WINTHROP UNIVERSITY | Instructional Technology Center
www.winthrop.edu/itc

Electronic Circuits

How to Make a Paper Circuit

What is a Circuit? A circuit is a **closed loop** through which charges can continually move. Charges run from positive to negative. In this activity, a circuit is made using copper tape to create a loop. Copper tape is **conductive**, which means electricity can freely travel within it. Water and most metals are considered conductive. Plastic, rubber, and wood are non-conductive materials. In this circuit, a battery will provide a charge, and the charge will follow the path made by the copper tape to light up a LED light. The path must be a closed loop between the battery and the LED light in order to work.

Materials

- Copper tape
- 3V coin cell battery
- Surface mount LED lights
- Card stock (8 ½ x 5 ½)
- Scissors
- Tape
- Pencil
- Ruler (optional)
- Marker

Procedure

1. Choose one corner and measure 3 ½ inches from each edge. Make a mark at each place, then fold over the corner of the construction paper at those marks to make a triangle.

2. Unfold the corner.

3. Place the battery in the folded section and trace the outline of the battery with a pencil.

4. Fold the corner a second time and use your pencil to scribble on top of the fold.

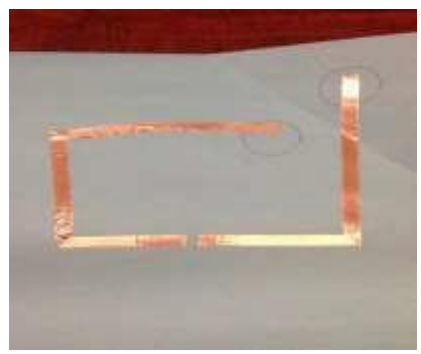
5. Unfold the corner again and trace the outline of the circle on the paper to make it darker.

Created by Anna Brenner, Joyce Camp, Ryan Loyst, and Lauren Seborowski- updated August 2018

6. Starting inside the circle in the top of the fold, place your copper tape in a straight 3-4 inch line moving along the short edge of the paper. Without tearing or cutting the tape, fold it to a corner and tape another 2-3 inches. Use your ruler to measure the distances.

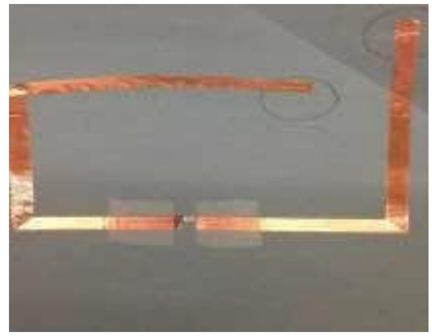
7. Leaving a small (1mm) gap, place another piece of copper tape following the long edge of the paper for 2 inches. Without tearing or cutting the tape, fold it to a corner and tape another 3-4 inches up the side of the paper.

8. Continue placing down the copper tape until it is the desired shape. End the tape before making a complete circuit. The tape should end inside the circle on the paper where the battery will sit.

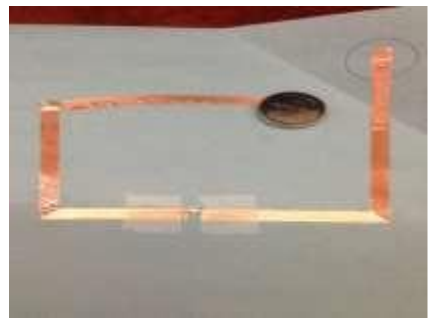


9. Choose an LED light. Look carefully to see which anode leg is shorter and mark it with a dark marker. This is the negative side. Then open the anodes straight across.

10. Place the LED over the gap in the copper tape with the long anode facing to the right, and the short anode facing left, then tape down the anodes on each side to secure them.



11. Place the battery negative side down on the battery circle located on the paper. The (+) sign should be facing up. (Remember that circuits flow from positive to negative)



12. Finally, close the circuit by folding the corner piece down over the battery and LED will light up!

*If your light did not light up, try flipping the battery over, and then pressing the corner down again. Remember; charges flow in a circuit from positive to negative.

