EP12 the Wheatstone Bridge

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 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 your 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

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

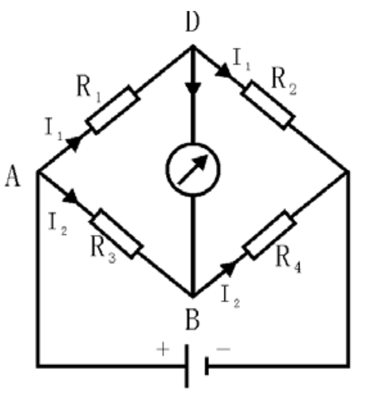

Fig. 1 the Wheatstone Bridge

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

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

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

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 ${R_1}/{R_2}$ is usually set at 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 that 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 can be propagated to the unknown resistance R_x. In order to reduce the errors, we can measure R_x again using exchanging method.

Remain the ratio ${R_1}/{R_2}$ as the same as above measurement, and exchange the positions of R_x and R_s, adjust R_s until the bridge is balanced. Substitute 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 relevant to R_1, R_2, so the decision is higher.

Portable bridges are available which have a self-contained galvanometer and dry cells. It provides a faster and more convenient method when measuring a large number of resistances. The ratio ${R_1}/{R_2}$ 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(shown in Fig.2), serve as the known resistance R. The unknown resistance R_x may be determined by multiplying the total resistance R 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.

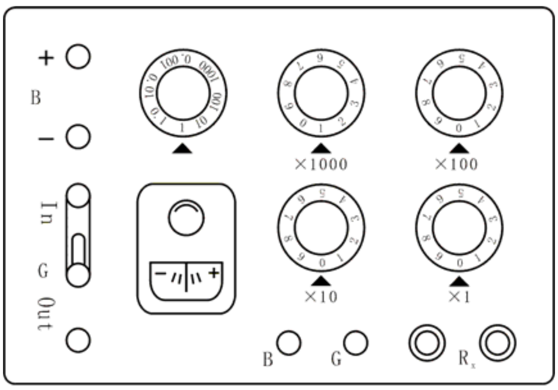

Fig.2 (a) panel board

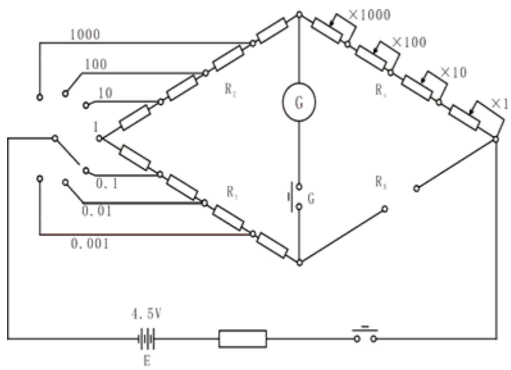

Fig.2 (b) Circuit

APPARATUS

QJ23 potable 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 potable bridge, you should press button B first then press button G. After having measured the resistances, you should relax button G first then relax button B. Fig.2(b) 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.

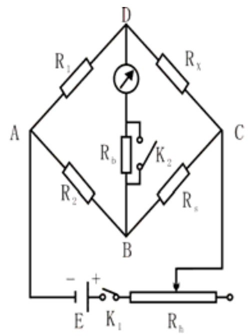

Fig. 3 self-built bridge measure resistances

2. According to the nominal value of the resistances that will be measured set the ratio 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 K1. Notice that key K2 is normally open 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 note whether the galvanometer shows a deflection. If it does, release K_g, change the value of R_s, and repeat (if it does not, you need check your circuit and move the sliding contact toward left as to reduce the value of R_h). Continue this procedure 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 K2 When the galvanometer shows no deflection on pressing K_g , close K2 and hold it 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 K1 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 Procedures 2 and 3 with another unknown resistance in place of the resistance just having been measured.

Complete table1.

DATA RECORDING AND PROCESSING

Table 1

Nominal values		
R_1 / R_2		
Resistances	R_s	R_s'

Using equation (6) you can get the unknown resistance R_x