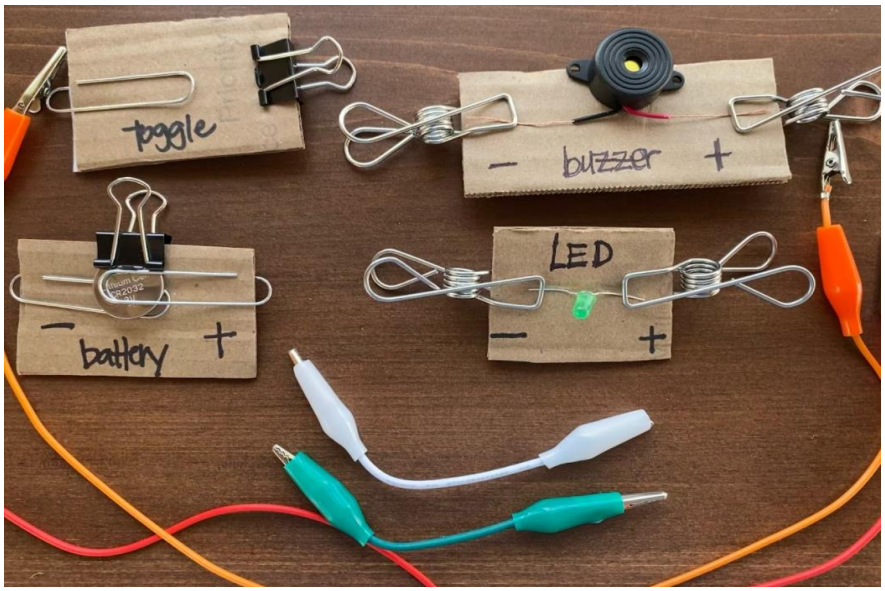
Teacher Lesson

Scrappy Circuits

Scrappy Circuits by Michael Carroll are an inventive "do-it-yourself" way to learn about electrical circuits. Circuits are made with pieces of cardboard and simple electronic items like LED lights, coin cell batteries, paper clips and metal clothespins. These circuit components or “bricks” can be experimented with in a variety of ways or you can have students build each circuit and answer corresponding questions on the student worksheet. Additional details and instructional videos can be viewed on the *Scrappy Circuits* website. Page numbers are referenced if using the book, *Scrappy Circuits*.

Note: The *Scrappy Circuits* website/book starts by dissecting a tealight for parts to use in building the primary bricks. However, the supplies from OEP will be sent as individual pieces as shown in the picture. OEP substituted the binder clips with metal clothespins to avoid having to sand down regular binder clips as described on page 10 of *Scrappy Circuits*.



SUPPLIES:

- Metal clothespins
- Binder clips
- Metal (uncoated) paper clips
- LED lights
- Coin (Button) Cell Batteries (CR2032)
- Alligator clips
- Buzzers
- Wirecutter/stripper
- Scissors

Not Included:

- Cardboard, Markers

ELECTRICITY & CIRCUITS BACKGROUND INFORMATION:

Electricity is moving electrons

- Atoms are the building blocks of the universe. Electrons are tiny particles found in atoms.
- The center of an atom is called the nucleus, made of particles called protons and neutrons.
- Electrons are constantly spinning and moving in levels around the nucleus.
- Electricity is a secondary source of energy. It can be transformed from other forms such as coal, petroleum, natural gas, biomass, and nuclear energy. Moving wind and water, as well as the heat from geothermal energy, can power a generator to produce electricity. Photovoltaic cells transform light energy from the sun to electricity.

Circuits

- Electrons flowing through a wire make a complete path called a circuit.
- A battery produces electricity, but only when it is part of a circuit.
- A battery produces direct current (DC).
- Direct current is different from alternating current (AC). AC is how we receive electricity in our homes and schools through the grid.
- When a switch is open no electricity flows or makes a complete path. When a circuit is closed, electrons can flow freely.
- Different materials are conductors of electricity. Silver is the best electricity conductor, but it isn't widely used due to its cost. Copper is the metal used in most homes' electrical systems.
- Some materials do not conduct electricity or resist the flow of electricity. These are called insulators.
- A series circuit is defined as having only one path through which electrical current can flow.
- A parallel circuit is defined as having more than one path through which electrical current can flow.

