A1 Simple electrical circuit

Subexperiment A1.1 The lamp should light up!
Subexperiment A1.2 Switching on and off
Subexperiment A1.3 Electro quiz

1 Main question

The following questions underlie the experiments and guide the activities:

- How do you build a simple electrical circuit? What problems could arise? (Subexperiment 1)
- How can you close or interrupt an electrical circuit, that is, switch it on and off? (Subexperiment 2)
- How can you check whether an electrical circuit is closed? (Subexperiment 3)
- How can you represent circuits schematically (sketched circuit diagrams)? (All subexperiments)

2 Background

2.1 Relevance to the curriculum

Many curricula require the topic of “electric current” to be covered in elementary school. Electric current is ubiquitous in our daily lives, and the students can certainly name a few electrically powered devices. Electric current is the “means of transport” for electrical energy (see experiment A5 “Generating” energy). Electrical conductivity as a property of materials can be thoroughly examined in elementary school. Regardless of the type of school, an understanding of the link between the properties and uses of materials is fundamental to the content of many later subjects, such as technology, physics, mechanisms, work, and economics.
Involvement with the experiments acquaints the students with compliance with safety rules and allows them to discover specific knowledge on simple circuits. A basic learning experience is understanding that electric current flows from a source through the connected devices and back to the source.
We know from many studies that students have numerous inadequate or flawed perceptions about electric current. Therefore, it is necessary to allow elementary school students to develop fundamentally correct perceptions about circuits: power source, electrical device, conductor, insulator, switch, short circuit.
However, at this early stage there is no need yet to introduce variables and units of measurement for describing the electrical circuit. In Experimento | 8+ only the term “electric voltage” is introduced. The curious “electricity novices” will be able to understand and draw initial circuits with graphic symbols after an introduction.
To pique and maintain natural curiosity and openness toward the topic of electricity, the teacher must have particularly good pedagogical skills for communicating the contents in a way suitable for children. This is why the discussion of the topic comes at the beginning of this series of experiments. The subject-specific background to each subexperiment provides thorough preparation for this.

Topics and terms

Battery, cable, circuit, component, “consumer”, current flow, electricity, loose connection, power source, sketched circuit diagram, switch, voltage

2.2 Skills

The students will ...

- come to understand the concept of a circuit. They will become acquainted with different versions of ordinary components and be able to use them properly.
- find possible technical solutions for simple switches.
- be able to identify and remedy possible sources of error in a simple circuit on their own.
- sketch simple diagrams of circuits they have designed themselves and understand the meaning of the symbols used in the diagrams.

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 Subexperiment A1.1 The lamp should light up!

4.1.1 Required materials

Material	Quantity
Battery	3
Battery holder	1
Cable with alligator clips	2
Incandescent lamp, 3.5 V (red or green)	1
Incandescent lamp socket 04	1

Material for the additional experiment	Quantity
LED, red (red case), 5 V	1

4.1.2 Organizational aspects

Facilities	At a simple table in the classroom
Time required	Approx. 45 minutes
Experimental variations	Instead of using the cable with alligator clips, the students can also use home-made cables consisting of interconnecting wires and paper clips (see “Do you need help?” in the guidebook).
Safety instructions	See the “Safety instructions on the topic of energy” in the guidebook (including information on short circuits and contact voltage).

4.1.3 Explaining the subexperiment in the teaching context

The students will design a simple circuit. They will learn that an electrical device (the incandescent lamp here) works only in a closed circuit. In addition, they will become familiar with the typical sources of error in the wiring of components and how they are remedied.

Technical background

Generally, **electric current** is understood as the movement of charge carriers (for example, electrons) in a common direction. This “directed” movement requires an external “impetus” to come about – an **electric voltage**. Current does not flow without voltage. The voltage is the cause of the current. Batteries are used as voltage sources in this subexperiment and the next ones.
A closed **circuit** must always be present to operate electrical devices like incandescent lamps or LEDs: The electrons flow from the battery’s negative pole to the device via a conducting connection and back to the battery’s positive pole via another conductor. The chemical processes inside the battery close the circuit.

Note: You will find a summary of the most important basic physics principles on current in the guidebook in the “Electric current and energy – Basic physics principles” handout, chapters 1 – 4.

