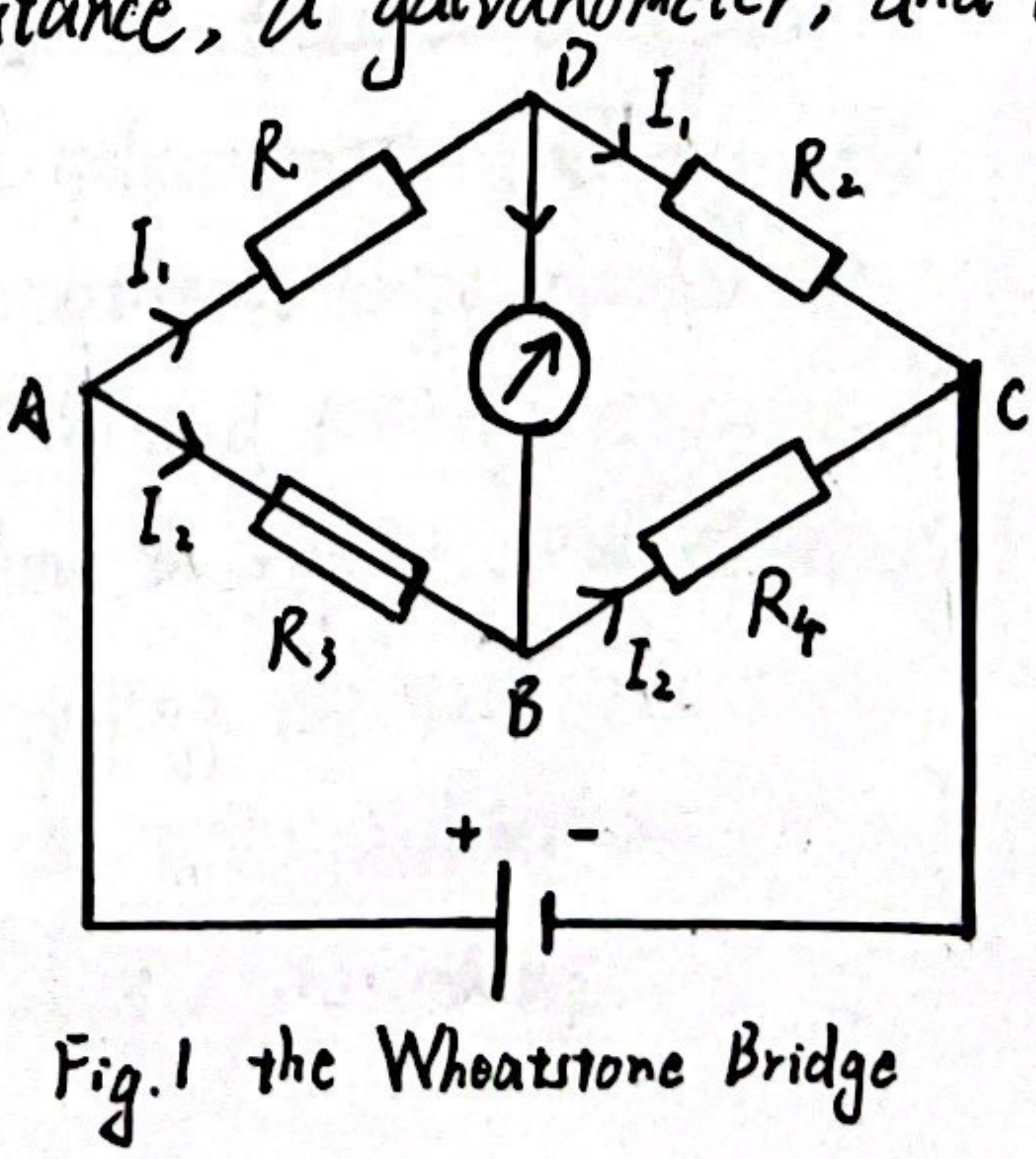

Fig. 1 the Wheatstone Bridge

For a condition of balance, no current flows through the galvanometer. Hence the current through R_1 is the same as the current through R_2, and the current through R_3, is the same as that through R_4. Moreover, because there is no current through G, there must be no voltage across it; hence, the potential drop across R_1 must be equal to that across R_3. This requires that

$$i_1 R_1 = i_2 R_3 \quad (1)$$

Similarly, the potential drop across R_2 must equal that across R_4, so that

$$i_1 R_2 = i_2 R_4 \quad (2)$$

Dividing the first equation by the second yields

$$\frac{R_1}{R_2} = \frac{R_3}{R_4} \qquad (3)$$

Therefore, if three of the resistances are known, the fourth may be calculated from equation (3).

