How do the length and cross-sectional area of a wire influence the value of its resistance?

Task

To examine the relationship between the value of the resistance of a wire and its length and cross-sectional area.

Equipment

Plug-in board	06033.00	1
Wire building block	39120.00	3
Universal holder	39115.02	2
Connecting cable, 25 cm, red	07313.01	1
Connecting cable, 25 cm, blue	07313.04	1
Connecting cable, 50 cm, red	07314.01	2
Connecting cable, 50 cm, blue	07314.04	2
Constantan wire, d = 0.2 mm, need approx. 1 m	06100.00	(1)
Constantan wire, d = 0.4 mm, need approx. 30 cm	06102.00	(1)
Multi-range meter	07028.01	2
Power supply, 0...12 V-,6 V~, 12 V~	13505.93	1
Ruler		

Set-Up and Procedure

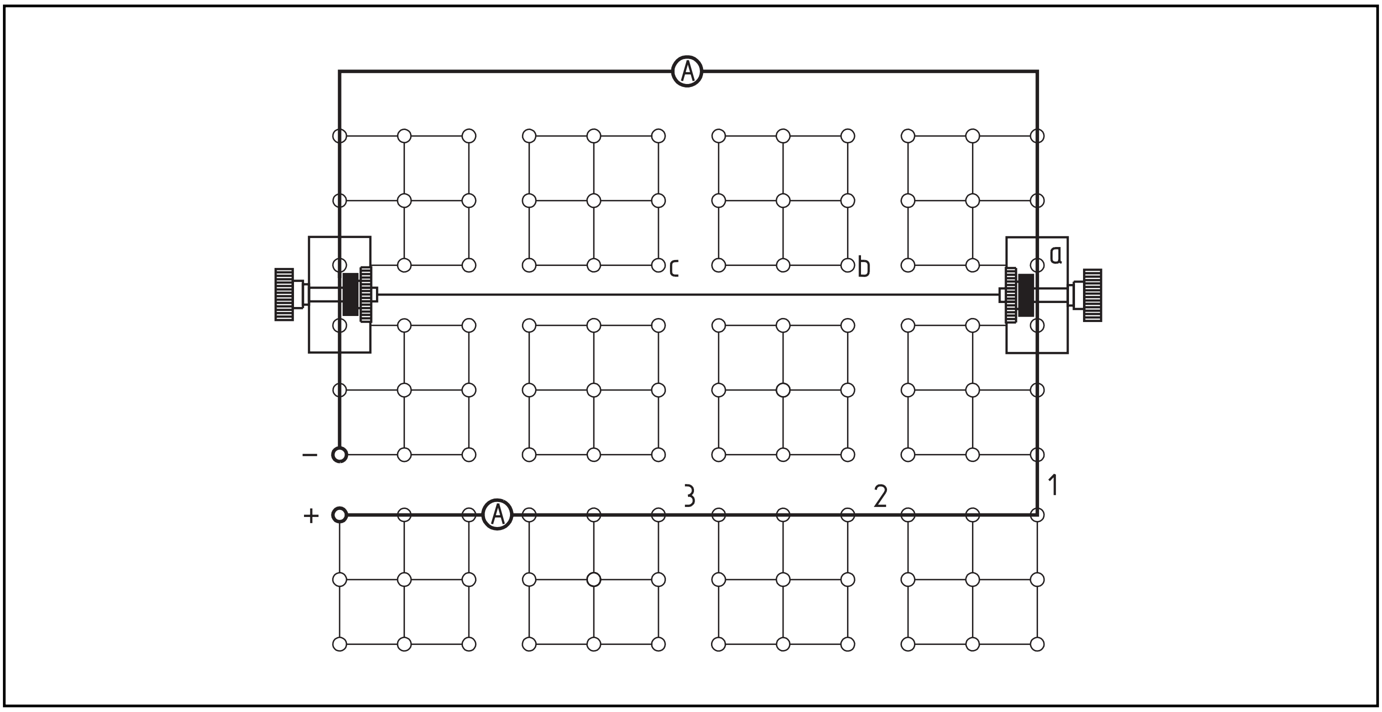
First experiment

— Connect up the circuit as shown in Fig. 1; fix an approx. 30 cm length of 0.2 mm diameter constantan wire between the universal holders.
— Measure the length of the inserted wire l and note the measured value in Table 1.
— Select the 1 V- and 300 mA- measurement ranges.
— Set the power supply to 0 V, then switch it on.
— Carefully increase the power supply voltage until the voltmeter shows 0.4 V.
— Read off the value of the current and note it in Table 1.
— Set the power supply back to 0 V.
— Free the constantan wire from the universal holder on the right.
— Move this universal holder from position a to position b and correspondingly change the connection to the voltmeter.
— Fix the constantan wire back in and complete the circuit with wire building block 2.
— Again set the power supply to 0.4 V; read off the current, measure the length of the wire l and enter both values in Table 1.