4.1.4 Ask about the students’ prior knowledge and ideas

When it comes to electricity and **current**, people are often afraid of contact with electricity. One reason is that they cannot see the current itself and an encounter with current can be painful. A good demonstration of the existence of electric charges is the electrostatic charging of a glass rod or balloon by rubbing it on wool, for example, and then moving it close to a person’s hair.

For an understanding of all the following experiments on current, it is particularly important that the students have the right idea of what a **circuit** is.
To this end, you can first connect a cable to itself and ask whether it is a circuit. It is not, of course, because the voltage source is missing. Now what? For a circuit to be of practical use, you also need an electrical device, such as a lamp. At this point the students will quickly notice that more than one cable is necessary because otherwise the device cannot be incorporated.
Students often think that the current flows only to the incandescent lamp and is consumed there, that is, that only a single cable is sufficient as a forward path. This perception is reinforced by the fact that all electrical devices (electric kettle, hairdryer, etc.) have one cable with a plug that is inserted into a socket. In reality, however, the flowing charge carriers are not consumed, because current can flow only if the charge carriers return to the voltage source again. Ask the students

about everyday encounters, for example, how many cables protrude from a ceiling if the ceiling light hasn't yet been connected. It is always more than one cable, and usually three. A sliced cable (for example, from a household appliance that is no longer used) can also be used for illustration.

Certainly, the students know little about the term **electric voltage**. Most of them are familiar with the high-voltage towers of overhead power lines in the countryside. Perhaps they are familiar with the term "volt" from handling batteries for electric toys (1.5-volt batteries). The volt is the unit of measurement of electric voltage. Since electric voltage is the cause of current flow, the students should become familiar with this term from the beginning and learn to refer to a battery or socket as a "voltage source."

4.1.5 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 	This experiment is about getting a lamp to light up using a simple electrical circuit.
The research question 	The following alternatives to the research question stated in the student instructions are possible: ▪ What circumstances might be responsible for your flashlight not lighting up? ▪ When does your flashlight light up again? ▪ Why does a lamp light up?
Collecting ideas and guesses 	Some possible guesses: **Related to the research question:** ▪ "It doesn't light up because the electrical circuit is not closed." ▪ "The batteries are dead or arranged incorrectly." ▪ "The incandescent lamp or the LEDs are defective or arranged incorrectly." **Related to the experiment:** "For the lamp to light up, I have to connect it to the battery. I need cable for this purpose." Segue from the guesses to the experiment.

Experimenting 	**Experiment setup:** ▪ Since the students are working with the materials for the first time in this experiment, explain the individual components (cables, incandescent lamp, etc.) and specify their purpose. ▪ Point out that the voltage used is harmless. Some may perhaps be “afraid” of current because they are familiar with the relevant precautions from home (“Don’t touch the socket,” etc.). However, it must be made clear that household voltage is a great deal stronger and can be very dangerous if handled incorrectly. ▪ Two different colors of cables should be used to visualize the different battery poles. In technology, a red cable is used for the connection to the positive pole and a black cable for the connection to the negative pole. **Conducting the experiment:** ▪ Point out the dangers if a battery is short-circuited. ▪ Discuss with the students how the devices are used and what possible sources of error exist. These errors and their remedies are listed on the supplementary sheet “Do you need help?” (for example, loose connections mainly occur when interconnecting wires are used, less often with cables with alligator clips). ▪ In the spirit of precise scientific work, the students should grasp the alligator clips only at the plastic covers (insulation, protection against electric shock). However, since the voltages used in the experiment are low, touching the conducting contacts is harmless. ▪ By tracing the wiring with their fingers, the students literally understand the circuit.
Observing and documenting 	The students will learn that not everything succeeds the first time. Guide them in remedying the errors on their own (see the document “Do you need help?”).
Analyzing and reflecting 	The students memorize the structure of a simple circuit. When they design other circuits, they can build upon this knowledge. **Basic rule: (answer to the cloze test)** The current flows from one pole of the battery holder to the lamp via the cable. Then the current flows through the lamp and to the other pole of the battery holder via the other cable. This is called a closed circuit. **Reference to the story to get the students thinking about the topic:** You have now learned how an electrical circuit is set up. You can therefore repair your flashlight: You must replace either the batteries or the lamp so that the electrical circuit is closed and so your flashlight will work again.

