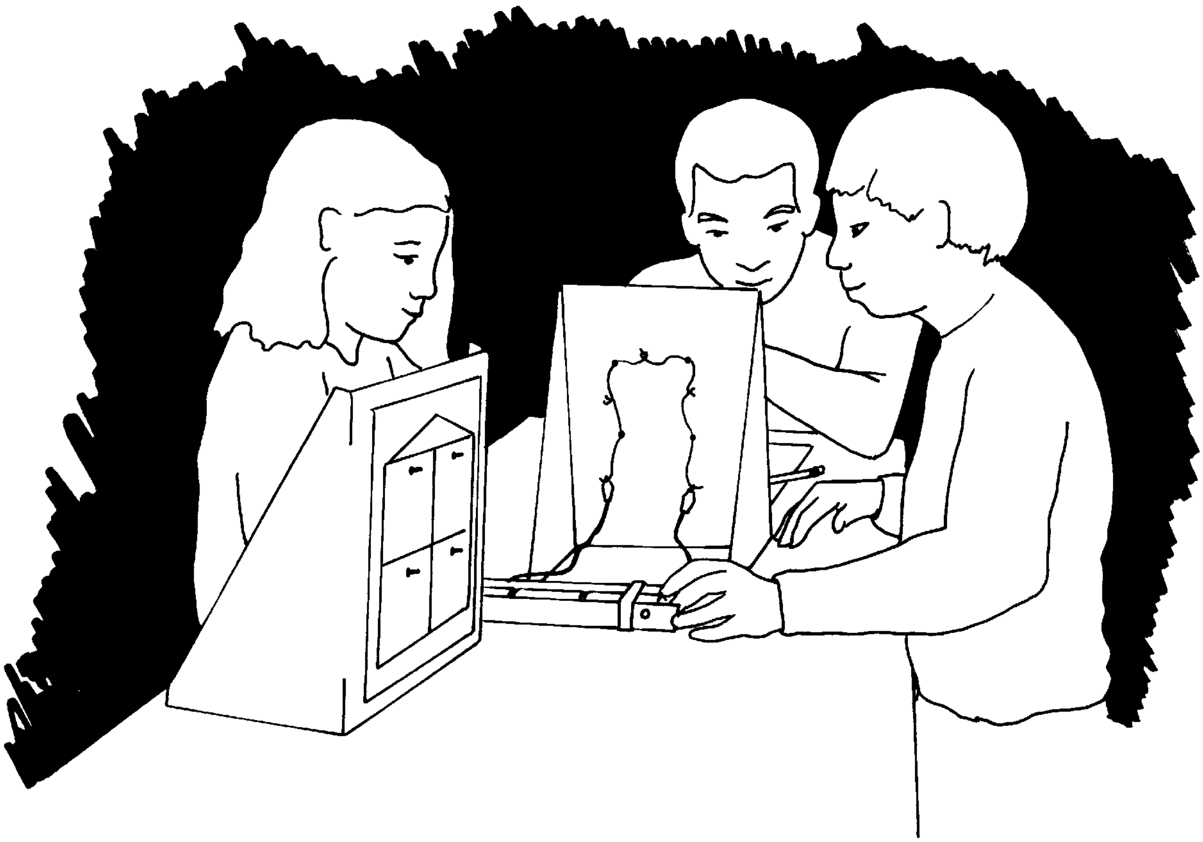
Explore It!

SCIENCE INVESTIGATIONS
IN OUT-OF-SCHOOL PROGRAMS



Wiring a House

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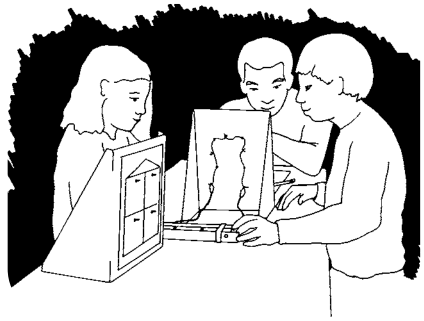


Wiring a House

OVERVIEW

Children love playing with batteries, bulbs, wires, and switches. Given the right materials, there is no end to how long some children will explore all the different ways these simple devices can be connected together. Play of this sort is undoubtedly foundational for real learning about the principles of electricity. However, most children would miss much of the learning potential of this kind of hands-on experience without a structure to help them piece together the behaviors of the mysterious entity called "electricity."

