interact
Learn Through Experience

FUDGE FACTORY

A simulation solving a scientific mystery while learning about electricity and magnetism

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STANDARDS

The nationwide movement for high standards has not only determined what students should learn, but also has mandated that students demonstrate what they know. FUDGE FACTORY is a standards-based program addressing National Science and English Language Standards. The content and skills taught in FUDGE FACTORY are targets of most state frameworks for scientific inquiry. The FUDGE FACTORY simulation provides the opportunity for performance assessment when students apply their science inquiry skills in Phase 1 as they complete experiments to investigate static and current electricity. In Phase 2, they use their research and critical thinking skills to determine what has caused a mysterious electrical failure at a Fudge Factory. The teamwork, record keeping, and problem-solving required in the simulation also address Applied Learning Standards.

National Science Education Standards

Content Standard A: Abilities Necessary to do Scientific Inquiry

- Ask questions about objects, organisms, and events in the environment.
- Design and conduct a scientific investigation.
- Use appropriate tools and techniques to gather, analyze, and interpret data.
- Think critically and logically to make the relationships between evidence and explanations.
- Recognize and analyze alternative explanations and predictions.
- Communicate scientific procedures and explanations.

Content Standard B: Physical Science

Transfer of Energy

- Electricity in circuits can produce light, heat, sound, and magnetic effects. Electrical circuits require a complete loop through which an electrical current can pass.
- Magnets attract and repel each other and certain kinds of other materials.
- Electrical circuits provide a means of transferring electrical energy when heat, light, sound, and chemical changes are produced.

Content Standard G: History and Natural Science

Science as a Human Endeavor

- Men and women of various social and ethnic backgrounds—and with diverse interests, talents, qualities, and motivations—using scientific inquiry made a variety of contributions throughout the history of science and technology.
- Although men and women using scientific inquiry have learned much about the objects, events, and phenomena in nature, much more remains to be understood. Science will never be finished.

History of Science

- Many individuals have contributed to the traditions of science. Studying some of these individuals provides further understanding of scientific inquiry, science as a human endeavor, the nature of science, and the relationships between science and society.

NCTE Standards for the English Language Arts

Standard 7 Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources to communicate their discoveries in ways that suit their purpose and audience.

California Applied Learning Standards

Standard 6 Students will understand how to apply communication skills and techniques. Students will demonstrate ability to communicate orally and in writing.

Standard 8 Students will understand the importance of teamwork. Students will work on teams to achieve project objectives.

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TABLE OF CONTENTS

Your students become true scientists as they work to solve a scientific mystery. After arriving at a fudge factory, they discover that operations are shut down due to a mysterious electrical failure. As students work to solve the mystery, they become better prepared to conduct and understand scientific investigations. Through using the scientific method during this simulation, they learn to hypothesize, observe, draw conclusions from factual information, and carefully record their endeavors—just as scientists do. Specifically, your students will gain the following:

Knowledge
- Steps of the scientific method
- How electricity works
- Characteristics of static electricity and current electricity
- Characteristics of electricity as it exists in nature
- Types of circuits
- Meanings of electricity-related vocabulary
- Safety precautions necessary for electricity management
- Historical background of famous scientists in the field of electricity and magnetism
- Relationships among electricity, magnetism, and motors

Skills
- Working as a team with classmates
- Conducting experiments according to the scientific method
- Enhancing language arts and problem-solving skills by accurately collecting and recording scientific data, observations, and questions
- Analyzing clues to determine their usefulness in solving a problem
- Reading for information
- Sharing and discussing information in meaningful ways

Feelings and Attitudes
- Developing and valuing a sense of teamwork
- Appreciating the value and usefulness of electricity
- Appreciating accurate record keeping
- Increasing confidence in applying the scientific method
- Developing healthy respect for the dangers posed by natural and artificially generated electricity

PURPOSE

OVERVIEW

Most students are fascinated by mysteries because they are able to take pieces of information and see how they fit together as they attempt to solve a problem. Unfortunately, some students are under the impression that all mysteries are connected with murder and suffering, because that is what they see on television and in the movies. Students need to recognize that real people investigate and solve mysteries of the non-violent kind daily in science, history, health, engineering, and many other disciplines. FUDGE FACTORY exposes your students to a scientific mystery. As they use the scientific method, they work as scientists do to solve a real mystery. This simulation will engage, excite, and challenge students as they actively increase their understanding of the scientific process. Students are motivated and excited as they uncover clues and gain information, much like a detective does. FUDGE FACTORY is part of Interact's Science Mystery Series, stressing the scientific method and discovery.

