THAT WORKS! You lit the bulb!

Cool! Now 2 parts of the bulb are connected to 2 ends of the cell...
ELECTRICITY
with bulbs, batteries,
foil, clothespins
and simple things

SCIENCE WITH SIMPLE THINGS SERIES

Conceived and
written by
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Illustrated by
PEG MARSON

TOPS LEARNING SYSTEMS

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activity 11: Electro-Squares
Gathering Materials

Listed below is everything you'll need to teach this module. Buy what you don't already have from your local supermarket, drugstore or hardware store. Ask students to bring recycled materials from home.

Keep this classification key in mind as you review what’s needed.

<table>
<thead>
<tr>
<th>general on-the-shelf materials:</th>
<th>special in-a-box materials:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal type suggests that these materials are used often. Keep these basics on shelves or in drawers that are readily accessible to your students. The next TOPS module you teach will likely utilize many of these same materials.</td>
<td>Italic type suggests that these materials are unusual. Keep these specialty items in a separate box. After you finish teaching this module, label the box for storage and put it away, ready to use again.</td>
</tr>
</tbody>
</table>

**(substituted materials):**

Parentheses enclosing any item suggests a ready substitute. These alternatives may work just as well as the original. Don’t be afraid to improvise, to make do with what you have.

**optional materials:**

An asterisk sets these items apart. They are nice to have, but you can easily live without them. They are probably not worth an extra trip to the store, unless you are gathering other materials as well.

Everything is listed in order of first use. Start gathering at the top of this list and work down. Ask students to bring recycled items from home. The Teaching Notes may occasionally suggest additional Extensions. Materials for these optional experiments are listed neither here nor under Materials. Read the extension itself to determine what new items, if any, are required.

Quantities depend on how many students you have, how you organize them into activity groups, and how you teach. Decide which of these 3 estimates best applies to you, then adjust quantities up or down as necessary:

- **Single Student:** Enough for 1 student to do all the experiments.
- **Individualized Approach:** Enough for 30 students informally working in pairs, all self-paced.
- **Traditional Approach:** Enough for 30 students, organized into pairs, all doing the same lesson.

**KEY:** special in-a-box materials | general on-the-shelf materials | *optional materials

<table>
<thead>
<tr>
<th>Q₁/Q₂/Q₃</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1 roll</td>
<td>masking tape, ¾ inch wide - see teaching notes 1 for possible substitutions</td>
</tr>
<tr>
<td>1 box</td>
<td>aluminum foil, light duty OK</td>
</tr>
<tr>
<td>1 / 15 / 15</td>
<td>pairs of scissors</td>
</tr>
<tr>
<td>3 / 30 / 30</td>
<td>dry cells, size D, 1.5 volt</td>
</tr>
<tr>
<td>2 / 30 / 30</td>
<td>flashlight bulbs, 4.5 volt, designed for 3 size D dry cells, often marked PR 3. Bulbs with a “collar” (a protruding rim of metal below the bulb) will work better than screw-in kinds. It is important to use bulbs from the same manufacturer with the same resistance rating so they will shine equally bright. See Teaching Notes 3 for an economical alternative.</td>
</tr>
<tr>
<td>1 box</td>
<td>paper clips</td>
</tr>
<tr>
<td>15 / 150 / 150</td>
<td>rubber bands: narrow, medium size are easiest to use</td>
</tr>
<tr>
<td>10 / 100 / 150</td>
<td>pennies</td>
</tr>
<tr>
<td>5 / 150 / 150</td>
<td>index cards, 3 x 5 inch preferable</td>
</tr>
<tr>
<td>1 / 2 / 3</td>
<td>paper punch tools</td>
</tr>
<tr>
<td>6 / 110 / 130</td>
<td>wooden spring-action clothespins</td>
</tr>
<tr>
<td>1 box</td>
<td>steel wool, unsoaped, fine grade, about as thick as human hair</td>
</tr>
<tr>
<td>1 / 10 / 30</td>
<td>straight pins: 1-inch steel pins</td>
</tr>
<tr>
<td>3 / 30 / 30</td>
<td>balloons, any size</td>
</tr>
</tbody>
</table>
Sequencing Activities

This logic tree shows how all the activities in this book tie together. In general, students begin at the trunk of the tree and work up through the related branches. Lower level activities support the ones above.

You may, at your discretion, omit certain activities or change their sequence to meet specific class needs. However, when leaves open vertically into each other, those below logically precede those above, and should not be omitted.

When possible, students should complete the activities in the same sequence as numbered. If time is short, however, or certain students need to catch up, you can use this logic tree to identify concept-related horizontal activities. Some of these might be omitted, since they serve to reinforce learned concepts rather than introduce new ones.

For whatever reason, when you wish to make sequence changes, you’ll find this logic tree a valuable reference. Parentheses in the upper right corner of each activity page allow you total flexibility. They are blank so you can pencil in sequence numbers of your own choosing.
Gaining a Whole Perspective

Science is an interconnected fabric of ideas woven into broad and harmonious patterns. Use extension ideas in the teaching notes plus the outline presented below to help your students grasp the big ideas — to appreciate the fabric of science as a unified whole.