— Set the voltage to 0, move the universal holder to position c and proceed as above to determine and note the measured values for I and l.
— Switch off the power supply.

Second experiment

— Connect up the circuit as shown in Fig. 1; again fixing the 0.2 mm diameter constantan wire between the universal holders.
— Select the 1 V- and 300 mA- measurement ranges.
— Set the power supply to 0 V, then switch it on.
— Carefully increase the power supply voltage until the ammeter shows 250 mA.
— Read off the value of the voltage and note it in Table 2.
— Set the power supply back to 0 V.
— Fix a second and finally a third piece of wire of the same material and the same length alongside (parallel to) the constantan wire already in position in the universal holders. In each case, measure and note the voltage at a current I = 250 mA as previously.
— Replace the 0.2 mm wires with a wire of 0.4 mm diameter and again measure and note the voltage at a current I = 250 mA.
— Switch off the power supply.

Fig. 1



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Measurement Results

Table 1

U / V	I / A	l / m	R / Ω	R/l / Ω/m
0.4				
0.4				
0.4				

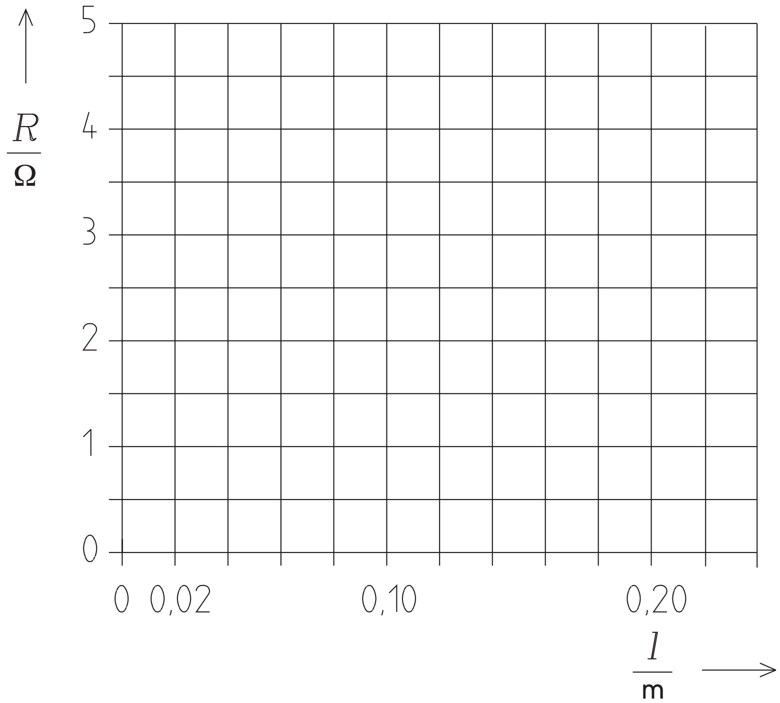
Table 2

Wires		I / A	U / V	R / Ω	A / mm^2	R · A / Ω · mm^2
Number	Diameter / mm					
1	0.2	0.25				
2	0.2	0.25				
3	0.2	0.25				
1	0.4	0.25				

Evaluation

1. Calculate the value of the resistance R = U /I for each length of wire and enter it in the 4th column of Table 1.
2. Plot a graph of the values of the resistance R against the length of the wire l in Fig. 2.