FUDGE FACTORY consists of three distinct phases.

- Phase 1 covers the basics of the characteristics of electricity and magnetism through brief written histories and basic science experiments and activities.
- Phase 2 explores more details and offers further examples of electricity and magnetism and related concepts as students work to solve the mystery.
- Phase 3 provides several options for extending this simulation, including ideas for culminating events and challenging independent study projects.

Phase 1: Momentous History (Optional)
In this phase, students learn about some of the major historical people and moments related to discoveries in the field of electricity and magnetism. Then they conduct experiments to illustrate these discoveries using the scientific method.

The EUREKA! MOMENTS provide teachable opportunities to explore the following: Benjamin Franklin and static electricity; Luigi Galvani and Alessandro Volta and generating electricity; Hans Christian Oersted and Andre-Marie Ampère turning electricity into magnetism; Michael Faraday and turning magnetism into electricity; Thomas Edison (his influence on the field of electricity) and controlling experimental design.

The EUREKA! ACTIVITIES re-enact and illustrate the moments in scientific history discussed in the EUREKA! MOMENTS, demonstrating the principles discovered and showing how scientists expanded on and sometimes corrected previous work done by others. These activities lay the groundwork for the scientific study in Phase 2.

If your students are already familiar with the scientific method and the concepts underlying the principles of electricity and magnetism, you may simply opt to have them read and discuss the contents of the Student Guide: Phase 1, then proceed to Phase 2.

Phase 2: Faraday's Fudge Factory
This phase, the main portion of the simulation, guides students through a scientific mystery set in a fudge factory where the components are not working because of problems with electricity. Divided into teams, students explore Faraday's Fudge Factory with "Ms. Faraday," the factory's owner, searching for clues and participating in a variety of laboratory explorations. Students apply what they have learned about electricity and magnetism to solve the mystery.

Students participate in daily group problem-solving sessions, called T.E.A.M. ACTIVITIES (**T**ogether **E**veryone **A**ccomplishes **M**ore), which provide additional information about science, electricity, and magnetism. Students receive information about the problems plaguing the factory's various operations in the form of CLUE SEARCH information sheets, written as narratives of students' experiences at the factory. Students then explore the questions raised by the CLUE SEARCH information and gain additional practice in using the scientific method as they complete six ELECTRICITY EXPLORATION activities.

At the end of each day, during a short debriefing session, students discuss what they have learned that day. Room by room, students report their recommendations to Ms. Faraday on a SCIENTIFIC DETECTIVE FORM. After working on the five mystery sessions in Phase 2 and going through a final debriefing session, students give Ms. Faraday their overall recommendations and suggestions.

Phase 3: Extensions (Optional)
Based on the interests and abilities of your students and the time available, decide whether you will extend the learning of this simulation with one or more of these activities.

- Oral presentations of group recommendations to a person acting as Ms. Faraday
- Challenge Projects
- Electrified Inventions Day
- Women Inventors Research Projects
- Eureka! Moment Re-enactments

1. **Preparation Reading**
Carefully and thoroughly read this Teacher Guide and both Student Guides *before* beginning this simulation. This will help you plan your time and adjust this simulation to meet your students' needs and abilities.

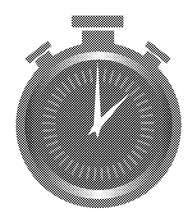
2. **Science Journals**
Each student in your class needs a Science Journal. Plan time every day during class for students to write their observations and conclusions in their journals. FUDGE FACTORY includes a duplicable MY SCIENCE JOURNAL master to use as a cover.
   a. Students make these journals by gluing their copy of MY SCIENCE JOURNAL to:
      - a composition book or notebook
      - folded construction paper (11" x 17")
   b. Each student's Science Journal should include:
      - GLOSSARY
      - SCIENTIFIC METHOD handout
      - pockets for additional handouts
      - at least 10 sheets of lined paper

