How can an electrical device be operated at a voltage higher than ist nominal voltage?

Problem
Investigate the voltage ratios in unbranched circuits for a series connection of resistors.

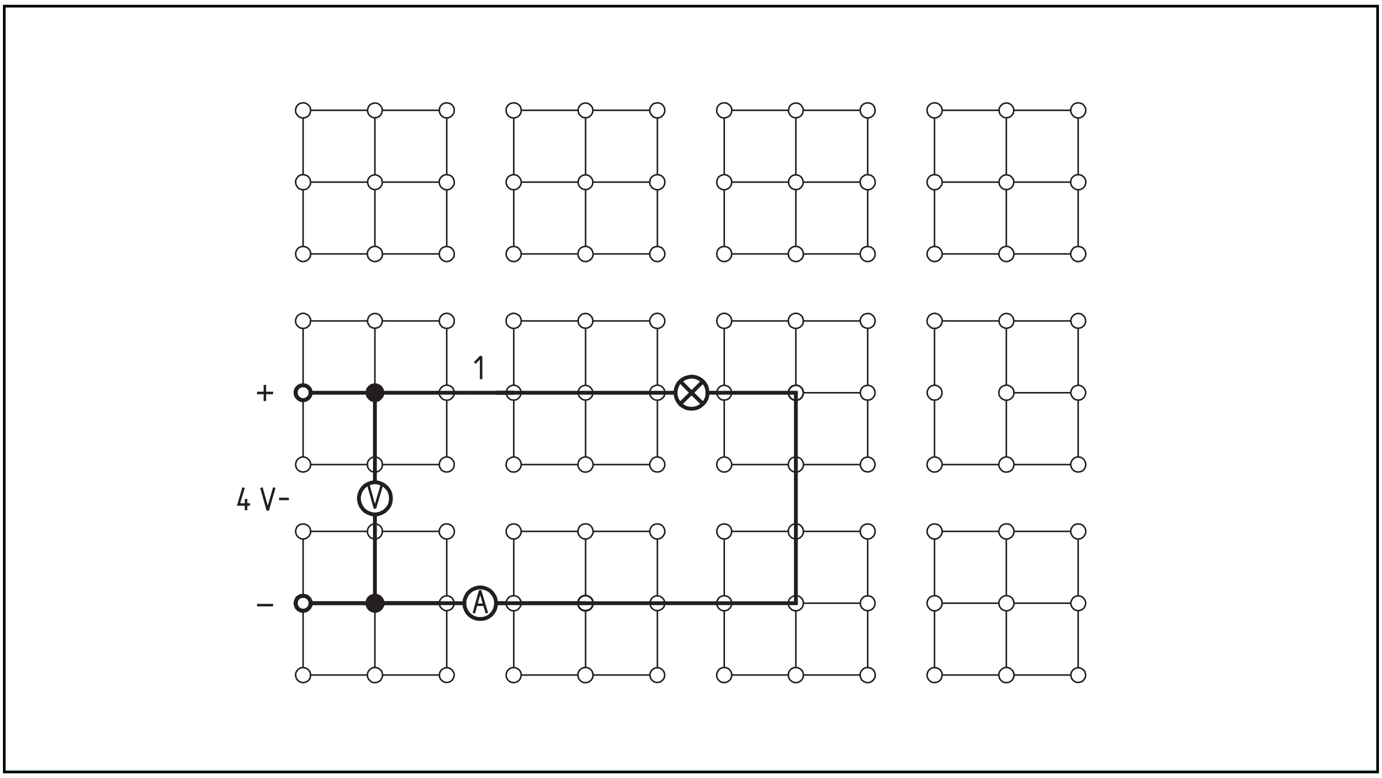
Equipment

Plug-in board	06033.00	1
Lamp holder E10	17049.00	1
Filament lamp, 4 V/0.04 A, E10, 1 pc.	06154.03	(1)
Resistor, 47 Ω	39104.62	1
Resistor, 100 Ω	39104.63	1
Wire building block	39120.00	3
Connecting cables, 25 cm, red	07360.01	1
Connecting cables, 25 cm, blue	07360.04	1
Connecting cables, 50 cm, red	07361.01	2
Connecting cables, 50 cm, blue	07361.04	2
Multi-range meter	07028.01	2
Power supply, 0...12 V-, 6 V~, 12 V~	13505.93	1

Set-Up and Procedure
First Experiment
- Set up experiment as shown in Fig. 1.
- Set direct voltage on power supply unit to 4 V and switch it on.
- Measure current and note brightness of filament lamp. Note current under (1).
- Remove wire building block 1 from circuit and replace with resistor R_P = 100 Ω.
- Observe brightness of lamp. Note observation.
- Increase voltage on power supply unit until the current reaches its original value. Note voltage.
- Switch power supply unit off.

Second Experiment
- Set up experiment as shown in Fig. 2.
- Switch on power supply unit and set direct voltage to 10 V (= U_T).
- Measure voltage at R_1 (partial voltage U_1). Note measurement in Table 1.
- Connect voltmeter parallel to R_2 (as shown in Fig. 2 with the dotted line). Measure partial voltage U_2 and enter measurement in Table 1.
- Switch power supply unit off.

Fig. 1



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Observations and Measurement Results

(1) I = ...

Brightness of filament lamp after connection of R_P: ....

