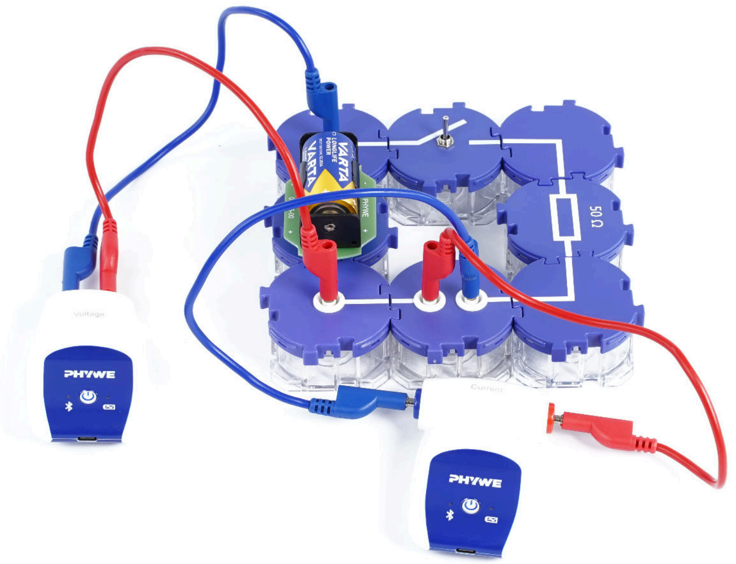
The internal resistance of a voltage source with Cobra SMARTsenseoltage source



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/6808ba207785b90002c5d5c3

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Teacher information

Application

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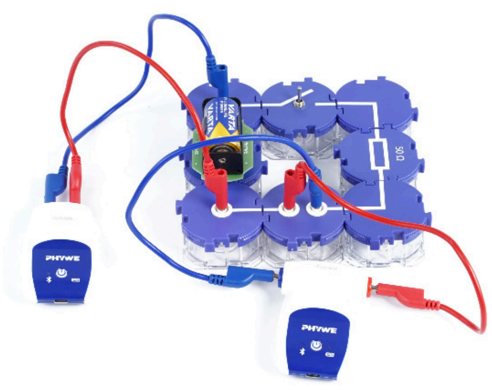

Experimental setup

Every electrical measuring device and every voltage source has an internal resistance. Because of this internal resistance, the terminal voltage of a loaded voltage source deviates from the original voltage in the unloaded state. However, power supply units are voltage-stabilised, so this deviation usually does not need to be taken into account during normal use. Commercially available dry batteries or mono cells, on the other hand, are not stabilised and therefore cannot be used in circuits that are sensitive to voltage fluctuations.

In this experiment, the internal resistance of a dry battery is analysed.

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Other teacher information (1/4)

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Prior knowledge

Students should be able to construct a simple circuit. They should also have understood the concepts of voltage, current and resistance.

Principle

A commercially available dry battery or mono cell is well suited for analysing the internal resistance of voltage sources. Its internal resistance is high enough to be measured easily, and it can be readily replaced if it is accidentally damaged by prolonged overloading. In contrast, a power supply unit is not suitable for such an analysis, as it is voltage-stabilised.

Other teacher information (2/4)

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Learning objective

The students will learn that voltage sources have an internal resistance.

Tasks

The students investigate whether a voltage source has an internal resistance. They build a circuit with resistors of different values, measure the current and clamping voltage and determine the internal resistance.

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Other teacher information (3/4)

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Notes on the structure and implementation

The measurements during the short circuit require special attention, because if the switch-on time is too long, the measured voltage can drop very sharply and the battery can become unusable. When experimenting, the students should always have the measured values for U_C and I displayed at the same time so that the duration of the short circuit is minimized.

Other teacher information (4/4)

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Further notes

If necessary, an experimental group can also use a "used" battery to investigate its behaviour under different conditions — for example, during a power interruption $(I = 0)$, a short circuit, or a low load. The short-circuit current and thus the internal resistance depend heavily on the battery’s state of charge. For this reason, the measurement results may vary between the different experiment groups.

A battery (or voltage source) is considered high quality if it delivers a particularly high short-circuit current, which indicates a particularly low internal resistance. It is advisable that only one experimental group investigates the short-circuit case and shares its results with the others to avoid degrading the quality of the remaining batteries.