Modifications/Suggested Lesson Plans

This lesson can be used to explain basic circuitry and the flow of electricity. Use of the ruler incorporates measurement and precision when students are creating their circuits. Students could also find the perimeter or area of their circuits. It can also be used in conjunction with Geometry or lessons about shapes, as students can design their circuits in more elaborate patterns or shapes and see how the flow of electricity is affected by these changes. Students can also build circuits and cover them in art in the shape of famous buildings and monuments. Students could also create collages of their portrait with circuitry hidden underneath. For more ideas and resources, check out these websites:

http://tinkering.exploratorium.edu/paper-circuits

https://www.makerspaces.com/paper-circuits/

http://www.sciencebuddies.org/science-fair-projects/project-ideas/Elec_p073/electricity-electronics/squishy-circuits-project-1

Created by Anna Brenner, Joyce Camp, Ryan Loyst, and Lauren Seborowski- updated August 2018

South Carolina Academic Standards and Performance Indicators

Science:

3.P.3A.2 Develop and use models to describe the path of an electric current in a complete simple circuit as it accomplishes a task (such as lighting a bulb or making a sound).

3.P.3A.3 Analyze and interpret data from observations and investigations to classify different materials as either an insulator or conductor of electricity.

6.P.3A.1 Analyze and interpret data to describe the properties and compare sources of different forms of energy (including mechanical, electrical, chemical, radiant, and thermal).

6.P.3A.3 Construct explanations for how energy is conserved as it is transferred and transformed in electrical circuits.

6.P.3A.4 Develop and use models to exemplify how magnetic fields produced by electrical energy flow in a circuit is interrelated in electromagnets, generators, and simple electrical motors.

Mathematics:

K.G.5 Draw two-dimensional shapes (i.e., square, rectangle, triangle, hexagon, and circle) and create models of three-dimensional shapes (i.e., cone, cube, cylinder, and sphere).

K.MDA.1 Identify measurable attributes (length, weight) of an object.

1.G.4 Identify and name two-dimensional shapes (i.e., square, rectangle, triangle, hexagon, rhombus, trapezoid, and circle).

2.G.1 Identify triangles, quadrilaterals, hexagons, and cubes. Recognize and draw shapes having specified attributes, such as a given number of angles or a given number of equal faces.

2.MDA.1 Select and use appropriate tools (e.g., rulers, yardsticks, meter sticks, measuring tapes) to measure the length of an object.

2.MDA.3 Estimate and measure length/distance in customary units (i.e., inch, foot, yard) and metric units (i.e., centimeter, meter).

4.G.1 Draw points, lines, line segments, rays, angles (i.e., right, acute, obtuse), and parallel and perpendicular lines. Identify these in two-dimensional figures.

4.MDA.3 Apply the area and perimeter formulas for rectangles.

5.MDA.4 Differentiate among perimeter, area and volume and identify which application is appropriate for a given situation.

Circuit Scribe

Circuit Scribe is an invention similar to littleBits, but the wiring that connects the modules is created by drawing lines on paper with a special pen filled with conductive ink. Circuit Scribe helps students learn basic circuitry while also employing their artistic talents. It also enables students with a limited understanding of digital electronics to participate in creating circuits.

The modules included in a Circuit Scribe set work best when placed on a metal surface because their positive and negative connection points are magnetic. There are some magnetic plates available in the ITC that double as infographics. These infographics explain the different modules available from the ElectronInks, and also offer tips on how to use the equipment.

Autodesk is creating a site that would allow you to create your own templates for Circuit Scribe circuits. Visit this link to sign up for more information. http://www.123dapp.com/circuitscribe

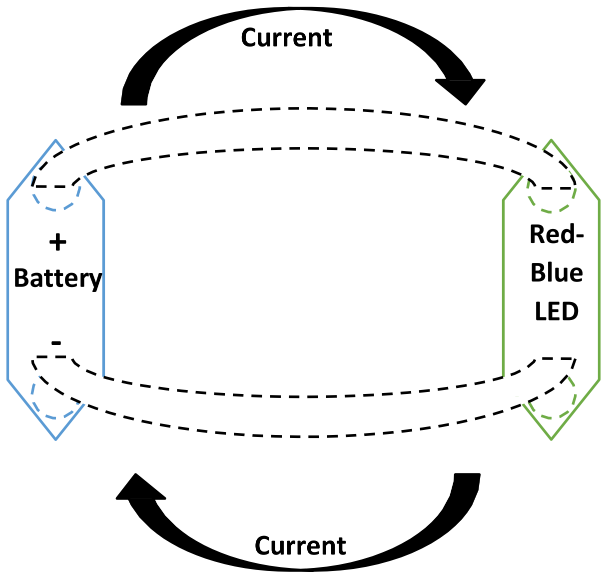
General Tips

- Circuit Scribe is recommended for students age 8+
- Should the connection "short" at any point, a red LED on the module will light up. If this red light turns on, quickly remove the module from the circuit and look for problems in the drawing. Do not let a module short circuit for an extended period of time, as it can damage the module.
- The company does not recommend drawing on one's skin with their pen, even though it is considered non-toxic. Ink can be washed with regular soap and water if it comes into contact with the skin.
- Slip a magnetic sheet behind the paper you are drawing on so that the modules connect completely with your drawn wires. As mentioned above, the terminals are magnetic and spring-loaded, so they work best when they have a metallic surface to adhere to.
- Here is a general breakdown of the modules sorted by color:
    - Blue- Power. Example: battery connection.
    - Red- Input modules. Example: a switch.
    - Grey- Connection. Example: a transistor.
    - Yellow- Output. Example: a LED light.
- When drawing circuits, make sure the bubbles are filled in completely. Also make sure there are no breaks in your wires (lines). The wires do not need to be straight, but they should be solid and slightly thicker than normal lines.

