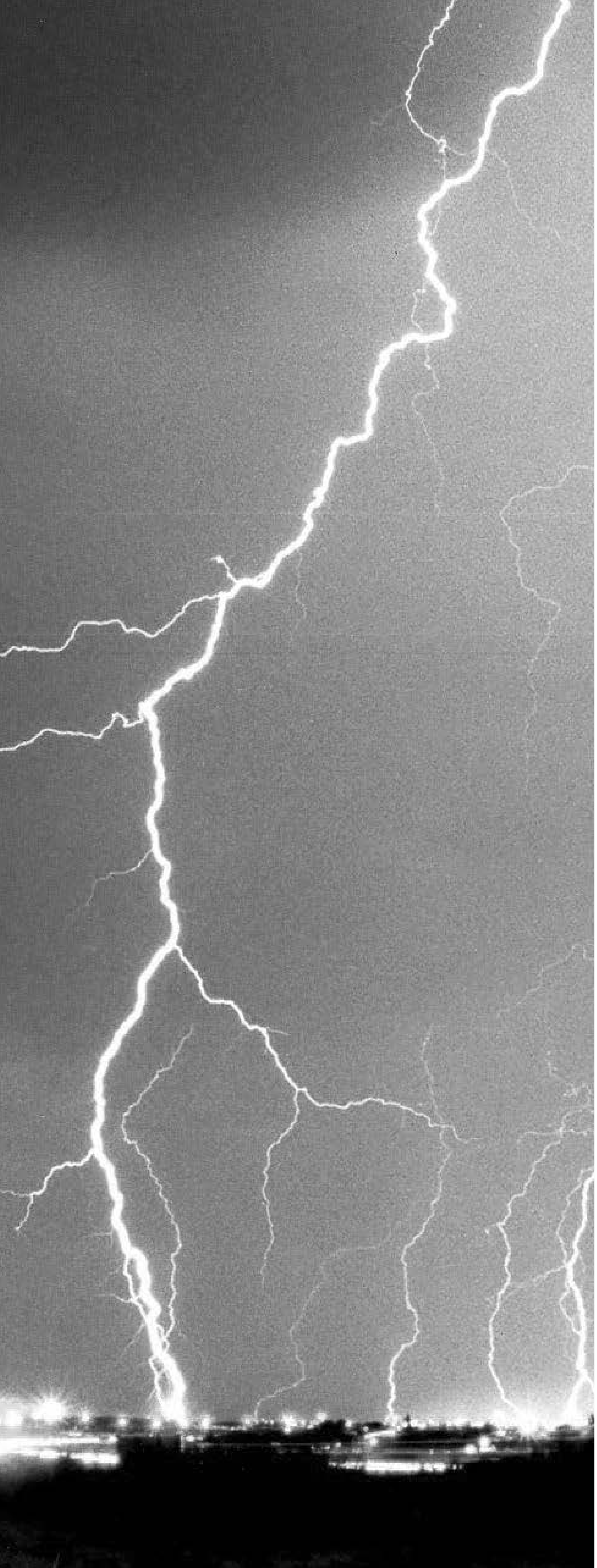
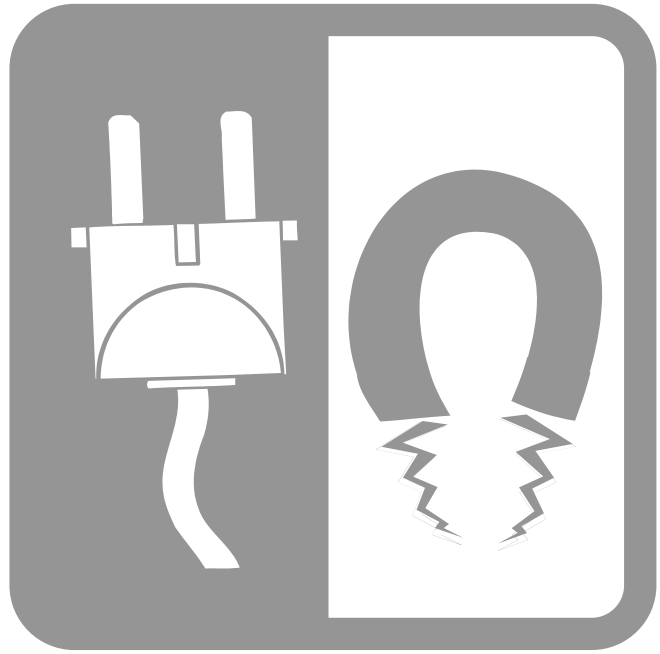




