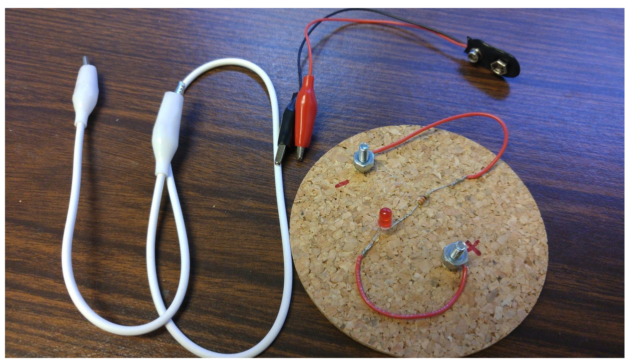
Circuits and electrical energy

Circuit tiles

Learning goals:

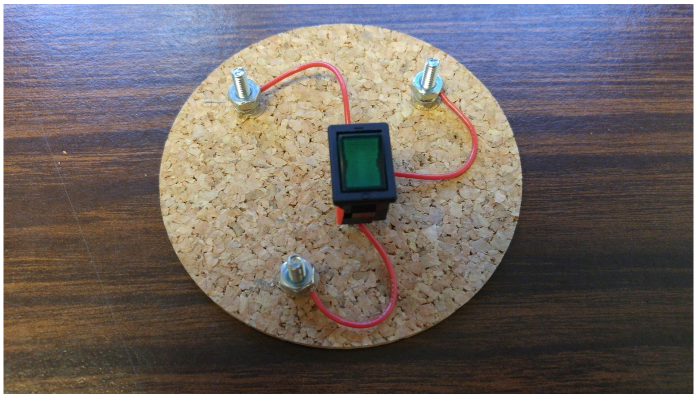
- Electricity that flows in a loop is called a circuit.
- Two lights can be connected one after each other in a circuit, but if one light in this type of circuit goes out, then all the lights will go out.
- Electronic devices can also be connected in parallel. When one light in parallel goes out, the others still stay on.
- The rate that energy is changed from electrical energy to other types of energy (like light) depends on how quickly the charges are moving (current) and how much energy per particle (voltage) is used by the device. LEDs connected in parallel are brighter because they have a higher current.



LED tile, battery clip with wire leads, and wire with alligator clips

Materials (per group):

- 1 battery (9V)
- 1 battery clip with wire leads
- 2 LED tiles (1 LED and 1 resistor connected in series with two screws or nails on either end, to which alligator clips can be connected)
- 4-8 wires with alligator clips
- Other tiles (e.g. motor, switch, resistor) or materials (e.g. paper clips, bottle caps) depending on level of students



Tile with a switch on it. The switch has three leads.

Materials (per class):

- Balls (1 per student, plus spares)
- 2 chairs or stools

Safety:

- Keep the batteries stored in the boxes, detached from the battery clips.
- The resistor may get warm. Ask students to disconnect the battery from the circuit when not in use.

Experiment 1: Can you light the LED?

1. **Engage:** Provide students with a battery in a battery holder and an LED tile. Ask students how they can get the LED to light up. What types of energy are involved? Is energy being transferred between different types of energy?
    a. Tell students safety information:
        i. NEVER connect the two wires from the battery to each other.
        ii. Electricity can be very dangerous - always ask an adult before you try any experiments at home.
2. **Explore:** Let students try different methods, and ask them to write down what they try and what they observed.
3. **Explain:** Ask students what worked and what didn't work.
    a. Explain that energy stored in the battery is transferred to electrical energy when the wires are connected, and then transferred to light energy by the LED. Explain that this only happens if the wires form a complete circuit, and ask if students have any ideas why. Write down the ideas on the board.
    b. Explain that LEDs have a positive and negative side, just like a battery, so they need to be placed in the right orientation to work. The + sign written on one tile should be connected to a - sign on another tile.