Most children also enjoy making model houses. Building structures that relate to their own lives and experiences engages their imagination and offers a medium for all kinds of group work and negotiation. In this project, the children combine these two areas of play—building structures and experimenting with electricity—and, in the process, learn practical rules of electrical wiring and the foundational principles of electricity. Whether they subsequently revisit these topics in formal educational settings or encounter them in their own lives, their experience with this project will provide them with understanding of, knowledge about, and context for this important topic.

Relationship to the National Science Standards

This guide is written for implementation in informal educational settings, such as after-school programs and summer camps. Given the nature of this kind of programming, it is not the intent of this guide to fully address the national science content standards. If done in a carefully guided manner, the activities can provide an experiential background for addressing, in part, the National Research Council's content standards for K–4*, such as properties of objects and materials and abilities necessary to do scientific inquiry.

In addition, if the activities are carried out with an informed attitude, spirit, and care, children can benefit in many ways:

- They will become better acquainted with the phenomena focused on in the investigations (e.g., properties of electrical circuits).
- They will practice basic skills (using simple equipment) and habits of mind (analysis) that will be helpful in the formal educational context.

Sequence of the Explorations

The sequence of the explorations has been designed such that each exploration builds upon the one(s) before. The first exploration starts out with a few materials and some simple problems. What children learn from these manipulations will help them in the later explorations where they have to apply what they have learned as well as think about the spatial arrangements of more complex wiring in two-dimensional and three-dimensional model houses. Therefore, it is strongly recommended that you follow the sequence as presented. Jumping to working with a model house without giving children adequate time to get acquainted with ways of connecting batteries and bulbs will result in their frustration and a sense of inadequacy.

Space and Storage

During the explorations, children will need ample table space. Each team of three or four children should have at least half of a six-foot work table to spread out their materials and to be able to view their houses and circuits from different angles without interfering with their neighbors.

Between sessions you will need to find somewhere to store the cardboard houses. It is vital to the success of this project that children be able to return to their houses during successive sessions to revise or change their circuitry. It is also important that the houses be stored away from children who are not involved in this project so that houses are not tampered with between sessions.

* National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.

OVERVIEW

SAFETY

With clear rules and codes of practice in place and with normal supervision of the group, this project should be perfectly safe for your children. However, there are particular health and safety issues that you and the children should be aware of while you carry out this project:

- Safety goggles should be worn by children while manipulating materials during all explorations.
- Children should never handle sharp knives (used for cutting cardboard) except under close adult supervision.
- Light bulbs are made of glass and are fragile. Children should ask a program leader or another adult for help if one breaks.
- While these activities are safe as presented, they should not be repeated using electricity from wall sockets or fixtures at home or in school.

In addition, you should be aware of the following concerns:

Electric Shocks

It is possible to receive weak electric shocks from the batteries recommended for this project, especially if several of them are linked together in a line. This may scare some children, but both the voltage and the current involved are far too small to pose a danger to safety. It is also possible that, in some circumstances (see notes on "short circuits" below), the wires in some circuits will become hot, again causing a scare for some children.

Therefore, it important that you reassure children of the safety of these activities if carried out as described, so that they don't miss out on the opportunity to explore electricity that this project guide offers them. It is also important, however, that *you do nothing to diminish their respect for and caution around domestic or other high-voltage electrical power supplies*. Stress to the children early and often that there is a dramatic difference of scale between flashlight batteries and the domestic electricity supply.

Batteries

While rechargeable batteries are generally recommended for environmental reasons, their use is not acceptable for this project. If a rechargeable battery is accidentally short circuited, the surge of electricity could heat up the wires very quickly and cause burning to fingers.

Also, do not use a car battery to carry out any of the activities in this project. Although car batteries are rated at only 12 volts, they can deliver a very high current load—up to 40 amps—which is enough to give a child a serious electric shock.

