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:

\[
R_x = \frac{s_1}{s_2} \cdot R \quad (1)
\]

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:

\[
R_x = R \quad (2)
\]

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............................. 520 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
Setup

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 $R \approx \frac{1}{2} R_x$.
- 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.