Note: common misconceptions at this age level (see reference [1])

- Only one wire is needed to connect the battery to the LED
- Current is "used up" by the LED

- Current leaves from both ends of the battery and meets at the LED in the middle

Model: How does a circuit work?

Use role-play to explain how circuits work:

- Have students stand in a circle. Ask for one volunteer to represent the light and one volunteer to represent the battery (or have the facilitator play one of the roles). The students that represent the battery and light should sit on the stools or chairs. The students on one side between the battery and the light will stand, while the others will sit on the floor. The standing students represent the wire attached to the higher voltage side of the battery, and the ones sitting will represent the wire attached to the lower voltage side of the battery.
- Hand each student a ball and explain that this represents the charges that flow through the circuit. Ask students if they know what electrons are. Explain that electrons are charged particles that are present in *all* materials, but they move around most easily in metals.
    - Check understanding by asking students why some materials conduct electricity but some do not. (Answer: metals conduct electricity because electrons move easily.)
- Explain that each student represents a part of the circuit: either part of the wire, the light, or the battery.
    - The battery is in charge of pushing the electrons through the circuit - it provides the force. When the person representing the battery says go, everyone passes the balls around the circuit. (The battery should pass the balls toward the higher voltage side.)
    - The wires allow charges to flow from one place to another easily. The people who represent pieces of the wire will pass one ball, while taking the next one. There is (almost) no transformation of energy as the particles move along the wire.
    - The light changes electrical energy to light energy. The height of the ball as it is passed to the person representing the light represents the energy that must be given to the ball by the battery. When the person then lowers the ball to pass to the next person, this represents the energy that is changed into light.

Before moving to the next experiment, define the terms “circuit”, “current”, and “voltage”:

- *Circuit*: a closed path that electricity can flow through
- *Current*: the flow of charged particles
- *Voltage*: The stored energy for each charged particle.

Experiment 2: LEDs in series

1. **Engage:** Ask students to predict how the brightness would change if they connect two LEDs one after the other in a loop with the battery.

    a. You may need to draw a picture on the board to show what you mean. Connect back to the model you made earlier using the balls.
2. **Explore:** Have them test their ideas. Ask them to describe what's happening.
    a. Once they correctly connect a series circuit, ask them what would happen if one of the lights burnt out. (Have them simulate this by unplugging one of the lights.)
3. **Explain:** Tell students that they just created a circuit with 2 LEDS *in series* and explain what this means.
    a. Explain that LEDs are a type of light that have a set voltage (energy per particle). If the battery's voltage is too low, then it will not light up the LED at all! Each of the LEDs on the tiles is connected to a resistor, a device that uses up any extra voltage to protect the LED - if you connected the battery to an LED without a resistor to protect it, then the LED could burn out!
    b. Explain that a resistor is a device that has a lower current when there is a lower voltage.
    c. Each LED has a set voltage, but in the series circuit, there are two resistors which cause the current to be slower because the voltage from the battery has to be divided up between all the parts of the circuit. (Remember that lower voltage means lower current for the resistors.) This means the speed of the particles passing through each LED is lower than it was for just one LED, and so it emits less light.
    d. If one light in a series circuit breaks, then all the lights will go out because the circuit is no longer completed.

Experiment 3: LEDs in parallel

1. **Engage:**
    a. Based on what they discovered in Experiment 2, ask students if they think all the electronic devices in their home are connected in a series circuit and why.
        i. Sample answer: it can't be in series because if a light bulb burns out, they can still use other devices, like the microwave or TV
    b. Ask if they can think of another ways to set up a circuit so that both LEDs will light up at the same time.
        i. Draw student ideas on the board. Have them test their ideas.
        ii. If students did not come up with a parallel circuit, draw this on the board, and ask if they think it would work.
2. **Explain:** Tell students that they just created a circuit with 2 LEDS *in parallel* and explain what this means.
    a. In the parallel circuit, each of the tiles gets the same voltage as the battery! Since the voltage isn't split between as many components as the series circuit, the current through each LED is greater due to the resistors. So even though the voltage (energy per particle) is the same as before, the particles are moving faster, so the amount of energy used over time is increased. This means that both the LEDs will light up, and will be brighter than the series circuit!