Short Circuits

If you connect a wire directly between the two ends of a battery (Figure 1), you will create what is called a **short circuit**. There are three problems with short circuits:

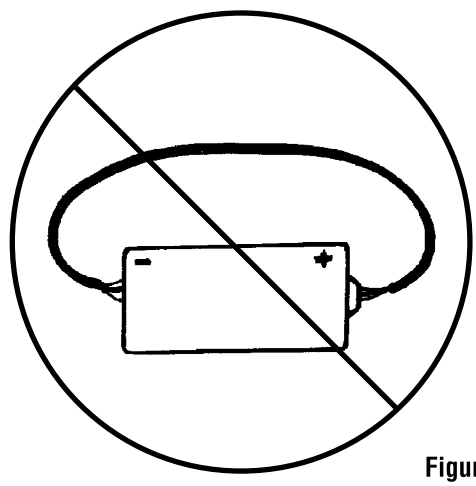


Figure 1
Short circuit.

1. You will drain the battery very quickly.
2. The surge of electricity through the wire may heat up the wire rapidly, possibly causing burns to children's fingers, and scaring them from using the materials.
3. The electrical power will be diverted from the intended light bulbs in your lighting circuits and will cause confusion about whether or not particular bulbs are wired correctly.

Sharp Blades

During this project, you or the children will have to cut up pieces of cardboard. We do not recommend that you allow children to use sharp blades except under close adult supervision. A safe alternative to a knife blade is a hacksaw blade (designed for cutting metal). These blades have no razor-sharp edges and can be safely used by children to cut cardboard quite effectively.

Wrap half of the blade with duct tape to make a handle. The other half of the blade will cut cardboard effectively (Figure 2).

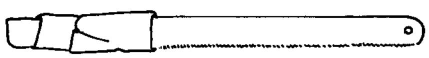


Figure 2
Hacksaw blade.

TEAMWORK

Explore It! projects are designed for teams of three or four children who will ideally remain a team throughout the project. However, use your own judgment as to whether to regroup children into new teams in the middle of the project if the initial team assignments are not serving the larger purposes of the curriculum—that is, for the children to have fun and learn something new.

For teams to work well, the members should be compatible and agree to their team assignments. However, we recommend that you not have the children create their own teams, unless they pay special attention to the issues of exclusion and cliques. Although it will certainly demand more of your supervision and intervention at first, there is much to be gained from steering children into mixed-gender and mixed-ability teams.

Assigning roles helps avoid many of the conflicts that arise among the children about control of and access to the materials. It also ensures that children who might otherwise sit back and let others take over (through either shyness or disengagement) are given the duty and authority to take part in the process. Here are some suggested roles:

- **Materials Manager**: Gathers the team's materials for the activity and prepares them for use.
- **Recorder/Reporter**: Makes drawings or notes relating to the team's work; records data; presents results and observations to the whole group.
- **Ambassador**: Watches what other teams are doing and talks with them about their techniques and discoveries.
- **Experimenter**: Takes the lead in manipulating the materials, e.g., measuring and mixing the ingredients, but shares the task with the rest of the team.

Each team member should be assigned one or two of these roles. However, it is important that all the children get a chance to experience all aspects of the project, so roles should be rotated every one or two sessions. No one should stay in one role for more than a couple of days. It is recommended that assignments not be changed in the middle of a session unless absolutely necessary.

Role assignments will work best if the program leader constantly reinforces them. Therefore, when calling on children, be sure to insist that the proper role-player carries out the action. After seeing you insist upon and respect the roles for some time, the children will gradually begin to follow your lead.

Special Notes About Materials

Alligator Cables

Alligator cables (Figure 3) consist of two miniature clamps attached to each end of a wire. They look like alligators' mouths and help you make easy connections between different parts of your circuitry. They are sometimes called crocodile clips. Alligator clips are available at most electric goods stores and at some hardware stores.

If you are unable to acquire alligator cables, these activities can be carried out by substituting a 9-inch length of plain, insulated wire with 1 inch stripped bare at both ends.

