PHYSICS EXPERIMENT

Ohm's Law

VERIFICATION OF OHM'S LAW.

- Verification of Ohm's law for a constantan wire and a brass wire.
- Verification of Ohm's law for constantan wires of various lengths.
- Verification of Ohm's law for constantan wires of various thickness.

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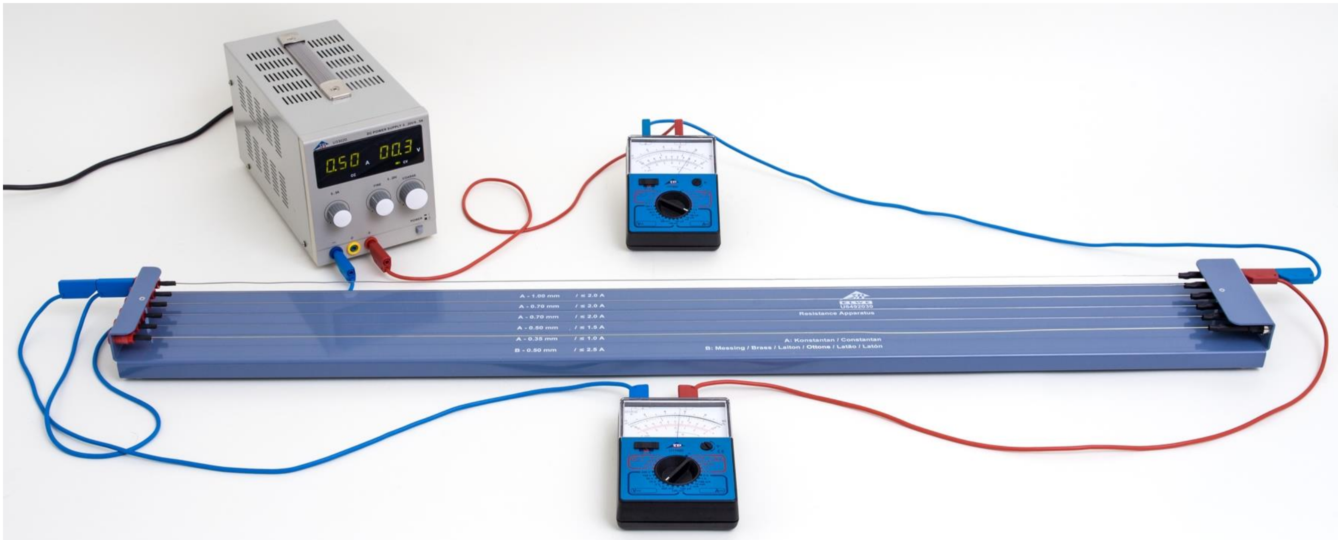

Fig. 1: Experiment set-up

BASIC PRINCIPLES

Georg Simon Ohm **was the first in 1825 to show that the current flowing through a simple conductor is proportional to the voltage applied.**

This means that Ohm's law applies:

(1) $U = R \cdot I$

The constant of proportionality R is the resistance of the conductor. For a metal wire of length x and cross-sectional area A, the resistance R is given by the following formula:

(2) $R = \rho \cdot \frac{x}{A}$.

The specific resistivity ρ depends on the material of which the wire is made.

In order to verify this fundamental relationship, an experiment is to be carried out to investigate the proportionality between current and voltage for metal wires of varying thickness, length and material. The resistivity will also be determined and compared with values quoted in literature.

LIST OF EQUIPMENT

1	Resistance Apparatus	1009949 (U8492030)
1	DC Power Supply 0-20 V, 0-5 A @230 V	1003312 (U33020-230)
or		
1	DC Power Supply0-20 V, 0-5 A @115 V	1003311 (U33020-115)
2	Analogue Multimeter AM50	1003073 (U17450)
1	Set of 15 Safety Experiment Leads, 75 cm	1002843 (U138021)

SET-UP AND PROCEDURE

- Set up the equipment as shown in Fig. 1. Connect the "+/–" sockets of the power supply to the sockets at the ends of the wires to be measured. Connect a multimeter between them to measure the current. The other multimeter should be connected in parallel with the sockets at the ends of the wire being measured in order to measure the voltage.

All the wires are of length x = 1 m.

