Measurement of low resistance

Related topics
Ohm's law, resistivity, contact resistance, conductivity, four-wire method of measurement.

Principle and task
The resistances of various DC conductors are determined by recording the current/voltage characteristic. The resistivity of metal rods and the contact resistance of connecting cords are calculated.

Equipment

Heat conductivity rod, Cu	04518.11	1
Heat conductivity rod, Al	04518.12	1
Universal measuring amplifier	13626.93	1
Digital multimeter	07134.00	2
Power supply 0-12 V DC/6 V, 12 V AC	13505.93	1
Connection box	06030.23	1
Connecting cord, 100 mm, yellow	07359.02	2
Connecting cord, 250 mm, red	07360.01	1
Connecting cord, 250 mm, blue	07360.04	1
Connecting cord, 500 mm, red	07361.01	2
Connecting cord, 500 mm, blue	07361.04	1
Connecting cord, 750 mm, yellow	07362.02	2
Connecting cord, 750 mm, blue	07362.04	1
Connecting cord, 2000 mm, yellow	07365.02	2

Problems
1. To plot the current/voltage characteristics of metal rods (copper and aluminium) and to calculate their resistivity.
2. To determine the resistance of various connecting cords by plotting their current/voltage characteristics and calculating the contact resistances.

Set-up and procedure
1. Connect the metal rod to the mains with an ammeter. Measure the voltage drop across the rod at two sockets on the side, using the amplifier (four-wire method of measurement, see Fig. 1).

   Settings of the amplifier: Low drift, R = $10^4\ \Omega$, Amplification: 10^3, Timer constant: 0 sec.

2. Connect a connecting cord into the circuit in place of the metal rod, using two double sockets with cross hole (Fig. 2a). Connect the voltmeter to the sockets of the connecting cord connector (similar to the four-wire method; measuring U_1 as shown in Fig. 2). The voltage dops not only across the pure line resistor R_1 but also across the two line/plug contact resistors R_{1p} as well.

Fig. 1: Recording the current/voltage characteristic of a metal rod.