Debate the best way to generate electricity. Divide your class into student teams. Each team should champion a particular energy source like solar, geothermal, wind, synthetic fuels or nuclear. Have at least one group advocate conservation.

Related TOPS modules that provide additional hands-on experience using simple materials include:

- 19 Electricity
- 20 Magnetism
- 33 Magnetism

Lightning that flashes across the sky is related to the cling in clothes that you have just removed from the dryer. Read about static electricity. Select one of these topics for further study:

- lightning
- capacitors
- electroscopes

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Study the technical applications of electricity in your community. Organize a field trip to your local power plant or electrical substation. Tour a building under construction that has the wiring already installed, but not the inside walls.

Write an essay about life without electricity. What inventions and conveniences would we have to do without? How would this affect our quality of life?

Read about electricity as it relates to other scientific disciplines.

- chemistry: reactions that make electricity (oxidation/reduction)
- biology: electric potentials within the body
- computers: integrated circuits, microchips and semiconductors
- physics: low temperature superconductors

Students who show special aptitude or unusual interest in electricity might wish to investigate these career possibilities:

- electrical engineer
- electrician
- electrical draftsperson
- electronics technician
- science researcher (see above)
Review / Test Questions

Photocopy these test questions. Cut out those you wish to use, and tape them onto white paper. Include questions of your own design, as well. Crowd them all onto a single page for students to answer on their own papers, or leave space for student responses after each question, as you wish. Duplicate a class set, and your custom-made test is ready to use. Use leftover questions as a class review in preparation for the final exam.

activity 1
Draw a way to light a bulb with a dry cell. Draw another way that doesn't work.

activity 2
Connect bulbs and dry cells with lines to show how to light each bulb.

activity 3
Predict if these bulbs will light. Give a reason for each prediction.

activity 4
Circle one group (A or B) to show which cells make a bulb shine brighter. Do this in all three rows of problems.

activity 5
Number these 5 groups of cells by how bright they make the bulb shine. Write 1 in the blank next to the brightest, 2 for the next brightest, and so on.

activity 6
You have discovered a UFO (unidentified fallen object) in your back yard. You want to find out if it's a conductor or insulator of electricity. Use words and pictures to tell what you would do.

activity 7
a. A bulb lights with holes 1, 4 and holes 4, 5. Therefore the bulb must light with hole(s) ______ as well.
b. Hole 1 lights only with 2. Hole 2 therefore cannot light with holes ______.

activity 8a
Which end of the dry cell is the positive pole? When you build a circuit, in what direction do the electrons flow?

activity 8b
Why must a circuit contact both ends of a dry cell to light the bulb?

activity 9
This circuit has a bypass at a, another bypass at b, and an open switch at c. Circle all true sentences about this circuit.

activity 10
Redraw this circuit using the correct symbols. Use arrows to show how electrons flow through the circuit.

activity 11
Diagram this circuit:

1 cell + 1 switch
1 cell + 1 switch
2 bulbs
in parallel

Use arrows to show how electrons should flow through the wire. You may use your electro-squares, if you wish.
activity 12
Compare each pair of circuits. Circle the one that produces more light.

1a.  

1b.  

activity 14
Six copper wires, 3 thin and 3 thick, have different lengths as shown. Circle the wire with the greatest resistance. Draw a box around the wire with the least resistance.

activity 15
To use less copper and thus save money, an electrician installs thinner copper wire in a home than the building code allows. Why is this a dangerous practice?

activity 16
Fill in the blanks with "on" or "off."

activity 17
It's a hot summer evening. All the kitchen lights are on and the air conditioner is humming. You put your dinner in the oven and turn on the temperature control. Suddenly everything goes dark. What's wrong? What should you do?

activity 18
Which steel wool fiber is more likely to get hot enough to pop a balloon, a thick strand or a thin strand? Explain.
**IT WORKS!**

1. Make some wire from aluminum foil and tape. To do this...

   ![Image showing a strip of foil]

   30 cm
   IS A LITTLE LONGER THAN THIS PAGE.

   ![Image showing a strip of foil]

2. Cut around the edge of the tape to make a foil ribbon.

   ![Image showing a foil ribbon being cut]

3. Fold the ribbon along its length, so the shiny side stays out and the tape is folded inside.

   ![Image showing a foil ribbon being folded]

4. Crease the fold along the edge of your table.

   ![Image of a person creasing the foil ribbon]

5. Use this foil ribbon to light a bulb with a dry cell.

   ![Image of a bulb being lit by a foil ribbon]

6. **This works:**

   ![Diagram of a dry cell and a bulb lit]

7. Using pictures like these, draw how you made the bulb light. Also draw a way you tried that didn't work.

   ![Diagram of a dry cell, foil ribbon, and bulb]

8. Tape your name to your dry cell. You will use it during this whole module on Electricity.

   ![Image of a name taped to a dry cell]

   **CONSERVE ENERGY:** make your dry cell last!
Objective

To discover by trial and error how to light a bulb with a dry cell and foil ribbon.