# THE SCIENCE OF ELECTRICITY

**Grade Levels:**

- Elem — Elementary Grade 5
- Int — Intermediate Grades 6-8
- Sec — Secondary Grades 9-12

**Subject Areas:**

- Science
- Language Arts
- Technology

NEED
National Energy Education Development Project

# TEACHER INFORMATION

## Background

Electricity is a necessary part of our daily lives. To many, it is a mystery. This hands-on, modeling and design activity allows students to visualize more simply what is involved in the generation of electricity. Students will create their own model generator, using magnets, wire, and simple lab items. After assembling the model to specifications, students can aim to optimize the design of the model, utilizing fewer or less costly materials to generate a larger amount of electrical output – a real-world challenge for electrical engineers.

*The Science of Electricity* modeling activity is found within several of NEED's energy source curriculum units, including our coal, hydropower, and nuclear guides. The teacher information on the subsequent pages provides a detailed list of the titles. All guides can be downloaded by visiting www.NEED.org. Each guide can help to round out your instruction by providing student text, and a teacher guide with additional supporting activities. *The Science of Electricity* activity serves as a great introduction to electricity generation for any energy source. This activity also strongly reinforces the requisite scientific process, problem solving, and engineering and design skills students must posess and utilize to meet standards for learning.


# THE SCIENCE OF ELECTRICITY

*TEACHER INFORMATION*

This activity can be found within the following NEED guides at www.NEED.org:

- *Wonders of Water*
- *Energy from Uranium*
- *Energy of Moving Water*
- *Understanding Coal*
- *Exploring Coal*
- *Exploring Hydroelectricity*
- *Exploring Nuclear Energy*
- *Get Your Motors Running*

### Calling All Engineers!

Share your students' designs with NEED. Did your students create a model that is awesome? We're always editing and improving our activities. If you've got a model that students could construct easily and affordably in the classroom that demonstrates the concepts as well or better than NEED's model, send it our way! Email their designs, specifications, instructions and/or pictures to info@need.org. Include "Science of Electricity Model Redesign" in the subject line.

## Objectives

- Students will be able to how electricity is generated.
- Students will be able to design a model and optimize its performance.

## Time

- Two to four class periods, or more, depending on the level of inquiry desired and the level of students in the classroom.

## Materials *FOR EACH GROUP OR CONSTRUCTION STATION*

The materials used in this activity can be found in a common lab setting, or easily procured from a lab supply company, hardware store, or craft store. Refer to the activity instructions for more specifics about each item, however, students may opt to change up the materials when optimizing their designs. Allow for variations in the materials where possible. Alternatively, a package of most of the items needed can be purchased from NEED. Contact NEED if you have any questions or difficulty locating a certain item.

- 1 Small bottle
- 1 Rubber stopper with ¼" hole
- 1 Wooden dowel (12" x ¼")
- 4 Strong rectangle magnets
- 1 Foam tube
- 1 Small nail
- 1 Large nail
- Spool of magnet wire
- Permanent marker
- 1 Pair sharp scissors
- Masking tape
- Fine sandpaper
- 1 Push pin
- 1 Multimeter with alligator clips
- Hand operated pencil sharpener
- Ruler
- Utility knife (optional)
- *Science of Electricity Model Instructions*
- *Science of Electricity Model* worksheet

## Preparation

- Gather the list of materials and set up construction stations. It may also be helpful to incorporate extra materials that students can use in their re-design process.
- Make copies of the instructions sheet and student worksheet.

**OPTIONAL:** Assemble a model ahead of time using the student instructions. This model will be used for demonstration purposes and also will allow you to assist students in troubleshooting during construction and redesign.

## ✔ Procedure

1. Ask students to discuss how electricity is generated. What is needed? What is inside a generator? Record ideas on the board.
2. Show students your sample model. Have students take turns operating it and recording the highest output they are able to generate from your model.
3. Depending on the level of students you are working with, you may have them assemble their own models using the instructions provided in order to make sure they fully understand how the model operates. Some students, however, may have a firm enough grasp from viewing your sample model and be able to move on.


