A4 Combining batteries

1 Main question

The question that guides the activities in this experiment is: What happens if the battery in the electrical circuit is too weak or too powerful?

2 Background

2.1 Relevance to the curriculum

The topic of “electrical circuit” is firmly established in elementary school curricula; however, there is ample leeway in handling the topic. If students are particularly interested in it, the topic can be studied further and expanded. By grappling with parallel and series connections of voltage sources in stages through the experiments, the students perform additional steps for a better understanding of everyday encounters and everyday phenomena. An especially valuable realization is that components and voltage sources must be sensibly matched with each other. Compliance with safety rules and the documentation of results in the form of a log are also explored in more depth.

Topics and terms

Parallel circuit, series circuit

2.2 Skills

The students will learn how to adapt voltage sources (number of batteries) to the requirements of electrical devices.

3 Additional information on the experiment

You will find additional media for preparing or for further study of this experiment on the Siemens Stiftung Media Portal: https://medienportal.siemens-stiftung.org

4 Conducting the experiment

Notes:

- The listed materials are designed to allow **one** group of maximum **five** students to conduct the experiment.
- Some of the electronic components may be available as different versions, such as cables (cables with alligator clips or interconnecting wires), lamps (incandescent lamps or LEDs), and switches. Feel free to provide the students with other equivalent components as an alternative to the materials indicated in the list. The students can work with the different versions of electronic components, match them to their function, and learn to use them properly.
- Only batteries and solar cells are used as voltage sources in Experimento | 8+. These are safe for the students due to their low direct current voltage.

4.1 Required materials

Material	Quantity
Aluminum foil	1 piece
Battery	7
Battery holder	1
Cable with alligator clips	6
Electrical tape	1
Incandescent lamp, 3.5 V and 6 V	2 of each
Incandescent lamp socket	2

Material for the additional experiment	Quantity
Electric motor	2
Interconnecting wire	4 pieces
Plant clip (as holder for the electric motor)	2
Propeller	2
Wire stripper	1

4.2 Organizational aspects

Facilities	At a simple table in the classroom
Time required	Approx. 45 minutes
Experimental variations	When an interconnecting wire is used: To close the electrical circuit, use electrical tape to firmly attach the wires to the batteries. The experiment with the 6-volt lamp serves to reinforce the insights gained with the 3.5-volt lamp. It is optional and can be used as a variation.
Safety instructions	See the “Safety instructions on the topic of energy” in the guidebook. The incandescent lamps were selected so that they withstand the gradual increase in the voltage. However, the number of batteries in the series circuit should be increased only one at a time.

4.3 Explaining the experiment in the teaching context

The students will connect batteries in series. They will become familiar with the benefit of this type of circuit and the aspects they need to keep in mind for series circuits.

Technical background

In experiment A3, incandescent lamps were connected in series and in parallel. These types of circuits are also possible for batteries. The following information on a battery is important:

- Voltage value (“rated voltage”) in volts [V]
- Polarity (indicated with a plus and a minus sign)

The **series connection** of batteries is used in numerous battery-operated devices to achieve a higher voltage than the voltage of the individual batteries. The total voltage of the batteries connected in series is equal to the sum of the voltages of the individual batteries. Batteries are also connected in series, for example, in the battery holder used in Experimento | 8+: Three 1.5-volt batteries connected in series supply a total voltage of 4.5 volts.
The polarity must be kept in mind when batteries are connected together. The voltages are added together only if the positive pole of one battery is connected to the negative pole of the next battery.

Fig. 1: Sketched circuit diagram of two batteries connected in series.

If like poles are brought into contact in the series circuit, this does not have a voltage-boosting effect. Rather, compensating currents may occur between the individual batteries if they do not have the same voltage rating and the same charge state. The batteries may then discharge even though the connected electrical device doesn't work (for example, lamp does not light up, motor does not rotate).

When batteries are **connected in parallel** (see additional experiment), the positive pole is connected with the positive pole and the negative pole is connected with the negative pole. The voltages are not added together. The total voltage is equal to the voltage of an individual battery. If the same electrical device is connected, the batteries connected in parallel have a longer life than a single battery.

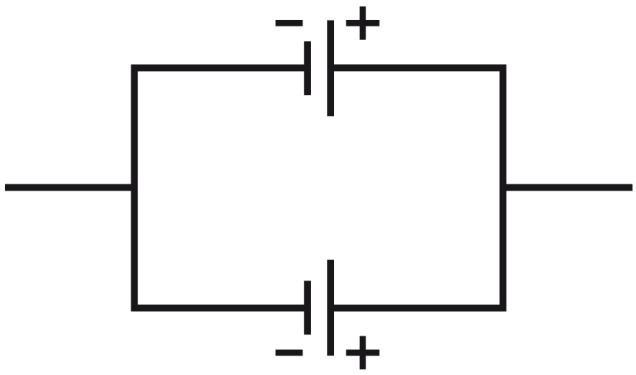


Fig. 2: Sketched circuit diagram of two batteries connected in parallel.

Note: You will find a summary of the most important basic physics principles about current in the guidebook in the "Electric current and energy – Basic physics principles" handout.