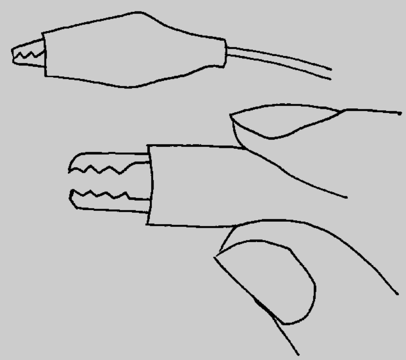


Figure 3
Alligator clips.

Batteries

Use 1.5-volt D-cell or C-cell alkaline batteries. Each team will need three batteries. Stay with either C or D batteries throughout this project. Mixing them up can cause confusion for the children. As noted in the Safety section, do not purchase rechargeable or car batteries.

Brass Fasteners

Use brass fasteners (Figure 4) that are at least 2 inches long for the battery pack and 3/4 inches long for the switches. Buy enough for each team to have at least eight fasteners.

Figure 4
Brass fastener.

Cardboard Boxes

The cardboard boxes used in this project should be 12 x 12 x 12 inches or larger. You will need to cut some in half (12 x 12 x 6 inches or larger) and leave others intact. Be sure that the whole box has a complete bottom and at least one flap at the top, which will become the "porch" (see Exploration 5). You will also need some spare boxes that can be cut up to make the interior walls of the 3-D houses in Exploration 5. Boxes can be salvaged from grocery, liquor, and wholesale stores.

Chart Paper, Standard Paper, and Writing Implements

Chart paper is used in most, if not all, of the following explorations for charts and notes. Also, children are expected to have writing implements and paper available for sketches and observations. These materials are not listed in each of the explorations.

Holiday Lights—Clear

Strings of mini-lights (Figure 5) are available in stores during November and December. Many varieties are sold—indoor, outdoor, single-colored, multi-colored, flashing—and strings come in lengths of 20, 35, 50, and 100 lights. Purchase enough strings of **clear** lights to provide each team with at least four bulbs, plus some spare bulbs in case some of them break.

Some brands of holiday lights require more power than others. If you find that a single bulb from the brand you purchased barely lights up when you connect it to a *single fresh* battery, consider increasing the number of batteries you use across all the activities (See page 21 for instructions on making a battery holder. Consider increasing the size to hold 4 batteries instead of 3.)

Figure 5
Holiday light bulb.

Motors

A simple hobby motor (Figure 6), approximately one inch in size, has a shaft that turns when the motor is powered. These can be purchased at most electric goods stores and hardware stores and from most science supply catalogs.

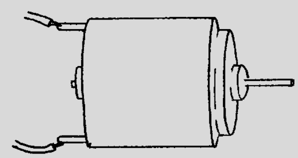


Figure 6
Electric motor.

Paper Clips

One box of jumbo (2-inch) clips should be sufficient for a group of 25–30 children.

Rubber Bands

Size #32 rubber bands is recommended for this project.

Wires

For this project, you want to obtain insulated, 22-gauge, red and black, solid-core or multi-strand copper wire. You can get wire at most electric goods stores and hardware stores and from most science supply catalogs.

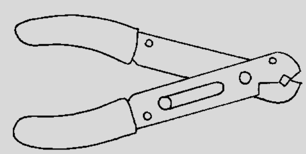


Figure 7
Wire strippers.

Wire Strippers

The standard wire stripper (Figure 7) is a scissors-like tool that can be preset to strip insulation from a particular gauge of wire. These are available at most electric goods stores and hardware stores and from most science supply catalogs. For a little more money, you can buy jaw-style wire cutters/strippers (Figure 8) that automatically prevent the user from cutting through the metal wire while removing the plastic insulation.

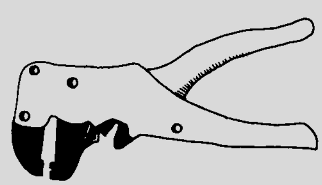


Figure 8
Jaw-style wire strippers.

ELECTRICITY AT HOME

EXPLORATION 1

1 EXPLORERS' SHEET

Discovery Questions

What does it take to get electricity to the lights in your house or any house like the one shown?

How would your life be different if you had no electricity at all for a long period of time?

WHAT TO DO

The worksheet called *How Does Electricity Get to the Light Bulbs?* shows a simple house with a kitchen, living room, and two bedrooms. Each room has a single electric light bulb.

