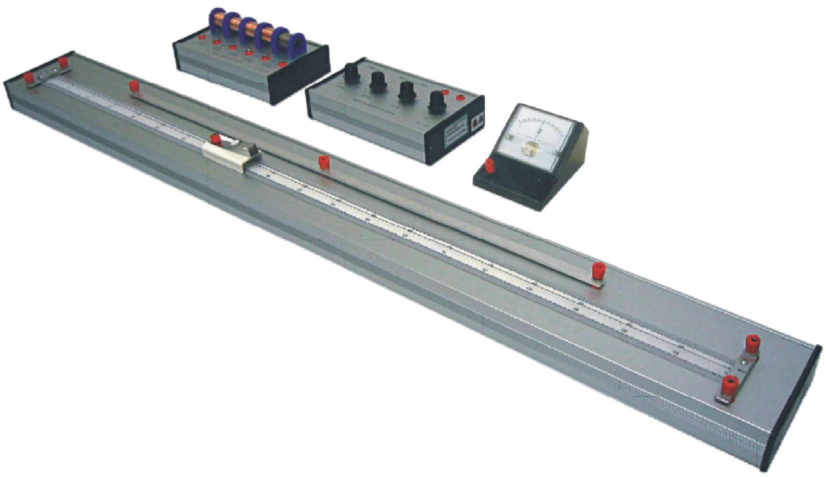
Experiment: Wheatstone Bridge Experiment



Purpose

To learn how to measure the coefficient of resistance of different metal wires using a Wheatstone bridge.

Theory

A Wheatstone bridge is an electrical circuit used to measure an unknown electrical resistance as shown in Fig. 1.There are four resistances named R_1, R_2, R_3 and R_4, and G is the galvanometer. When the switch is turned on, it means that the current which flows through R_1 and R_2 should be the same, and represented by I_1, the current which flows through R_3 and R_4 is the same, and represented by I_2. The potential difference between two points A and B is zero. The potential of the two points is the same, so

$$I_1R_1 = I_2R_3 \qquad (1)$$

$$I_1R_2 = I_2R_4 \qquad (2)$$

Divide the above equations, we obtain

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

or

$$R_2 = R_1(\frac{R_4}{R_3}) \qquad (4)$$

From the above equations, if R_2 is the unknown resistance, the other three resistances are known, we can obtain the value of the resistance using the above method.

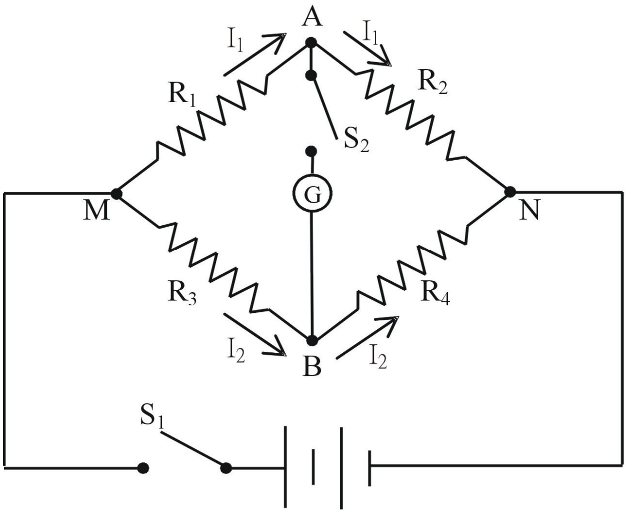


Fig.1

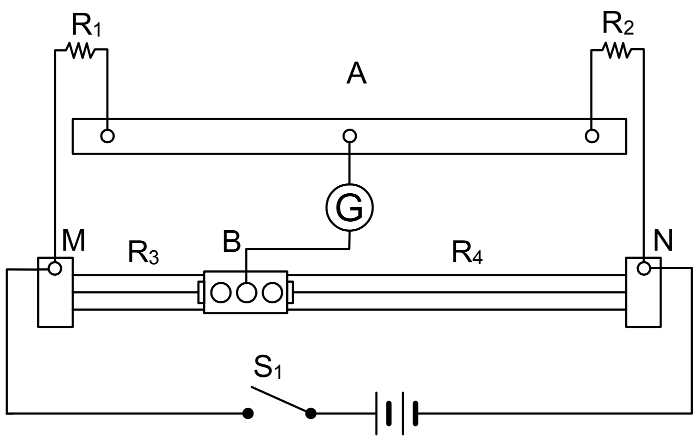


Fig.2

The Wheatstone bridge circuit is as shown in Fig. 2. MN is the metal wire, the point B divides MN into MB and BN, and the resistances are R_3 and R_4. Each resistance is proportional to its length, so

$$R = \rho \frac{L}{A} \tag{5}$$

ρ is the resistivity, L is the wire length, and A is the wire cross-sectional area. So the ratio of R_3 and R_4 is equal to the ratio of MB and BN. If we can find a spot to make the reading become zero, and equation (5) can be written as:

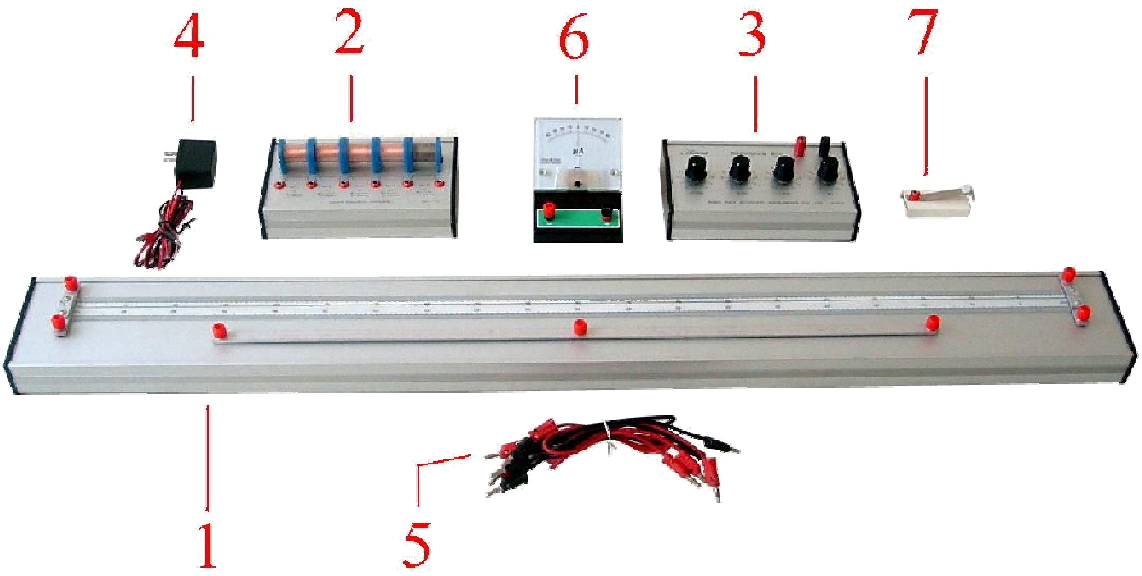
$$R_2 = R_1 \left(\frac{\overline{BN}}{\overline{MB}}\right) \tag{6}$$

We can set the variable resistance as R_1, different resistance values can be selected. The unknown resistances are set as a, b, c, d and e, respectively. The material of the first four is copper (not pure copper), the last is nickel chromium.

Unknown resistance	a	b	c	d	e
Material	Co	Co	Co	Co	Ni-Cr
Diameter(mm)	0.28	0.14	0.28	0.14	0.14
Length(m)	10	10	20	20	10
Resistivity(Ω · m)	1.67×10^{-8}				1.08×10^{-6}

At a temperature of 20°C, the resistance of a wire of standard copper is $1.7\times10^{-8}\,\Omega\cdot m$, and the resistance of a Ni-Ch wire is $1.08\times10^{-5}\,\Omega\cdot m$

Instrument



NO	Accessory	Quantity
1	Slide Wire Bridge	1
2	Unknown Resistance Box	1
3	Variable Resistance Box	1
4	DC Power Supply	1
5	Wire	6
6	Galvanometer	1
7	Probe	1

Procedure

1. Set up the wires as shown in Fig. 2. R_1 is the resistance of the variable resistance box, R_2 is the resistance of the unknown resistance box, G is the galvanometer, and B is the probe.

2. Turn on the power supply power supply and adjust the resistance. Then, push the probe to make it connect to the metal line. The galvanometer deflects at this time, but if deflection is too large, you need to adjust the resistance to an appropriate value. When the deflection is small, move the probe to make the galvanometer reading back to zero, then we can obtain the length of MB and BN.

3. According to equation 1 to 6 to obtain the value of R_2, and substitute R_2 into equation 1 to 5 to obtain the coefficient of resistance of the unknown resistance.

Experimental Record

Unknown resistance	Resistance R_1 (Ω)	$\overline{MB}$ (cm)	$\overline{BN}$ (cm)	Unknown resistance			ρ (Ω · m) $\rho = \frac{\pi D^2 R_2}{4L}$
				R_2 (Ω) $R_2 = R_1(\frac{\overline{BN}}{\overline{MB}})$	D (m)	L (m)	
a							
a							
a							

Unknown resistance	Resistance R_1 (Ω)	$\overline{MB}$ (cm)	$\overline{BN}$ (cm)	Unknown resistance			ρ (Ω · m) $\rho = \frac{\pi D^2 R_2}{4L}$
				R_2 (Ω) $R_2 = R_1(\frac{\overline{BN}}{\overline{MB}})$	D (m)	L (m)	
a							
a							
a							

Unknown resistance	Resistance $R_1\,(\Omega)$	$\overline{MB}$ (cm)	$\overline{BN}$ (cm)	Unknown resistance			$\rho\,(\Omega \cdot \text{m})$ $\rho = \frac{\pi D^2 R_2}{4L}$
				$R_2\,(\Omega)$ $R_2 = R_1(\frac{\overline{BN}}{\overline{MB}})$	D (m)	L (m)	
a							
a							
a							

Unknown resistance	Resistance $R_1\,(\Omega)$	$\overline{MB}$ (cm)	$\overline{BN}$ (cm)	Unknown resistance			$\rho\,(\Omega \cdot \text{m})$ $\rho = \frac{\pi D^2 R_2}{4L}$
				$R_2\,(\Omega)$ $R_2 = R_1(\frac{\overline{BN}}{\overline{MB}})$	D (m)	L (m)	
a							
a							
a							

Unknown resistance	Resistance R_1 (Ω)	$\overline{MB}$ (cm)	$\overline{BN}$ (cm)	Unknown resistance			ρ (Ω · m) $\rho = \frac{\pi D^2 R_2}{4L}$
				R_2 (Ω) $R_2 = R_1(\frac{\overline{BN}}{\overline{MB}})$	D (m)	L (m)	
a							
a							
a							

Note: Coefficient of resistance $\rho = \frac{\pi D^2 R_2}{4L}$

The copper wire used in this experiment is not 100% pure copper, so the experimental results and the theoretical value are different.

Questions and Discussions

1. Analyze the resistance of a, b, c and d and explain the relationship between the resistance and the diameter of the wire.

2. 1. Analyze the resistance of a, c, b and d and explain the relationship between the resistance and the length of the wire.

3. 1. Analyze the resistance b and e and explain the relationship between the resistance and coefficient of resistance

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