3. **Schedule**
The schedule of this simulation is flexible. Study the Unit Time Chart. It is organized by investigations, not by days. If you plan 45 to 60 minutes per day, Phase 1 activities will take approximately five to seven days to complete. If you choose to have your students create their own inventions as an extension activity, schedule additional time. Students can complete these inventions in class or as homework. Using the same amount of daily class time, Phase 2 will take approximately eight days.
   a. Be sure to look carefully through each phase to determine how you can best use this simulation in your class.
   b. If your students need background knowledge of electricity and magnetism and related concepts, Phase 1 prepares them for Phase 2.
   c. Even if your students have some knowledge of electricity and magnetism concepts, consider reading and discussing the EUREKA! MOMENTS in the Student Guide: Phase 1.
   d. If you decide to have your students take what they have learned in this simulation one step further, add the time you think they will need to complete the optional Phase 3.

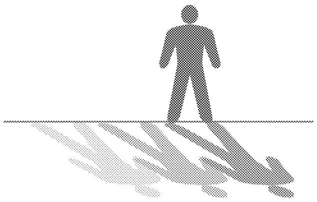
TEACHING TIP

If you do not have enough class time for journal writing, assign this as homework.

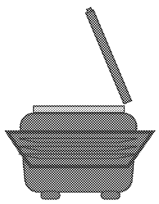
The GLOSSARY provides an excellent reference for the terminology used throughout this unit. Encourage your students to use this tool!



See the Unit Time Chart on page 15 to plan your time.



You may allow your students to continue in the same group throughout the simulation or regroup them for Phase 2.



4. **Grouping Students**
Divide your students into groups of four to six, to remain together throughout the simulation. If the number of students does not divide evenly, some students must be responsible for sharing more than one set of T.E.A.M. ACTIVITY strips during Phase 2.

5. **Duplication**
Make copies of the following pages in the quantity indicated in *italics*. The duplication master pages begin on page 61.

Phase 1
YOUR SCIENCE JOURNAL* — *class set*
MY SCIENCE JOURNAL* — *class set*
SCIENTIFIC METHOD* — *class set*
PROTONS AND ELECTRONS — *class set*
EUREKA! ACTIVITY 1 — *class set*
ELECTRIC SPIDER — *class set*
EUREKA! ACTIVITY 2 — *class set*
EUREKA! ACTIVITY 3 — *class set*
EUREKA! ACTIVITY 4 — *class set*
EUREKA! ACTIVITY 5 — *class set*
* Denotes reproducibles needed in Phase 2, even if you opt to not do Phase 1.

Phase 2
CLUE SEARCH 1 - The Office Room — *class set*
CLUE SEARCH 2 - The Cooking Room — *class set*
CLUE SEARCH 3 - The Refrigeration Room — *class set*
CLUE SEARCH 4 - The Packaging Room — *class set*
CLUE SEARCH 5 - The Boiler Room — *class set*
WHAT ARE T.E.A.M. ACTIVITIES? — *class set*
INTRO. T.E.A.M. ACTIVITY — *one set of strips per group*
INTRO. T.E.A.M. ACTIVITY RECORD — *one per group*
T.E.A.M. ACTIVITY 1 — *one set of boxes per group*
T.E.A.M. ACTIVITY 1 RECORD — *one per group*
T.E.A.M. ACTIVITY 2 — *one set of boxes per group*
T.E.A.M. ACTIVITY 2 RECORD — *one per group*
T.E.A.M. ACTIVITY 3 — *one set of strips per group*
T.E.A.M. ACTIVITY 3 RECORD — *one per group*
ELECTRICITY EXPLORATION 1 — *class set*
ELECTRICITY EXPLORATION 2 — *class set*
ELECTRICITY EXPLORATION 3 — *class set*

ELECTRICITY EXPLORATION 4A — *class set*
ELECTRICITY EXPLORATION 4B — *class set*
ELECTRICITY EXPLORATION 5 — *class set*
SCIENTIFIC DETECTIVE RECORD FORM — *five per group*

6. **Materials**
Carefully note the materials you will need in this simulation. Note, too, the separate listings for Phase 1 (which is optional), Phase 2, and Phase 3 (also optional). Gathering these materials ahead of time will help you run this simulation smoothly. Check the Daily Directions for additional details.

