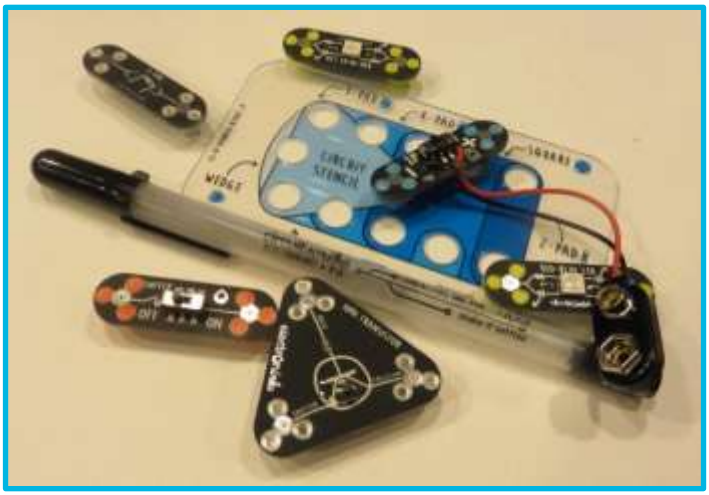
Sketching Circuits

Lesson Focus

Expanding on understanding of simple circuits, this lesson explores conductivity and introduces students to the new technique of drawing electrical pathways for circuitry with pens. Students will design, and build a simple circuit using drawn connectors and construct a device for testing materials for conductivity. Note: This lesson plan is designed for classroom use only, with supervision by a teacher familiar with electrical and electronic concepts.



Lesson Synopsis

The Sketching Circuits activity encourages student teams to build a simple circuit using a silver pen on paper to light an LED, and then create a circuit to test materials for conductivity.

Age Levels

8-12

Objectives

- Learn about alternatives to wiring in electrical circuitry.
- Learn about the electrical properties of different materials.
- Learn how conductors and insulators react to electric current.
- Learn to predict outcomes and draw conclusions.
- Learn about teamwork and working in groups.

Anticipated Learner Outcomes

As a result of this activity, students should develop an understanding of:

- electrical properties
- conductors and insulators
- circuits and current flow
- making and testing predictions
- teamwork

Lesson Activities

Students learn how to create a working circuit using pens instead of wiring. Students work in teams to develop and build a working circuit to light an LED and also to develop a circuit for testing whether materials are conductors or insulators.

Alignment to Curriculum Frameworks

See attached curriculum alignment sheet.

Internet Connections

- TryEngineering (www.tryengineering.org)
- Circuit Scribe (www.circuitscribe.com)
- Vocative Drawing Circuits Demo: www.vocativ.com/339063/japanese-pen-electrifies-drawings-literally/
- Scientific Tuesdays: (www.youtube.com/watch?v=BwKQ9Idq9FM)
- AgIC Circuit Marker Demo (www.youtube.com/watch?v=FAC3kqzWm4g)

Recommended Reading

- DK Eyewitness Books: Electricity (ISBN: 978-1465408990)
- Electronics for Kids: Play with Simple Circuits (ISBN: 978-1593277253)
- Teach Yourself Electricity and Electronics (ISBN: 978-1259585531)