For example, if R_1, R_2, and R_s are known, R_x can be computed

$$R_x = \frac{R_1}{R_2} R_s \qquad (4)$$

The ratio $\frac{R_1}{R_2}$ is usually set at ~~some~~ some integral power of 10, such as 0.01. 0.1. 1. 10, 100, etc, for simplicity in computation. We can get the resistance of R_s from the standard resistance box, and then R_x can be obtained.

From above example we know the unknown resistance R_x is decided by R_1. R_2 and R_s (read from standard resistance boxes) The standard resistance boxes are not enough accurate, so there are some errors in R_1, R_2, and R_s, and the errors, we can measure R_x again using exchanging method.

Remain the ratio $\frac{R_1}{R_2}$ as the same as above measurement, and exchange the position of R_x and R_s, adjust R_s until the bridge is balanced. Substitude R_s for R_s', then:

$$R_x = \frac{R_2}{R_1} R_s' \qquad (5)$$

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

$$R_x = \sqrt{R_s R_s'} \qquad (6)$$

According to equation (6) R_x is no relavant to R_1. R_2, so the decision is higher.

Portable bridges are available which have a self-contained galvanometer and dry cells. It ~~provide~~ provides a faster and more convenient method when ~~measure~~ measuring a large number of resistances. The ratio $\frac{R_1}{R_2}$ can be set at any integral power of 10 between 0.001 and 1000 by a single dial switch. The group of four dials marked 1000, 100, 10, and 1, respectively (show in Fig. 2), serve as the known R. The unknown resistance R_x may be determined by multiplying the total resistance R. ~~The~~ resistance R. ~~unknown resistance~~ recorded on these four dials by the reading on the ratio dial (or multiplier), when the galvanometer shows the bridge as balanced. A battery potential of approximately 2-5 volts is required.