- For measurements using wires made of various materials, connect the fourth wire from the top (constantan, d = 0.5 mm) or the sixth wire from the top (brass, d = 0.5 mm) as described above.
- For measurements with wires of length x = 1 m, connect the second (or third) wire from the top (constantan, d = 0.7 mm) as described above. For measurements with wires of length x = 2 m, first connect the "–" socket of the power supply to the left-hand end of the second wire from the top. Then connect the socket at the right-hand end of the second wire from the top to the socket at the left hand end of the third wire from the top. Finally, connect the socket at the right-hand end of the third wire from the top (via the ammeter) to the "+" socket of the power supply. This series connection of the two constantan wires of the same thickness d = 0.7 mm and length x = 1 m is equivalent to a single wire of thickness d = 0.7 mm which is double the length, x = 2 m.
- For measurements on wires of different thickness, connect the first, second (or third), fourth and fifth wires from the top (constantan with d = 1, 0.7, 0.5, 0.35 mm) as described above.
- For all three sets of measurements, set the voltage in suitable steps and measure the current until the maximum permissible current level is reached (2 A for constantan with d = 1 mm or 0.7 mm, 1.5 A for constantan with d = 0.,5 mm, 1 A for constantan with d = 0.35 mm and 2.5 A for brass with d = 0.5 mm). Make a note of all the values (Tables 1 – 3).

SAMPLE MEASUREMENT

Wires of differing materials

Table 1: Measurements for a constantan wire and a brass wire of length x = 1 m and thickness d = 0.5 mm.

Constantan		Brass	
U / V	I / A	U / V	I / A
0.6	0.29	0.2	0.60
1.2	0.49	0.3	0.90
1.8	0.74	0.4	1.20
2.4	0.99	0.5	1.49
3.0	1.24	0.6	1.78
3.6	1.48	0.7	2.10

Wires of differing length

Table 2: Measurements for constantan wires of differing lengths x but constant thickness d = 0.7 mm.

x = 1 m		x = 2 m	
U / V	I / A	U / V	I / A
0.4	0.32	0.4	0.32
0.8	0.62	0.8	0.62
1.2	0.96	1.2	0.96
1.6	1.26	1.6	1.26
2.0	1.56	2.0	1.56
2.4	1.87	2.4	1.87

Wires of differing thickness

The cross-sectional area A is calculated from the thickness of the wire d as follows:

$$(3) \quad A = \frac{\pi}{4} \cdot d^2$$

Table 3: Measurements for constantan wires of differing thickness d and cross-sectional area A, all of length x = 1 m.

d = 1 mm A = 0.79 mm²		d = 0.7 mm A = 0.38 mm²		d = 0.5 mm A = 0.2 mm²		d = 0.35 mm A = 0.1 mm²	
U / V	I / A	U / V	I / A	U / V	I / A	U / V	I / A
0.2	0.33	0.4	0.32	0.6	0.29	0.7	0.14
0.4	0.65	0.8	0.62	1.2	0.49	1.4	0.28
0.6	0.98	1.2	0.96	1.8	0.74	2.1	0.42
0.8	1.30	1.6	1.26	2.4	0.99	2.8	0.57
1.0	1.63	2.0	1.56	3.0	1.24	3.5	0.71
1.2	1.96	2.4	1.87	3.6	1.48	4.2	0.85

EVALUATION

- For each of the various parameters, ρ, x and d, plot the measurements in a graph of U against I (Figs. 2, 3, 5).
- In each case, match straight lines to the measured values $U(I)$. The ohmic resistance R can then be found in each case by using Equation (1) (Tables 4, 6, 7).
- In the case of measuring wires made of different materials (2), calculate the resistivity ρ from the known values of length x and thickness d (Table 5).
- In the case of measuring wires of different lengths and thicknesses/cross-sections, plot the values of the resistance against the lengths x or the inverse of the cross-sectional area A, draw a straight line through the points (Figs. 4, 6). The gradient of the line can be used to calculate the resistivity ρ from the known values of thickness d and length x, as shown in Equation (2).