Get Wired
Using wire strippers or scissors, strip the wires ahead of time. You should be able to reuse your wires. You will need:
- *six 8-inch wires per group*
- *four 8-inch insulated copper wires per group*
- *one 12-inch insulated copper wire per group*
- *one 24-inch insulated copper wire per group*
- *one 30-inch insulated copper wire per group*
- *one 12-inch magnet wire (enamal coated, 32 gauge) per group*
- *one 2-3 inch nichrome wire (#32) per group*

Phase 1
EUREKA! MOMENT 1
- Science Journals* — *class set* (see Setup Directions #2)
- Group Science Folders
    - Construction paper (11" x 17") — *one per group*
    - Pencils — *class set*
    - Stapler — *one per group*
- Eureka! Activity 1
    - Balloon (inflated) — *one per group*
    - Paper spider (found on ELECTRIC SPIDER handout) — *one cutout per group*
    - Scissors — *one per group*
    - Stopwatch or clock with a second hand — *one per group*
    - String or yarn, 12"-14" long — *one per group*
    - Wool cloth (any size) — *one per group*

* Denotes items needed in Phase 2, even if you opt to not do Phase 1.

TEACHING TIP

Enlist parents and students to help you gather the supplies you'll need.

CAUTION *Do not allow students to strip wires themselves. This is potentially hazardous and demands too much class time.*

Electronics stores and science supply houses will most likely have these materials. Basic electricity or magnetism kits will have most items.

TEACHING TIP

Fabric stores often give free samples.

- Protons and Electrons Activity
    - 6" x 6" (15 cm x 15 cm) positive (+) signs (protons) — *half class set*
    - 6" x 6" (15 cm x 15 cm) negative (-) signs (electrons) — *half class set*

EUREKA! MOMENT 2

- Eureka! Activity 2
    - Bowl of liquid (e.g., salt water, lemon juice) — *one per group*
    - Dimes or aluminum foil folded to dime-size — *five per group*
    - Paper towel (two-inch squares) — *nine per group*
    - Pennies — *five per group*

EUREKA! MOMENT 3

- Eureka! Activity 3
    - Battery (D or lantern) — *one per group*
    - Compass — *one per group*
    - Insulated copper wire, 24-inch (61-cm) or longer with half-inch (1-cm) insulation stripped from each end — *one per group*
    - Insulated copper wire, 12-inch (30-cm) with half-inch (1-cm) insulation stripped from each end — *one per group*
    - Iron filings or small paper clips — *several per group*
    - Lightbulb — *one per group*
    - Lightbulb holder — *one per group*
    - Nail (long) — *one per group*
    - Tape (electrical or duct) — *one per group*

EUREKA! MOMENT 4

- Eureka! Activity 4
    - Bar magnet — *one per group*
    - Compass — *one per group*
    - Insulated copper wire, 30-inch (76-cm) or longer with half-inch (1-cm) insulation stripped from each end — *one per group*
    - Iron filings — *several per group*
    - Thin card (4" x 6" note card, large enough to cover force field bar magnet will create) — *one per group*

EUREKA! MOMENT 5

- Eureka! Activity 5
    - Art paper (12" x 18") — *for each group*
    - Markers, colored pencils or crayons — *class set*

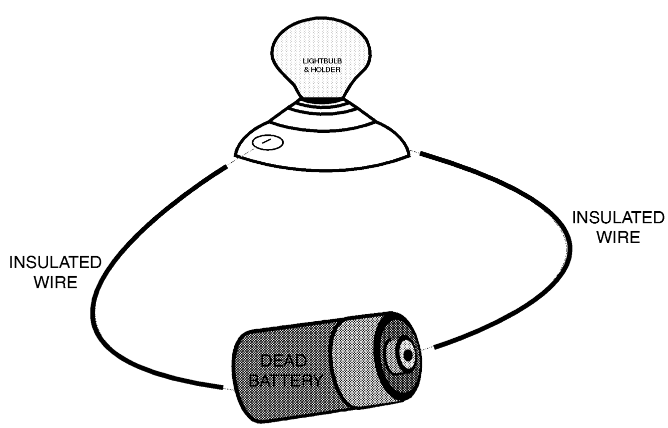
TEACHING TIP

Be sure to use electrical or duct tape when performing experiments. Masking tape can become a conductor and burn or catch on fire. Scotch tape can melt.

