The internal resistance of the voltage source

(Item No.: P1381800)

Curricular Relevance

Area of Expertise:	Education Level:	Topic:	Subtopic:	Experiment:
Physics	Age 14-16	Electricity	The electrical resistance	The internal resistance of the voltage source

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Easy	10 Minutes	10 Minutes	2 Students

Additional Requirements:

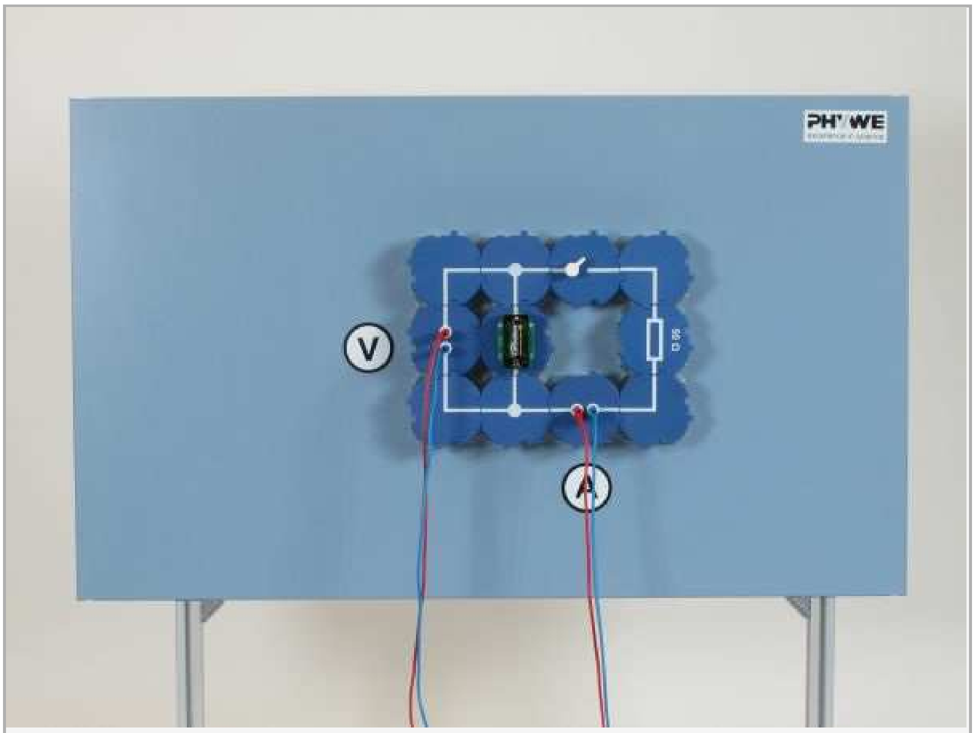
Experiment Variations:

Keywords:

Principle and equipment

Principle

The internal resistance R_i of a voltage source is to be examined by measuring the current and the voltage across the terminals under different loads.



Experimental set-up

Equipment

Position No.	Material	Order No.	Quantity
1	Multimeter ADM2, demo., analogue	13820-01	2
2	Demo Physics board with stand	02150-00	1
3	Switch on/off, module DB	09402-01	1
4	Connector interrupted, module DB	09401-04	3
5	Resistor 1 Ohm,module DB	09411-10	1
6	Resitor 10 Ohm,module DB	09412-10	1
7	Resistor 50 Ohm,module DB	09412-50	1
8	Electr.symbols f.demo-board,12pcs	02154-03	1
9	Connector, straight, module DB	09401-01	1
10	Connector, angled, module DB	09401-02	4
11	Connector, T-shaped, module DB	09401-03	2
12	Battery holder module (C type), SB	05605-00	1
13	Connecting cord, 32 A, 1000 mm, red	07363-01	2
14	Connecting cord, 32 A, 1000 mm, blue	07363-04	2
15	Battery cell, 1.5 V, baby size, type C	07922-01	1