4.1.6 Further information

In the student instructions

Doing further research 	▪ The LED allows current to flow in only one direction. The positive pole of the battery holder must be connected to the longer LED leg, negative pole of the battery holder to the shorter LED leg. ▪ The LED used here shines less brightly compared to the incandescent lamp. ▪ The students deepen their understanding of the fact that a battery has polarity and electric current has a direction.

4.1.7 Reference to values

What is your opinion? 	In the discussion about values for this experiment, the teacher can provide a prompt or tell a story in which a problem is posed. Both actions lead to a discussion based on reflections. What's important is that the reference to values can be established in the experiment. The discussion can focus either on learning-process-related values (for example, working reliably in groups) or on object-related values (for example, handling paper as a resource). The student instructions for **A1.1 The lamp should light up** address learning-process-related values and object-related values. **Prompt related to the learning process:** Immediately after the experiment, a prompt related to the learning process for the value "team orientation" can be easily integrated. The aim is to discuss the implementation of team orientation, for example, offering help to others, approaching them, listening to others, and allowing them to finish speaking. ▪ Observation by the teacher: "I observed that some groups did not work well together." **Dilemma related to the learning process:** As an alternative, a dilemma related to the learning process for the value "team orientation" can also be integrated at the end of the student instructions. The students should express their opinions about it. **Dilemma related to working in a group:** Paul is very shy. Frank and Frieda have to conduct an experiment in a group with Paul. Frank and Frieda are not thrilled about it and proceed to conduct the experiment by themselves. Paul would like to help and quietly gives them tips. However, the other two do not listen to him. As the teacher checks on the group, she says, "Are you sure that your experiment is working? You're missing water, aren't you?" Paul thinks to himself, "That's what I told them." *Think about it:* Should Paul say something or remain quiet?

Possible statements by the students:

What goes well in group work?	What doesn't go well in group work?
▪ Working together is fun. ▪ A lot of ideas come up.	▪ I am faster by myself. ▪ One person does all the work.

Objective:

The students should reflect on what went well and what didn't go well when they worked in the group.
The value of team orientation (reviewing/optimizing work together as a team) is addressed in the process.

Object-related dilemma:

An object-related dilemma can be integrated in the discussion of the values "dependability" and "initiative" at the end of the student instructions. The students should express their opinions about it.

Dilemma related to a sister and the light: Hugo frequently quarrels with his older sister. She thinks she always knows better only because she is older. Hugo's sister is often the last one in the bathroom in the morning and frequently leaves the light on. Their mother has often told her that she shouldn't do that because it is important to save electricity. As Hugo is walking to the bus to ride to school, he sees that the light in the bathroom is still on.

Think about it: What would you do in Hugo's place?

Possible statements by the students for and against turning off the light:

For turning off the light	Against turning off the light
▪ You want to save electricity. ▪ You want to help your mother. ▪ You think you still have enough time to catch the bus.	▪ You will miss the bus. ▪ You are annoyed at your sister. ▪ You want your sister to get scolded.

Objective:

The students should consider how they can dependably keep agreements or proceed on their own initiative. The values of dependability (complying with established rules and keeping agreements) and initiative are addressed.

Alternatives:

Statements or questions as prompts related to the story told in the student instructions are also suitable for encouraging discussion.
The values of initiative, dependability, and environmental awareness are addressed.

	▪ **For discussion:** “A student told me that he forgot to turn the light off at home again today when he went to school.” ▪ **Question for discussion:** Think about the situations when you turn on the light. When do you really need the light and when could you manage without it? **Notes:** The students should reflect on values and express their opinions. It may turn out that several values are addressed.

4.1.8 Reference to technology

In the student instructions

The students will sketch a diagram of a simple electrical circuit.
The following components can be replaced without having to make a new drawing: cables, incandescent lamps and lamp sockets, batteries, battery holders.

