What happens when two filament lamps are connected in series?

EEP 2.4

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Problem

1. Connect two identical filament lamps in series and interpret the resulting effect.
2. Investigate which laws apply for current and resistance in the entire circuit when two technical resistors are connected in series.

Equipment

Plug-in board	06033.00	1
Lamp holder E10	17049.00	1
Filament lamp, 4 V/0.04 A, E10, 2 pcs.	06154.03	(1)
Resistor, 47 Ω	39104.62	1
Resistor, 100 Ω	39104.63	1
Wire building block	39120.00	4
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.
— Switch on power supply unit and note brightness of filament lamp.
— Replace wire building block 1 with the second filament lamp. Observe brightness of the two filament lamps and compare with previous brightness of one filament lamp.
— Note observations under (1).
— Switch power supply unit off.

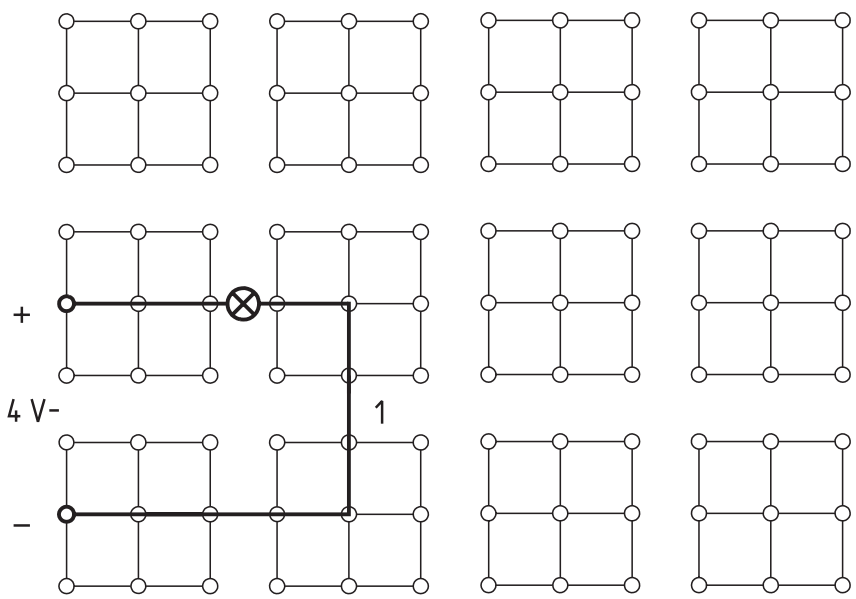
Second Experiment

— Set up experiment as shown in Fig. 2, using resistor R_1 (47 Ω) initially. Select measurement ranges 10 V- and 300 mA-.
— Switch on power supply unit and set direct voltage to 9 V.
— Measure current and enter under (2) in Table 1.
— Replace resistor R_1 with resistor R_2 (100 Ω).
— Adjust voltage to 9 V. Measure current and note.
— Replace wire building block 1 with resistor R_1.
— Adjust voltage once again to 9 V. Measure current and note.
— Switch power supply unit off.

Third Experiment

— Change series connection as shown in Fig. 3.
— Switch on power supply unit and set direct voltage to 10 V.
— Take successive measurements of current before R_1, between R_1 and R_2, and after R_2 and note. To do this, after taking the first measurement, connect the current meter to the circuit where the wire building block 1 and/or 2 were plugged in.
— Note measurements under (3) and switch power supply unit off.

