Teacher Guide: Circuit Builder

Learning Objectives

Students will:

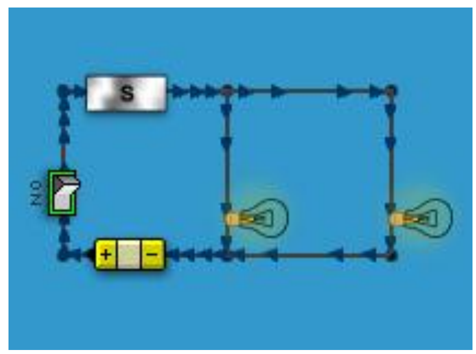
- Determine how to light a light bulb with a battery and wires.
- Classify materials as conductors or insulators.
- Compare the properties of series circuits and parallel circuits.
- Observe the effect of voltage on current.
- Explain how a fuse can prevent short circuits.

Vocabulary

circuit, closed circuit, conductor, current, fuse, insulator, open circuit, parallel circuit, series circuit, short circuit

Lesson Overview

The *Circuit Builder* Gizmo™ allows students to build a wide variety of circuits on a 5-by-4 pegboard. Components include wires, light bulbs, batteries, fuses, and nine test materials.



One of millions of circuits that can be built in the *Circuit Builder* Gizmo

The Student Exploration contains three activities:

- Activity A – Students determine which materials will complete a circuit.
- Activity B – Students investigate series circuits.
- Activity C – Students investigate parallel circuits and short circuits.

Suggested Lesson Sequence

1. **Pre-Gizmo activity: Can you light a light bulb?** (15 – 30 minutes)
   Separate your students into groups. Each group gets a battery, a small light bulb (such as a flashlight bulb), and several wires. (Use insulated wires that are stripped at each end so that about 1 cm of wire is exposed.) The challenge is to make the light bulb shine. When students have figured it out, discuss what was required for the bulb to light.

2. **Prior to using the Gizmo** (10 – 15 minutes)
   Before students are at the computers, pass out the Student Explorations and ask students to complete the Prior Knowledge Questions. Discuss student answers as a class, but do not provide correct answers at this point. Afterwards, if possible, use a projector to introduce the Gizmo and demonstrate its basic operations.

3. **Gizmo activities** (10 – 15 minutes per activity)
   Assign students to computers. Students can work individually or in small groups. Ask students to work through the activities in the Student Exploration using the Gizmo. Alternatively, you can use a projector and do the Exploration as a teacher-led activity.

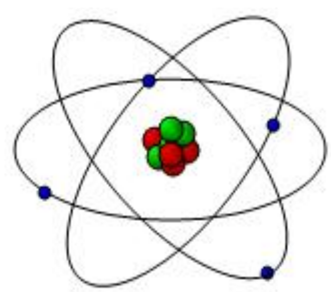
4. **Discussion questions** (15 – 30 minutes)
As students are working or just after they are done, discuss the following questions:

- What must be true of a circuit for charge to flow?
- What kinds of materials tend to be conductors? Insulators?
- What happens when one bulb is added to a series circuit? Parallel circuit?
- What happens when one bulb is removed from a series circuit? Parallel circuit?
- How does a fuse help prevent short circuits?

5. **Follow-up activity: Electricity activities** (45 – 90 minutes)
A wide variety of circuits experiments can be done with simple materials: AA and 9-volt batteries (battery holders optional but very useful), insulated wire, alligator clips, light bulbs, small motors, and electrical tape. Here are some experiments to try:

- Build an open circuit, and then test a variety of materials to see which ones will conduct electricity and complete the circuit. Besides metals, conductors include pencil leads (actually made of graphite), salt water, and acids such as vinegar.
- Create an electromagnet by wrapping a wire around an iron nail, then connecting the ends of the wire to a 9-volt battery. Try to pick up small objects like paper clips with your magnet.
- Build parallel and series circuits. Compare the brightness of light bulbs in each circuit. Try to determine which type of circuit will drain a battery more quickly (advanced). Discuss advantages and disadvantages of parallel versus series circuits.
- Make fuses from steel wool and other materials. (Note: Goggles are required. Fuses heat up and should not be touched. See **Web resources**.)