1. On the worksheet, draw all the things that are needed to get electricity to the light bulbs in the house. (Some of the things may be outside the house.)
2. What would life be like if the electric power stayed off for a long time? List all the machines or devices in your house that use electricity. How would you get by without them?

WHAT TO THINK ABOUT

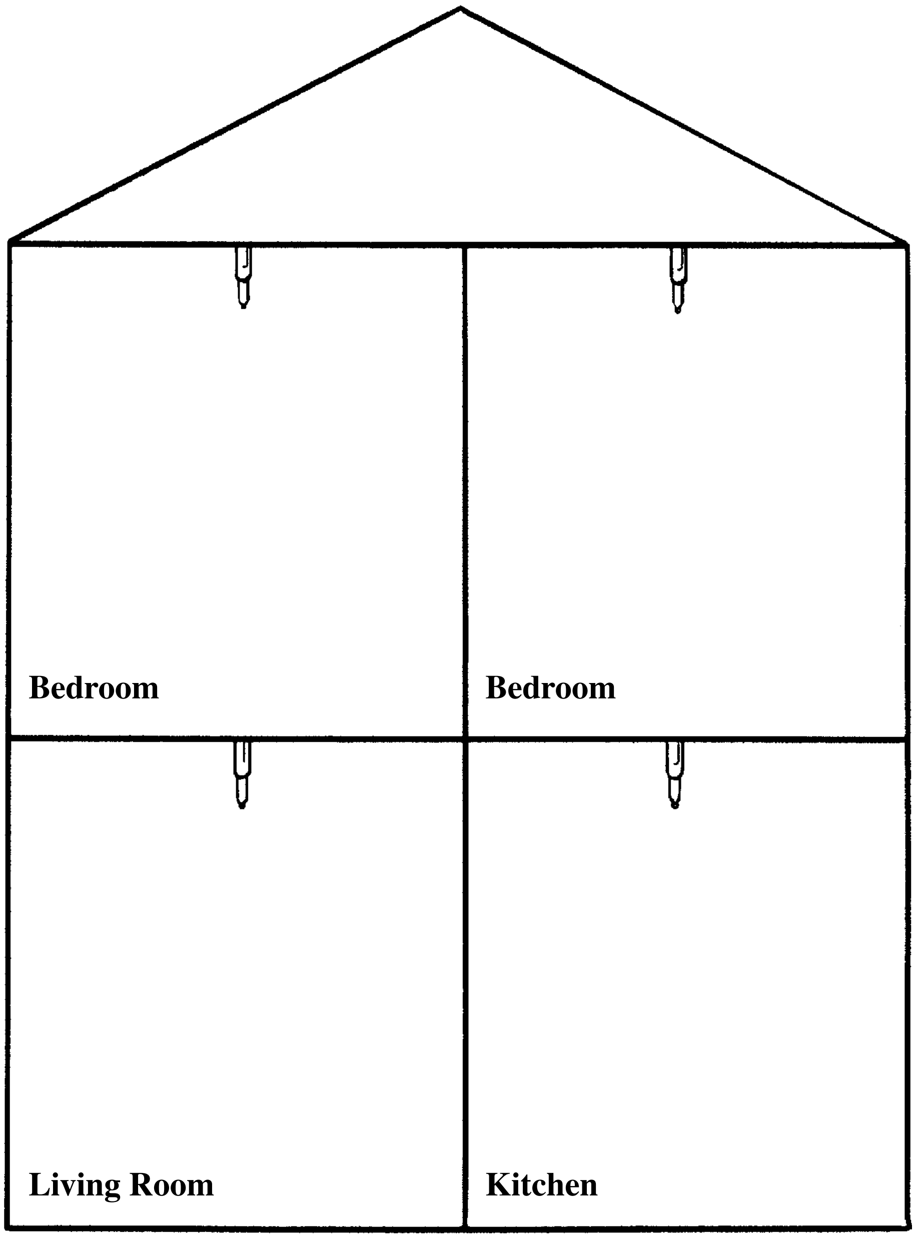
Imagine that there was suddenly no electricity. Think of all the ways you would be affected. Here are some ways. Can you think of more?