Phase 2
"Sparking Their Appetite" - Intro.
- Science Journals (if Phase 1 was not completed) — *class set* (see Setup Directions #2)
- Group Science Folders (if forming new groups)
  - Construction paper (11" x 17") — *one per group*
  - Pencils — *class set*
  - Stapler — *one per group*

Office Suite
- T.E.A.M. ACTIVITY
  - Battery (size D) — *one per group*
  - Wire, eight-inch (20-cm) with half-inch (1-cm) insulation stripped from each end — *one per group*
  - Lightbulb — *one per group*
- Electricity Exploration 1
  - Faulty circuit setup — *one per group*
    - Battery (dead, size D) — *one per setup*
    - Lightbulb — *one per setup*
    - Lightbulb holder — *one per setup*
    - Tape (electrical or duct) — *one per group*
    - Wires, eight-inch (20-cm) with half-inch (1-cm) insulation stripped from each end — *two per setup*

Set up materials as shown here, but use a dead battery. Cover all connections with electrical or duct tape (not shown) so that students will have to check these more closely.



TEACHING TIP

If you wish, you could include a poor wire connection instead of a dead battery. In such a case, adjust experiment answers accordingly.

You may find it helpful to mount these setups on a piece of cardboard, taping down the components as you tape over the connections.

TEACHING TIP

It is OK to use fewer types of materials than 12, but be sure to include fudge.

Use electrical or duct tape when performing experiments. Masking tape can become a conductor and burn or catch on fire. Scotch tape can melt.

- Substitute circuit components:
    - Battery (working, size D) — *one per group*
    - Lightbulb — *one additional per group*
    - Lightbulb holder — *one additional per group*
    - Wires, eight-inch (20-cm) with half-inch (1-cm) insulation stripped from each end — *two additional per group*
- Stiff cardboard (optional) — *one piece per group*

The Cooking Room

- Electricity Exploration 2
    - Items made from rubber, plastic, paper, cotton, copper, wood, fudge, steel, wool, aluminum, leather, nickel — *one of each per group*
    - Battery (any size) — *one per group*
    - Lightbulb — *one per group*
    - Lightbulb holder — *one per group*
    - Paper towels — *one wet and one dry per group*
    - Tape (electrical or duct) — *one per group*
    - Wires, eight-inch (20-cm) with a half-inch (1-cm) of the insulation stripped from each end — *three per group*

The Refrigeration Room

- Electricity Exploration 3
    - Battery (C or larger) — *two per group*
    - Lightbulbs — *two per group*
    - Lightbulb holders — *two per group*
    - Tape (electrical or duct) — *one per group*
    - Wires, eight-inch (20-cm) with a half-inch (1-cm) of insulation stripped from each end — *six per group*

The Packaging Room

- Electricity Exploration 4A
    - Base (such as a plastic or Styrofoam cup) — *one per group*
    - Battery (D-cell) — *one per group*
    - Dowel, half-inch (1-cm) or other round object — *one per group*
    - Magnet (strong, but small) — *one per group*
    - Magnet wire, 12-inch (30-cm), enamel-coated, 32 gauge (or thinner) — *one per group*
    - Paper clips (uncoated) — *two per group*
    - Rubber band (thick) — *one per group*
    - Sandpaper — *one piece per group*
    - Tape (electrical or duct) — *one per group*

- Electricity Exploration 4B
  - Battery (D-cell) — *one per group*
  - Lightbulb — *one per group*
  - Lightbulb holder — *one per group*
  - Semiconductor diode (400v) — *one per group*
  - Tape (electrical or duct) — *one per group*
  - Wire, eight-inch (20-cm) with half-inch (1-cm) insulation stripped from each end — *three per group*

The Boiler Room

- Electricity Exploration 5
  - Battery (lantern) — *one per group*
  - Brads (one-inch or long enough to go through the cardboard) — *two per group*
  - Clay — *two lumps per group*
  - Corrugated cardboard, 2" x 3" (5 x 7 cm) — *one per group*
  - Insulated copper wire, eight-inch (20-cm) with half-inch (1-cm) insulation stripped from each end — *four per group*
  - Lightbulb — *one per group*
  - Lightbulb holder — *one per group*
  - Nichrome wire (#32) 2-3-inch (5-7.5-cm) — *one per group*
  - Paper clips (uncoated) — *three per group*