CONTINUED ON NEXT PAGE

4. Have students complete the worksheet to show they understand how the model works. Explain that generating electricity requires a few simple things: motion, magnets, and wire.
5. After students have a good understanding of how the generator model works, explain the challenge. Students will need to design a generator model that employs the same concepts to generate electricity, but requires fewer or different materials and/or generates more output. You may decide if you would like students to attempt to achieve one or both of the options. Explain to students that this is called optimization.
6. It may be necessary to provide students with an overview of guidelines for the design and redesign process. Make sure students are aware of the timeline to complete their best model, and explain that they may test, redesign, and retest as many times as needed or desired in that time frame. Communicate to students what you will require from them throughout the process. Depending on the group, you may require that students submit drawings and specifications for each step of their design process.

**OPTIONAL:** If desired, this may be structured as a contest within the classroom, giving awards to students for best redesign, highest output, least materials, or categories of your choosing.

## Extensions

1. Allow students to procure some of their own materials to complete their designs. Recycle bins can often be very handy for sourcing additional supplies.
2. Provide students with a budget for materials and construction. Ask them to complete a cost analysis of their best model and decide how they might improve their design to come in under budget.
3. Provide students with extra time and materials to add to the generator to produce electricity from another source, other than the motion energy of their hands.

# SCIENCE OF ELECTRICITY MODEL INSTRUCTIONS

## Question

How is electricity generated?

## Caution

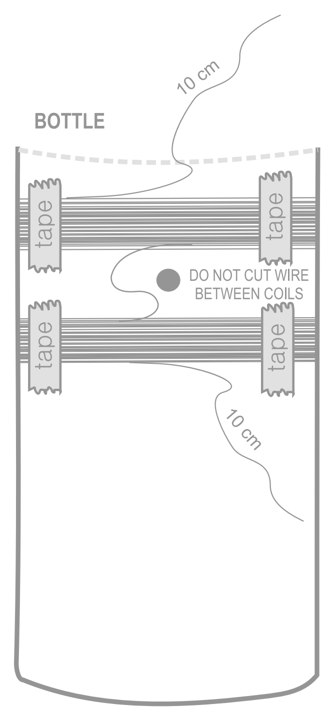
- The magnets used in this model are very strong. Refer to page 7 for more safety information.
- Use caution with nails and scissors when puncturing the bottle.

## Materials

- 1 Small bottle
- 1 Rubber stopper with ¼″ hole
- 1 Wooden dowel (12″ x ¼″)
- 4 Strong rectangle magnets
- 1 Foam tube
- 1 Small nail
- 1 Large nail
- Spool of magnet wire
- Permanent marker
- 1 Pair sharp scissors
- Masking tape
- Fine sandpaper
- 1 Push pin
- 1 Multimeter with alligator clips
- Hand operated pencil sharpener
- Ruler
- Utility knife (optional)

## Preparing the Bottle

1. If needed, cut the top off of the bottle so you have a smooth edge and your hand can fit inside. This step may not be necessary. If necessary, a utility knife may be of assistance.
2. Pick a spot at the base of the bottle. (HINT: If the bottle you are using has visible seams, measure along these lines so your holes will be on the opposite sides of the bottle.) Measure 10 centimeters (cm) up from the base and mark this location with a permanent marker.
3. On the exact opposite side of the bottle, measure 10 cm up and mark this location with a permanent marker.
4. Over each mark, poke a hole with a push pin. Do not distort the shape of the bottle as you do this.
   ***CAUTION:*** Hold a rubber stopper inside the bottle behind where the hole will be so the push pin, and later the nails, will hit the rubber stopper and not your hand, once it pokes through the bottle.
5. Widen each hole by pushing a nail through it. Continue making the hole bigger by circling the edge of the hole with the side of the nail. (A 9/32 drill bit twisted slowly also works, using a rubber stopper on the end of the bit as a handle.)
6. Sharpen one end of the dowel using a hand operated pencil sharpener (the dowel does not have to sharpen into a fine point). Push the sharpened end of the dowel rod through the first hole. Circle the edge of the hole with the dowel so that the hole is a little bigger than the dowel.
7. Remove the dowel and insert it into the opposite hole. Circle the edge of the hole with the dowel so that the hole is a little bigger than the dowel. An ink pen will also work to enlarge the hole. Be careful not to make the hole too large, however.
8. Insert the dowel through both holes. Hold each end of the dowel and swing the bottle around the dowel. You should have a smooth rotation. Make adjustments as needed. Take the dowel out of the bottle and set aside.
9. With a permanent marker, label one hole "A" and the other hole "B."