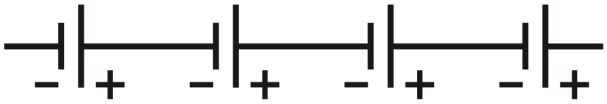
4.4 Ask about the students' prior knowledge and ideas

The students are already familiar with interconnected batteries from their everyday life, for example, when they replace batteries in a remote control or a flashlight. Through this experiment they will learn what this interconnection achieves, namely a higher voltage. An indication of the higher voltage is the brightness of the connected incandescent lamp, which can be demonstrated quite well in this experiment.
Before or during the experiment, the students may ask themselves whether excessive voltage can destroy the incandescent lamp. The children like to imagine the "destruction" as an explosion. If enough materials are available and the teacher has sufficient prior knowledge, an incandescent lamp can be connected to a sufficiently high voltage as a demonstration or alternatively a video can be shown. The procedure can dispel the students' fear because they can then see what to expect when the incandescent lamp is "destroyed" (a flash when the filament burns out; a bursting of the glass bulb is not to be expected).
The students should already have learned about a simple electrical circuit.

4.5 The research cycle

Important aspects and information regarding the individual process steps of the research cycle during the experiment for students:

Recognizing the problem/phenomenon 	To generate a sufficiently high voltage, for example, to get a device to run, batteries must sometimes be connected in series so that their voltage is added.
The research question 	The following alternatives to the research question stated in the student instructions are possible: ▪ How can you achieve higher voltage in the electrical circuit you built?
Collecting ideas and guesses 	Some possible guesses: **Related to the research question:** ▪ “The more batteries, the more brightly the lamps shine.” ▪ “The incandescent lamp always shines at the same brightness no matter how many batteries you connect.” ▪ “The 6-volt lamp always shines nearly twice as brightly as the 3.5-volt lamp.” **Related to the experiment:** ▪ “If too many batteries are connected to the incandescent lamp, the lamp could explode. May we try that out?” ▪ “How is that supposed to work? I can’t put the batteries together without the battery holder.” ▪ “Loose connections are impractical; the light would flicker. Therefore, we can’t analyze the experiment.” Segue from the guesses to the experiment.
Experimenting 	**Experiment setup:** ▪ The batteries must be connected together with the correct polarity (positive pole to negative pole). ▪ Tightly crumpled aluminum foil can be inserted between the positive pole of one battery and the negative pole of the next battery. Aluminum conducts current. This prevents loose connections. ▪ Provide assistance if necessary when the students join the batteries together. Teamwork is necessary here: One student presses the batteries close together while the other student tapes them tightly together using electrical tape.

	Conducting the experiment: ▪ Comprehension question: Why can't you conduct the experiment by gradually filling the battery holder? (Answer: If not all batteries have been inserted, the electrical circuit is not closed.) ▪ The 6-volt lamp generally shines less brightly with one to three batteries than the 3.5-volt lamp. The correlation between required operating voltage and the information on the component will become clear.
Observing and documenting	As each battery is added to the series connection, the incandescent lamp shines more brightly. **Results to be expected:** 3.5-volt lamp: 1 battery: much less brightly 2 batteries: less brightly 3 batteries: equally brightly 4 batteries: equally brightly The results are similar for the experiment with the 6-volt lamp. With four batteries, however, the 6-volt lamp will shine more brightly than with three batteries.
Analyzing and reflecting	**Results to be expected:** (Answers to student questions) 1. With two, three, and four batteries, the lamp shines more brightly than with one battery because more voltage is available. 2. If you connect the lamp to five to ten batteries connected in series, the lamp will be destroyed at some point because the voltage is too high. 3. Sketched circuit diagram:  Fig. 3: Sketched circuit diagram of four batteries connected in series. **Reflection:** The students will compare the series connection of batteries and incandescent lamps with the guidance of the teacher: ▪ **Incandescent lamps:** The voltage is allocated to the incandescent lamps; the lamps shine less brightly than one lamp by itself. ▪ **Batteries:** The voltages of the batteries are added together. An incandescent lamp shines more brightly than with only one battery. **Reference to the story to get the students thinking about the topic:** You have now learned that your remote control works only with two 1.5-volt batteries because the voltage is otherwise too low.

4.6 Further information

In the student instructions

Doing further research 	The students will build a parallel circuit with two batteries and discover that the motor rotates just as fast as if only one battery were connected. With the batteries connected in series, the motor runs faster. To answer the question of which motor runs longer, the students must conduct the experiment for an extended period. The motor connected to the parallel circuit will run longer (about twice as long). ▪ Provide assistance with the parallel wiring of the batteries. Use the interconnecting wire and firmly tape it to the poles. ▪ The plant clip serves as a holder for the motor.

Miscellaneous

It is important that components and battery voltages be matched with each other in the daily handling of electronic components. If the battery voltage is too low for the components, then the components will not work as intended (for example, an incandescent lamp will not shine brightly). In contrast, if the battery voltage is too high, the components can become damaged (for example, the incandescent lamp will burn out). The voltage values are a good guideline for planning electrical circuits: The respective voltage values in volts (V) are indicated on all batteries and nearly all components. Example: For an incandescent lamp with an indicated voltage of 3.5 volts, a battery with a capacity of 1.5 volts is barely sufficient, a battery or battery combination with a total capacity of 3 volts is ideal, and a battery or battery combination with a capacity of 9 volts can destroy this incandescent lamp.

In everyday life, people must pay attention to the voltage information, for example, when charging rechargeable batteries. A smartphone battery has a different operating voltage than a notebook battery. If the charger supplies the wrong voltage, the rechargeable battery can be destroyed.