Necessary voltage: U = ...

(2) Table 1

U_T/V	U_1/V	U_2/V
10		

Evaluation

1. Summarize the results of the first experiment and answer the question posed in the header.

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....

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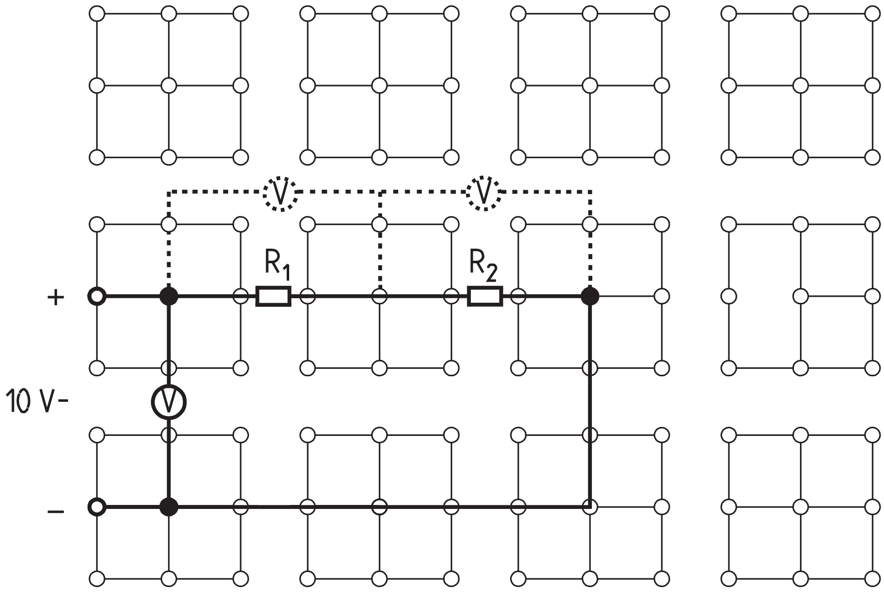
Fig. 2



2. With possible measurement errors in mind, a general relationship of the values in Table 1 is apparent. Express this relationship in your own words and in the form of an equation.

3. Enter the measured values for partial voltage U_1 and U_2, the given values for resistance R_1 and R_2, and the resulting quotients U_1/U_2 and R_1/R_2 into Table 2.

Table 2

U_1/V	U_2/V	R_1/ Ω	R_2/ Ω	U_1/ U_2	R_1/R_2

Express the relationship apparent from the right side of the table in your own words and in the form of an equation.

4. Complete Table 3:

Table 3

$\frac{U_T/R_T}{A}$	$\frac{U_1/R_1}{A}$	$\frac{U_2/R_2}{A}$

Express the general relationship apparent from Table 3 in your own words and in the form of an equation. You should now know a law for series connection that expresses this relationship. What is this law?

5. Name some applications for series connections.

Voltage in a Series Connection

(How can an electrical device be operated at a voltage higher than ist nominal voltage?)

The first experiment serves as an introduction to the function of preconnected resistors and a quantitative analysis of the law on voltage in series connections.
You may want to have the students carry out a variant of this introductory experiment using a string of Christmas tree lights where the students set up a string of lights with two identical filament lamps (4 V / 0.04 A).

Notes on Set-Up and Procedure
Before starting the experiments, make sure to tell the students that the voltmeter must be poled correctly. Switching errors often occur if it is connected in parallel to the respective partial resistors.

Observations and Measurement Results
(1) I = 0.04 A
Brightness of filament lamp after connecting R_P: minimal
Necessary voltage: U = 8 V

(2) Table 1

U_T/V	U_1/V	U_2/V
10	3.1	6.7

Evaluation
1. After connecting R_P to the circuit, the filament lamp shines much more weakly than previously.
   It only shines as brightly as before at a considerably greater voltage (in this case, double the original voltage).
   Therefore, it is possible to operate an electrical device at a voltage higher than its nominal voltage when a resistor (preconnected resistor) is added to the circuit in front of the device.
2. In a series connection, the total voltage is equal to the sum of the values for partial voltage:

$$U_T = U_1 + U_2.$$

3. Table 2

U_1/V	U_2/V	R_1/ Ω	R_2/ Ω	U_1/ U_2	R_1/R_2
3.1	6.7	47	100	0.46	0.47

In a series connection, the partial voltages behave the same as the partial resistance values:

$$U_1/ U_2 = R_1/R_2.$$

4. Table 3

$\frac{U_T / R_T}{A}$	$\frac{U_1 / R_1}{A}$	$\frac{U_2 / R_2}{A}$
0.068	0.066	0.067

In a series connection, the quotient of total voltage and total resistance is equal to the quotient of the values for partial voltage and the respective partial resistance:

$$U_T/R_T = U_1/R_1 = U_2/R_2.$$

This relationship is expressed in the law $I_T = I_1 = I_2$, since

$$U / R = I.$$

5. Some applications are, for example:
   — preconnected resistor for voltage indicators
   — preconnected resistors for various electronic circuits
   — Christmas tree lights

Notes
The term “total current” was not used because it may lead to confusion.
If there are enough voltmeters for any or all experiment groups to have 3 each, then they can be included in the circuit from the start.

Voltage in a Series Connection

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Room for notes