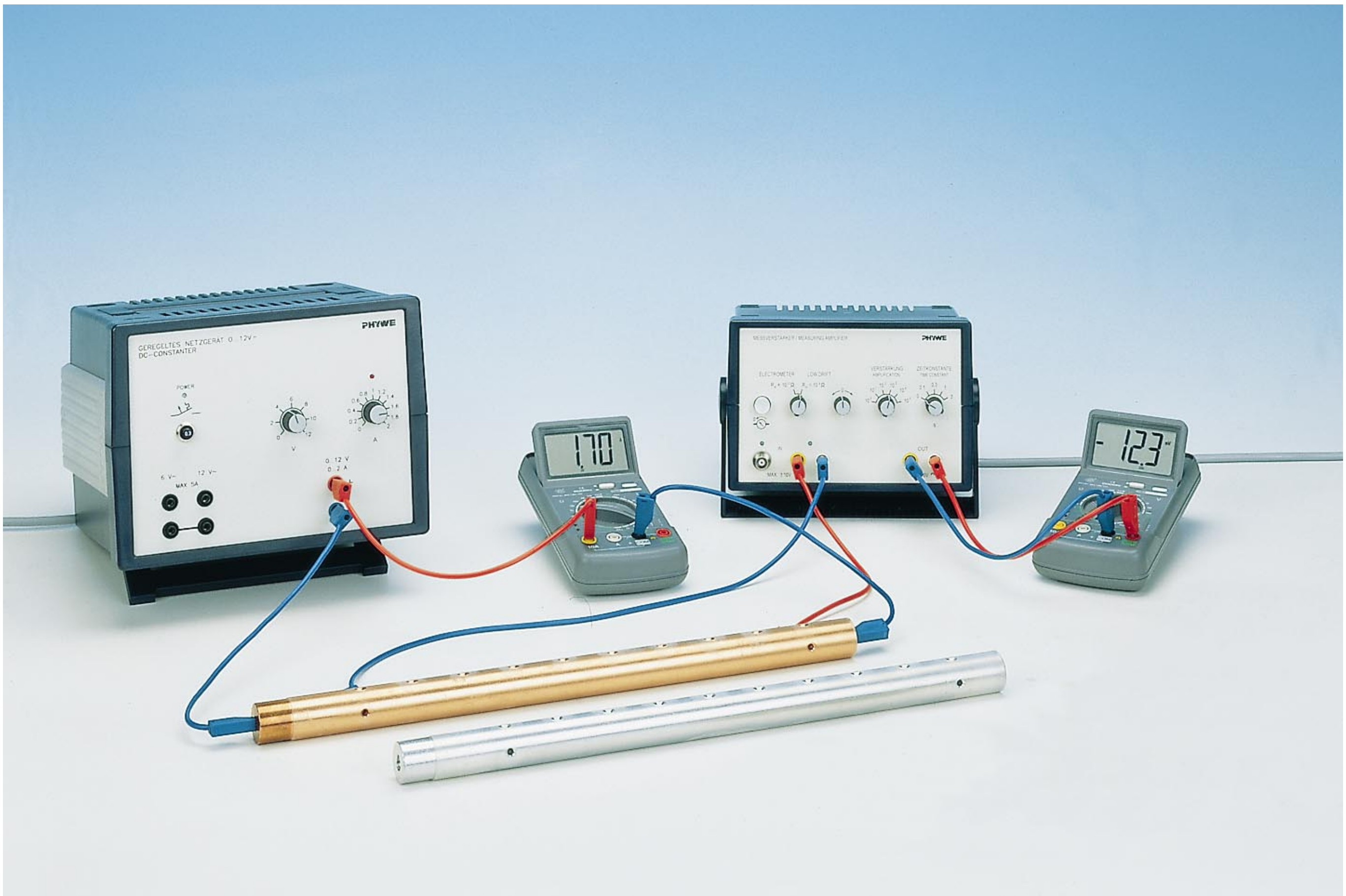
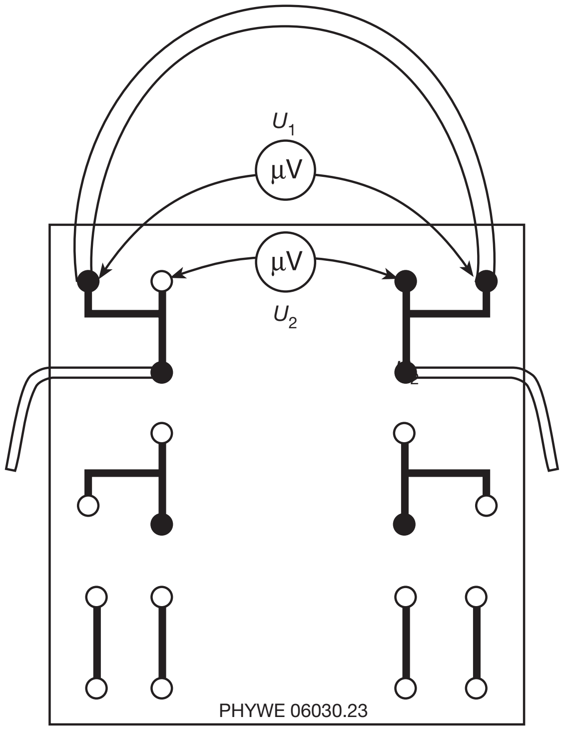
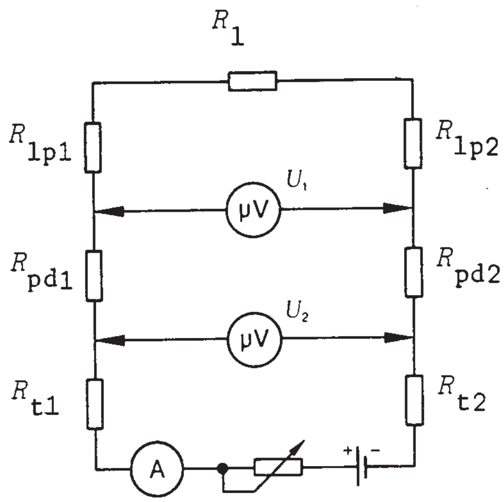


Fig. 2: Measuring the contact resistance and resistivity of connecting cords
a) sketch of the set-up

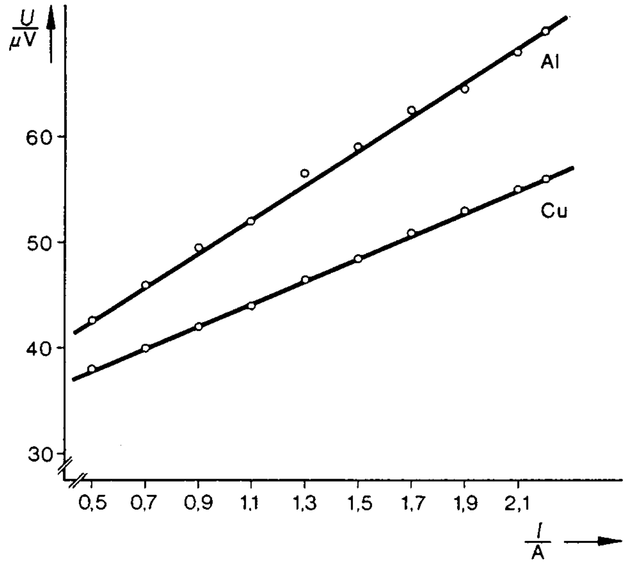


Determine the total resistance of the connecting cord with connectors by connecting the Voltmeter to the holes in the double sockets (measuring U_2 in Fig. 2). The plug/double socket contact resistances R_{pd} are obtained by comparing U_1 and U_2.



b) equivalent circuit diagram: R_t, R_{pd} and R_{1p} are contact resistors, R_1 a line resistor.