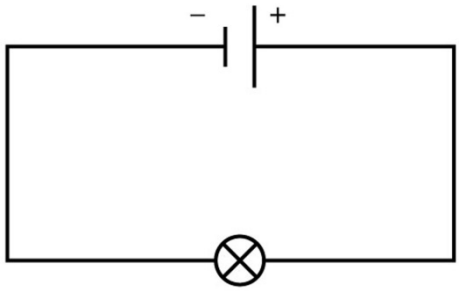

Fig. 1: Sketched diagram of a simple circuit with an incandescent lamp.

Notes:

- Experience shows that some students will not limit themselves to the abstract graphic symbols but will include details of the real components in their sketched circuit diagrams. Point out that they should use only the specified symbols.
- Make sure that the students draw a closed circuit. If necessary, support them in correcting their sketch and talk with them about the importance of this technical concept. Explain that the circuit is closed even though the battery symbol looks open. The whole symbol stands for the self-contained battery.
- In the graphic symbol for the battery, the long terminal is the positive pole and the short terminal is the negative pole. This is reversed in some battery holders, whereby that is a random decision by the manufacturer; there’s no technical reason behind this.

4.2 Subexperiment A1.2 Switching on and off

4.2.1 Required materials

Material	Quantity
Battery	3
Battery holder	1
Cable with alligator clips	3
Clothespin	1
Incandescent lamp, 3.5 V (green or red)	1
Incandescent lamp socket 04	1
Paper clip, 26 mm	2
Slide switch	1

Material for the additional experiment	Quantity
Aluminum foil	1
Adhesive tape	1
Brass fastener	4
Cardboard, standard letter size	1
Cork tile	1
LED, red (red case), 5 V	1
Paper clip, 26 mm	4
Pin	4
Thumbtack	2

4.2.2 Organizational aspects

Facilities	At a simple table in the classroom
Time required	Approx. 45 minutes
Experimental variations	You can also conduct the experiment with an LED. Observe the correct polarity of the terminals.
Safety instructions	See the “Safety instructions on the topic of energy” in the guidebook.
Cleanup	Take apart the home-made switches.

4.2.3 Explaining the subexperiment in the teaching context

First, the students will integrate an ordinary switch into a circuit. Next, they will build their own switch using a clothespin.

Technical background

A switch interrupts and closes a circuit by breaking or establishing an electrical contact. A switch has a movable conductive element whose position determines whether the current flow is interrupted (switch off) or whether the current can flow (switch on). If the switch has interrupted the circuit, electrons can no longer flow; an incandescent lamp cannot light up in an interrupted circuit.

4.2.4 Ask about the students’ prior knowledge and ideas

A light switch actually looks like a very simple construction and yet the students will have trouble at the beginning imagining how it works. They will have rather diffuse and divergent ideas about the following:

- How a switch works mechanically.
- Where exactly it must be installed in a simple circuit.

The students should say where they encounter switches in everyday life and express their ideas about how a switch works and why there are different types of switches (rotary switch, toggle switch, etc.).

You can guide the explanations in the desired direction by pointing out how many different states a switch must have. The students should already be familiar with one of the two states (on: current flows, lamp lights up). The other state (off: current does not flow, lamp does not light up) can now be derived.
The students should have already learned about a simple circuit and also be familiar with the associated sketched circuit diagram.

4.2.5 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 	This experiment is about the phenomenon of being able to turn electrical devices on and off. This can be illustrated based on the example of a light, a computer, or other electrical devices.
The research question 	The following alternatives to the research question stated in the student instructions are possible: ▪ Why is a switch important in an electrical circuit? ▪ For which electrical circuits are switches important? ▪ How many switch positions are there for a light switch?
Collecting ideas and guesses 	Some possible guesses: **Related to the research question:** ▪ “The switch prevents current from flowing.” ▪ “The switch disconnects the current flow.” ▪ “When I use the switch, I press something on the cable so that current does not flow.” ▪ “Something moves in the switch so that you can interrupt the circuit.” **Related to the experiment:** ▪ “I can install the switch in two ways between the battery and the incandescent lamp.” ▪ “It doesn’t matter where I install the switch.” Segue from the guesses to the experiment.

Experimenting

Experiment setup:

The switch should not be connected directly to the battery, that is, without the incandescent lamp between them. This will generate a short circuit and the battery will become unusable. To prevent this, only three cables are specified in the experiment.

