Wheatstone bridge

LEP 4.1.02

Related topics
Kirchhof f's laws, conductor, circuit, voltage, resistance, parallel connection, series connection.

Principle and task
The Wheatstone bridge circuit is used to determine unknown resistances. The total resistance of resistors connected in parallel and in series is measured.

Equipment

Resistance board, metal	06108.00	1
Slide wire meas. bridge, simple	07182.00	1
Connection box	06030.23	1
PEK carbon resistor 1 W 5% 10 Ohm	39104.01	1
PEK carbon resistor 2 W 5% 100 Ohm	39104.63	1
PEK carbon resistor 1 W 5% 150 Ohm	39104.10	1
PEK carbon resistor 1 W 5% 330 Ohm	39104.13	1
PEK carbon resistor 1 W 5% 680 Ohm	39104.17	1
PEK carbon resistor 1 W 5% 1 kOhm	39104.19	1
PEK carbon resistor 1 W 5% 4.7 kOhm	39104.27	1
PEK carbon resistor 1 W 5% 10 kOhm	39104.30	1
PEK carbon resistor 1 W 5% 15 kOhm	39104.32	1
PEK carbon resistor 1 W 5% 82 kOhm	39104.40	1
PEK carbon resistor 1 W 5% 100 kOhm	39104.41	1
Power supply, 5 V/1 A, +/-15 V	13502.93	1
Digital multimeter	07134.00	1
Connecting cord, 500 mm, red	07361.01	2
Connecting cord, 500 mm, yellow	07361.02	2
Connecting cord, 500 mm, blue	07361.04	2

Problems
1. Determination of unknown resistances.

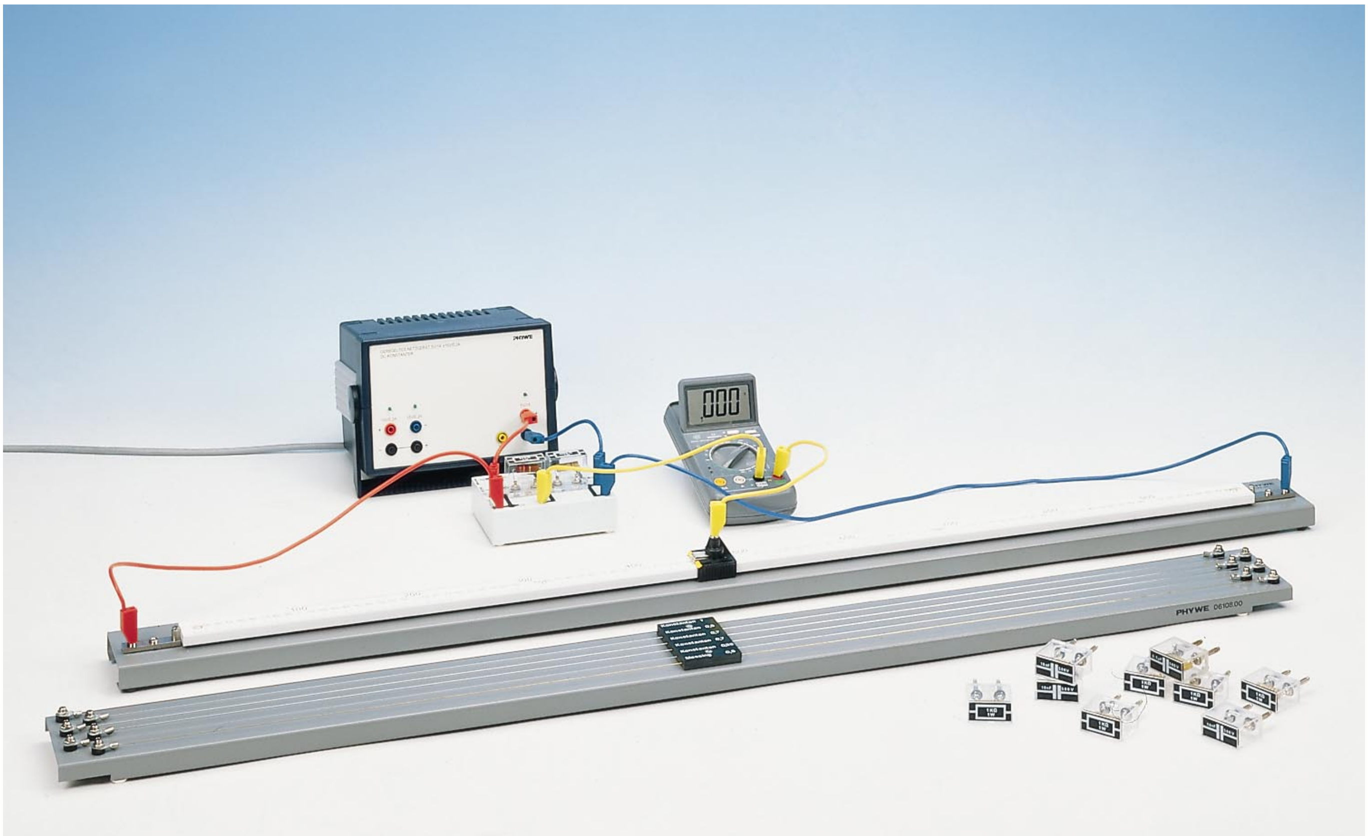
   Determination of the total resistance
2. of resistors in series,
3. of resistors in parallel.
4. Determination of the resistance of a wire as a function of its cross-section.