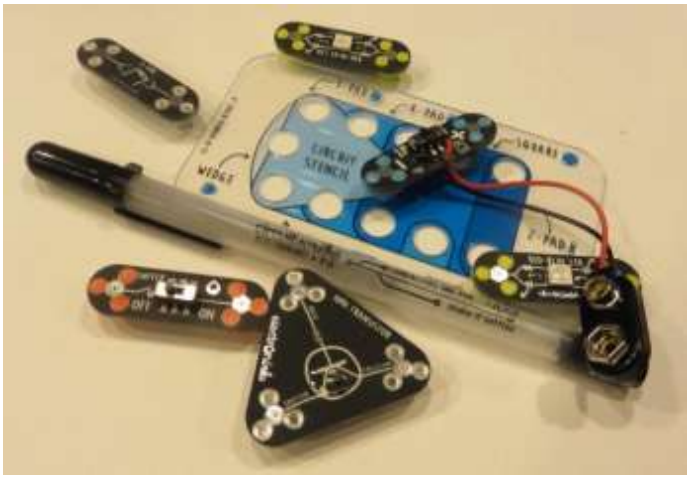
Optional Writing Activity

- Write an essay (or paragraph depending on age) describing how the ability to draw circuitry could potentially impact or improve a product we use every day.

For Teachers: Teacher Resource

Lesson Goal

The Sketching Circuits activity encourages student teams to build a simple circuit using a silver pen on paper to light an LED, and then create a circuit to test materials for conductivity.



Lesson Objectives

- Learn about alternatives to wiring in electrical circuitry.
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- Learn how conductors and insulators react to electric current.
- Learn to predict outcomes and draw conclusions.
- Learn about teamwork and working in groups.

Materials

- Student Resource Sheets
- Student Worksheet
- Set of materials for each team of students:
  - Paper
  - Pencil
  - Ruler
  - Circuit Scribe Kit (available on Amazon Item B00M2AV2G2 at $39 or MiniKit $18, from manufacturer, or other sites) (Note: we recommend purchasing additional Circuit Scribe Pens which are sold more cost effectively in sets.)
  - Set of materials for conductivity testing such as metal paper clip, paper, eraser, aluminum foil, metal pen, rubber band, pencil, coin, key.

Procedure

1. Provide students with reference sheets on simple circuits and insulators and conductors, perhaps as homework reading on the night prior to the activity.
2. Divide students into teams of 3-4 students and distribute Student Worksheets and materials to each group.
3. Have each team develop a circuit using the Circuit Scribe kit that can light an LED. This lesson includes a sample voting circuit, which could be used for younger students to replicate or as an example. Students should be encouraged to be creative; suggest viewing online samples for inspiration that makes use of the flexibility of the conductive pen.

4. Students should draw a schematic of their planned drawn circuit project with regular pencil or pen and review the idea and circuitry plan with their teacher.
5. Once approved, and using the provided Circuit Scribe pen and components, teams build their paper circuit and present their project to the class.
6. Student teams then design and draw a circuit that can be used to test a range of materials for conductivity.
7. Teams use the tester circuit to evaluate a range of materials.
8. Student teams share challenges, successes, and reflections with the class.

For extension or advanced students:

1. Challenge students to use other components in the kit, such as a switch or slide potentiometer (depending on which kit used).

◆ Time Needed

45 Minutes

◆ Safety

- While the pen is non-toxic according to the manufacturer, it should not be put near the mouth.