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Safety instructions

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

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Student information

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Motivation

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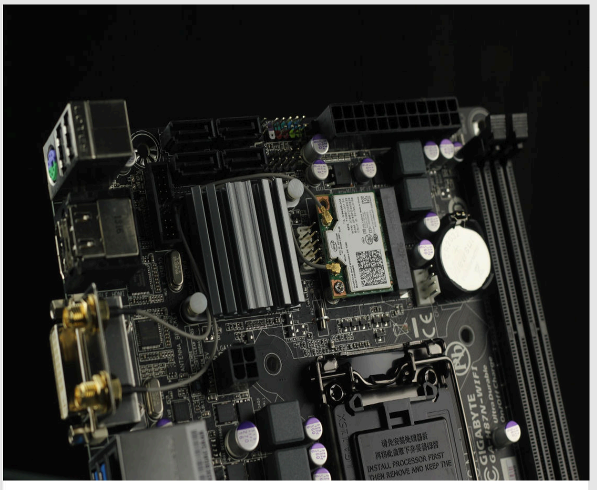

Main board with processor - example of a sensitive circuit

Voltage sources and measuring devices have an internal resistance, which causes the output voltage to differ when a component is connected compared to when no load is present. These voltage fluctuations can potentially damage sensitive circuits, such as processors.

It is therefore important to understand the voltage variations caused by internal resistance in order to enable appropriate voltage stabilisation.

In this experiment, you will analyse the internal resistance of a dry battery.

Tasks

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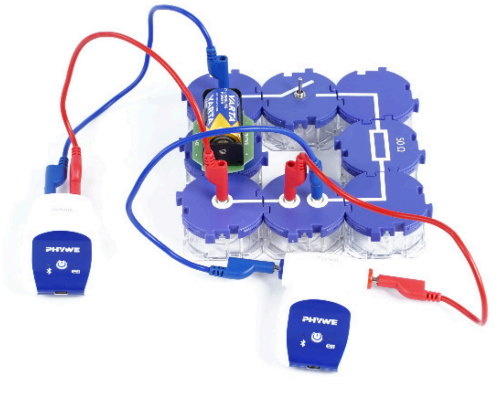

Experimental setup

Investigate whether voltage sources also have a resistance:

- Build a circuit with resistors of different values.
- Measure the current I in the circuit.
- Measure the clamping voltage U_C of the voltage source.
- Determine the internal resistance R_i of the voltage source by evaluating the measured data.

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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	Angled connector module, SB	05601-02	2
4	T-shaped connector module, SB	05601-03	2
5	Interrupted connector module with sockets, SB	05601-04	2
6	Angled connector module with socket, SB	05601-12	2
7	On-off switch module, SB	05602-01	1
8	Socket module for incandescent lamp E10, SB	05604-00	2
9	Resistor module 50 Ohm, SB	05612-50	1
10	Connecting cord, 32 A, 250 mm, red	07360-01	1
11	Connecting cord, 32 A, 250 mm, blue	07360-04	1
12	Connecting cord, 32 A, 500 mm, red	07361-01	1
13	Connecting cord, 32 A, 500 mm, blue	07361-04	1
14	Battery Type C 1.5 V - Pack of 2 pieces	07400-00	1
15	Filament lamp 6 V/3 W, E10, 10 pcs.	35673-03	1
16	Straight connector module, SB	05601-01	2
17	Battery holder module (C type), SB	05605-00	1
18	measureAPP - the free measurement software for all devices a	14581-61	1

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Setup (1/3)

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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

Setup (2/3)

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- Set up the circuit as shown in the illustration on the left and the illustration on the right.
- The switch is initially open.

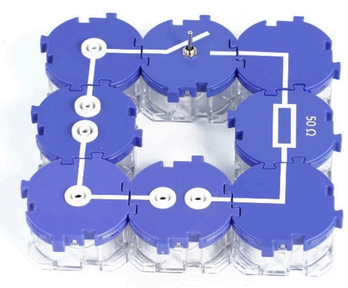
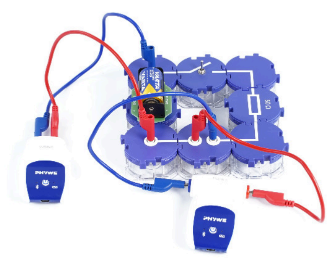


Fig. 1

Fig. 2



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Setup (3/3)

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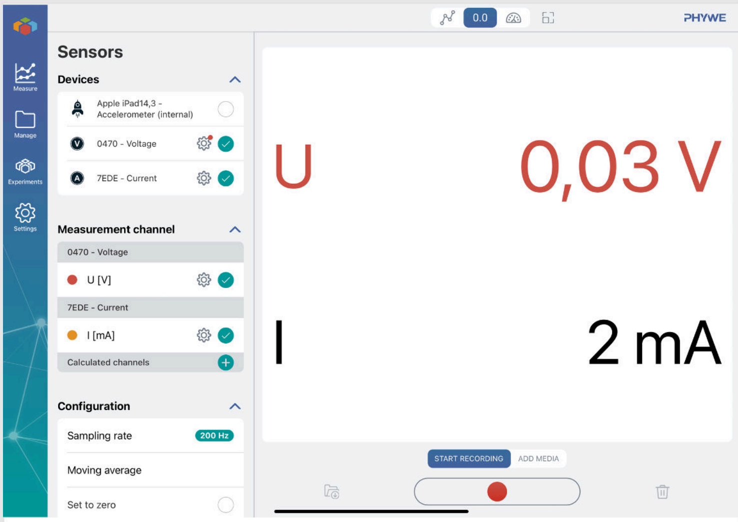

Screenshot of the app

- Start both Cobra SMARTsense sensors by pressing and holding the power button on each device for about three seconds.
- Then launch the measureAPP and connect to both sensors by selecting them under "Devices".
- Set the display to show numerical values by clicking on "0.0" at the top of the app. You can see an example of this on the left-hand side. Please note that the displayed values may vary slightly from what you observe on your own device.