Phase 3 (Optional)

Challenge Projects

- Materials needed for various projects (e.g., poster, game, book)
- Supplies necessary for experiments as desired

Electrified Inventions

- Materials needed to make models of inventions
- Display boards for written information and photos, if desired

Women Inventors

- Research material/resources
- Display boards for written information and photos, if desired
- Materials needed to make models of invention

EUREKA! MOMENT Re-enactments

- Simple props as desired
- Supplies necessary to re-enact one of the Eureka! Activities

7. **Teaching Schedule Per Lesson**
   a. During Phase 1 the class reads a different EUREKA! MOMENT each day. Decide if you will read these short essays aloud with the class, or if students will read and discuss the information within their groups. The general daily format is:
      • Read EUREKA! MOMENT
      • Complete the related EUREKA! ACTIVITY
      • Debriefing discussion
      • Write in Science Journals
   b. During Phase 2 your students explore problems at the factory room by room. The general daily format is:
      • T.E.A.M. ACTIVITY
      • CLUE SEARCH
      • ELECTRICITY EXPLORATION
      • SCIENTIFIC DETECTIVE RECORD FORM

8. **Teaching Options: Phase 1**
   The following are suggestions for modifying Phase 1:
   a. EUREKA! ACTIVITIES
      You may read and discuss the EUREKA! MOMENTS as a class lesson by lesson, then when you have read all five, allow teams of students to rotate through Eureka! Activity stations set up to investigate the principles and re-enact the history.
   b. You may stop at Step 6 in EUREKA! ACTIVITY 5 and not have students make a model or other display materials for their Electrified Inventions.
   c. T.E.A.M. Activities
      For advanced students you may give necessary definitions and guidelines, then have groups design their own T.E.A.M. Activity information strips to be used with Phase 1. They then exchange and check strips between groups.

TEACHING TIP

Under this plan, you need only one or two sets of supplies for each of the five Eureka! Activities.

9. **Teaching Options: Phase 2**
   The following are suggestions for modifying Phase 2:
   a. Students complete all the T.E.A.M. ACTIVITIES, one by one, before doing any of the rest of Phase 2.
   b. Set up Electricity Exploration stations for all groups to rotate through the six activities. Allow two hours of class time for all six.
   c. Provide the five CLUE SEARCHES one at a time and have students fill out the corresponding SCIENTIFIC

DETECTIVE FORMS, keeping in mind the four T.E.A.M. ACTIVITIES and the six ELECTRICITY EXPLORATIONS they have completed.

The advantages of this variation include:

- Since groups rotate through the ELECTRICITY EXPLORATION stations, you need only one or two sets of supplies for each activity per class.
- You can easily use longer class periods if this works better in your schedule.
- Students must more fully assimilate the information they gathered in the T.E.A.M. ACTIVITIES and ELECTRICITY EXPLORATIONS, then apply this knowledge as they evaluate the CLUE SEARCH information.
- Students' conclusions on the SCIENTIFIC DETECTIVE RECORD FORMS serve as informal assessments of what they have learned during the simulation.

10. **Guest Speakers**
You can enhance this unit by inviting a physicist, electrical engineer, or electrician to speak to your class during or after this simulation. Local universities or businesses might have someone willing to spend time sparking scientific interest in your students.

11. **Culminating Event(s)**
You may conclude the FUDGE FACTORY unit with formal presentations or an open house where students demonstrate what they have learned to administrators, other classes, family, friends, and the larger community. Consider one or more of the following suggestions:
    a. Oral Presentations—Have groups present their recommendations to "Ms. Faraday," the owner of Faraday's Fudge Factory (school principal, yourself, or other dignitary).
    b. Challenge Projects—Students present their projects to Ms. Faraday and/or other visitors.
    c. Electrified Inventions Day—Set a date, time, and venue for having guests view your students' work.
    d. Women Inventors—Students research a specific female inventor and present their projects (including a model of the invention, if desired) to an audience.
    e. Eureka! Moment Re-enactments—Students re-enact the moments in history explored in Phase 1.