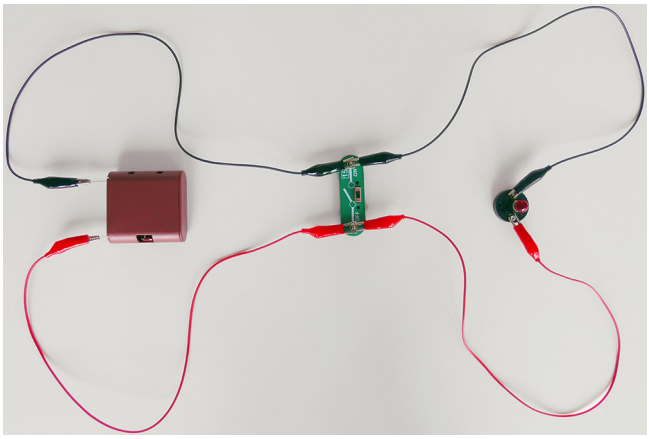

Fig. 2: Short circuit of a switch
(corresponds to a “parallel connection” of the switch and lamp).

Conducting the experiment:

- The assignment is to find out where in the circuit the switch must be installed.
- By recreating a switch based on a figure, the students will learn to understand the basic concept of a switch.
- Depending on the clothespin, the cables can also be connected directly to the clothespin.

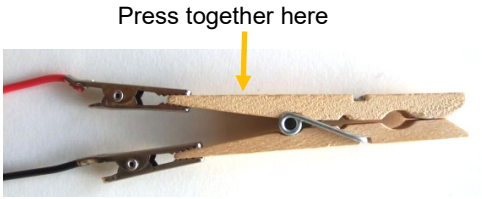

Fig. 3: Switch made from a clothespin and cables with alligator clips.

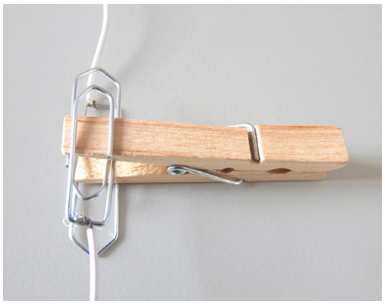

Fig. 4: Switch made from a clothespin and paper clips with interconnecting wires.

- The students will not design their own switches until later (see “Doing further research”).
- If the lamp does not turn on or off when the switch is operated, the students should check the cables to make sure they work and the structure of the electrical circuit (see the document “Do you need help?”).

Observing and documenting 	When they design their own switches, the students will determine that correct functioning of the switch depends on their precise work and good connections. **Most important observations:** ▪ The switch must be installed between the battery and the incandescent lamp. ▪ When I operate the switch, the lamp goes on and off. If nothing happens, then I have to check the components and connections.
Analyzing and reflecting 	The students formulate how a switch works (with the help of a cloze test). The concept of a closed circuit is further reinforced in the process. **Answer:** When I turn the switch on, the circuit is closed. The lamp lights up. When I turn the switch off, the circuit is interrupted. The lamp does not light up. **Reference to the story to get the students thinking about the topic:** You have now learned that the switch interrupts the electrical circuit and therefore current no longer flows. Your vacuum cleaner even has two switches that must both be turned on for the current to flow.

4.2.6 Further information

In the student instructions

Doing further research

- A cork tile or piece of sturdy cardboard is helpful when the students build switches: They can stick brass fasteners or thumbtacks into these materials.
- If the students are unable to come up with their own ideas, prompt them to build a switch with an unbent paper clip.

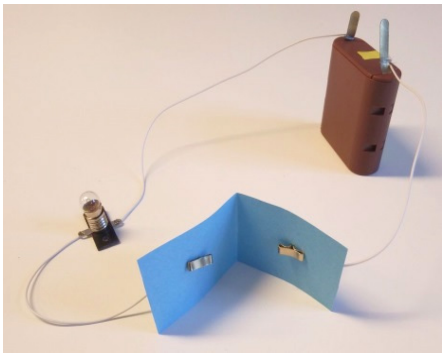

Fig. 5: Example of a pressure switch.