INTRODUCING THE COMPONENTS:

It is likely the components used in Scrappy Circuits will be new to students. Before students dive into brick building, it may be helpful to allow the students time to explore the parts they will be using. An expanded version of the chart below is included on the student worksheet.

Part	**I notice…**	**I wonder…**	**I learned…**
Battery			
LED			
Buzzer			
Alligator Clips			

BUILDING THE CORE BRICKS:

Below are pictures of the primary bricks students will need for the projects on the student worksheet.

Battery Brick (pages 12-13 & 18-19 of *Scrappy Circuits*)

The power source for the circuits is a 3-volt coin cell battery. Take note of the two sides of the battery. The positive side is smooth and is marked with a + sign. The negative side is not labeled.

Supplies Needed:

- CR2032 coin battery
- Two paper clips
- Cardboard
- Marker
- Binder Clip (optional)

Scrappy Circuits use binder clips instead of paper clips. If you choose to build them this way, you may need to sand the binder clips to increase conductivity.

Cut a square of cardboard. Position the battery between the two paper clips. Be sure you are using the long part of the paper clip.
Label the brick with the +/- sides. The negative side touches the bottom paperclip. The positive side touches the top paperclip.

It may be helpful to secure the brick with a binder clip as shown in the picture. The binder clip is not part of the circuit, it just holds the battery in place securely as students are building their circuits.

The back of the battery brick is important too. You want to make sure the paper clips are NOT touching on the back. That is why it is important to use the longer parts of the paper clip on the front.

If you are using a binder clip to secure the batter as pictured, the binder clip can not touch either paper clip on the front or the back.

LED Brick (pages 13-14 & 20-21 of *Scrappy Circuits*)

LED stands for Light Emitting Diode. A diode is a semiconductor that allows electricity to flow in only one direction. Included here are a few basics about the 5mm LED lamps included in your supplies.

- A diode is a semiconductor that allows electricity to flow in only ONE direction. A diode is like a valve for electric current, it can only flow one way through the diode. Think of the electricity like a car traveling on a one-way street.
- Since LEDs conduct current in one direction, you need to know which way to connect the LED light in your circuit.
- The positive (longer) leg of the LED must connect to the positive terminal of the battery, so circuits must be arranged so the same signs are connected, positive to positive and negative to negative. This is different from how batteries work! (page 13 of *Scrappy Circuits*)

Supplies Needed:

- LED
- Two metal clothespins
- Cardboard
- Marker

Scrappy Circuits uses binder clips instead of metal clothespins. If you choose to build them this way, you may need to sand the binder clips and add aluminum foil to the LED legs to increase conductivity.

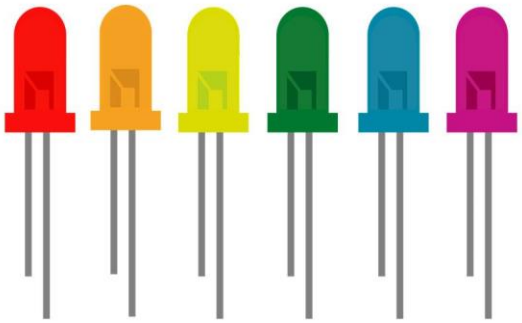
Cut a square of cardboard. Bend the LED legs and secure each one with a metal clothespin. Label the +/- legs with a marker.

Want to know more about LEDs? See the full blog article at *LED Supply: How Does a 5mm LED Work?*

> 5mm LEDs are super helpful as they can easily be powered from a small battery source and last a long time. This makes it simple to incorporate them in many electronics or put lights where they normally could not go. The name 5mm LED is dubbed from their dimensions: the epoxy case on top is about 5mm in diameter. These super small light sources are simple to use, but we can't overlook certain steps in setting up our LED circuit.
>
> An LED is a variant of the basic diode. A Diode is an electronic component that only conducts electricity in one direction. Diodes have what is called a forward voltage rating which determines the minimum voltage difference between the Anode (+) and Cathode (-) in order to allow electrons to flow (ahhh..sweet electricity). An LED is basically the same as a Diode, with the key difference being it generates light when the electricity flows.