Fig. 1



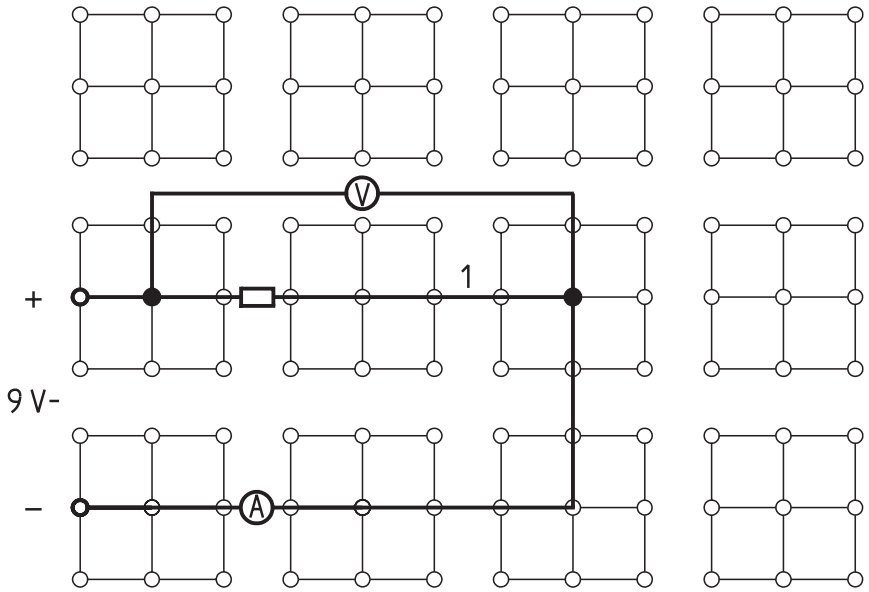
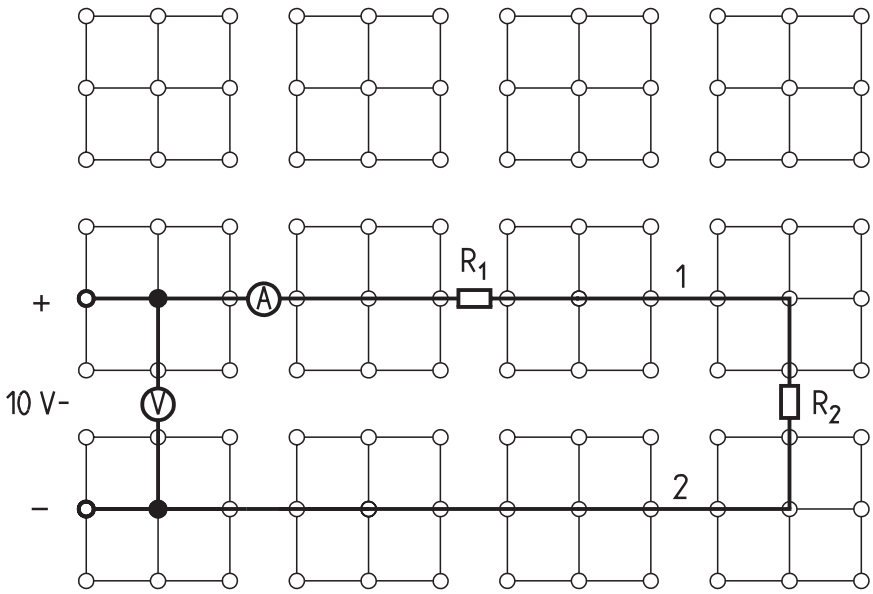


Fig. 2

Fig. 3



Observations and Measurement Results

(1)

(2) Table 1

Resistors in circuit	U / V	I /A	R /Ω
R_1 (Nominal value = 47 Ω)			
R_2 (Nominal value = 100 Ω)			
R_1 and R_2 in series			

(3) Current before R_1: I = ...

Current between R_1 and R_2: I = ...

Current after R_2: I = ...

Evaluation

1. Explain the observation you made under (1).

2. Calculate the values for resistance R_1 and R_2 as well as the resistance (R_T) for the series connection of the components and enter the values in the last column of Table 1.
   With possible measurement errors in mind, what general relationship can you see between total resistance R_T and the values for partial resistance?
   Explain this relationship and write an equation to express it.

3. Express the findings entered in (3) in your own words and write an equation to express the results.

4. Explain the findings.

(What happens when two filament lamps are connected in series?)

The first experiment is a qualitative introduction to the topic and the laws of series circuits.
These experiments provide a quantitative approach to the laws. In the second experiment, R_1 and R_2 are not switched right away. The students must first determine the experimental values for resistance. This allows them to draw an analogy to the first experiment and compare the measured values for R_1 and R_2 with the value for R_T.

Notes on Set-Up and Procedure
The connected voltage must remain constant in the second experiment. The students must check the voltage before measuring current each time and set it to 9 V.

Observations and Measurement Results
(1) When the second filament lamp is connected in series to the first lamp, both lamps shine with equal intensity, although weakly.

(2) Table 1

Resistors in circuit	U / V	I /A	R /Ω
R_1 (Nominal value = 47 Ω)	9	0.193	46
R_2 (Nominal value = 100 Ω)	9	0.090	100
R_1 and R_2 in series	9	0.060	150

(3) Current before R_1: $I = 0.064$ A
Current between R_1 and R_2: $I = 0.064$ A
Current after R_2: $I = 0.064$ A

Evaluation
1. When both filament lamps are connected in series, the current is weaker since the lamps only shine weakly. The resistance in the circuit, therefore, is greater than the resistance with only one lamp.
2. See the calculated values for resistance in Table 1, last column.
   In a series connection, total resistance is equal to the sum of the values for partial resistance:

$$R_T = R_1 + R_2.$$

3. In a series connection, the current is the same everywhere in the circuit:

$$I = I_1 = I_2.$$

4. Free electrons flow from the negative pole of the source of current towards the positive pole. The same number of electrons that flow away from the negative pole must arrive at the positive pole. The same number of electrons must flow through each section of the conductor in a given amount of time. Therefore, the current is the same in each section of the circuit.

(What happens when two filament lamps are connected in series?)

Room for notes