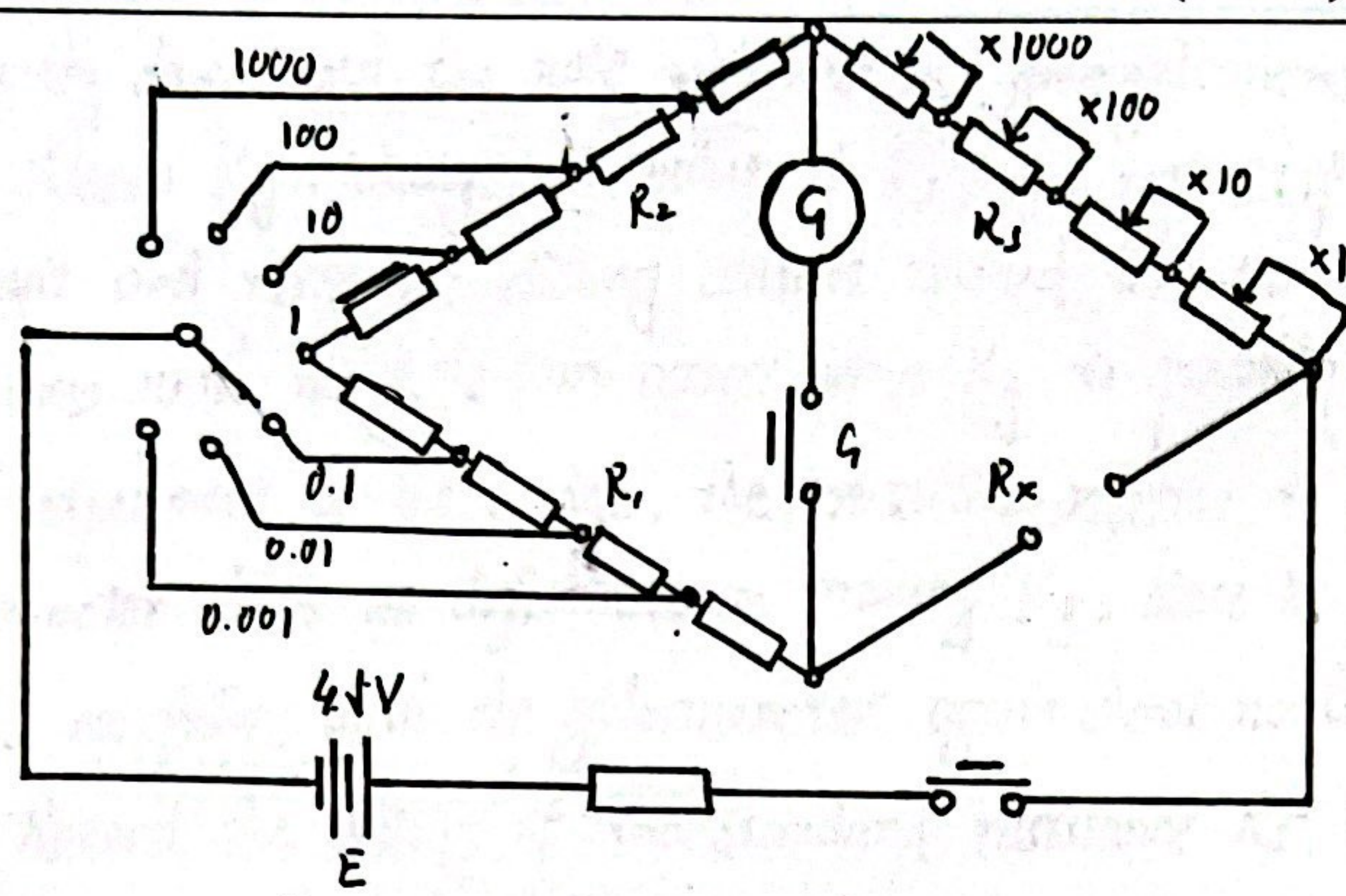

Fig. 2 Circuit

APPARATUS

QJ23 portable Wheatstone bridge、DC supply or dry cell、Galvanometer、Standard resistance boxes(three)、Switches(two)、Carbon resistors(three, among of them, one is protective resistor)、Slide-wire resistor.

CAUTION

B is the battery switch, and G is the galvanometer switch. When you use the portable bridge, you should press button B first then press button G. After having measured the resistances, you should relax button G ~~then~~ first then relax button B. Fig.2 is the circuit of a portable bridge.

PROCEDURE

A. Using self-built Wheatstone Bridge measuring resistances

1. Connect up the self-built form of the bridge as shown in Fig.3. Let R_h be a slide resistor., R_b be a protective resistor, and R_1, R_2, R_s be the standard resistance boxes. R_x is the unknown resistance. Before closing any switches, have the circuit approved by the instructor.