- No elevators. Too bad if you live on the 14th floor.
- No microwave oven, no refrigerator, and no freezer. It's back to cooking *everything* from over a fire.
- No telephones, no e-mail, and no TV. More time for writing letters and reading books.

EXPLORERS' SHEET 1

How Does Electricity Get to the Light Bulbs?

1. Add details to this picture to show where electricity comes from and how it gets to the lights in the house.
2. Label your picture to tell what each part does.



ELECTRICITY AT HOME

EXPLORATION 1

MATERIALS

For Each Team
- 1 Explorers' Sheet, including the *How Does Electricity Get to the Light Bulbs?* worksheet

Shared
- pencils (colored and standard)

For the Program Leader
- batteries*
- holiday light bulbs*
- wire*

**Additional information is available under Special Notes About Materials (pages xv-xvi) for those materials noted with an asterisk.*

PREPARING FOR THE EXPLORATION

Make one copy of the Explorers' Sheet, including the *How Does Electricity Get to the Light Bulbs?* worksheet, for each team. However, wait to pass them out until after you have explained the task at hand.

INTRODUCING THE EXPLORATION

Begin by telling the children that over the next few weeks they will learn many things about batteries, bulbs, and other electrical devices. Show them all the materials they will be using during this project (batteries, bulbs, wire) and explain that their goal is to learn how to set up a lighting system in a toy house. Tell them that once they are familiar with how to use these electrical gadgets, they will make a house out of cardboard, and then they will wire it up with lights and other devices. Then pass out the Explorers' Sheet, including the *How Does Electricity Get to the Light Bulbs?* worksheet.

Refer children to the first Discovery Question on the Explorers' Sheet: What does it take to get electricity to the lights in your house or any house like the one shown? Tell them that their task is to draw on the worksheet all the things that are needed (in addition to the bulbs themselves) to make the lights in the house come on. Tell them that they should work as a team and that the team diagram should contain all the ideas of the team members, even if there is disagreement in the team about the details. Explain to them that some of the things that are needed might be outside the house.

If the children seem stuck or if they cannot think of very many components to the electrical system to draw on the *How Does Electricity Get to the Light Bulbs?* worksheet, you might lead them through the process in a systematic way as follows:

- Draw the light bulbs in each room.
- Add switches for each light.

- Draw wires to the basement and draw whatever fuse boxes, etc., they think belong there.
- Draw power lines, poles, and whatever else they think necessary to bring the electricity into the house from the outside.

Leading the Exploration

As the children think about the problem and fill in their diagrams, walk among then and ask them to talk about the various things they are drawing. Avoid making any comments about their drawing skills (good or bad). Ask them to explain or clarify what it is they are trying to draw. Encourage them to write labels next to items on their diagrams to make it easier to understand what they have drawn.

When most of the teams have drawn as much as they can, call the whole group together to share what they know. As always in *Explore It!* discussions, pool the children's ideas.

Leading the Discussion

Make a Chart of Electrical Devices

As the children report out from their teams, create a chart on the wall (for a sample, see Table 1) to record all the electrical devices they have included in their diagrams and what they believe to be the function of each device. Write down an abbreviated version of what each team says for each component of their electrical system. If teams disagree about the function or name of a component, record each idea on the chart as a new line item. Even if you are sure something is incorrect, put it down anyway. This is a **brainstorm**.[1] Later you will come back to the list and ask the children if they still agree with what they said earlier and, if not, to explain why they have changed their minds.

[1] Brainstorming is a technique commonly used to help people spill out whatever they think they know about a topic. It is very important that the program leader or recorder of children's ideas makes NO judgments about which ideas are "right" or "wrong" and allows no put-downs or other comments from other participants in response to someone's ideas. For more on this technique, see *The Implementation Guide to Explore It! Projects.*

Table 1. Sample Chart of Electrical Devices

Device	Where It Goes	What It Does
Circuit breakers	In the basement	Stops you from getting electric shocks, cuts off the power
Wires	In the walls, on poles outside	Brings electricity to the plugs, to the house
Light bulb	Walls, ceilings	Makes it light in the house

When the whole group has reported out, ask the children to debate the different answers they have generated. At this point, you should stress that you are not going to say who is right or wrong. You are most interested in everybody's reasons for whatever they believe. By the end of this discussion, you should have a very good idea of how accurately (or otherwise) the children think about the electrical systems in a typical house. See the comments in the Background section for more information on this topic.

