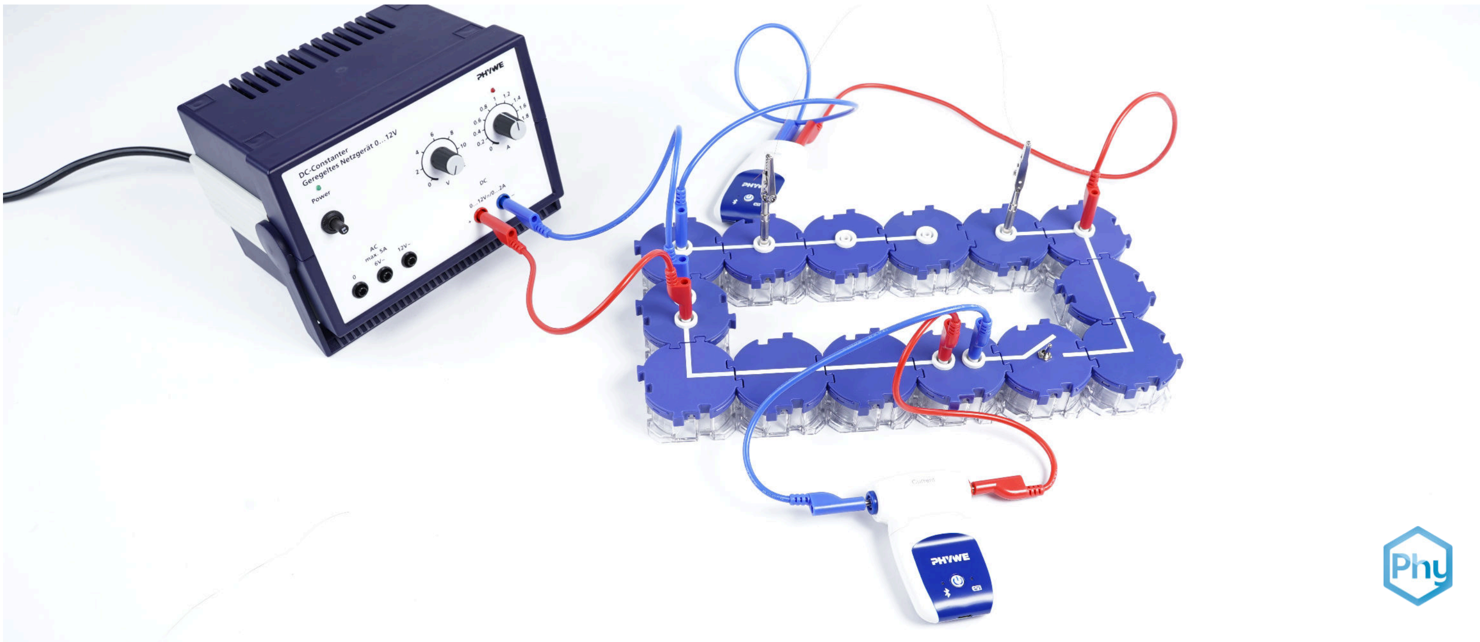
The resistivity of wires with Cobra SMARTsense



Physics | Electricity & Magnetism | Simple circuits, resistors & capacitors

Difficulty level	Group size	Preparation time	Execution time
medium	-	10 minutes	10 minutes

This content can also be found online at:

https://www.curriculab.de/c/681877854cf6ee000293a774

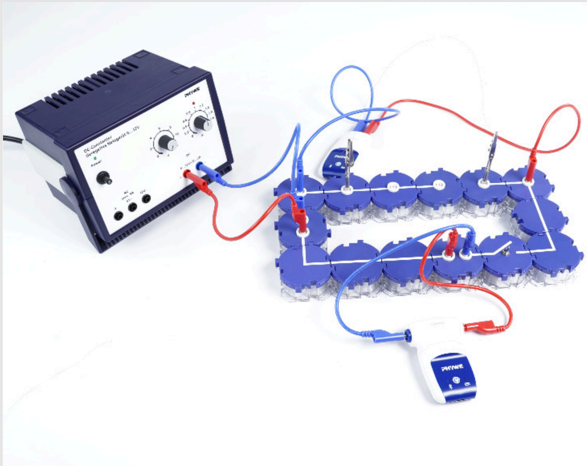
Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Teacher information

Application



Experimental setup

All electrical devices usually have to be charged with a cable or are connected to the mains via a cable. However, they have different requirements in terms of current and voltage values. These are regulated by resistors, which also exist in cables, so that the electrical devices are not damaged. The following applies:

$$R = \rho \cdot (L/A)$$

with the length L, the cross-sectional area A and the material-dependent specific resistance ρ. The specific resistance ρ of some commonly used materials and its effect on heat transfer are investigated experimentally in this experiment.