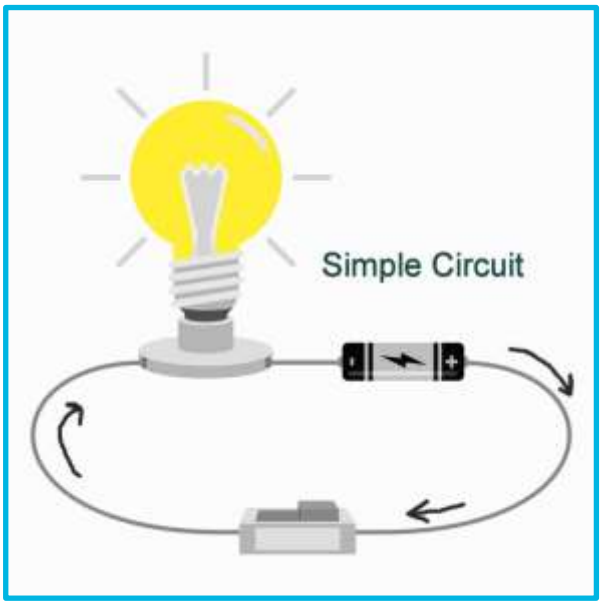
◆ Tips

- Teachers should consider distributing the student resource sheets as reading material/homework for the night before the activity will be conducted in class.
- Suggested solution examples for the simple circuit and the conductive test are available at the end of this lesson.
- The Circuit Scribe kit is a safe, basically fail proof way for younger students to experiment with circuits. The components are magnetized and attach to a metal plate (provided). Everything snaps in place and there are many options for experimentation. Contents include:
    - Circuit Scribe pen, with silver and water-based non-toxic ink.
    - Steel plate that is placed under any paper you use (paper not included with kit, but copy paper, construction paper, others will work)
    - Components (LED, Battery connection, switches, etc.) are incorporated into magnetic modules that snap onto the paper (with steel sheet underneath). Each component has embedded circuitry so there is no need for student wiring or soldering.
    - Circuit stencil to help students draw circles at the exact width of each component.
- There are several configurations of Circuit Scribe kits…ranging from the Mini Kit which has fewer components and a smaller pen, to a large maker kit with many components. Pricing currently ranges from about $18 for Mini kit up to $80 for full kit, depending upon where you purchase. The pens will run out eventually, so purchasing a couple of extra pens might be wise. You can order from the manufacturer, from school or electrical supply companies, or from online retailers such as Amazon.
- There are ways to attempt this lesson using graphite pencils, which does work, but has inconsistent results based on graphite quality, density, and paper, and requires manual connections between components. A graphite test could be an extension idea for some students.

Student Resource: What is a Simple Circuit?

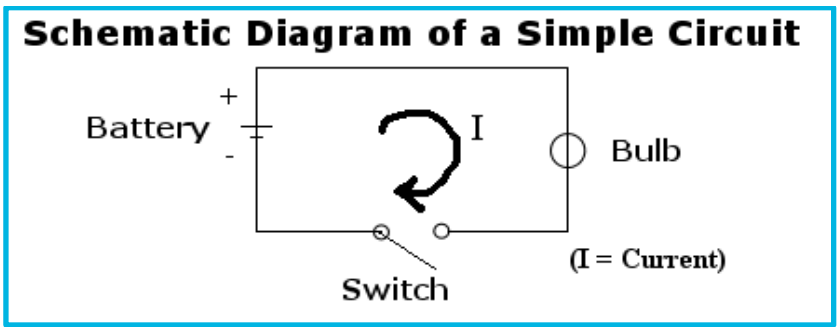
◆ Simple Circuit

A simple circuit consists of three minimum elements that are required to complete a functioning electric circuit: a source of electricity (battery), a path or conductor on which electricity flows (wire) and an electrical resistor (lamp) which is any device that requires electricity to operate. The illustration below shows a simple circuit containing, one battery, two wires, a switch, and a bulb. The flow of electricity is from the high potential (+) terminal of the battery through the bulb (lighting it up), and back to the negative (-) terminal, in a continual flow when the switch is in the on position so current can flow.



◆ Schematic Diagram of a Simple Circuit

The following is a schematic diagram of the simple circuit showing the electronic symbols for the battery, switch, and bulb.



Student Resource: What Are Conductors and Insulators?

◆ **Conductors/Conductivity**

Conductivity is the ability or power to conduct or transmit heat, electricity, or sound. Conductors are materials that electricity easily passes through, that do not resist the flow of electricity. Examples are copper, aluminum, steel, silver, gold, electrolytes. Not all materials conduct electricity equally well.

◆ **Insulators**

Insulators are materials that resist the flow of electricity, so electricity does not easily pass through. Examples are plastic, wood, rubber, cloth, air, glass. Some materials are better electricity insulators than others.

◆ **Challenge**

Do you think the following items are more likely conductors or insulators?