Life Without Electricity

Once you have heard and recorded everyone's ideas about how electricity gets to the lights in your houses, switch the conversation to the second Discovery Question on the Explorers' Sheet:
What would life be like without electricity?

On the back of the sheet the children used to illustrate the electrical supply, have them make a simple two-column chart (as shown in Table 2). In the left-hand column, they should list electrical devices they use at home. In the right-hand column, they should describe how they would accomplish what the electrical device does (or what they would do instead) if the power went off and stayed off.

Table 2. Sample *What We Would Do Without Electricity* Chart

Device	What We Would Do Without Electricity
Toaster	Eat raw bread, toast it on a gas stove
TV, Computer	Read books, sleep more, play outside, be bored
Elevator	Move downstairs, walk up, set up a pulley for groceries
Alarm clock	Sleep in, get a wind-up clock
Telephone	Visit friends

Discussion Questions

Ask the following questions to continue the discussion. (Answers are provided in the Background section.)

1. Which electrical devices must be inside the house? outside the house?
2. What does an electrical wire look like? What is it made of? What parts does it have? What does each part do?
3. What are some things that electricity can travel through and things that it cannot?

ELECTRICITY AT HOME

EXPLORATION 1

RATIONALE

Children have a wide variety of impressions about what makes electrical devices work. Some (but not all) children know about power stations and supply cables, but many are still unclear about what roles these things play. Some even assume that the light switches themselves are a kind of power source while others give this role to the electricity meter or the circuit breakers in the basement. By tinkering with and exploring the very simple electrical circuitry described in this project, the children will have an opportunity to work out for themselves some of the basic principles of electricity.

ANSWERS TO DISCUSSION QUESTIONS

Below are answers to the Discussion Questions suggested on page 6 of this guide. This information is provided in order to help you understand some of the issues that may come up in discussion with the children. It is not intended that this information be "taught" to the children, or even passed on in this form at all. Rather, it is hoped that by having access to the "answers" to common questions, program leaders will be better able to steer the children towards discovering some of this information for themselves as a result of their investigations with the materials.

1. **Which components are usually inside the house? outside the house?**

   Inside: bulbs, wires, switches, circuit breakers. Outside: electricity meter, supply box, cables, supply poles, power stations (various types).

2. **What does an electric wire look like? What is it made of? What parts does it have? What does each part do?**

   Electric wire is made of metal, usually copper (yellow/orange color). Sometimes this metal is a single strand and sometimes it is made of many very thin strands running next to each other. Often there is a plastic cover on the outside. This is called **insulation**. Insulation does not conduct electricity. It protects us from electric shocks and stops the electricity from leaking away before it gets where we want it to go. Some electric wires have two or more insulated current-carrying wires and one uninsulated ground (earth) wire all wrapped inside an external plastic coating.

3. **What are some things that electricity can travel through and things that it cannot?**

   Electricity flows through metals very easily; therefore, they are referred to as good **conductors** of electricity. Water is also a good electrical conductor, and because people have a lot of water in their bodies, electricity that comes into contact with the periphery of their bodies easily travels through them, sometimes causing damage to sensitive organs.

   Electricity does not flow easily through glass, plastic, and rubber (except at extremely high voltages); thus, these materials are called **insulators**.

   At very high voltages (in the thousands or millions of volts), almost all materials conduct electricity to some extent—even air (hence lightning and electric sparks). At the voltages used in this project (1.5–4.5 volts), all dry, nonmetallic materials (paper, cloth, tape, plastic, rubber) do not conduct electricity and can, therefore, be thought of as electrical insulator materials.

FURTHER EXPLORATION

Take the children on a field trip to see "big electricity" in the form of power stations, power transmission lines, or other industrial-sized components of the electric grid (Figure 9). Real world visits are valuable experiences for children, and they can also stimulate thinking and creativity in relation to the project at hand.

Figure 9
High voltage electrical transmission lines.