The Basic Circuit

Electrical circuits are created so that electricity can flow from one point to another. The flow of electricity is called **current**. Current transforms energy to turn on lights, power motors, make music, and run nearly every other electronic we are familiar with in the 21st century.

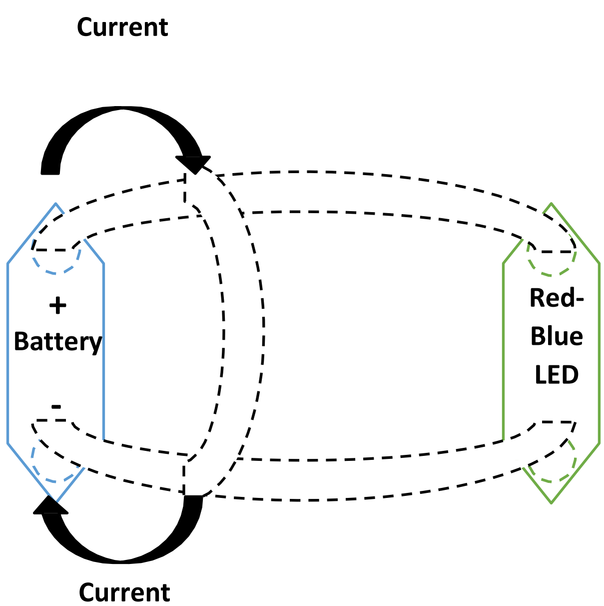
Complete the activity below to become acquainted with a basic circuit:



Current always flows from the positive end (+) of a terminal to the negative end (-).

Try it! Flip the battery around and see what changes in your circuit.

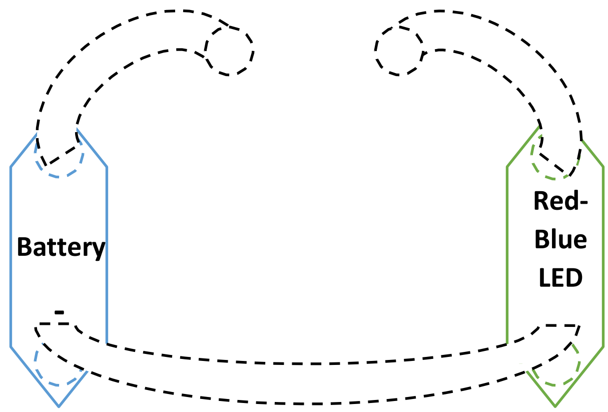
Current always follow the path of least resistance. Try this circuit and see what happens:



Conductivity

Current is measured in **Amperes** (**Amps**). Amperes indicate a material's **conductivity**.
A **conductor** is a material that allows current to flow through it.
An **insulator** is a material that does not allow current to flow through it.
We can test how conductive a material is by setting up the circuit below:

+



Make sure you leave space between the top wires so that you can test a material's conductivity.

Use items from around the room to see if they are **conductors** or **insulators**, and complete the table below:

Material	**Conductor?**	**Insulator?**
Paper Clip		
Rubber Band		
Aluminum Foil		
Pipe Cleaner		
Fabric		
Pencil		
Your Finger!		

What traits do all of the conductors share?

What traits do all of the insulators share?

What other materials do you think would be good conductors?