Fig. 3: Current/voltage characteristics of a copper rod and an aluminium rod.



Theory and evaluation

The resistivity ρ of the metal is determined from the resistance R of the rod and its dimensions. The rod has a diameter of 2.5 cm (cross section $A = 4.91 \times 10^{-4}$ m^2) and is 31.5 cm long (length l) between the two voltmeter connections.

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

Ohm's law

$$U = R \cdot I \qquad (2)$$

The regression lines of the measured values in Fig. 3 give

$R_{Cu} = 11.5 \pm 0.3$ µΩ

for the copper rod, and

$R_{A1} = 19.1 \pm 0.2$ µΩ

for the aluminium rod.

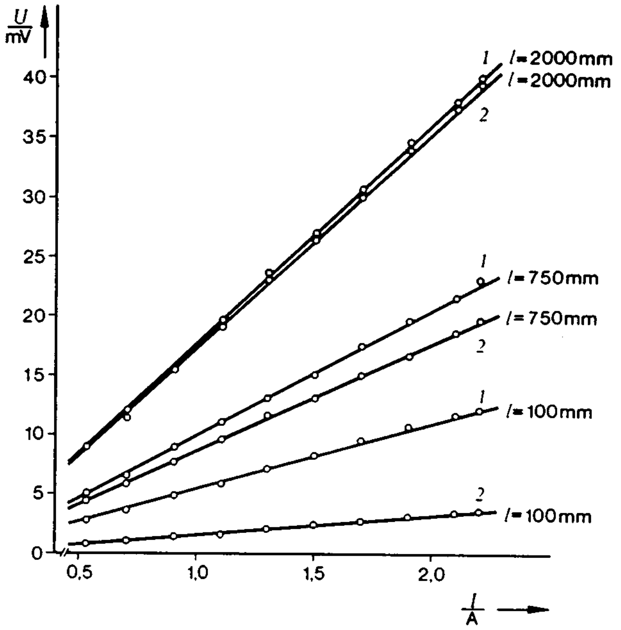
The values of resistivity obtained using equation (1) are:

	measured $\rho/10^{-8}$ Ω	Bibliographic data at 20°C $\rho/10^{-8}$ Ω
Cu	1.79	1.68
Al	2.98	2.72

The aluminium rod is not pure, it contains other additions.

The copper wire in the cords has a cross section A of 2.5 mm^2.

Fig. 4: Current/voltage characteristics of some connecting cords of different lengths.



The line resistance R_1 of the connecting cords can be calculated using (1):

$$R_1 = \rho \cdot \frac{l}{A}$$

The line/plug contact resistance can be established from the difference between the line resistance R_1 calculated and the resistance R_1 measured.

R_1 is determined from the slope of the straight lines in Fig. 4.

l/mm		R_1/mΩ	R_1/mΩ	$(R_1 - R_1)$/mΩ
100	1 2	0.67	5.6 1.6	4.9 0.9
750	1 2	5.0	10.7 9.1	5.7 4.1
2000	1 2	13.4	18.6 18.2	5.2 4.8

The average of the line/plug contact resistance values is:

$$R_{1_\rho} = \frac{R_1 - R_1}{2} = 2.1 \text{ m}\Omega$$

The plug/double socket contact resistance can be determined by comparing the voltages U_1 and U_2 (see Figs. 2):

$$R_{pd} = \frac{U_1 - U_2}{I}$$

In accordance with Figs. 2b,

$$U_1 = R_1 \cdot I$$

with

$$R_1 = R_1 + R_{1p_1} + R_{1p_2}$$

and

$$U_2 = R_2 \cdot I$$

with

$$R_2 = R_1 + R_{pd_1} + R_{pd_2}$$

For a connecting cord 100 mm long the measured values give:

$$R_2 = 64.4 \text{ m}\Omega$$
$$R_1 = 5.6 \text{ m}\Omega$$

The plug/double socket contact resistance is therefore of the order of

$$R_{pd} = 30 \text{ m}\Omega$$