Fig. 2



3. Which relationship between R and I can be presumed from the graph?

4. To check your presumption, calculate the quotients from R / I and enter them in the last column of Table 1. What can you establish from them?

5. Calculate the values of the resistance R = U /I and the corresponding cross-sectional areas of wire and enter them in the 4th and 5th columns of Table 2.

6. Which relationship can be presumed between the values of the resistance R and the corresponding cross-sectional areas A?

7. Calculate the products R ·A and enter them in the last column of Table 2. What can you establish from them?

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Working out the equation $R = \rho \cdot l / A$ is relatively time consuming. The relationships $R \sim l$ and $R \sim 1/A$ should first be recognized. We recommend for this that the separate groups of students each only carry out one of the experiments, and following this, in a joint evaluation, the knowledge be gained that $R \sim l / A$.

Notes on Set-Up and Procedure

Setting up the circuit will not cause the students any problems. Take particular care to ensure that fixed wires do not sag and that, on changing the position of the one universal holder in the first experiment, the voltmeter is correctly connected and the wire building block properly re-plugged.

Measurement Results

Table 1

U / V	I / A	l / m	R / Ω	R/l / Ω/m
0.4	0.120	0.202	3.33	16.5
0.4	0.168	0.146	2.38	16.3
0.4	0.271	0.089	1.48	16.6

Evaluation

1. Refer to the 4th column of Table 1.
2. Refer to Fig. 2.
3. Presumed relationship: R and l are proportional to each other, because the points on the graph give a straight line.
4. Refer to the 5th column of Table 1
   This establishes that R / l = constant, i.e. $R \sim l$.
5. Refer to the 4th and 5th columns of Table 2.
6. The resistance decreases when the cross-sectional area increases. Presumably R and A are inversely proportional to each other.
7. Refer to the last column of Table 2.
   This establishes that $R{\cdot}A$ = constant, i.e. $R \sim 1/A$

Fig. 2

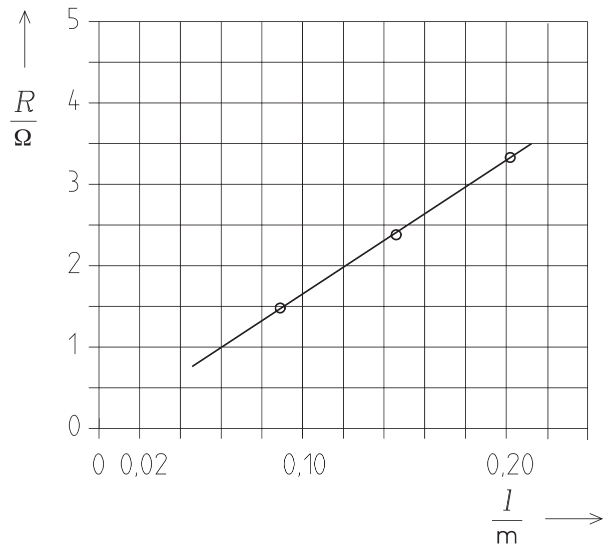

Table 2

Wires		I / A	U / V	R / Ω	A / mm²	R · A / Ω · mm²
Number	Diameter / mm					
1	0.2	0.25	0.818	3.27	0.031	0.10
2	0.2	0.25	0.410	1.64	0.063	0.10
3	0.2	0.25	0.270	1.08	0.094	0.10
1	0.4	0.25	0.208	0.83	0.126	0.10

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The dependence of the resistance of a wire on its length and cross-sectional area

(How do the length and cross-sectional area of a wire influence the value of its resistance?)

Room for notes