5mm LEDs are a type of LED that hold the die on an anvil post that is encased in an epoxy dome for protection. Connections are then made via the two legs or prongs that come out of the bottom. As we mentioned, a diode only allows flow in one direction. This makes it crucial to differentiate between the positive side (the Anode) and the negative side (the Cathode). With 5mm LEDs it is easy, notice that the legs are different lengths? The longer leg is the Anode and the shorter of the two is the Cathode.

Each LED should list a 'Forward Voltage' that defines the amount of voltage required in order to conduct electricity and produce light. If you try to supply anything less than this amount the LED will remain open and non-conductive.
Once the voltage dropped across an LED reaches the forward voltage, your LED will light up. If you have multiple LEDs in series, you must account for the sum of their forward voltage ratings.



What does all this mean as you build Scrappy Circuits?
There are three important things to remember:

1. The long leg of the LED is the positive side. The shorter end is the negative leg. Be sure to label these on your bricks. Once the bricks are built, it is hard to tell which leg is longer.
2. Since electricity only flows in one direction across a diode, the LED will only emit light when the positive end of the LED is connected to the positive terminal of the coin battery.
3. Forward Voltage is a concept beyond the 4th grade standards, however, it is important to understand its impact as your students are building their circuits.
    - In a series circuit with more than one LED, each LED must have an accompanying battery.
    - In a parallel circuit with more than one LED, the LED color is important. Blue, green and white LEDs work together. Red and yellow LEDs work together. However, in parallel a blue/green/white lamp and red/yellow lamp will not work in the same circuit. Pictures of these projects will be shown below.

Toggle/Binder Clip Switch Brick (page 22 of *Scrappy Circuits*)
This is the simplest switch to use with Scrappy Circuits. Toggle switches are also common in the real world. A light switch is an example of a toggle switch. Lights go on (and stay on) when you flip the switch. When the switch is flipped back, the lights go off.

Supplies:

- Binder clip
- Paper clip
- Cardboard

Toggle switch in the off position

Toggle switch in the on position

Flip the binder clip down to connect with the paper clip.

Want to explore other switches? *Scrappy Circuits* devotes an entire chapter to different switches starting on page 65.

Buzzer Brick (pages 51-52 & 55 of *Scrappy Circuits*)

Using a piezo buzzer, you can add sound to your circuits. A piezo buzzer has polarity and electricity will only flow in a single direction. The red wire is the positive lead and the black wire is the negative lead.

Supplies:

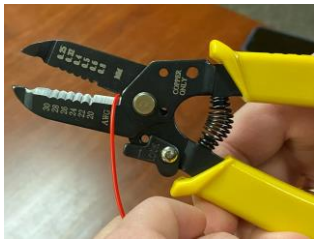
- Piezo buzzer
- Wirecutter/stripper
- Two metal clothespins
- Brads (optional)
- Cardboard
- Marker

The buzzer has long leads, so you may want to cut them shorter to make this brick. It is also helpful to strip the ends so a longer portion of the wire is exposed. Connect the wires to the cardboard with the metal clothespins. Label the red wire + and the black wire -.

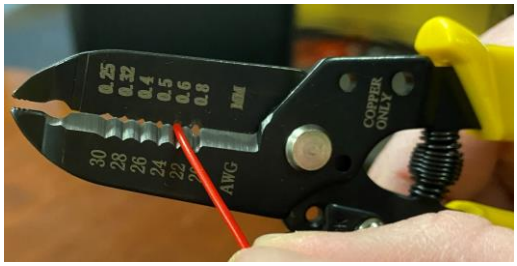
Optional: Attach the buzzer to the cardboard using brads. This will make the brick more secure as students build the circuits.

How to Cut/Strip the Buzzer Wire

If you aren't familiar with using wire cutters, follow these instructions. You may want to practice by cutting the wires a little longer than you intend to use.