Scientific Background



To understand electrical current, consider the structure of an atom. Atoms consist of three types of particles: **protons** (red) and **neutrons** (green) inside the nucleus, **electrons** (blue) outside the nucleus. Protons are positively charged and electrons are negatively charged. Positively charged objects are attracted to negatively charged objects, and vice versa. Positively charged objects are repelled by other positively charged objects, and there is also repulsion between negatively charged objects.

Some atoms hold on to their electrons tightly. Other atoms lose their electrons easily. Within a metal, many electrons float among the atoms, free to move one way or another. When no outside charge is present, electrons will move randomly. But if a charge is placed on one side, the electrons will either drift toward a positive charge or away from a negative charge. This net flow of charge is called **current**. By convention, current is usually shown moving from the positive terminal of a battery to the negative. This is opposite the actual movement of electrons. (This convention was established by Benjamin Franklin, long before the discovery of electrons.) The *Circuit Builder* Gizmo allows the user to view either conventional current (positive to negative) or electron flow (negative to positive).

As electrons move through a wire, they cause the wire to heat up. In a typical light bulb, a thin wire called a **filament** heats up to temperatures over 2000°C (3600°F), causing it to glow white-hot. Current also produces a magnetic field, which can be used for many applications.

A **battery** is a device that uses a chemical reaction to produce current. Batteries usually consist of two kinds of metals and an acid. On the **negative terminal** of the battery, the acid reacts with one of the metals. The reaction produces positively charged **ions** and electrons. When a wire is connected to the battery, electrons from the wire react with the ions on the **positive terminal** of the battery. This creates a net flow of electrons from the wire to the positive terminal, and a flow of electrons from the negative terminal to the wire. (Individual electrons move slowly within the wire from one terminal to the other.)

The **voltage** of a battery describes the potential energy difference between electrons on one terminal and those on the other. The current in each segment of a circuit is determined by the voltage across that segment and the **resistance** within the segment. Items such as light bulbs or motors reduce the flow of electrons as they use the electric current. For this reason they are called **resistors**. Current can be increased by increasing voltage or decreasing resistance. In a **short circuit** there is almost no resistance, and current is dangerously high.

In a **series circuit**, the total resistance increases as you add light bulbs. Adding light bulbs to a series circuit will cause the others to dim. But in a **parallel circuit**, the overall resistance actually *decreases* when you add more bulbs because you are giving the current more paths to take, like opening up a new lane on a highway. Adding new bulbs won't affect the other bulbs because the voltage will be the same across each branch of the circuit. The downside to parallel circuits is that they will drain the battery much more quickly than an equivalent series circuit.

Technology Connection

Typical light bulbs are also known as **incandescent** light bulbs. Incandescent bulbs are not very efficient because they produce so much heat. An alternative to an incandescent bulb is a **compact fluorescent lamp** (CFL). A flourescent bulb contains a gas-filled tube, coated in phosphor. When an electric current passes through the tube, the gas emits ultraviolet light (which is not visible). The ultraviolet light then stimulates the phosphor coating to emit white light. A CFL uses less than half the energy of a comparable incandescent bulb. Using less energy saves money and helps the environment as well. See the **Selected Web Resources** for more energy-saving ideas.

Compact fluorescent bulb

Selected Web Resources

Electricity for kids: http://scifiles.larc.nasa.gov/text/kids/D_Lab/acts_electric.html
Electricity activities: http://www.exploratorium.edu/snacks/iconelectricity
Fuse activity: http://www3.nsta.org/main/news/pdf/ss0002_28.pdf
Electrical circuits simulation: http://www.andythelwell.com/blobz/
Current basics: http://www.glenbrook.k12.il.us/gbssci/phys/Class/circuits/u9l2c.html
How batteries work: http://sxxz.blogspot.com/2005/03/how-do-batteries-work.html
Electricity misconceptions: http://amasci.com/miscon/eleca.html#frkel
Energy story: http://www.energyquest.ca.gov/story/index.html#table
Energy conservation tips: http://www.climatecrisis.net/takeaction/whatyoucando/index.html