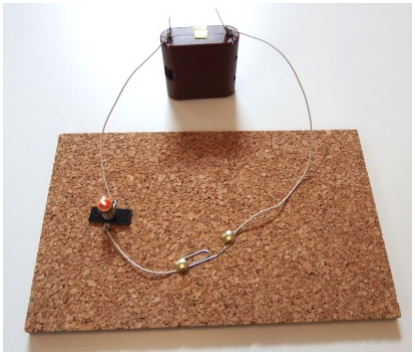

Fig. 6: Switch made with an unbent paper clip and thumbtacks.

- Alternatively, the switch made with the clothespin can be modified so that it opens the circuit when it is pressed (contacts are not attached at the end where the clothespin prongs are apart, but at the end where the prongs are together, thus where they are always touching).
  This uses a different switching principle and allows the switch to be turned off briefly.

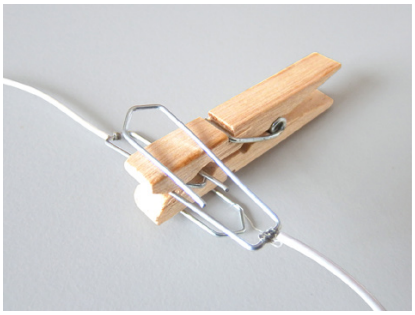

Fig. 7: Switch made with a clothespin, modified.

- The students will compare their designs with each other and describe how each switch works.

Miscellaneous

- Switches can be divided into different categories: rotary switch, slide switch, pressure switch.
- It is possible to build a circuit with several switches. In practice, such designs are often integrated for safety reasons (series connection), for example, for a washing machine or microwave oven: The start switch will not work until the door is closed.
- The students could also glue circuit diagrams created and copied by the teacher onto letter size cardboard and then attach circuit components using the available materials.

4.2.7 Reference to values

What is your opinion?

In the discussion about values for this experiment, the teacher can provide a prompt or tell a story in which a problem is posed. Both actions lead to a discussion based on reflections. What's important is that the reference to values can be established in the experiment. The discussion can focus either on learning-process-related values (for example, working reliably in groups) or on object-related values (for example, handling paper as a resource). The student instructions for **A1.2 Switching on and off** address object-related values.

Object-related dilemma:

An object-related dilemma can be integrated in the discussion of the value "initiative" at the end of the student instructions. The students should express their opinions about it.

Dilemma related to breakfast: It's Sunday and your parents are still sleeping. You want to surprise them by making them breakfast. You have already arranged everything on a tray. All that's missing is the toast, which is your father's favorite thing to eat. When you turn on the toaster, the fuse blows.

Think about it: What would you do?

Possible statements by the students for and against waking up the parents:

Reasons for waking up the parents	Reasons against waking up the parents
▪ You are afraid to reset the fuse yourself. ▪ You are not allowed to go to the fuse box yourself. ▪ You really want to serve toast for breakfast.	▪ You don't want your surprise to be ruined. ▪ You know how to reset the fuse because you've done it many times. ▪ You run to the bakery and pick up fresh rolls, even though your father doesn't like them as much as toast.

Objective:

The students should reflect upon how they can proceed on their own initiative or whether they reliably adhere to the rules. The values of initiative and dependability are addressed.

	Alternatives: Statements or questions as prompts related to the story told in the student instructions are also suitable for encouraging discussion. In addition to the values of initiative and dependability, the value of environmental awareness is addressed (treating the environment carefully). ▪ **For discussion:** I save electricity by switching the television to standby mode. ▪ **Question for discussion:** Think about the devices that are often switched on at home. Which devices could you switch off to save electricity? **Notes:** The students should reflect on values and express their opinions. It may turn out that several values are addressed.

4.2.8 Reference to technology

In the student instructions

The students will sketch a diagram of an electrical circuit with a switch.
The type of switch can be changed without needing to sketch a new circuit diagram.

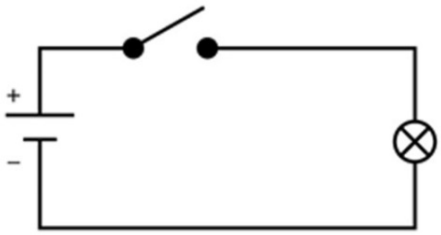

Fig. 8: Sketched diagram of a simple circuit with an incandescent lamp and switch (open).