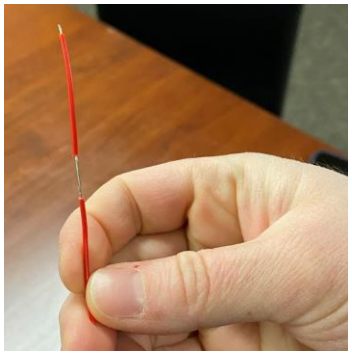


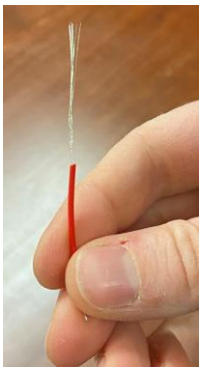
1. Cut the wire to the desired length. Put the wire all the way into the wire cutter, like a pair of scissors. You want to leave enough of the insulation visible so students can easily see the red/black ends since this is how they identify the +/- sides of the buzzer.



2. Insert the wire in the 22 awg/0.6mm slot and close the handles. This will cut through the insulation on the wire, without cutting the wire all the way through. If needed, you may need to rotate the wire in the slot. A quarter turn in each direction should be enough.

3. Pull the insulation to the cut end of the wire to fully remove the insulation.





BUILDING CIRCUITS:

Great work brick building! Now it's time to start creating circuits.

Supplies:

- Core Bricks
- Alligator Clips

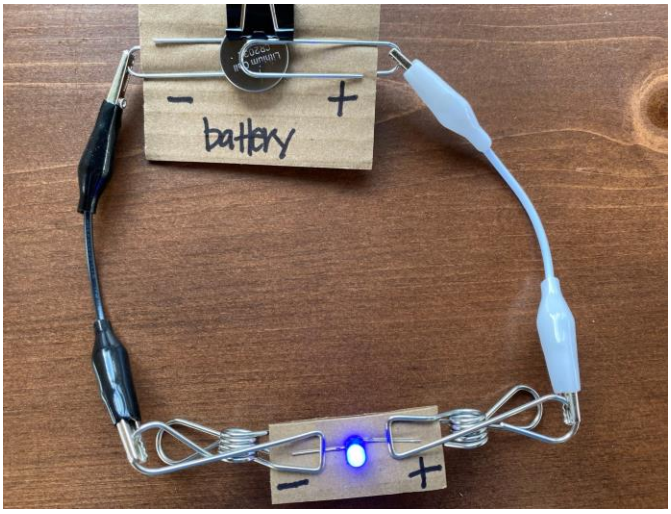
The book *Scrappy Circuits* gives other options for connecting clips on pages 29-31. The simplest scrappy clip is to fold/twist aluminum foil into a wire. However, the reliability can greatly vary based on construction. Alligator clips are the most reliable conducting clips and are the best place to start. After your students are familiar with the circuit structure, they can begin inventing other connecting clips.

The six projects recommended are based on Ohio's 4th Grade Learning Content Standards and are the basis of the accompanying student worksheet.

Project 1: LED Light and Battery

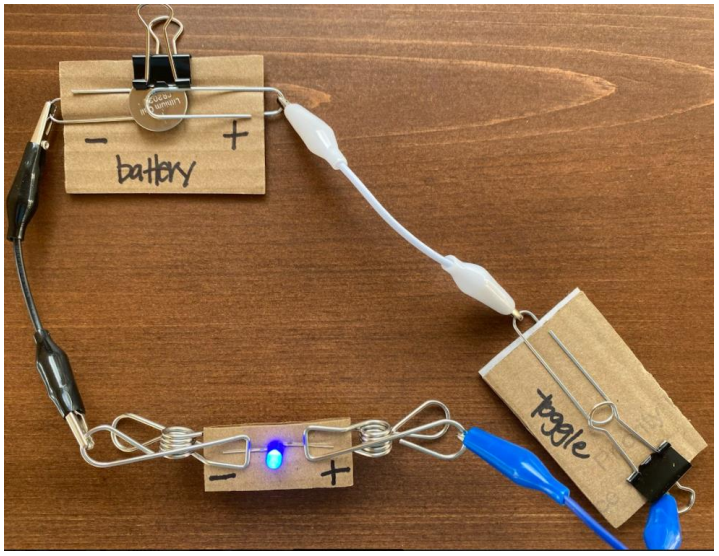
Using alligator clips, connect the positive side of the battery to the positive side of the LED.