Lesson Notes

The foil conducting ribbons used in these lessons are strong, flexible, tangle-proof, and much easier for young children to use than copper wire. Using paper clips with the ribbons, students make secure connections when they build circuits. A completed circuit that is supposed to turn on, turns on – the first time!

1-2. Some students may cut the foil into strips before they apply the tape. This doesn’t work. They’ll create a mess and have to start over. If you wish to avoid students handling (or mishandling) strips of sticky tape altogether, you can pre-tape the foil yourself, and have them simply cut out the strips.

Most any kind of tape will work. We recommend that you use 3/4 inch masking tape, which folds into convenient 3/8 inch width conducting strips. Alternatively, apply 2 inch packaging tape to the foil and divide it into 3 separate strips.

3. Aluminum foil conducts electricity, but tape does not. If your students fold the strip with the tape on the outside, they’ll end up with a useless strip of non-conducting ribbon. This is less likely to happen if you supply opaque or colored tape; even young children usually guess that the shiny foil side is the “working” part of the ribbon.

But what happens if your students stick clear tape to the foil? They can’t see it, so may accidently fold the nonconducting side out. To avoid this, step 1 asks students to apply tape to the dull side of the foil, while step 3 directs them to fold the shiny side (untaped) to the outside.

6. It may seem surprising that students of high school age, and even adults, don’t generally know how to light the bulb. They usually need to do a lot of trial and error investigating. Such exploratory activity is, of course, ideal. Don’t be too quick to come to the aid of puzzled students.

Younger students, however, may become frustrated beyond their ability to cope. Help them out by twising the foil ribbon around the top of the bulb collar (see step 1 of activity 4). With this connection in place, your younger scientists will soon discover the other connections and light the bulb.

Sometimes students complain of being “shocked”. Electricity produced by size D cells is totally safe, not strong enough to harm anyone. What they actually feel is the heat generated through the ribbon when it inadvertently connects both poles of the cell. Without a light bulb providing resistance, electron flow is great enough to heat up the ribbon.

Caution students to disconnect these “hot” wires immediately, since they quickly drain the cell of its energy.

7. There are many different ways to light a bulb with a cell and wire. Your students will discover many of these variations in activities 1-3.

It’s conceptually important to clearly indicate how the contact points on the bulb and cell are interconnected. Watch out for drawings where the bulb looks like an undifferentiated blob, the cell like a box, and the foil ribbon like a railroad track. Refer your students to the schematic drawings provided.

8. This step is optional but recommended. If your students understand that they must continue to use their own cells throughout the entire module, they will more readily conserve energy. Remind them again to immediately disconnect energy-draining hot wires.

Answers

7. [Diagram showing correct method]

Materials

- Aluminum foil. Pre-cut rectangles about 30 cm long. See lesson note 1-2.
- Masking tape or packaging tape (opaque is desirable. See notes 1-2 and 3.
- Scissors.
- Size D dry cells (1.5 v), one per student. If fresh, they should last for this entire unit.
- Flashlight bulbs, one per student. Use a size designed for 3 dry cells, or 4.5 volts. It may be marked PR 3. It is important to use bulbs from the same manufacturer with the same resistance rating so they will shine equally bright – a requirement for later activities.
Who are those TOPS folks, anyway?

**Ronald Jay Marson** graduated from Seattle Pacific University with a B.S. in Chemistry, and from Harvard University with an M.A.T. in Science Education. For three years he taught science and math, and supervised student teaching in Ghana, West Africa, as a Peace Corps volunteer. That’s where idealism bumped into reality.

With ingenuity and wit, Ron made do with limited resources, using recyclables and local materials to teach his classes. Returning home, he refined his “science with simple things” approach while teaching at a boarding school in Utah.

Ron’s rich and varied experience as an educator, his facility as an explainer of complex concepts, and his respect for the curiosity and native intelligence of children, all come together in his books.

As founder of TOPS Learning Systems, a non-profit educational corporation, Ron has provided quality education based on resources available to everyone. His goal as an educator is to nurture a love of learning as new generations become their own best teachers.

Ron stays refreshed running, backpacking, and engaging friends in deep and searching conversation.

**Peg Nazari Marson** was working as a freelance artist and graphic designer when she met Ron in 1981. In her character-building, starving-artist years, she worked as a printer’s assistant, apple picker, bank teller, telephone operator, legal secretary, teacher’s aide, sign designer and woodworker. One of her all-time favorite jobs was tutoring at-risk high school students in language arts, math and science. She often incorporated diagrams and drawings to help her students understand connections and concepts. Illustrating TOPS lessons was a natural culmination of her work history.

When she’s not busy drawing people for TOPS, Peg works on her own art, and has had successful solo gallery exhibits. She paints and draws in a variety of subjects, media and styles, but especially loves colored pencil and watercolor. Learning to do her illustrations on a computer screen – using a mouse instead of a pen – was an ultimately satisfying challenge.

Peg rounds out her life growing flowers organically and struggling to keep weeds at bay in the lush Willamette Valley. She delights in spending time with her grown daughter, Leah, and awesome grandson Griffin.

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