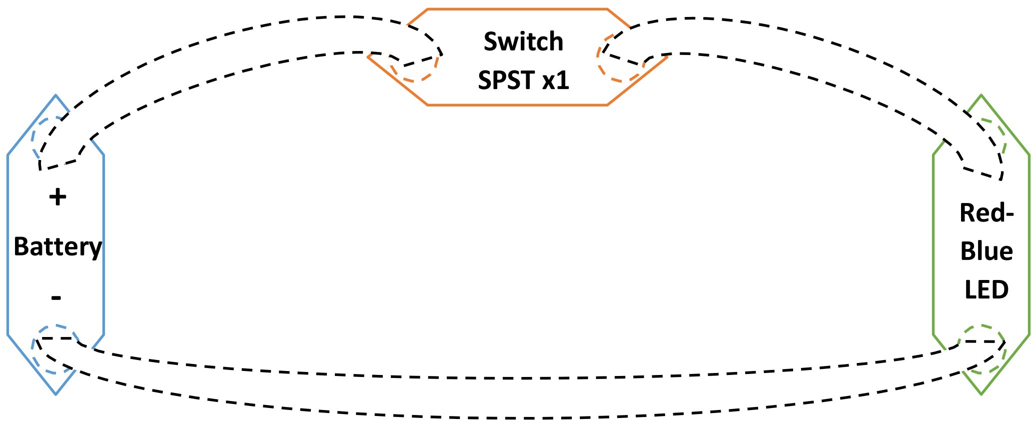
What purpose might insulators serve?

Created by Anna Brenner, Joyce Camp, Ryan Loyst, and Lauren Seborowski- updated August 2018

The Switch

Current can be **inhibited** (blocked) in many ways. One way is to include a switch (or some other form of input) which "breaks" the circuit apart. When the switch is off, we say that a circuit is **open**. When the switch is on, we say that a circuit is **closed**.

Create the circuit below to see how a switch works in practice:



Paper "Push-Button" Switch

You can use Circuit Scribe to create a more innovative type of switch using only paper and your pen.

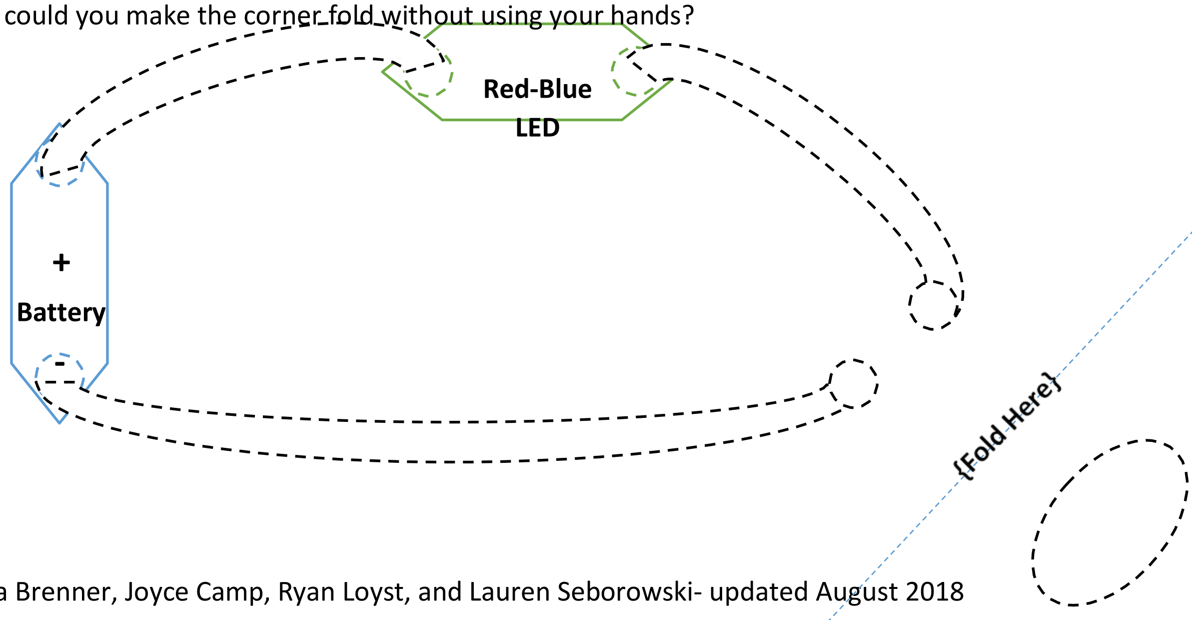
Below is an example of how to create a "push-button" switch, AKA a "momentary" switch.

[Complete these questions after completing the circuit]

Now that you see Circuit Scribe's versatility, what other materials could you use to create circuits?

Challenge: How could you create a circuit that is 10 feet long?

Challenge: How could you make the corner fold without using your hands?



Resistance

Another way to inhibit current is to add **resistance**. The easiest way to add resistance to a circuit is to use a 2-pin component called a **resistor**.