Set-up and procedure

- Connect up the circuit as shown in Fig. 1, first using resistor $R_1 = 50\Omega$; select the 3 V- and 100 mA- measurement ranges.
- With the switch open, measure the terminal voltage U_{Kl} for $I_L = 0$ i.e. without a load on the voltage source; enter the measured value in Table 1.
- Close the switch, read off the terminal voltage U_T and current I_L (under load); note the measured values.
- Change to the 300 mA- measurement range; replace resistor $R_1 = 50\Omega$ with resistor $R_2 = 10\Omega$; measure U_T and I_L and note the measured values.
- Change to the 3 A- measurement range; replace resistor $R_1 = 50\Omega$ with resistor $R_2 = 1\Omega$; measure U_T and I_L and note the measured values.
- Briefly (!) close the switch and, during the short circuit, measure U_T and I_L; note the measured values.

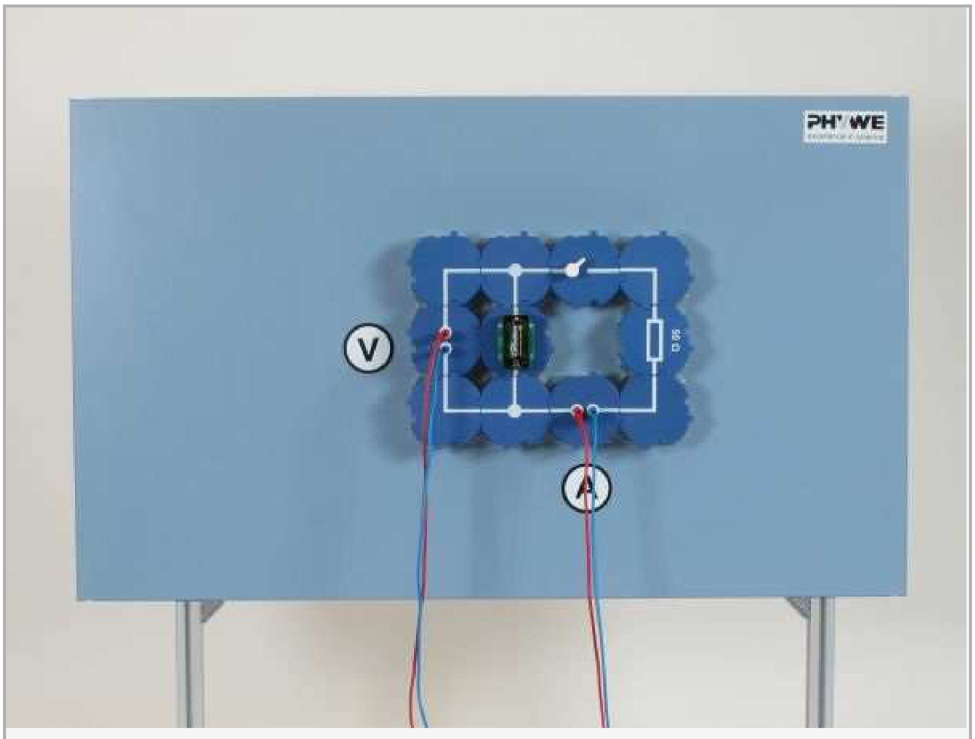


Fig. 1

Observation and evaluation

Observation

Table 1

Resistance $\frac{R}{\Omega}$	Load current $\frac{I_L}{A}$	Terminal voltage $\frac{U_{Kl}}{V}$
	0	1.53
50	0.029	1.8
10	0.13	1.43
1	0.77	0.95
0	1.62	0.37

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Evaluation

The terminal voltage U_T of the voltage supply decreases with increasing load, i.e. with increasing (load) current I_L.

This indicates that the voltage supply has a resistance. This resistance is called the internal resistance R_i.