## Generator Assembly: Part 1

1. Tear 6 pieces of tape approximately 6 cm long each and set aside.
2. Take the bottle and the magnet wire. Leave a 10 cm tail, and tape the wire to the bottle about 2 cm below hole A. Wrap the wire clockwise 200 times, stacking each wire wrap on top of each other. Keep the wire wrap below the holes, but be careful not to cover the holes, or get too far away from the holes.
3. DO **NOT** cut the wire. Use two pieces of tape to hold the coil of wire in place; do not cover the holes in the bottle with tape (see diagram).
4. Without cutting the wire, move the wire about 2 cm above the hole to begin the second coil of wraps in a clockwise direction. Tape the wire to secure it in place.

5. Wrap the wire 200 times clockwise, again stacking each wrap on top of each other. Hold the coil in place with tape.
6. Unwind 10 cm of wire (for a tail) from the spool and cut the wire.
7. Check your coil wraps. Using your fingers, pinch the individual wire wraps to make sure the wire is close together and close to the holes. Re-tape the coils in place as needed.
8. Using fine sandpaper, remove the enamel coating from 4 cm of the end of each wire tail, leaving bare copper wires. (This step may need to be repeated again when testing the model, or saved for the very end).

## Rotor Assembly

1. Measure 4 cm from the end of the foam tube. Using scissors, carefully score a circle around the tube. Snap the piece from the tube. This piece is now your rotor.
2. On the flat ends of the rotor, measure to find the center point. Mark this location with a permanent marker.
3. Insert the small nail directly through the rotor's center using your mark as a guide.
4. Remove the small nail and insert the bigger nail.
5. Remove the nail and push the dowel through, then remove the dowel and set aside. Do **NOT** enlarge this hole.
6. Stack the four magnets together. While stacked, mark one end (it does not matter which end) of each of the stacked magnets with a permanent marker as shown in Diagram 1.
7. Place the magnets around the foam piece as shown in Diagram 2. Make sure you place the magnets at a distance so they do not snap back together.
8. Wrap a piece of masking tape around the curved surface of the rotor, sticky side out. Tape it down at one spot, if helpful.
9. Lift the marked end of Magnet 1 to a vertical position and attach it to the rotor. Repeat for Magnets 2, 3, and 4.
10. Secure the magnets in place by wrapping another piece of masking tape over the magnets, sticky side in (Diagram 3).

*WARNING: These magnets are **very** strong. Use caution when handling.*

Diagram 1

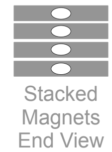



Diagram 2

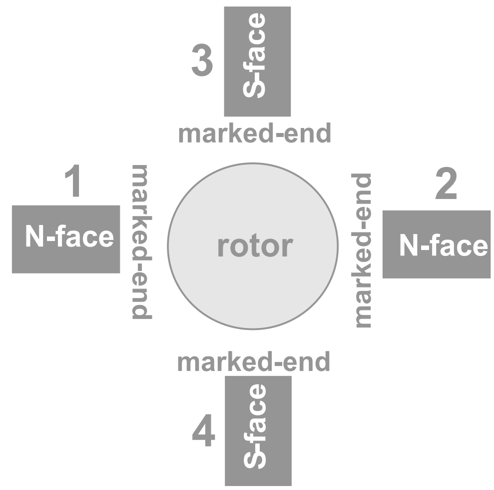
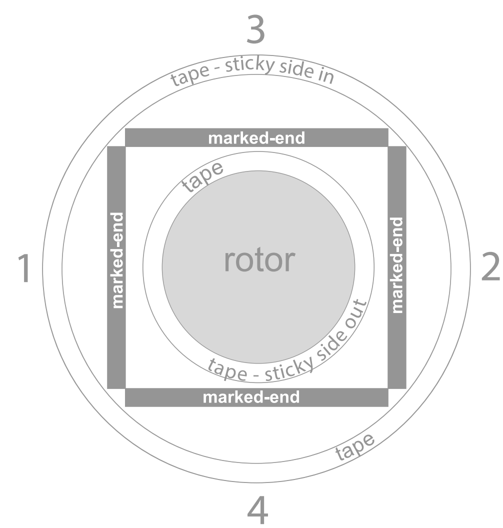
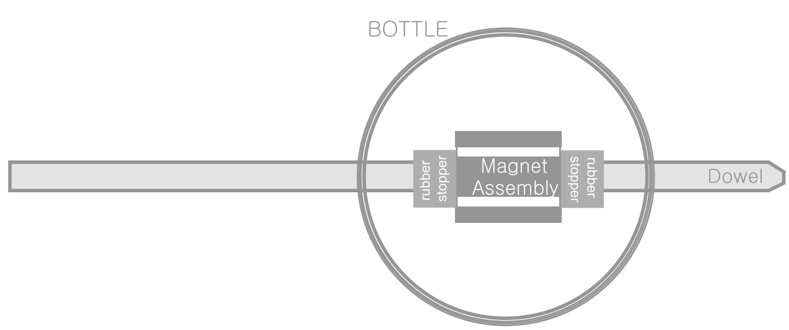