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Other teacher information (1/3)

PHYWE

Prior knowledge

Students should be able to construct a simple circuit and be familiar with the basic principles of current and voltage. Ideally, the concept of specific resistance should already have been addressed theoretically, particularly in relation to the cross-sectional area and length of a wire.

Principle

The electrical resistance of a material depends not only on its shape (length and cross-sectional area), but also on its material-specific resistivity. The latter is significantly lower for metals than for other materials, although the specific resistivity can still vary considerably between different metals.

Other teacher information (2/3)

PHYWE

Learning objective

Based on the experimentally determined relationships $R \propto l$ (for constant ρ and A) and $R \propto 1/A$ (for constant ρ and l), the combined relation $R \propto l/A$ is established. This leads to the introduction of resistivity ρ as a material-specific constant, resulting in the equation $R = \rho \cdot l/A$. Using this equation, students are expected to experimentally determine the resistivity ρ for common conductor materials.

Task

The specific resistivity of three different materials (copper, iron, and constantan) is to be determined using wires made from each material. For this purpose, the wires are integrated into an electric circuit, and the voltage is measured at a constant current. The length of the clamped wire segments is then recorded in order to calculate the respective specific resistivities during the evaluation.

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Other teacher information (3/3)

Remarks

In contrast to the determination of ρ for constantan, additional factors must be considered when determining ρ for iron and especially for copper. For example, the relative error in the voltage measurement is high for copper due to its low resistance, and for iron, contact problems may occur due to rust on the wire surface.

The specification of a constant direct current of $250\ \mathrm{mA}$ is therefore important to prevent the wires from overheating and to avoid having to change the measurement range for voltage and current.

Safety instructions

The general instructions for safe experimentation in science lessons apply to this experiment.

Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

PHYWE

Student information

Motivation

PHYWE

Charge your smartphone

To charge your smartphone, a conductive cable is typically used to allow current to flow from the socket into the phone's battery. How well the current flows through this cable depends on various factors, including the electrical resistance of the conductor. This resistance is determined by the material's specific resistivity. By choosing the right material, the resistance of the cable can be optimised.

In this experiment, you will investigate the specific resistivity of different materials.

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

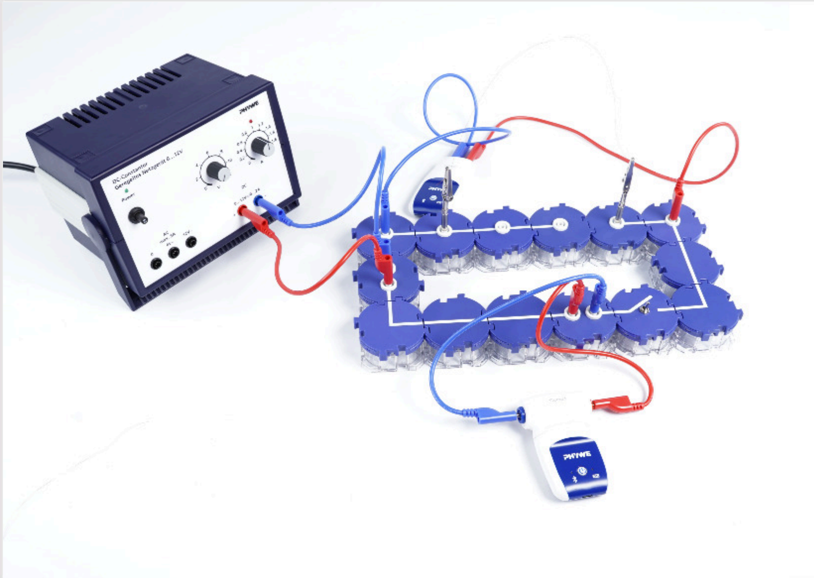
info@phywe.de
www.phywe.de

Tasks

What are the specific resistances of some metals?