The load current I_L effects a voltage drop $R_\mathrm{i} \cdot I_\mathrm{L}$ at the internal resistance R_i so that the terminal voltage drops to

$$U_{Kl} = U_0 \text{--} R_i \cdot I_L$$

U_0 is the terminal voltage of the voltage source without load, the source voltage. Using $R_i \cdot I_L = U_i$, then

$U_{Kl} = U_0 \text{--} U_i$ or $U_0 = U_{Kl} + U_i$.

When the resistance in the outer circuit R_a is known, then $R_0 = R_a + R_i$ is true, i.e each circuit is a series connection of R_i and the resistance in the circuit R_a.

A graphical representation of the resistance in the outer circuit R_a in dependence on the load current (Fig. 2) shows a linear function with negative slope. The larger the internal resistance of the voltage source, the steeper the slope of the straight line, i.e. the larger the drop in the terminal voltage under increasing load.

The internal resistance can be determined from the slope of this load line:

$$R_i = \Delta U_{Kl} / \Delta I_L \ .$$

For the battery used in this experiment, we have from Fig. 2:

$$R_i = \Delta U_{Kl} / \Delta I_L \approx 0{,}5V / 0{,}7A = 0{,}71\Omega \ .$$

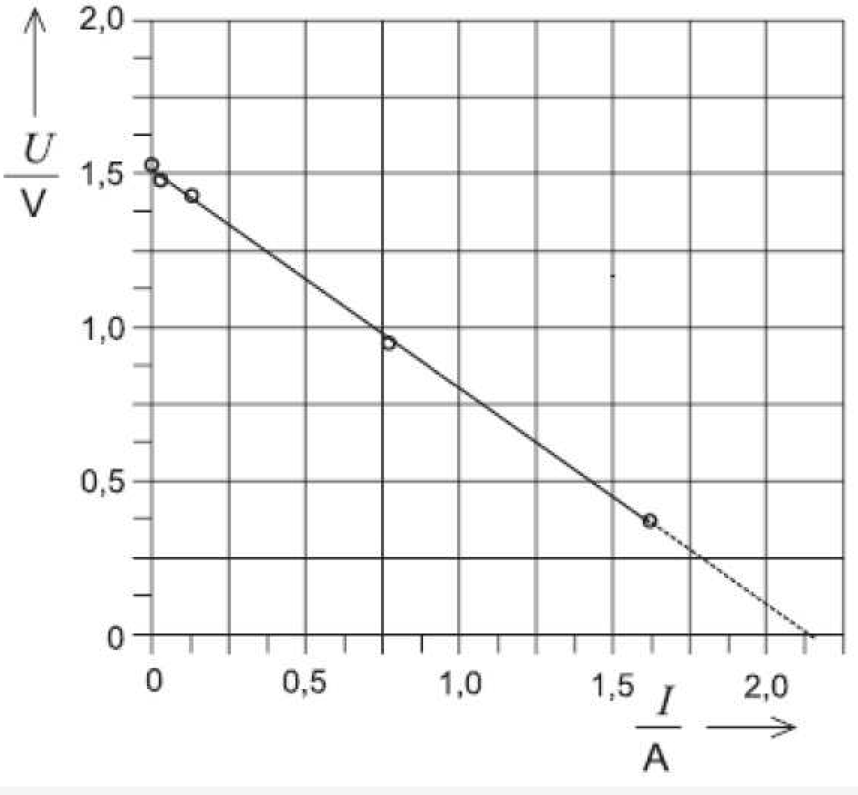

Fig. 2

Remarks

Commercially available dry batteries are very suitable for the examination of internal resistance. Their internal resistance is high enough to be measurable, and they are easily replaceable should they be damaged by overloading for too long. The power supply is not suitable for this examination of internal resistance, because it is voltage stabilized. Voltage sources used in practice differ in their internal resistances. The value of R_i must be very low for a car battery, for example, for sufficient current to be supplied to start up the motor.