 **Eraser** ☐ Conductor ☐ Insulator	 **Aluminum Foil** ☐ Conductor ☐ Insulator	 **Rubber Bands** ☐ Conductor ☐ Insulator
 **Pencil/Graphite** ☐ Conductor ☐ Insulator	 **Paper Clips** ☐ Conductor ☐ Insulator	 **Plastic Caps** ☐ Conductor ☐ Insulator
 **Coins** ☐ Conductor ☐ Insulator	 **Cork** ☐ Conductor ☐ Insulator	 **Keys** ☐ Conductor ☐ Insulator

Student Resource: What are LEDs?

A Light-Emitting Diode – or LED -- is a semiconductor device built to emit light when activated. Different chemicals give different LEDs their colors. When powered at the proper level, they can last much longer than incandescent lightbulbs and do not break easily. They can display many different colors, can be very small, and are extremely efficient. Most of the energy they consume makes light, not heat. Most LEDs are very small, less than 1 mm, and so can be integrated in to many products.

◆History

The first visible-spectrum (red) LED was developed in 1962 by Nick Holonyak, Jr. while working at General Electric. In 1972, M. George Craford, a former graduate student of Holonyak, invented the first yellow LED and improved the brightness of red and red-orange LEDs by a factor of ten. In 2014, the Nobel Prize in Physics was awarded to a team of scientists (Isamu Akasaki, Hiroshi Amano, and Shuji Nakamura) "for the invention of efficient blue light-emitting diodes which has enabled bright and energy-saving white light sources" While red and green LEDs had been available for many years at that time, the blue LEDs were a big challenge for scientists and engineers around the world. The blue version was needed to be able to mix with the red and green ones to produce white light…without white light we would not have had LED-based computer and TV screens.

◆Color and Shape Selection

LEDs are produced many shapes and sizes, and while the color of the plastic lens is usually the same color as the light emitted, this is not always true. Many blue LEDs actually have clear or colorless plastic lenses, like the one to the right.

◆Applications

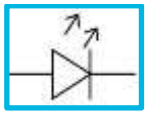
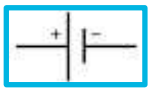
At first, LEDs were used as indicator lamps for simple electronic devices, where they replaced small incandescent bulbs and allowed products to be smaller. They were soon popularized and used in digital clocks and calculators. Quickly, manufacturers and consumers found that the small size and efficiency of these little lights made them the perfect choice for many applications. As an example, a white LED lightbulb converts over 50% of the electricity it uses into light…an incandescent bulb only converts about 4% into light. So now the applications are widespread…from car headlamps and taillights, camera flashes, and computer and television screens. If you look closely at your local traffic lights, you may find that what looks like a big bulb from a distance is actually a round pattern of red, green and yellow LEDs!

Student Worksheet:

◆ Planning

You and your team will be creating a simple circuit using a conductive pen instead of wiring. Because the paper can be folded, you have the opportunity to be very creative! You may use the separate worksheet to build your own voting station…or come up with your own idea that incorporates two LEDs and allows for someone to interact with your circuit. You may be creative and draw a flower that lights up, set up an interactive quiz, or anything which lights up two LEDs. You should conserve the special pen for lines that require current to flow and other drawing tools like colored pencils, crayons, or markers for other decorations.

In the box below, draw with a normal pencil your planned circuit --- you will want to save the special pen for the final version. Be sure to mark where your battery and LED will be placed and consider any folding you might need to factor into the design. You can use the following electronic symbols in your sketch:

LED:  Battery: 

You can use the template that comes with your kit to draw the circles to match the magnetic base of each component.

Once your teacher approves the planned design your team may move on to construction!

Student Worksheet:

◆ Drawing, Building, and Testing

Using your approved pencil sketch as a plan, create your paper circuit. Remember to use the circuit pen only for lines necessary to carry current and use other drawing tools for any instructions, decorations, or other writing needed.