Extend

Ideas to extend this activity:

- Have students explore what materials conduct electricity:
  - Connect one end of the battery to an LED tile. Connect a material between the other end of the battery and the other end of the LED tile.
  - Ideas for materials: paper clips, bottle caps, popsicle sticks
- Give students a switch tile, and have them figure out how it works.
- Give students a motor tile. Talk about how electrical energy is converted to motion energy, and challenge students to change the speed of the motor.
- Do the light-up art extension (below)

Art extension: light up sculptures or jewelry

Learning goal: Students use what they know about circuits to create a piece of light-up art using LEDs and coin cell batteries.

Materials (per student)

- 1 flat (coin-cell) battery
- LEDs (can use several, but must all be the same color)
- Wires
- Electrical tape
- Clothes pin (to act as a switch -- wrap wires around ends of clothes pin, then clip onto battery to turn on (see “circuit bugs” reference))
- Art supplies (construction paper, markers, pipe cleaners, craft sticks, googly eyes, glue, glitter, stickers, etc.)
- Scissors (to cut electrical tape and art supplies)

Materials for the facilitator:

- Wire cutter/stripper
- Wires with alligator clips (for demonstration purposes, see “notes and tips”)

Safety:

- Do not clip an alligator clip around the coin cell battery.

Lesson plan:

1. Tell students that they will put their knowledge of circuits to the test by making a piece of art that lights up. **For the summer camp:** Tell students that they will present their art projects at the showcase on Friday!
   a. Show them an example. Tell them that they can do something similar, or use their imaginations to make something completely different.

2. Explain that the terminals of the coin cell battery are the flat top and bottom. Since these have a lower voltage than the batteries they used before, the LEDs do not need resistors to protect them.
    a. DO NOT connect an alligator clip around the battery! (This would create a short circuit.)
3. Show students how they can use the clothes pin as a switch for their art piece.

Notes and tips:

- Ask students if they are planning to use a series or parallel circuit and why.
    - They should ultimately choose a parallel circuit based on the experiments they did earlier, but if they don't come to that conclusion on their own, help them use the alligator clips to connect two LEDs in series, then to the battery to see that one coin cell battery does not have enough voltage to light two LEDs at once.
- The voltage of the LED depends on its color, and because there are no resistors being used in these circuits, the student will have to choose just one color of LED to use. If two different colored LEDs are placed in parallel in the same circuit, only the one with the lower voltage will light up. (This is because the two voltage drops must be the same in a parallel circuit, but the lower voltage of the two LEDs is not strong enough to light up the higher-voltage LED.)
- Have students check all LEDs before getting started to make sure they work. (The coin battery does not have a high enough voltage to burn out the LEDs, so you can just stick the coin in between the two leads of the LED.)
- To connect wires to the LEDs: strip the insulation off the end of the wire. Twist the filaments together, then twirl around one of the leads of the LED. Repeat for the other lead of the LED.
- Use the battery to check that each LED still works (indicating that the electrical connection between the LED lead and the wire is good.) Remember which are positive and negative wires for each LED! (It may help to twist all positive terminals together.)

References:

[1] Common misconceptions
[2] Circuit bugs
[3] Sewing circuits

Acknowledgements

This module was created by Ashley DaSilva.

Appendix: constructing the tiles

To construct the tiles:

1. Cut lengths of wire to connect the device to the screws. Use as many leads as necessary for the device.
2. Strip the ends of the wire leads (both ends). Twist the ends of multiple-filament wire to help them stay together.
3. Twist the end of each wire lead around the end of the device to make a connection to the device.
4. Glue the device onto the center of the tile. Attach enough screws upside-down onto the tile so that each lead can be attached to a screw.
5. Twist the opposite end of each lead wire onto the screw. Attach a nut to hold it in place.

Alligator clips were attached to the leads of the 9V battery clips to make it easier to connect the battery.