Wires of differing materials

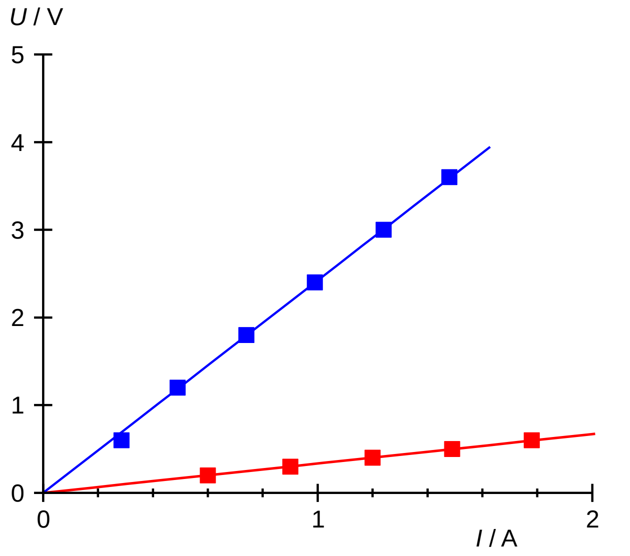

Fig. 2: Graph of U against I for constantan wire (blue) and brass wire (red), length x = 1 m and thickness d = 0.5 mm.

Table 4: Ohmic resistance of a constantan wire and a brass wire of length x = 1 m and thickness d = 0.5 mm determined from the gradient of the straight lines through the points in Fig. 2.

Material	R / Ω
Constantan	2.423
Brass	0.335

From (2) the following is true:

$$R = \rho \cdot \frac{x}{A} \Rightarrow \rho = R \cdot \frac{A}{x} . \quad (4)$$

Table 5: Resistivity ρ of constantan and brass as determined from (4) and compared with values quoted in literature.

Material	ρ / (Ω·mm²·m⁻¹)	
	Measurement	Literature
Constantan	0.476	0.490
Brass	0.066	0.065

The values determined by measurement are well in agreement with those quoted in literature.

Wires of differing length

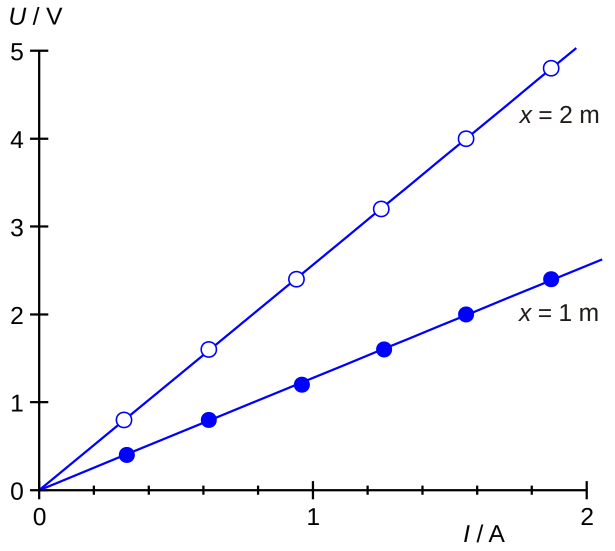

Fig. 3: Graph of U against I for constantan wires of various lengths x and thickness d = 0.7 mm.

Table 6: Ohmic resistance of constantan wires of differing length x but constant thickness d = 0.7 mm determined from the gradient of the straight lines through the points in Fig. 3.

x / m	R / Ω
1	1.277
2	2.564

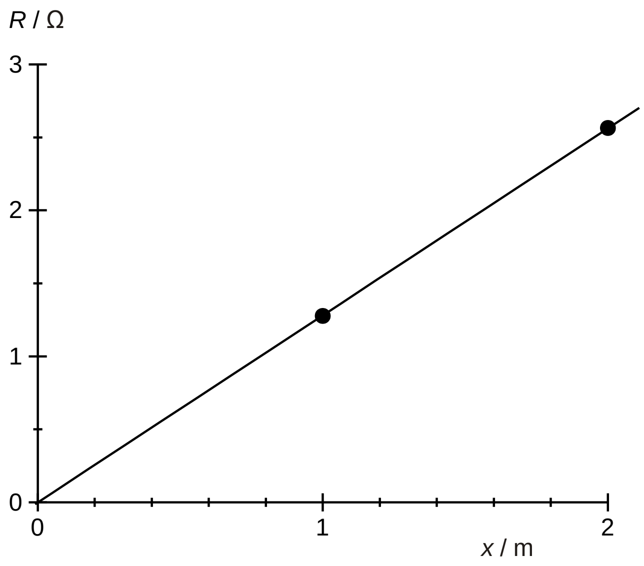

Fig. 4: Resistance R as a function of length x.