Resistors vary in their **resistance value**, a measure of how much resistance the resistor adds to the circuit. The resistance value is measured in **Ohms**. To figure out how much resistance a resistor provides, follow the table below and enter the numbers into this formula:

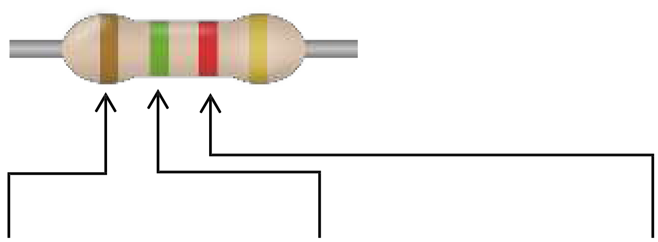
Resistance = [(Digit in Band 1)(Digit in Band 2)] x (Multiplier)

Note: The digits are not multiplied together. The first digit is the *tens place value* and the second digit is the *ones place value* of a single number. That number is then multiplied by the Multiplier.

Example: The resistor shown below has, from left to right, a brown band, a green band, and a red band. Ignore band 4 for now. We will discuss it in a later activity.

$\therefore$

Resistance = [(1)(5)] x 100, or 1,500 Ohms.



Color	Band 1	Band 2	Multiplier
Black	0	0	1
Brown	1	1	10
Red	2	2	100
Orange	3	3	1000
Yellow	4	4	10,000
Green	5	5	100,000
Blue	6	6	1,000,000
Violet	7	7	10,000,000
Gray	8	8	
White	9	9	

To use resistors in your Circuit Scribe circuits, you will need to use the **2-Pin Module**.

The 2-Pin Module has two holes (called sockets) in the center of the board. These sockets are made to accommodate the two metal wires located on each side of the resistor.

To insert a resistor, bend the wires so that they are perpendicular to the module. Then, insert the wires into the sockets, as shown below:

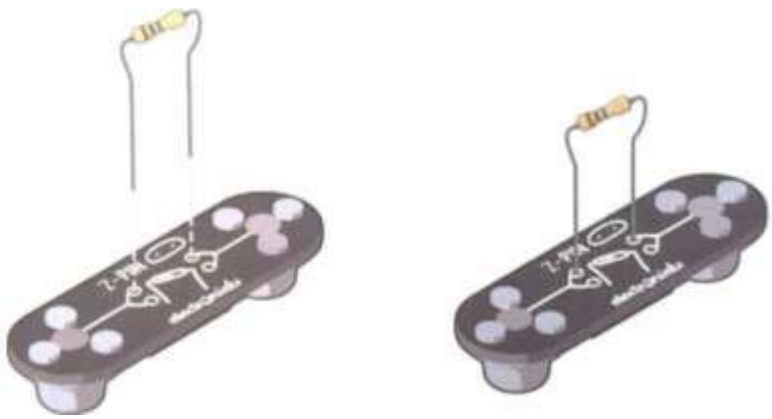
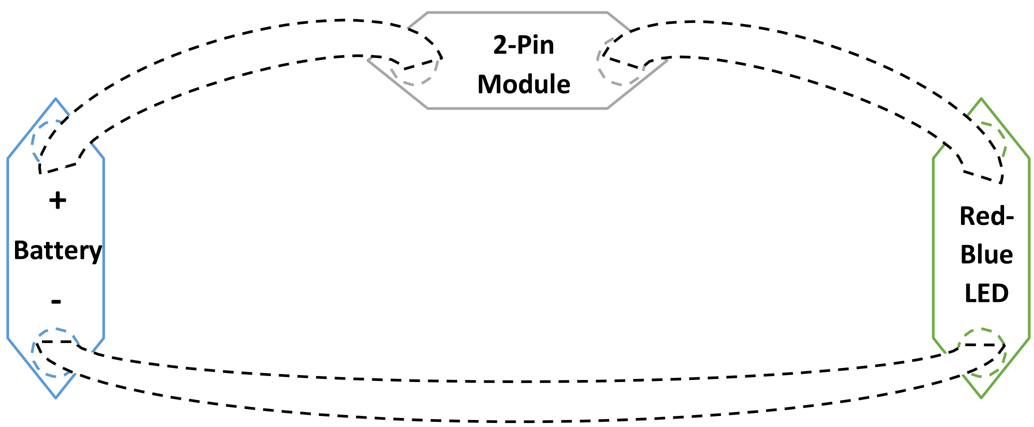


Image Source: Russo, A. & Noguera, J. C. (2014). ***CircuitScribe*: *draw your own circuits workbook + sketchbook,*** **rev. B1. ElectronInks. URL: http://www.electroninks.com**

Try different resistors in the circuit below to see how they affect the brightness of the LED:



Does a higher resistance value make the LED brighter or dimmer? A lower resistance value?

Write a rule that explains LED brightness in relation to resistance value.

How do you think resistance value would affect other outputs (like motors or buzzers)?