Diagram 3




## Generator Assembly: Part 2

1. Slide the sharp end of the dowel through Hole A of the bottle.
2. Inside the bottle, put on a stopper, the rotor, and another stopper. The stoppers should hold the foam rotor in place. If the rotor spins freely on the axis, push the two stoppers closer against the rotor. This is a pressure fit and no glue is needed.
3. Slide the sharp end of the dowel through Hole B until it sticks out about 4 cm from the bottle.
4. Make sure your dowel can spin freely. Adjust the rotor so it is in the middle of the bottle.



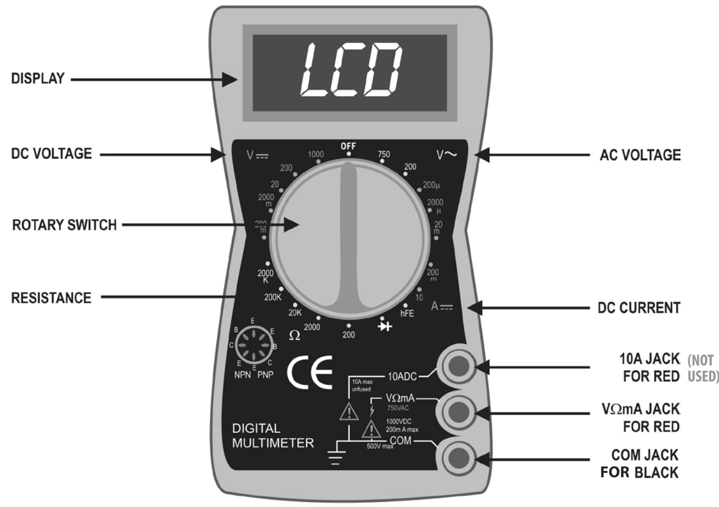
## Assembly Notes

- The stoppers can be cut in half so that one stopper is made into two, to allow for more materials. These often slide more easily on the dowel. This must be done using sharp scissors or a utility knife, and can often be dangerous. As this step is not required (the kit supplies you with two stoppers to use), exercise extreme caution.
- If the foam rotor fits snugly on the dowel, put the stoppers on the outside of the bottle to help center the rotor in the bottle. Leave enough space to allow free rotation of the rotor.
- The dowel may be lubricated with lip balm or oil for ease of sliding the stoppers, if necessary.
- If a glue gun is available, magnets can be attached to the rotor on edge or on end to get them closer to the coils of wire. Use the magnet to make an indentation into the foam. Lay down a bead of glue, and attach the magnets. If placing the magnets on end, however, make sure they clear the sides of the bottle for rotation.

## Testing the Science of Electricity Model

1. Connect the leads to the multimeter to obtain a DC Voltage reading.
2. Connect one alligator clip to each end of the magnet wire. Connect the other end of the alligator clips to the multimeter probes.
3. Set your multimeter to DC Voltage 200 mV (millivolts). Voltage measures the pressure that pushes electrons through a circuit. You will be measuring millivolts, or thousandths of a volt.
4. Demonstrate to the class, or allow students to test, how spinning the dowel rod with the rotor will generate electricity as evidenced by a voltage reading. As appropriate for your class, you may switch the dial between 200 mV and 20 volts. Discuss the difference in readings and the decimal placement.*
5. Optional: Redesign the generator to test different variables including the number of wire wraps, different magnet strengths, and number of magnets.

*Speed of rotation will impact meter readings.