Recommended Reading for Students

Ardley, N. *The Science Book of Electricity.** San Diego: HBJ/Gulliver Books, 1991.

Ardley, N. *The Science Book of Magnets**. San Diego: HBJ/Gulliver Books, 1991.

Berger, M. *All About Electricity**. New York: Scholastic, 1995.

Billings, C.W. *Superconductivity: From Discovery to Breakthrough*. New York: Cobblehill Books/Dutton, 1991.

Challoner, J. *My First Batteries and Magnets Book**. New York: Dorling Kindersley, 1992.

Kerrod, R. *Electricity and Magnetism*. New York: Marshall Cavendish, 1994.

Madgwick, W. *Magnets and Sparks**. Austin, TX: Raintree Steck-Vaughn, 1999.

Math, I. *More Wires and Watts*. New York: Charles Scribner's Sons, 1988.

Parker, S. *Electricity* (Eyewitness Science Series). New York: Dorling Kindersley, 1992.

VanCleave, J. *Physics for Every Kid*. New York: John Wiley & Sons, 1991.

Note: * Indicates books which are easier-to-read.

Recommended Resources for Teachers

Library Video Company
P.O. Box 580
Wynnewood, PA 19096
1-800-843-3620
Science videos and CD-ROMs.

Carolina Biological Supply Company
2700 York Road
Burlington, NC 27215
1-800-334-5551
Experiment supplies, kits, posters, and resource books.

On-line Resources

Interact's website provides links to some excellent electronic resources to enhance this unit. Please visit our website at **www.interact-simulations.com**, click on the Resources button and find FUDGE FACTORY.

UNIT TIME CHART

Phase 1: Momentous History (Optional)

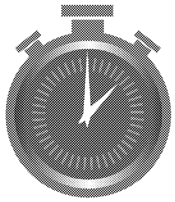
EUREKA! MOMENT 1	EUREKA! MOMENT 2	EUREKA! MOMENT 3	EUREKA! MOMENT 4	EUREKA! MOMENT 5	
Student Guide Phase 1 EUREKA! ACTIVITY 1 GLOSSARY MY SCIENCE JOURNAL YOUR SCIENCE JOURNAL SCIENTIFIC METHOD	Student Guide Phase 1 EUREKA! ACTIVITY 2 Science Journals	Student Guide Phase 1 EUREKA! ACTIVITY 3 Science Journals	Student Guide Phase 1 EUREKA! ACTIVITY 4 Science Journals	Student Guide Phase 1 EUREKA! ACTIVITY 5 Science Journals	

Phase 2: Faraday's Fudge Factory

INTRO	Office Suite	Cooking Room	Refrigeration Room	Packaging Room	Boiler Room
Student Guide Phase 2 INTRO. TEAM ACTIVITY GLOSSARY MY SCIENCE JOURNAL YOUR SCIENCE JOURNAL	Student Guide Phase 2 Science Journals T.E.A.M. ACTIVITY 1 CLUE SEARCH 1 ELECTRICITY EXPLORATION 1 SCIENTIFIC DETECTIVE RECORD FORM Debriefing	Student Guide Phase 2 Science Journals T.E.A.M. ACTIVITY 2 CLUE SEARCH 2 ELECTRICITY EXPLORATION 2 SCIENTIFIC DETECTIVE RECORD FORM Debriefing	Student Guide Phase 2 Science Journals T.E.A.M. ACTIVITY 3 CLUE SEARCH 3 ELECTRICITY EXPLORATION 3 SCIENTIFIC DETECTIVE RECORD FORM Debriefing	Student Guide Phase 2 Science Journals CLUE SEARCH 4 ELECTRICITY EXPLORATION 4A, 4B SCIENTIFIC DETECTIVE RECORD FORM Debriefing	Student Guide Phase 2 Science Journals CLUE SEARCH 5 ELECTRICITY EXPLORATION 5 SCIENTIFIC DETECTIVE RECORD FORM Final Debriefing Analysis of all clues Solving of mystery

Phase 3: Extensions (Optional)

EXTENSIONS					
You determine the content and timing of PHASE 3. Optional presentations of groups' conclusions Challenge Projects ELECTRIFIED INVENTIONS Women Inventors EUREKA! MOMENT Re-enactments					



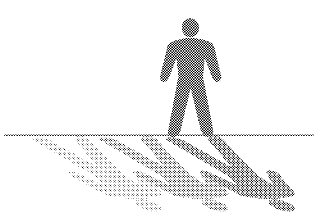
Estimated activity time
90 minutes

TEACHING TIP

If your students are familiar with the scientific method and basic electricity principles and experienced in doing electricity experiments, you may wish to simply read and discuss the Student Guide: Phase 1, then proceed to Phase 2.