What happens if the negative side of the LED is connected to the positive side of the battery?



Project 2: LED Light, Battery and Switch

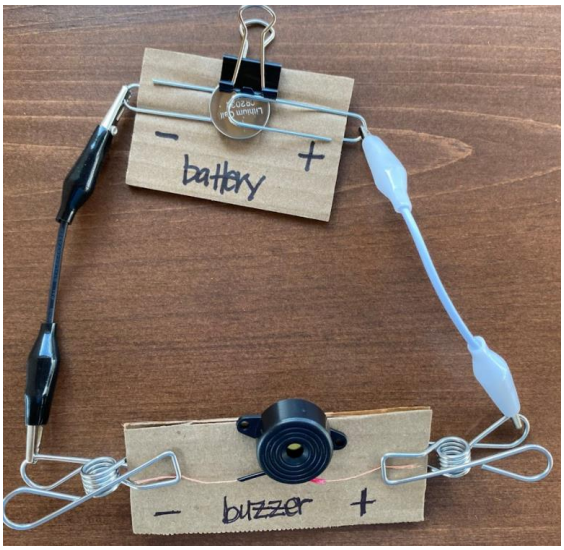
Use the same circuit as in Project 1, but add a toggle switch. Turn the light on and off.



Project 3: Buzzer and Battery

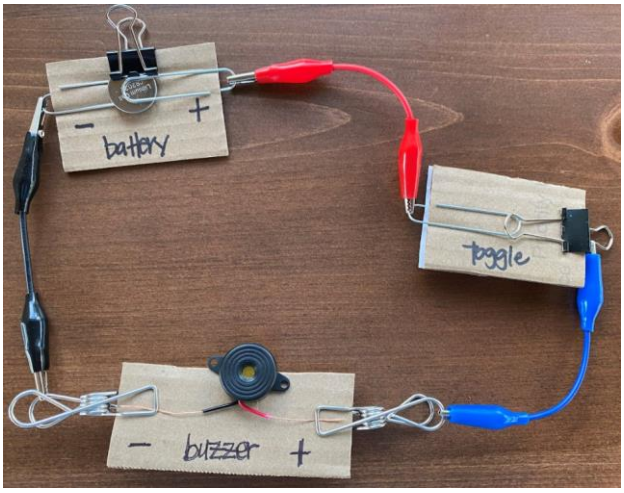
Using alligator clips, connect the positive side of the battery to the positive side of the buzzer.

What happens if the negative side of the buzzer is connected to the positive side of the battery?

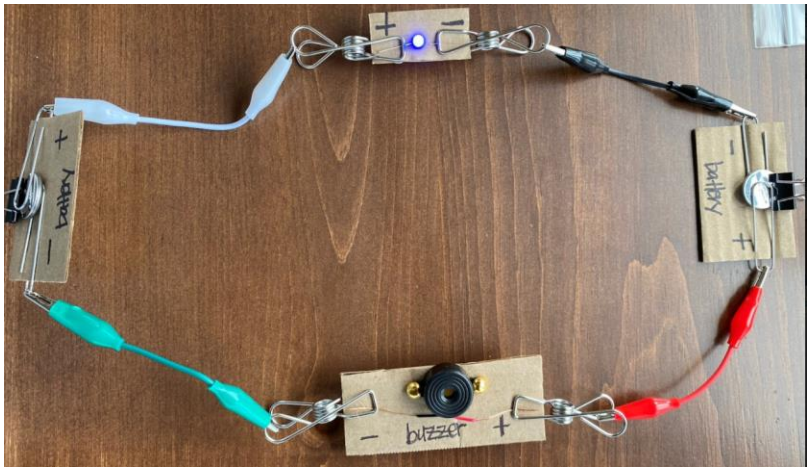


Project 4: Buzzer, Battery and Switch

Use the same circuit as in Project 3, but add a toggle switch. Turn the buzzer on and off.