4.3 Subexperiment A1.3 Electro quiz

4.3.1 Required materials

Material	Quantity
Battery	3
Battery holder	1
Brass fastener	10
Cable with alligator clips	3
Colored pencils	1 package
Glue	1
Incandescent lamp, 3.5 V (green or red)	1
Incandescent lamp socket 04	1
Interconnecting wire	5 pieces, 20 cm each
Paper, standard letter size	2 sheets
Scissors	1
Screwdriver (Phillips)	1
Thin cardboard, standard letter size	1
Thick cardboard, as a base for “punching” the holes	1
Wire stripper	1

4.3.2 Organizational aspects

Facilities	At a simple table in the classroom
Time required	Approx. 90 minutes
Experimental variations	▪ Variations of the simple electro quiz with 3 – 5 question/answer pairs: interactive graphic (for example, naming the respiratory organs), interactive map (for example, countries and capital cities), electronic dictionary, vocabulary quiz, etc. ▪ An LED can also be used in place of the incandescent lamp as the signal generator for the testing device. ▪ A professional continuity tester can be obtained from a home improvement store and made available to a group as a testing device. The students will learn that the professional device is built according to a very simple principle.
Safety instructions	See the “Safety instructions on the topic of energy” in the guidebook.
Cleanup	The students generally want to keep the finished quiz boards.

4.3.3 Explaining the subexperiment in the teaching context

The students will design a simple electro quiz with approx. 3 – 5 pairs of images or words.

Technical background

The basic concept of a closed circuit is explored in more depth with the electro quiz.
The circuit here consists of two elements:

- Testing device: An incandescent lamp (or an LED) and a battery are connected together. The incandescent lamp and the battery each have a cable connected on the open side. In technology, this type of circuit is implemented in a continuity tester (see section 4.3.7).
- Wired circuit board: Pairs of brass fasteners are electrically interconnected.

The principle: The two cables, the incandescent lamp, and a battery form an open circuit: The incandescent lamp lights up only when the circuit is closed. If you connect the contacts of the testing device with the correct pair of brass fasteners, then the cable that connects the two brass fasteners closes the circuit. This kind of device is called a “continuity tester.” It checks whether current can flow between two particular locations.

The circuit board of the electro quiz is a very simple version of a printed circuit board that is now found in nearly every electronic device (computer, calculator, smartphone, etc.). The entire processing logic in electronic devices (including computers) is based on this simple principle: Either current flows or doesn’t flow (because there are only two possibilities, we refer to this principle as “binary signal processing”).
For complex or confusing circuits, the continuity tester can be used to easily test whether two points of the circuit are electrically connected.

4.3.4 Ask about the students’ prior knowledge and ideas

It is unlikely that the students are familiar with a continuity tester from everyday life. If they have seen electrical installations at some point, they may be familiar with a phase tester (usually a small screwdriver with a light in the handle and a contact at the upper end). However, that is not the same! (see section 4.3.7).
Some students who have seen the inside of a computer, for example, are familiar with printed circuit board assemblies. The cables on a circuit board are not wires, but copper coatings. The teacher could bring a circuit board from a broken PC to class as a study object.
The students should have already learned about a simple circuit and should also be familiar with the associated sketched circuit diagram.

4.3.5 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 	This experiment is about applying the learned material, namely building an electrical circuit in the form of an electro quiz. In the process, different ideas can be used for the areas of application in which an electro quiz can be created.
The research question 	The following alternatives to the research question stated in the student instructions are possible: ▪ What happens when unrelated terms are touched? ▪ What happens when related terms are touched?
Collecting ideas and guesses 	Some possible guesses: **Related to the research question:** ▪ “There must be a connector between the question card and the correct answer card.” ▪ “Current must not flow between cards that are not related.” ▪ “I could also connect all the wrong terms together and install a buzzer that makes a sound whenever someone connects the wrong terms with each other.” **Related to the experiment:** “I can hide the cables by running and gluing them behind the box.” Segue from the guesses to the experiment.
Experimenting 	**Experiment setup:** ▪ Encourage the students to create a plan for the electro quiz wiring before they begin wiring. The master copy can be used as the design template for the question/answer cards (see section 4.3.8). ▪ Drill the holes: The thick cardboard is used as a base. Place the screwdriver at the position where the hole should be made. Then use a flat hand to give the screwdriver a quick, firm tap. **Conducting the experiment:** ▪ The students will reinforce the concept of a “closed circuit” through the complex design of the circuit. ▪ In addition to manual dexterity, this experiment calls for creativity. ▪ Tip: First wind the wire around the brass fastener and then bend the legs apart.