**Note: Your multimeter may look different than the one shown. Read the instruction manual included in the multimeter box for safety information and complete operating instructions.**

## Troubleshooting

If you are unable to get a voltage or current reading, double check the following:

- Did you remove the enamel coating from the ends of the magnet wire?
- Are the magnets oriented correctly?
- The magnet wire should not have been cut as you wrapped 200 wraps below the bottle holes and 200 wraps above the bottle holes. It should be one continuous wire.
- Are you able to spin the dowel freely? Is there too much friction between the dowel and the bottle?
- Is the rotor spinning freely on the dowel? Adjust the rubber stoppers so there is a tight fit, and the rotor does not spin independently.

## Notes

- The *Science of Electricity Model* was designed to give students a more tangible understanding of electricity and the components required to generate electricity. The amount of electricity that this model is able to generate is very small.
- The *Science of Electricity Model* has many variables that will affect the output you are able to achieve. When measuring millivolts, you can expect to achieve anywhere from 1 mV to over 35 mV.
- More information about measuring electricity can be found in NEED's *Energy Infobooks*. You may download these guides from www.NEED.org.

## ⚠ Magnet Safety

The magnets in the *Science of Electricity Model* are very strong. In order to separate them, students should slide/twist them apart. Please also take the following precautions:

- When you set the magnets down, place them far enough away from each other that the magnets won't snap back together.
- The tape should hold the magnets on. If you want something stronger and more permanent you can use hot glue.
- When you are finished with the magnets and ready to store them, put a small piece of cardboard between them.
- Keep magnets away from your computer screen, cell phone, debit/credit cards, and ID badges.

# SCIENCE OF ELECTRICITY MODEL

Observe the science of electricity model. Draw and label the parts of the apparatus.

Explain how electricity is generated using appropriate vocabulary.

# Youth Awards Program for Energy Achievement

**All NEED schools have outstanding classroom-based programs in which students learn about energy. Does your school have student leaders who extend these activities into their communities? To recognize outstanding achievement and reward student leadership, The NEED Project conducts the National Youth Awards Program for Energy Achievement.**

This program combines academic competition with recognition to acknowledge everyone involved in NEED during the year—and to recognize those who achieve excellence in energy education in their schools and communities.

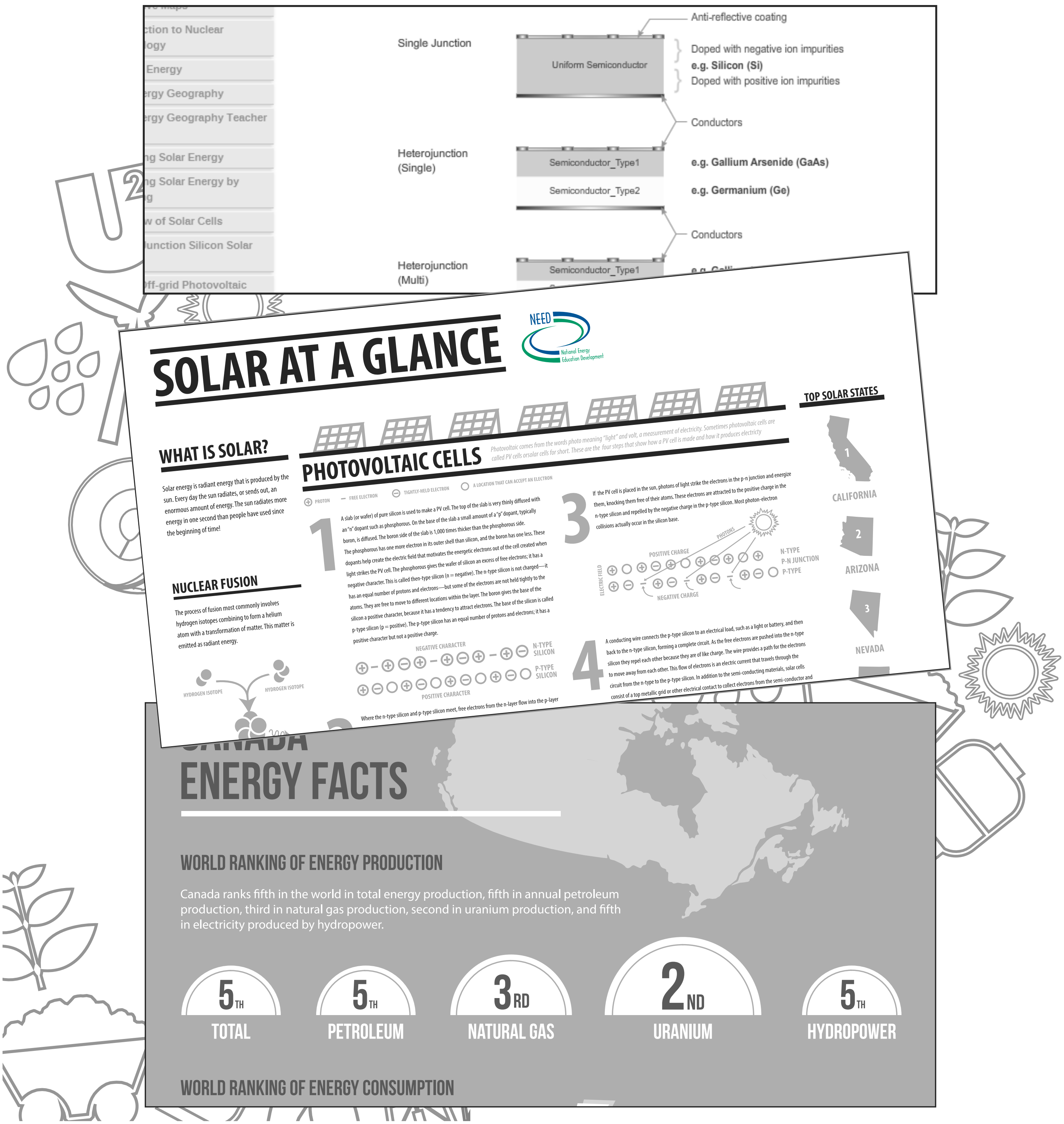
## What's involved?