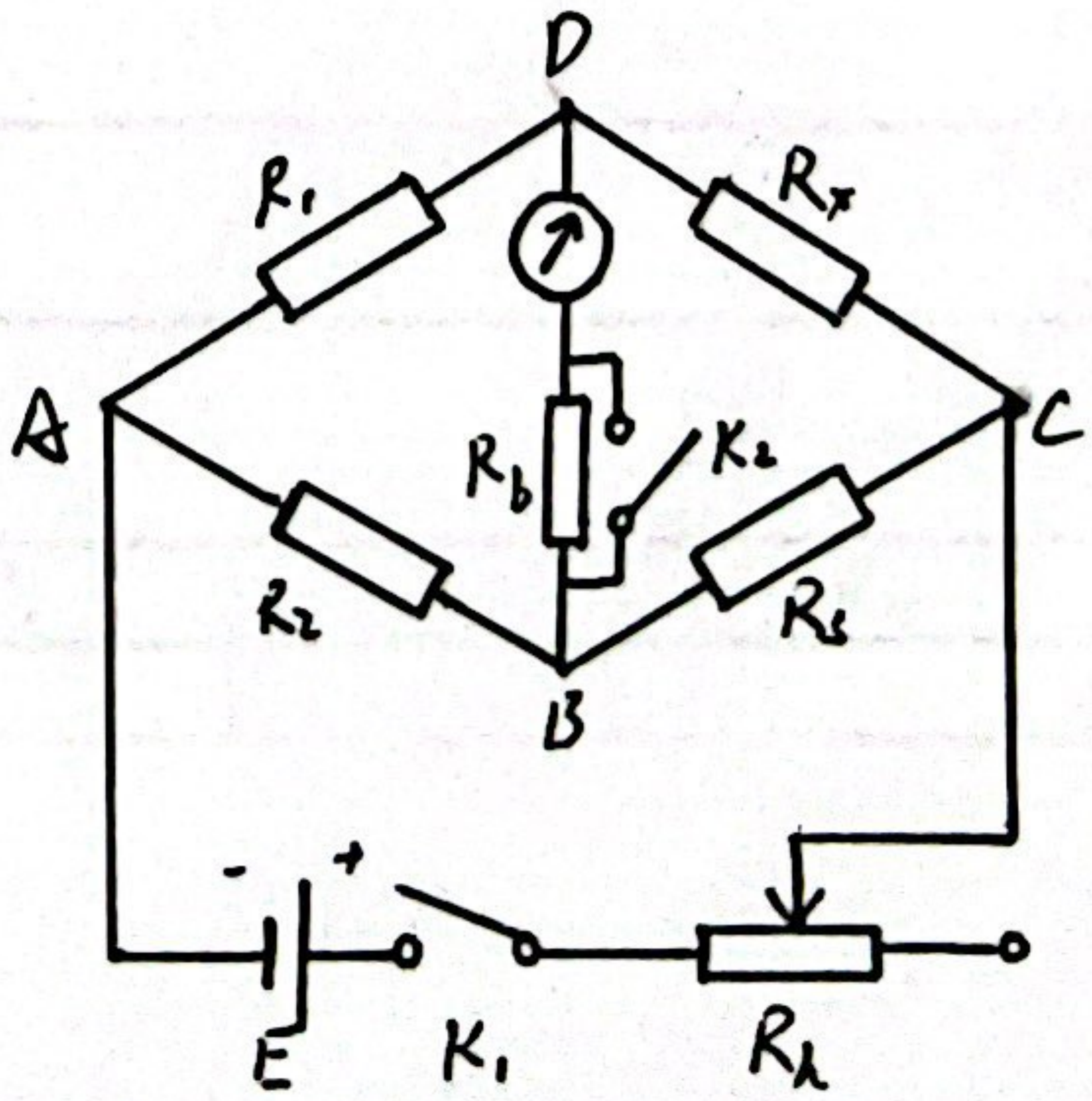

Fig.3 self-built bridge measure resistances

2. According to the nominal value of the resistances that will be measured set the ratio $\frac{R_1}{R_2}$ and the compared resistance R_s, and assure of the measured values of the unknown resistances having 4 significant figures.
Move the sliding contact at the right end, and then turn your apparatus on by closing switch K_1. Notice that key K_2 is normally open ~~and~~ and should remain so for the moment so that the protective resistor is in series with the galvanometer. Press contact K_g on the board

of the galvanometer gently down and the note whother the ~~gatr~~ galvanometer shows a deflection. If it does, release K_g, change the value of R_s, and repeat (if it does not, you need to check you circuit and move the sliding contact toward left as to reduce the value of R_x). Continue this precedure until no deflection occurs when K_g is pressed.

3. For the most sensitive adjustment of the bridge, the protective resistor is short-circuited with key K_2 when the galvanometer shows no deflection on pressing K_g, close K_2 and hold it ~~do~~ down. Adjust the value of R_s carefully, until the galvanometer again shows no deflection when contact key is tapped. Record the setting of the standard resistance R_s. Open switches K_1 when you have finished your measurements.
4. Exchange the position of R_s and R_x, then repeat Procedures 2 and 3, and you will get the measured resistance R_s'. Using equation (6) you can get the unknown resistance R_x.
5. Repeat Procedure 2 and 3 with another unknown resistance in place of resistance just having been measured
6. Complete Table 1

B Using portable Wheatstone bridge measuring resistances

Measure the same resistances using portable Wheatstone bridge and compared the results with the values having been measured using self-built bridge.

DATA RECORDING AND PROCESSING

Table 1

Nominal values	1010 Ω					
R_1/R_2	1:1					
Resistances	R_s	R_s'	R_x	R_s	R_s'	R_x
	1007.03 Ω	1011.21 Ω	1009.12 Ω			

Calculate the uncertainty U_R and express the results (as:

$$R = R \pm U_R$$

Record from a portable Wheatstone bridge:

$R_x = 1007.03\,\Omega$ $\quad$ $R_{2x} = 1011.21\,\Omega$

Since the multiplying power of measurement is $\times 1$, the accuracy $\Delta R = 1\times 0.2\% = 0.002$,
Since this measurement has no A class uncertainty, the B class uncertainty of R_s measurement
$u_1 = 1007.03\times 0.002 = 2.01$, u_2 of R_s' is $1011.21\times 0.002 = 2.02$.

Because $R_x = \sqrt{R_s\cdot R_s'} \Rightarrow \ln R_x = \frac{1}{2}\ln R_s + \frac{1}{2}\ln R_s'$, we have $\frac{\partial \ln R_x}{\partial R_s} = \frac{1}{2}\cdot\frac{1}{R_s}$, $\frac{\partial \ln R_x}{\partial R_s'} = \frac{1}{2}\cdot\frac{1}{R_s'}$

Hence,
$$\frac{u_{R_x}}{R_x} = \sqrt{\left(\frac{\partial \ln R_x}{\partial R_s}\right)^2 u_1^2 + \left(\frac{\partial \ln R_x}{\partial R_s'}\right)^2 u_2^2}$$
$$= \sqrt{\frac{u_1^2}{4R_s^2} + \frac{u_2^2}{4R_s'^2}}$$
$$= \sqrt{\frac{2.01^2}{4\times 1007.03^2} + \frac{2.02^2}{4\times 1011.21^2}}$$
$$= 0.00141$$

$u_{R_x} = 0.00141 \times R_x = 1.42\,\Omega$

Therefore, $R = (1009.12 \pm 1.42)\,\Omega$ $(P = 0.997)$

ERROR ANALYSIS

1. The precision of the resistance will lead to errors.
2. The sensitive of the resistance box will lead to errors.
3. The problem of keeping decimal places in the calculation will lead to errors.
4. The unreasonable resistance ratio setting will occur errors in calculation.
5. The wires have resistance, which can also cause errors.