Set-up and procedure
The values of the resistors to be measured are made invisible and encoded as follows.

x 1	=	270	Ohm
x 3	=	15	KOhm
x 8	=	4.7	KOhm
x13	=	150	Ohm
x16	=	680	Ohm

The experimental set up is as shown in Fig. 1. The resistance to be investigated (single, parallel-connected, series-connected and wire resistances) are shown in Fig. 2 as R_x. Since the slide wire measuring bridge gives the best reading accuracy in its central part, it is useful to bring the measuring resistance R successively to the order of magnitude of R_x. The measuring instrument G (setting 100 μA $\triangleq$ 100 mV) should be balanced to zero by moving the slider.
The power unit is so designed that resistances from milliohms to Megohms can be investigated, but in the milliohm range the

Fig. 1: Experimental set up for determining an unknown resistance with the Wheatstone bridge.



resistances of the connecting leads must be taken into account. Through the pilot light, the power unit is short-circuit-proof.

Theory and evaluation

With branched circuits, in the steady-state condition, Kirchhoff's 1st law applies at every junction point:

$$\sum_{\nu} I_{\nu} = 0 \qquad (1)$$

where I_ν are the current values which lead to or from the junction point.

It is customary to take I_ν as negative if the corresponding current in the ν-th conductor is flowing away from the junction point.

For every closed loop C in a network of linear conductors, in the steady-state condition, Kirchhoff's 2nd law applies:

$$\sum_{\nu} (I_{\nu} R_{\nu} - U_{\nu}^{e} = 0 \qquad (2)$$

where R_ν is the resistance in the ν-th conductor and U_ν^e the voltage.

For the Wheatstone bridge circuit, one obtains

$$R_x = R \cdot \frac{R_1}{R_2} = R \cdot \frac{l_1}{l_2}$$

for an unknown resistance R_x with the designations of Fig. 2, in the balanced condition.

R_{X1}	268	Ω
R_{X3}	15.0	kΩ
R_{X8}	4.81	kΩ
R_{X13}	151	Ω
R_{X16}	682	Ω

Table 1: Resistances measured with the Wheatstone bridge.

From (1) and (2), there follows

$$R_{tot} = \sum_{i} R_i$$

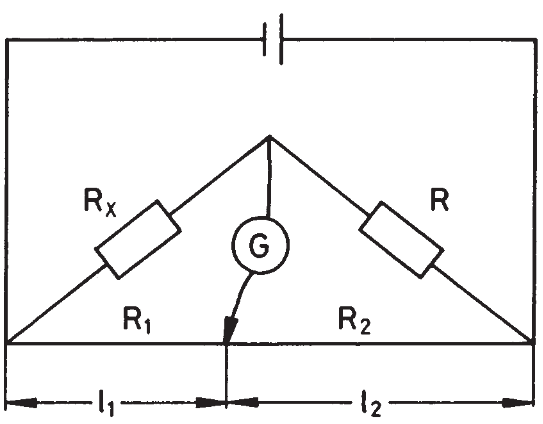


Fig. 2: Wheatstone bridge circuit.

for resistances R_i connected in series, and for resistances connected in parallel

$$\frac{1}{R_{tot}} = \sum_{i} \frac{1}{R_i}$$

1.	$R_{X1'}$	$R_{X13'}$	R_{X16}	85	Ω
2.	$R_{X1'}$	R_{X13}		96.6	Ω
3.	$R_{X1'}$	R_{X16}		192	Ω
4.	$R_{X1'}$	R_{X13}		420	Ω
5.	$R_{X1'}$	$R_{X13'}$	R_{X16}	1100	Ω
6.	$R_{X1'}$	$R_{X13'}$	R_{X16}	260	Ω

Table 2: Total resistance of resistors connected in parallel (lines 1, 2 and 3), in series (lines 4 and 5) and in series-parallel (line 6).

For a uniform conductor of length l and cross-sectional area A, the resistance is

$$R = \rho \cdot \frac{1}{A} \qquad (3)$$

where ρ is the resistivity of the material.

From the regression line to the measured values of Fig. 3 with the exponential statement

$$Y = A \cdot X^B$$

the exponent

$$B = - 1.998 \pm 0.05 \qquad \text{(see (3))}$$

is obtained.

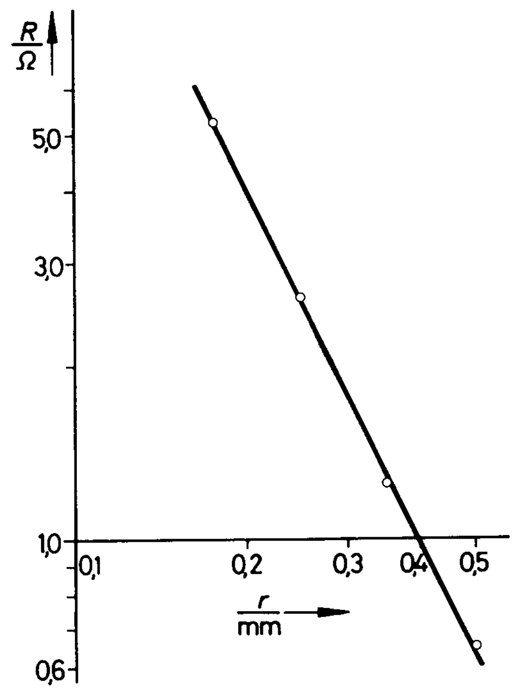


Fig. 3: Resistance of a conductor wire as a function of its radius r.