Procedure (1/2)

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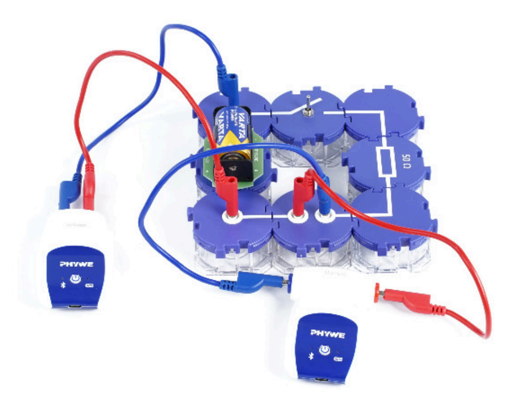

Experimental setup

- Measure the clamping voltage U_C for $I = 0$ A i.e. without loading the voltage source. Note your measured values in the table in the log.
- Close the circuit, read the terminal voltage U_C and the current I (under load). Note your measured values in the table.
- Break the circuit and install the light bulb instead of the resistor.
- Close the circuit and read again U_C and I and note down your measured values.

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Procedure (2/2)

- Open the switch and install two bulbs in parallel (fig. above).
- Close the circuit and read again U_C and I and note down your measured values.
- Open the switch and replace the bulbs with a line module (fig. below).
- Close the switch briefly (!), measure U_C and I for the short circuit and enter the values in the table in the log.

Note: The short-circuit current may only flow for a very short time so that the voltage source is not destroyed.

Report

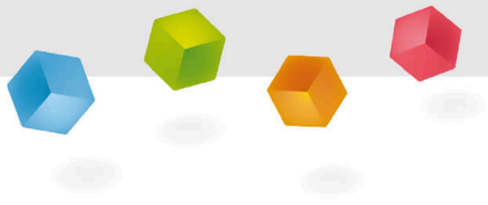

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Table 1

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Enter your measured values in the table.

Circuit	I [A]	U_C [V]
Switch open		
$50\ \Omega$ Resistance		
1 light bulb		
2 light bulbs		
Short circuit		

Task 1

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How can the relationship between the load I and the clamping voltage U_C be described?

- The load and the clamping voltage are independent of each other.
- The clamping voltage decreases under load, and the greater the load, the more it decreases.
- The clamping tension increases under load, and the greater the load, the greater the increase.

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Task 2

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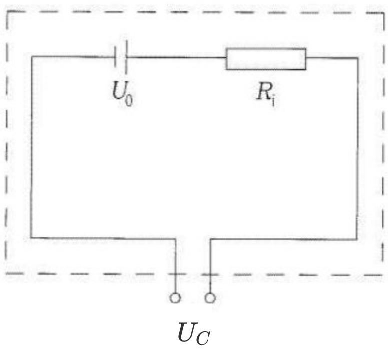
Here you can see an equivalent circuit diagram for the voltage source with its internal resistance R_i. About R_i the voltage drops under load $R_\mathrm{i} \cdot I$ from. With U_0 is the voltage that the unloaded voltage source (i.e. at $I = 0\ \mathrm{A}$). Formulate the relationship between U_0 and U_C in an equation. (Note: Remember the law of series connection $U_\mathrm{tot} = U_1 + U_2$).



Drag the equations into the correct boxes!

From the equation ______ follows with $U_1 = U_0$ and ______ the context ______

$U_2 = -I \cdot R_\mathrm{i}$ | $U_\mathrm{tot} = U_1 + U_2$ | $U_C = U_0 - I \cdot R_\mathrm{i}$

Check

Task 3

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Substitute the equation found in task 2 with R_i um. Which equations are correct?

- ☐ $R_\mathrm{i} = I/(U_C - U_0)$
- ☐ $R_\mathrm{i} = I/(U_0 - U_C)$
- ☐ $R_\mathrm{i} = (U_0 - U_C)/I$
- ☐ $R_\mathrm{i} = U_0/I - U_C/I$
- ☐ $R_\mathrm{i} = (U_C - U_0)/I$

Check

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Task 4

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Use the measured values in Table 1 to calculate the internal resistance in the event of a short circuit R_i of the analysed voltage source.

I [A]	U_C [V]

U_0 [V] $(I = 0)$	R_i [Ω]

Slide	Score / Total
Slide 19: Context U_{C} and I	0/1
Slide 20: Clamping voltage equation	0/3
Slide 21: Equation R_{\text{i}}	0/2

Total amount 0/6

Solutions Repeat Export text

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