Once complete, answer the following questions:

1. Did you need to redesign your original pencil plan prior to building your final circuit? If so, what changed?

2. Do you think that drawing a circuit is easier than working with wires? Are there any reasons why you think a wire circuit would be more appropriate?

3. Describe a design that another student team developed that you thought was particularly creative!

4. How do you think paper circuits might be used in everyday life? Would this be a new product, or adapting or improving an existing product?

◆ Conductive Material Test

Now that you've built a simple circuit, try building a circuit that could be used to test a range of materials (provided to you) for conductivity. With an LED included in your testing circuit you will be able to see if a material is a conductor if it lights up!

As before, in the box below, draw with a normal pencil your planned conductive testing circuit. Once your teacher approves the planned design your team may build it.

Student Worksheet:

◆ Conductive Testing

In the box below, document the materials you examined in your conductive test circuit, and include your results.

Material Tested	Insulator or Conductor	Observations

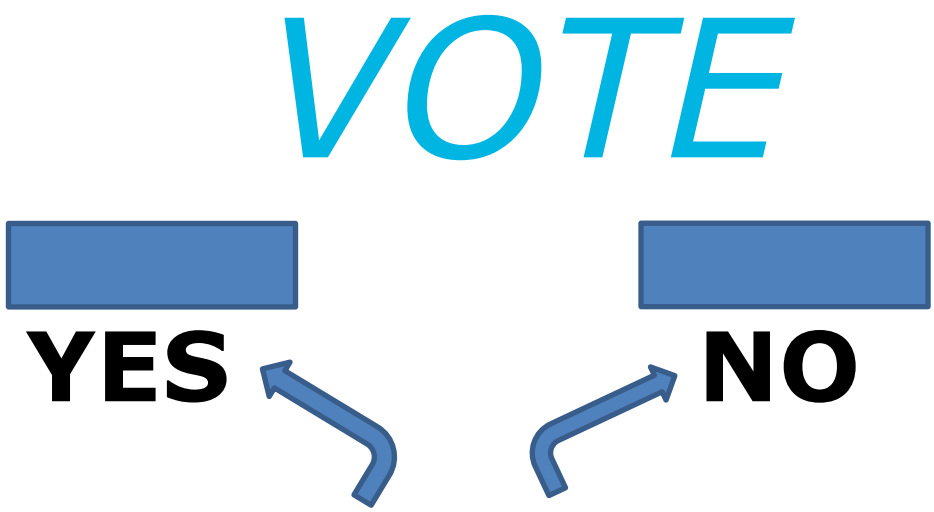
◆ Review and Reflections

1. Were you able to create a circuit that could test for conductivity?

2. Were there any materials that you tested that surprised you?

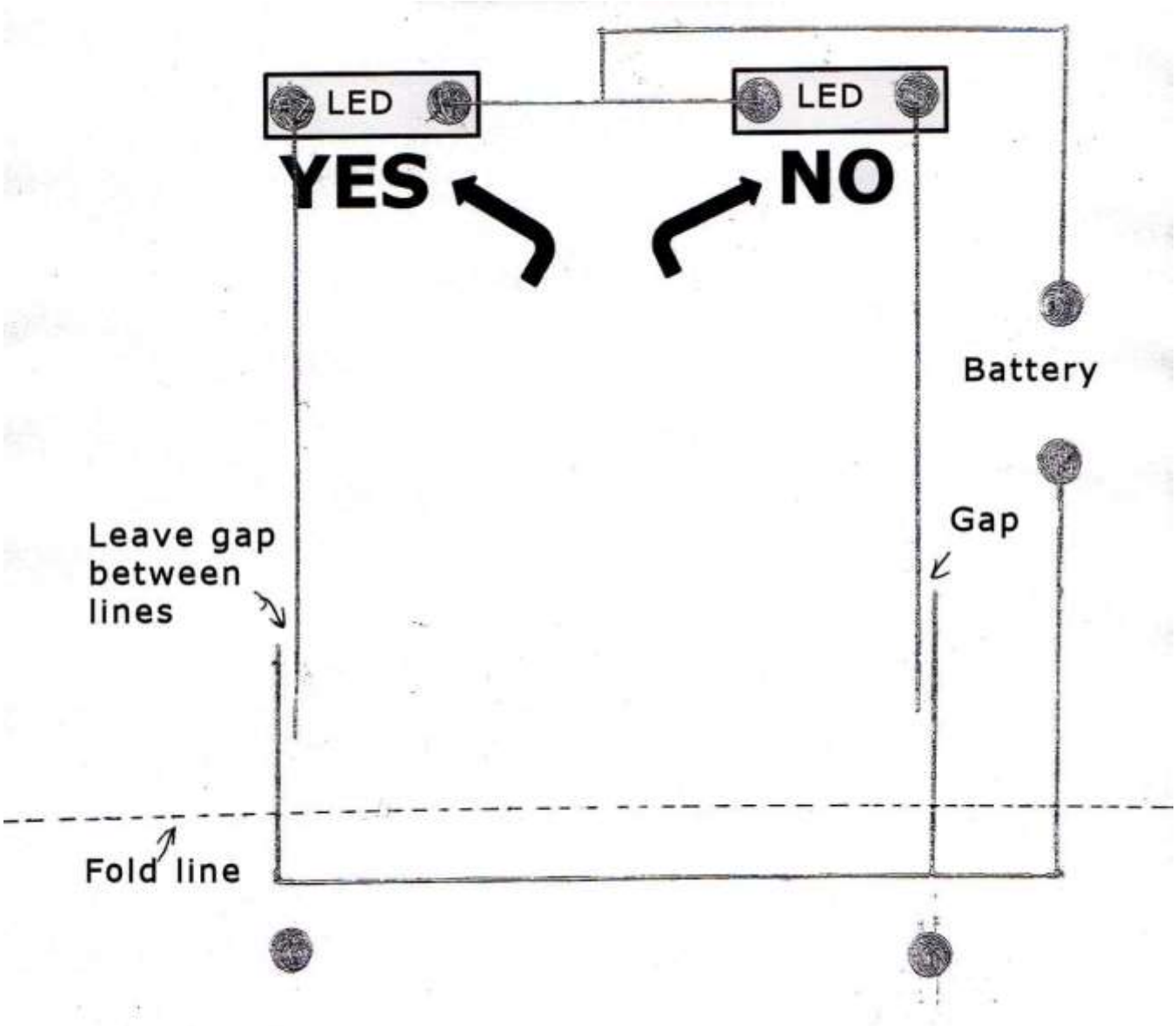
3. Why is it important to know whether a material is an insulator or a conductor?

Student Voting Worksheet:

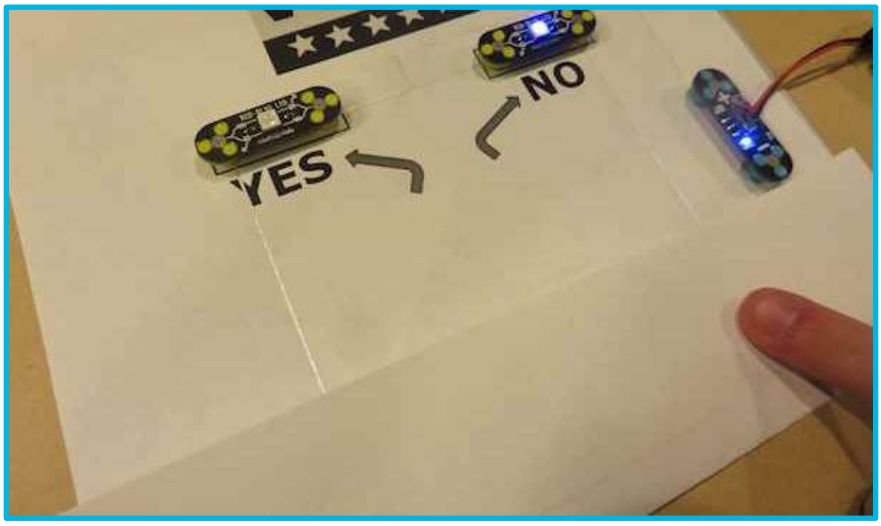


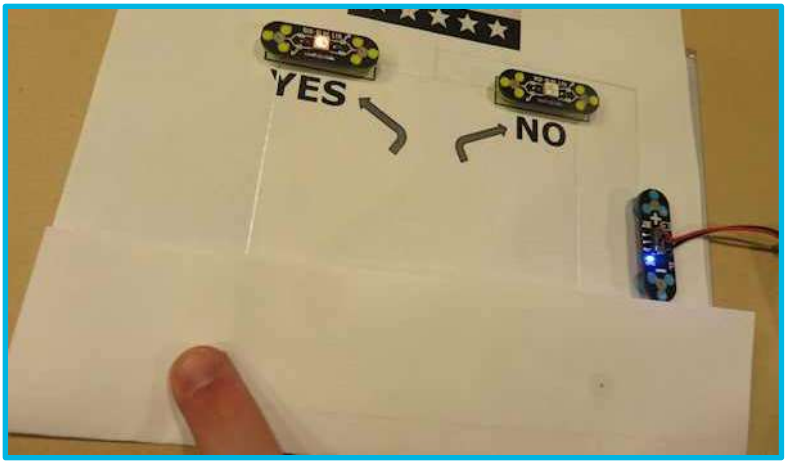
For Teachers:
Sample Solution Voting Template

VOTE



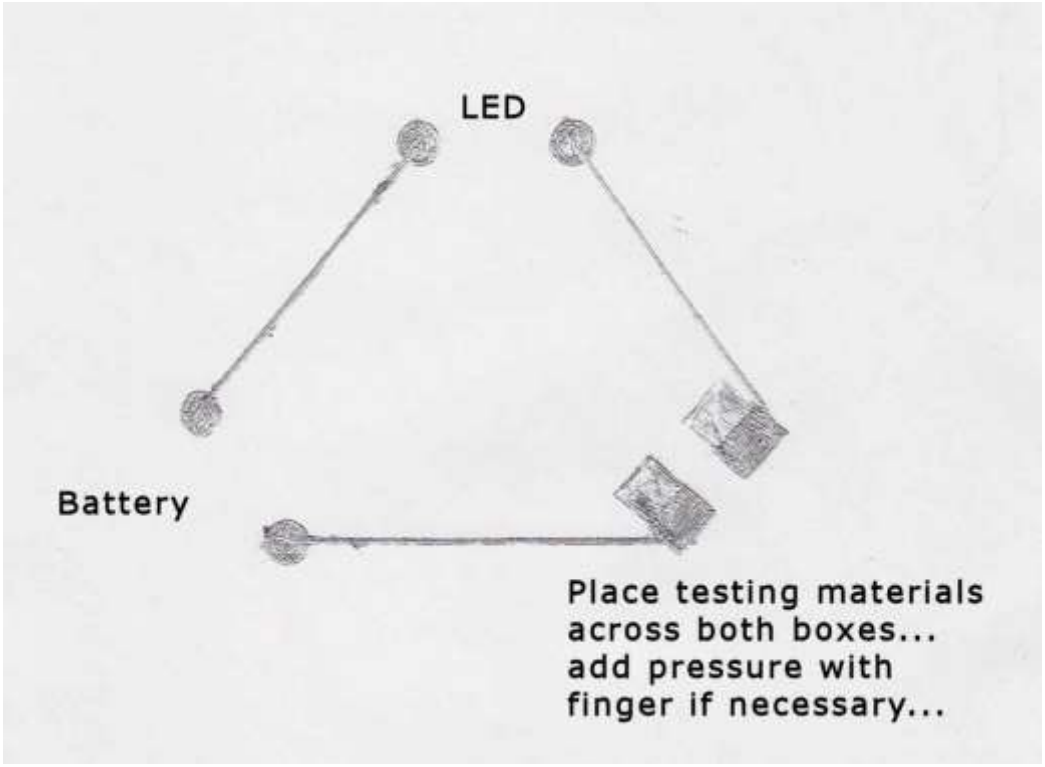
For Teachers:
Sample Solution Voting Photos