- Determine the resistivity ρ from the gradient a of a straight line through the measurement points $R(x)$:

(5) $R = \rho \cdot \frac{x}{A} = \frac{\rho}{A} \cdot x = a \cdot x$ where $a = \frac{\rho}{A}$

(6) $$a = \frac{\rho}{A} \Leftrightarrow$$
$$\rho = a \cdot A = 1.281 \frac{\Omega}{\mathrm{m}} \cdot 0.38\ \mathrm{mm}^2 = 0.487 \frac{\Omega \cdot \mathrm{mm}^2}{\mathrm{m}}$$

The value determined by measurement is well in agreement with the value for constantan quoted in tables, $\rho = 0.49\ \Omega \cdot \mathrm{mm}^2 \cdot \mathrm{m}^{-1}$.

Wires of differing thickness

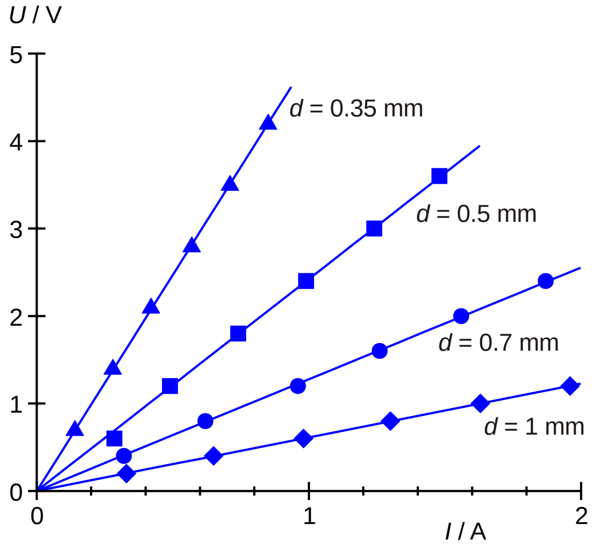

Fig. 5: Graph of U against I for constantan wires of various thickness d and length x = 1 m

Table 7: Ohmic resistance of constantan wires of various thicknesses d and cross section A but the same length x = 1 m, as determined from the gradient of the straight lines through the points in Fig. 5.

d / mm	A / mm²	R / Ω
0.35	0.10	4.941
0.50	0.20	2.423
0.70	0.38	1.277
1.00	0.79	0.613

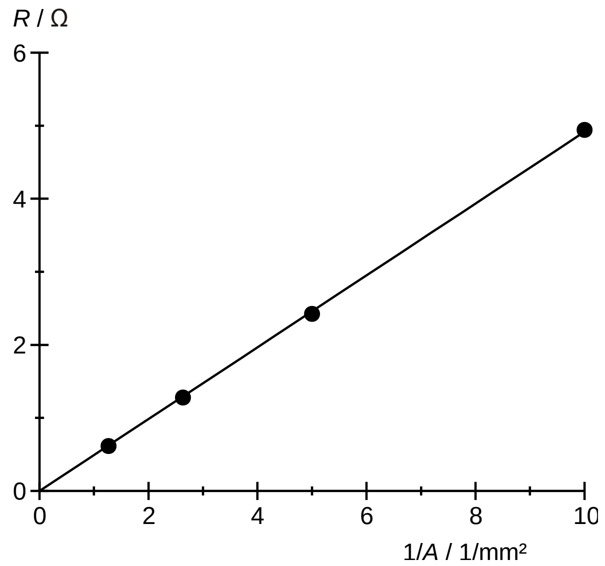

Fig. 6: Resistance R as a function of the inverse of the cross-sectional area A

- Determine the resistivity ρ from the gradient b of a straight line through the measurement points $R(1/A)$:

(7) $R = \rho \cdot \frac{x}{A} = \rho \cdot x \cdot \frac{1}{A} = b \cdot \frac{1}{A}$ where $b = \rho \cdot x$

(8) $b = \rho \cdot x \Leftrightarrow \rho = \frac{b}{x} = \frac{0.492\ \Omega \cdot \mathrm{mm}^2}{1 m} = 0.492 \frac{\Omega \cdot \mathrm{mm}^2}{\mathrm{m}}$

The value determined by measurement is well in agreement with the value for constantan quoted in tables, $\rho = 0.49\ \Omega \cdot \mathrm{mm}^2 \cdot \mathrm{m}^{-1}$.