Observing and documenting 	The typical sources of error may occur in circuits. Due to the more complex wiring, however, errors are more difficult to find. The remedying of errors is more in-depth (see the document “Do you need help?”). **Answer to the cloze test:** When I touch the testing device to the matching pair of cards, the circuit is closed. When I touch an incorrect pair of cards, the circuit is interrupted.
Analyzing and reflecting 	▪ Touching the two wired brass fasteners with the testing device closes the circuit (if the pair is correct). ▪ From their observations of what went well and what was problematic, the students can write down rules for “clean” wiring. ▪ The structure of electrical devices and electronic circuits becomes easier to understand. **Results to be expected** Answer sentence: The cable that connects a matching pair of cards closes the testing device’s circuit. **Reference to the story to get the students thinking about the topic:** You have built your electro quiz so that the incandescent lamps light up only when the matching pictures are touched.

4.3.6 Further information

In the student instructions

Doing further research 	The electro quiz is built so that it consists of a baseplate and exchangeable question/answer tiles (for master copy, see section 4.3.8). If the cards that were previously glued on can no longer be removed, they can remain on the board and the new card tiles are simply laid on top. The students will recognize that the various question/answer tiles work only on their own baseplate, not on those of the other groups (unless by coincidence the groups have wired their baseplates exactly the same).

4.3.7 Reference to technology

From the experiments, the students know that the circuit must be closed starting from the voltage source, via the “consumer,” and back to the voltage source. They are to become familiar with an application showing that this principle can be used in technology to test the proper functioning of the “consumer.”

In the student instructions

Tracking down technology 	The student instructions show a photo of a **measurement using a continuity tester** as a reference to everyday life. The students should name the device and discuss its purpose and functioning. Questions and tips are offered to help the students. The work assignment serves to solidify the learning results and document the students' progress.

The photo motif – the measuring of the current flow via the coiled filament of a halogen lamp – corresponds to the setup of the student experiment insofar as it includes a lamp that is lit up by closing the circuit. Here, the red light-emitting diode (LED) of the continuity tester lights up if the coiled filament of the tested lamp does not have an interruption. If the LED does not light up, the halogen lamp is burned out.
It will be interesting to see how the students sketch the two circuit diagrams, especially how they sketch the broken incandescent lamp. Some will recognize that the incandescent lamp in the testing device works like a switch: If the incandescent lamp is undamaged, the circuit is closed; if the incandescent lamp is broken, the circuit is interrupted.

Important note: Risk of confusion with phase testers:
Most of the students are generally not familiar with the continuity tester from everyday life; some may perhaps know about them from buying lamps at home improvement stores. Most of them will be familiar with the phase tester. However, a phase tester is not used to check continuity, but whether a voltage is applied to the voltage source, normally the socket. If this is the case, then the phase tester lights up because a circuit is closed with a ground via the person and via a glow lamp in the phase tester's handle. If you are confident in handling this device, you can demonstrate it in class. However, you must point out that as a matter of principle, the students must not perform measurements and experiments with high-voltage current.

You will find the answers to the questions asked in the student instructions on the answer sheet in the guidebook. In the "Experimento | 8+: Tracking down technology" media package, which is available on the Media Portal, you will find additional technical information compiled in a link list. This media package also includes all of the individual photos as well as the work assignment as a prepared worksheet.

Miscellaneous

Continuity testers are not suitable for all devices! A continuity tester cannot provide information on functioning for complex electrical consumers with upstream electronics such as energy-saving light bulbs, LED lamps, and televisions. In this case, the test (continuity test or voltage measurement) must take place at certain components in the inner workings of the electronics.

4.3.8 Master copy for the electro quiz

- The quiz topic is entered on the top line.
- The rectangles ("cards") on the left and right are colored or labeled.
- The holes for the brass fasteners are predrilled in the dotted circles.
- The center strip is cut out along the dotted line.