Determine the specific resistances of wires:

- Copper
- Iron
- Constantan



Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Equipment

Position	Material	Item No.	Quantity
1	Cobra SMARTsense Current - Sensor for measuring electrical current	12902-01	1
2	Cobra SMARTsense Voltage - Sensor for measuring electrical voltage	12901-01	1
3	Straight connector module, SB	05601-01	4
4	Angled connector module, SB	05601-02	2
5	Interrupted connector module with sockets, SB	05601-04	2
6	Junction module, SB	05601-10	2
7	Straight connector module with socket, SB	05601-11	2
8	Angled connector module with socket, SB	05601-12	2
9	On-off switch module, SB	05602-01	1
10	Alligator clips, bare, 10 pcs	07274-03	1
11	Connecting plug, 2 pcs.	07278-05	1
12	Connecting cord, 32 A, 250 mm, red	07360-01	1
13	Connecting cord, 32 A, 250 mm, blue	07360-04	1
14	Connecting cord, 32 A, 500 mm, red	07361-01	2
15	Connecting cord, 32 A, 500 mm, blue	07361-04	2
16	Copper wire, d = 0.2 mm, l = 100 m	06106-00	1
17	Iron wire, d = 0.2 mm, l = 100 m	06104-00	1
18	Constantan wire, 15.6 Ohm/m, d = 0.2 mm, l = 100 m	06100-00	1
19	PHYWE Power supply, 230 V,DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	1
20	measureAPP - the free measurement software for all devices a	14581-61	1

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Additional equipment

PHYWE

Position	Equipment	Quantity
1	Ruler (approx. 30 cm)	1

Setup (1/3)

PHYWE

To measure with the **Cobra SMARTsense sensors**, the **PHYWE measureAPP** is required. The app can be downloaded free of charge from the respective app store (QR codes below). Please check that **Bluetooth is enabled** on your device (smartphone, tablet, desktop PC) before starting the app.

iOS

Android

Windows

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Setup (2/3)

PHYWE

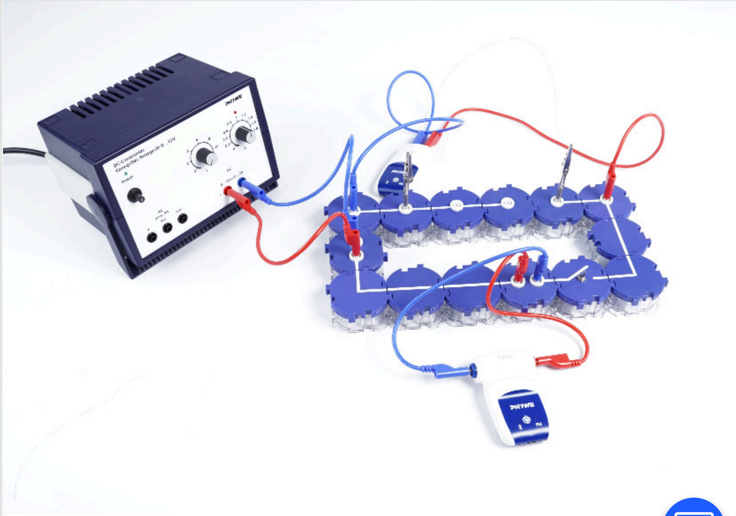
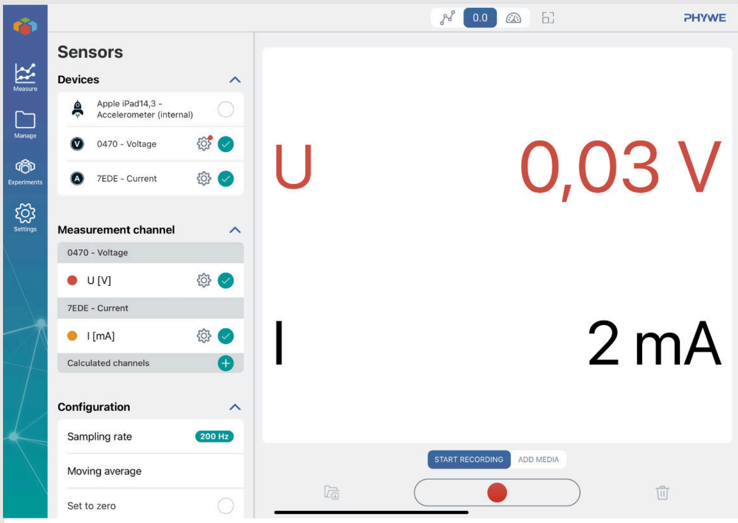


Fig. 1 Experimental setup

- Set up the experiment as shown in the diagram on the left. You can view the circuit by pressing the blue button.
- Connect the power supply (on the left), the voltage sensor (top), and the current sensor (bottom) to the circuit as illustrated.
- Attach the copper wire using two crocodile clips, and make sure to place the clips in the outer positions.

