Determining resistances using a Wheatstone bridge

Experiment Objectives

- Understanding the null method for the Wheatstone bridge.
- Exact determination of resistances.

Basic Information

The bridge circuit introduced by Charles Wheatstone in 1843 represents one possibility to measure resistance. The value of an unknown resistance R_x can thus be exactly determined by a comparison with a resistance R that is known very precisely.

The experiment puts voltage U on a 1 m long pilot wire with constant width. The wire ends are connected to the unknown resistance R_x and another, series connected resistance R that is variable but known very precisely (see Illustration 2). A sliding contact splits the pilot wire into two sections of lengths s_1 and s_2. The sliding contact is connected to the crosspoint between R_x and R through an ammeter inserted as a null indicator. If the current is aligned on zero, then:

$$R_x = \frac{s_1}{s_2} \cdot R \qquad (1)$$

Therefore the resistance measurement is, with the null balance, independent of the current applied and can also be done with non-stabilized power supplies.

The best measuring accuracy for this experimental configuration is achieved with a symmetric assembly, i.e. if the sliding contact is positioned in the middle of the pilot wire, so that both sections s_1 and s_2 have the same length. Then:

$$R_x = R \qquad (2)$$

The known resistance R should therefore have a measurement as exact as possible that is about as much as the resistance R_x to be determined.

Alternatively, with equation 2, the unknown resistance can be determined directly, in that the sliding contact is initially positioned in the middle and the variable resistance is subsequently adjusted such that the ammeter is aligned on zero. The value of the variable resistance R then corresponds directly to the value R_x wanted.

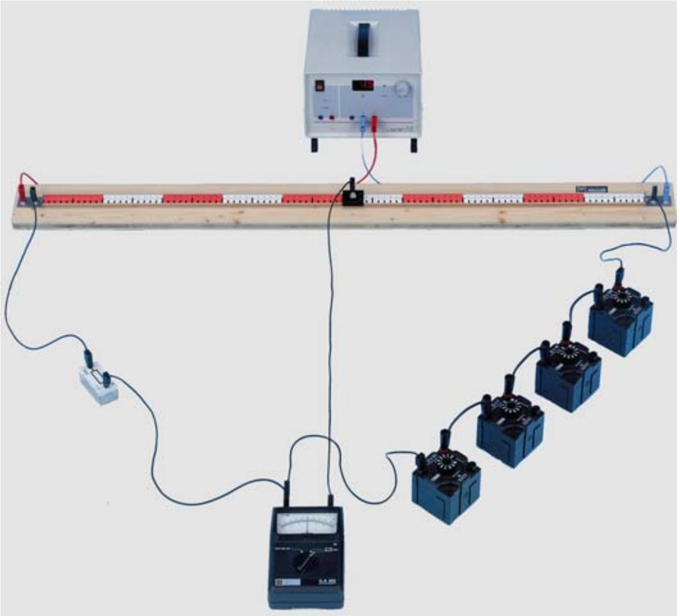

Illustration 1: Experiment setup

Apparatus

1 Demonstration bridge, 1 m long........................ 536 02

1 Measuring resistor 10 Ω, 4 W........................... 536 121
1 Measuring resistor 100 Ω, 4 W......................... 536 131
1 Measuring resistor 1 kΩ, 4 W........................... 536 141

1 Resistance decade 0 ... 1 kΩ............................ 536 776
1 Resistance decade 0 ... 100 Ω.......................... 536 777
1 Resistance decade 0 ... 10 Ω............................ 536 778
1 Resistance decade 0 ... 1 Ω.............................. 536 779

1 DC power supply 0...+/- 15 V............................ 521 45
1 Galvanometer C.A 403...................................... 531 13

3 Connecting leads, 50 cm, black........................ 501 28
1 Pair of cables, 1 m, red/blue.............................. 501 46

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Setup

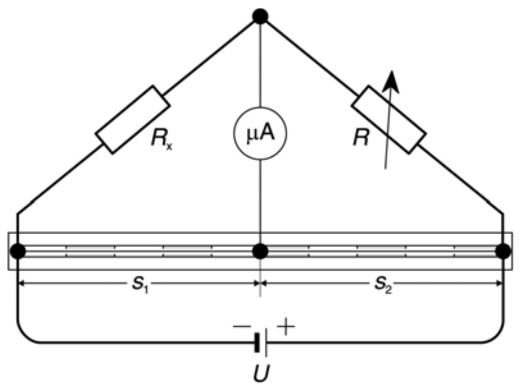

Illustration 2: Circuit diagram

Experiment setup according to Illustrations 1 and 2. Insert the measuring resistor 10 Ω as unknown resistance R_x. The voltage at the power supply may not be more than 2 V, and the current through the resistance decades may not be more than 250 mA.

Procedure

Null balance by setting s_1 and s_2:

– At the resistance decades, set $R \approx ½ R_x$.

– Switch the DC power supply on and set the voltage to 1 V.

– Set the wire lengths s_1 and s_2 so that the ammeter indicates I = 0 A in the smallest measuring range. Record the values R_x, R, s_1 and s_2 in a table.

– Incrementally increase the value of R at the resistance decade and repeat the experiment.

– Repeat the experiment with different measuring resistors.

Null balance by adapting the resistance decades:

– Make the wire lengths s_1 and s_2 exactly 50 cm (split at midpoint).

– Attach the measuring resistor 10 Ω and set the resistance decades reasonably.

– Set the power supply's voltage to 1 V.

– Set the resistance decades so that the ammeter indicates I = 0 A in the smallest measuring range. Record the values R_x and R in a table.

– Repeat the experiment with different measuring resistors.

Measurement Examples and Analysis:

Null balance by setting s_1 and s_2:

Table 1: Measuring resistor 10 Ω

$\frac{R_x}{\Omega}$	$\frac{R}{\Omega}$	$\frac{s_1}{\text{cm}}$	$\frac{s_2}{\text{cm}}$	$\frac{R_x = \frac{s_1}{s_2} \cdot R}{\Omega}$
10 ±2%	3.00	77.1	22.9	10.1
	5.00	67.0	33.0	10.2
	10.0	50.0	50.0	10.0
	15.0	40.0	60.0	10.0
	20.0	34.0	66.0	10.3
	30.0	26.0	74.0	10.5

Table 2: Measuring resistor 100 Ω

$\frac{R_x}{\Omega}$	$\frac{R}{\Omega}$	$\frac{s_1}{\text{cm}}$	$\frac{s_2}{\text{cm}}$	$\frac{R_x = \frac{s_1}{s_2} \cdot R}{\Omega}$
100 ±2%	30.0	77.3	22.7	103
	50.0	67.0	33.0	102
	100	51.0	49.0	104
	150	41.0	59.0	104
	300	26.0	74.0	105

Table 3: Measuring resistor 1 kΩ

$\frac{R_x}{\Omega}$	$\frac{R}{\Omega}$	$\frac{s_1}{\text{cm}}$	$\frac{s_2}{\text{cm}}$	$\frac{R_x = \frac{s_1}{s_2} \cdot R}{\Omega}$
1000 ±2%	300	77.0	23.0	1004
	500	66.7	33.3	1002
	1000	50.0	50.0	1000
	2000	33.2	66.8	994
	3000	24.8	75.2	989

Null balance by adapting the resistance decades

Table 4: Resistance decade measurement

$\frac{R_x}{\Omega}$	$\frac{R}{\Omega}$
10 ± 2%	10.0
100 ± 2%	101
1000 ± 2%	996