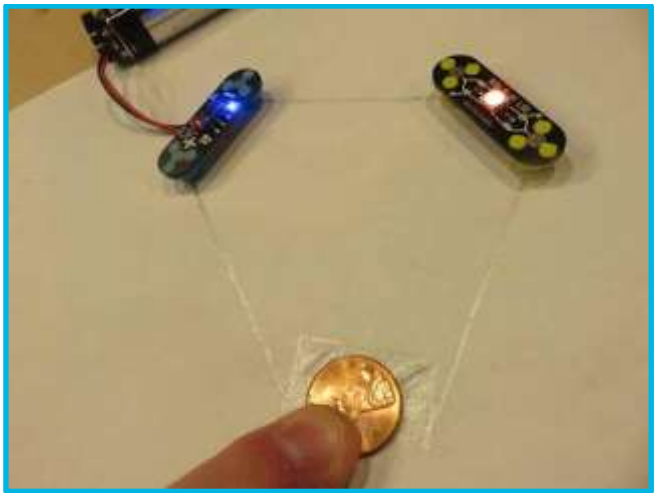




For Teachers:
Sample Solution Testing Template

The following is just a simple sample of how a testing template could be drawn for this lesson. Encourage students to come up with their own design and be creative.





For Teachers: Alignment to Curriculum Frameworks

Note: Lesson plans in this series are aligned to one or more of the following sets of standards:

- U.S. Science Education Standards (http://www.nap.edu/catalog.php?record_id=4962)
- U.S. Next Generation Science Standards (http://www.nextgenscience.org/)
- International Technology Education Association's Standards for Technological Literacy (http://www.iteea.org/TAA/PDFs/xstnd.pdf)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (http://www.nctm.org/standards/content.aspx?id=16909)
- U.S. Common Core State Standards for Mathematics (http://www.corestandards.org/Math)
- Computer Science Teachers Association K-12 Computer Science Standards (http://csta.acm.org/Curriculum/sub/K12Standards.html)

◆ Next Generation Science Standards (grades 3-5, middle school)

Students who demonstrate understanding can:

- 3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- 3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- 3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.
- 4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.
- 4-PS3-4. Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.
- MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
- MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

For Teachers: Alignment to Curriculum Frameworks

◆ U.S. Common Core State Standards for Mathematics (grades 3-5)

- Grade Three: Represent and Interpret Data (CCSS.MATH.CONTENT.3.MD.B.4)
- Grade Four: Represent and Interpret Data (CCSS.MATH.CONTENT.4.MD.B.4)
- Grade Five: Represent and Interpret Data (CCSS.MATH.CONTENT.5.MD.B.2)

◆ International Technology Education Association's Standards for Technological Literacy (grades 3-5)

- Chapter 8 – The Attributes of Design
  - Definitions of Design
  - Requirements of Design
- Chapter 9 – Engineering Design
  - Engineering Design Process
  - Creativity and Considering all ideas
  - Models
- Chapter 10 – The Role of Troubleshooting, Research and Development, Invention, and Experimentation in Problem Solving
  - Troubleshooting
  - Invention and innovation
  - Experimentation
- Chapter 11 – Apply the Design Process
  - Collect information
  - Visualize a solution
  - Test and evaluate solutions
  - Improve a design
- Chapter 16 – Energy and Power Technologies
  - Energy comes in different forms
  - Tools, machines, products and systems