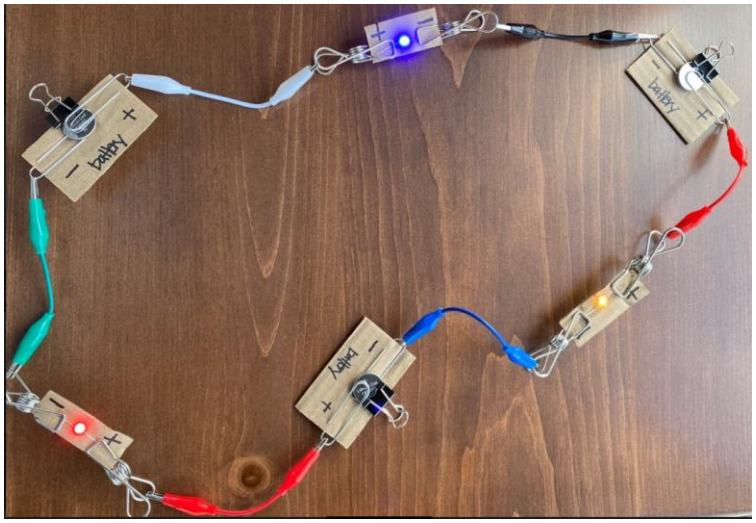
Project 5: Series Circuits



LED, Buzzer and Batteries in Series

In series circuits, each load (LED or buzzer) requires a battery. Remember both the LED and buzzer require the positive side of the load to be connected to the positive side of the battery.

What happens if you disconnect the circuit at any point? All lights/buzzers will go off since there is a single path for the electricity to flow.



Three (or more) LED's in Series

Connect LEDs in the same manner as the LED/buzzer combo. Each LED will be connected to a battery.

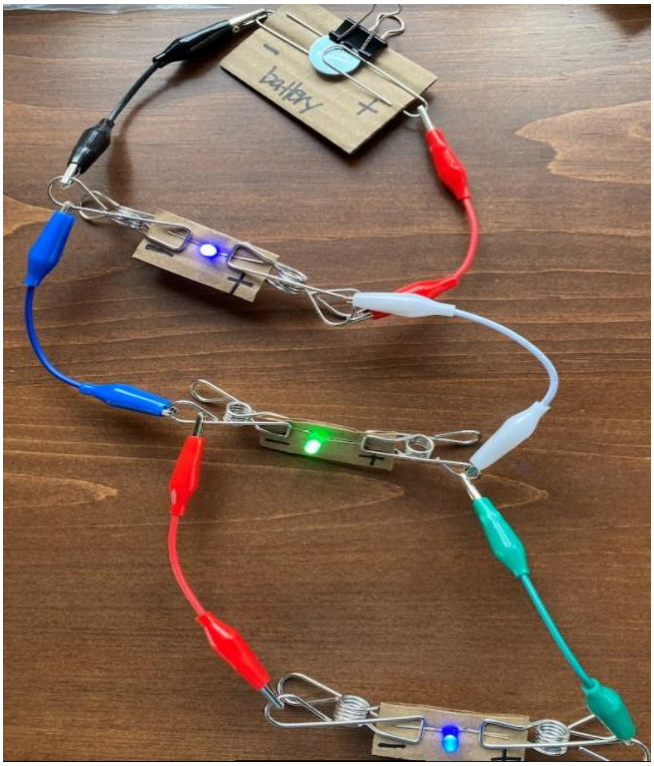
In series, the color of the LED is not important.

Project 6: Parallel Circuits

Two (or more) LED's in Parallel

A single battery will power multiple LEDs in a parallel circuit. However, this is when the color of the LED lights is a factor. (Remember forward voltage?)

In parallel, red and yellow will work together and blue and green will work together.



Do your students love Scrappy Circuits? To see other brick and circuit options, refer to the provided text, *Scrappy Circuits,* by Michael Carroll. Additional resources and videos can be found at scrappycircuits.com.