Setup (3/3)

PHYWE



Screenshot of the app without power supply switched on

- Switch on both Cobra SMARTsense sensors by pressing and holding the power button on each device for about three seconds.
- Then open the measureAPP and connect to both sensors by selecting them under "Devices".
- Adjust the display so that the measured values are shown as numbers. To do this, tap on "0.0" at the top of the app. An example of the display can be seen on the left.

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

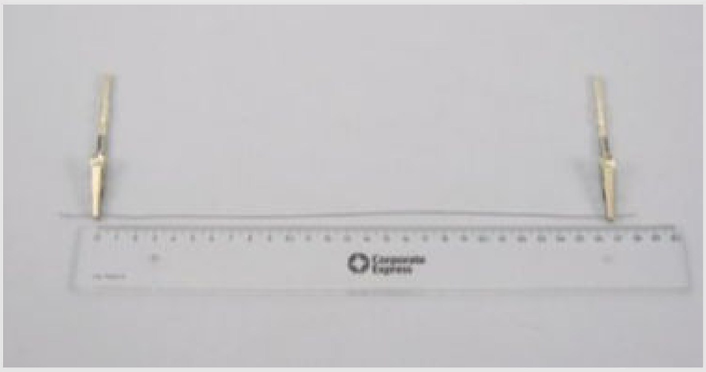
info@phywe.de
www.phywe.de

Procedure

PHYWE

Set the power supply to $0\ \mathrm{V}$ and switch it on. Carefully increase the voltage until the current sensor shows a current of $250\ \mathrm{mA}$. Record the voltage in your log.

Then measure the length l of the clamped copper wire, as shown in the illustration, and record this value as well.



- Now clamp first the iron wire and then the constantan wire between the crocodile clips instead of the copper wire and proceed in the same way as before. Note both the voltage values and the lengths of the clamped wires in the log.
- Set the power supply unit to $0\ \mathrm{V}$ and switch it off.

PHYWE

Report

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Task 1

PHYWE

Note your measured values in the table. Calculate from the pairs of values for the voltage U and the current I the resistance values of the analysed wires. The following equation applies to the resistance of a wire: $R = \rho \cdot l \, / \, A$. The size ρ is called specific resistance or resistivity. It is a material constant. Calculate the resistivity of the materials from which the analysed wires are made. Use $d = 0.2 \text{ mm}$ and enter the results of your calculations in the last column of the table.

Equipment	I [A]	U [V]	l [m]	$R[\Omega]$	$\rho[\Omega \cdot \text{mm}^2/\text{m}]$
Copper					
Iron					
Constantan					

Task 2

PHYWE

What would be a possible definition of the specific resistance? Look at the unit of resistivity in the last column of the table. The specific resistance of a material indicates the resistance of a cable of this material at ...

- ... any length and a cross-section of 1 mm^2.
- ... a length of 1 m and a cross-section of 1 mm^2.
- ... any length and any cross-section.
- ... a length of 1 m and any cross-section.

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Task 3

PHYWE

Although iron is cheaper than copper, copper is favoured as a conductor material in electrical engineering and electronics. Why?

- ☐ Copper has a higher specific resistance.
- ☐ Copper has a lower specific resistance.
- ☐ Less copper is needed to achieve the same performance, so copper is more favourable to use overall.
- ☐ Copper looks and feels better.
- ☐ Iron is more susceptible to corrosion and is therefore damaged more quickly.

Check

Task 4

PHYWE

The specific resistance is also temperature-dependent, but is usually specified for $20^\circ\mathrm{C}$. The table values for the specific resistances of the analysed materials are for $20^\circ\mathrm{C}$:

$\rho_{\text{copper}} = 0.017\ \Omega \cdot \mathrm{mm}^2/\mathrm{m}$

$\rho_{\text{iron}} = 0.10 \ldots 0.13\ \Omega \cdot \mathrm{mm}^2/\mathrm{m}$

$\rho_{\text{constantan}} = 0.50\ \Omega \cdot \mathrm{mm}^2/\mathrm{m}$

If the results of your measurements deviate relatively strongly from this: How can the deviations be explained?

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Slide	Score / Total
Slide 18: Definition of specific resistance	0/1
Slide 19: Copper as a conductor material	0/3

Total amount 0 / 4

Solutions Repeat Export text

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de