Students and teachers set goals and objectives, and keep a record of their activities. Students create a digital project to submit for judging.  In April, digital projects should be uploaded to the online submission site.

Want more info? Check out **www.NEED.org/Youth-Awards** for more application and program information, previous winners, and photos of past events.

# Looking For More Resources?

Our supplemental materials page contains PowerPoints, animations, and other great resources to compliment what you are teaching!
**This page is available at www.NEED.org/educators.**



# NEED's Online Resources

## NEED'S SMUGMUG GALLERY

**http://need-media.smugmug.com/**

On NEED's SmugMug page, you'll find pictures of NEED students learning and teaching about energy. Would you like to submit images or videos to NEED's gallery? E-mail info@NEED.org for more information.
Also use SmugMug to find these visual resources:

### Videos

Need a refresher on how to use Science of Energy with your students? Watch the Science of Energy videos. Also check out our Energy Chants videos! Find videos produced by NEED students teaching their peers and community members about energy.

### Online Graphics Library

Would you like to use NEED's graphics in your own classroom presentations, or allow students to use them in their presentations? Download graphics for easy use in your classroom.

## SUPPLEMENTAL MATERIALS

Looking for more resources? Our supplemental materials page contains PowerPoints, animations, and other great resources to compliment what you are teaching in your classroom! This page is available under the Educators tab at www.NEED.org.

## THE BLOG

We feature new curriculum, teacher news, upcoming programs, and exciting resources regularly. To read the latest from the NEED network, visit www.NEED.org/blog_home.asp.

## EVALUATIONS AND ASSESSMENT

Building an assessment? Searching for standards? Check out our Evaluations page for a question bank, NEED's Energy Polls, sample rubrics, links to standards alignment, and more at www.NEED.org/evaluation.

## E-PUBLICATIONS

The NEED Project offers e-publication versions of various guides for in-classroom use. Guides that are currently available as an e-publication will have a link next to the relevant guide title on NEED's curriculum resources page, www.NEED.org/curriculum.

## SOCIAL MEDIA

Stay up-to-date with NEED. "Like" us on Facebook! Search for The NEED Project, and check out all we've got going on!

Follow us on Twitter. We share the latest energy news from around the country, @NEED_Project.

Follow us on Instagram and check out the photos taken at NEED events, instagram.com/theneedproject.

Follow us on Pinterest and pin ideas to use in your classroom, Pinterest.com/NeedProject.

## NEED ENERGY BOOKLIST

Looking for cross-curricular connections, or extra background reading for your students? NEED's booklist provides an extensive list of fiction and nonfiction titles for all grade levels to support energy units in the science, social studies, or language arts setting. Check it out at www.NEED.org/booklist.asp.

## U.S. ENERGY GEOGRAPHY

Maps are a great way for students to visualize the energy picture in the United States. This set of maps will support your energy discussion and multi-disciplinary energy activities. Go to www.NEED.org/maps to see energy production, consumption, and reserves all over the country!

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