TEACHING TIP

Prepare these signs ahead of time for an activity on electrical charges.



Groups of 4-6 students

EUREKA! MOMENT 1

Materials

- Student Guide: Phase 1 — *class set*
- YOUR SCIENCE JOURNAL — *class set*
- MY SCIENCE JOURNAL cover — *class set*
- GLOSSARY — *class set*
- SCIENTIFIC METHOD — *class set*
- PROTONS AND ELECTRONS (Optional) — *class set*
- EUREKA! ACTIVITY 1 — *class set*
- ELECTRIC SPIDER — *one cutout per group*
- Science Journals and Group Science Folders
    - Construction paper (11" x 17") — *class set + one per group*
    - Notebook paper — *10 sheets per student*
    - Pencils — *class set*
    - Stapler — *one per group*
- Eureka! Activity 1
    - Balloon (inflated) — *one per group*
    - Paper Spider (found on ELECTRIC SPIDER handout) — *one cutout per group*
    - Scissors — *one per group*
    - Stopwatch or clock with a secondhand — *one per group*
    - String or yarn, 12" -14" long — *one per group*
    - Wool cloth (any size) — *one per group*
- Protons and Electrons Activity
    - 6" x 6" (15 cm x 15 cm) positive (+) signs (protons) — *half class set*
    - 6" x 6" (15 cm x 15 cm) negative (-) signs (electrons) — *half class set*
- Chalkboard or overhead and transparency

Procedure

1. Divide students into groups of four to six students each. These students will work together throughout the simulation. See **Setup Directions #4, Grouping Students**, for more information.

2. Distribute, read and discuss YOUR SCIENCE JOURNAL.

3. Distribute the MY SCIENCE JOURNAL cover and the GLOSSARY. Have students make their Science Journals. See **Setup Directions #2**, **Science Journals**, for more information. Have students place the handouts in their Science Journals when they have completed them.

4. Distribute one sheet of construction paper to each group and have each group make its own folder. Direct students to store within this folder all important information they gather in the simulation.

5. **Read or tell** the following information:

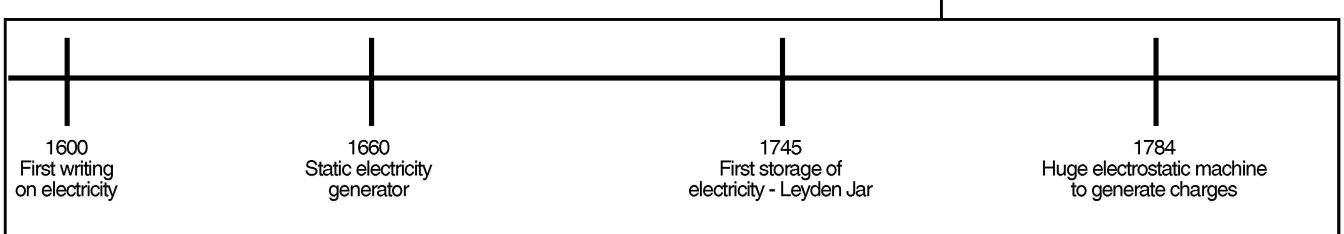
The Ancient Greeks found that if they rubbed amber it would attract light things such as feathers. The word ***electron*** *is the Greek word for amber. In 1600, William Gilbert (1544-1603), Queen Elizabeth I's doctor, published the earliest known writing on electricity. He studied natural magnets, called* ***lodestones****, and*

understood that the earth itself was a giant magnet with two poles. He also designed the first electrical instrument, which crudely measured the strength of an electric charge. In 1660, Otto von Guericke (1602-1686), a German, developed a machine that generated ***static electricity*** *charges. The ability to generate static electricity charges allowed scientists to study the properties of electricity more easily. Then, in 1745, Pieter van Musschenbroek (1692-1761), of the University of Holland in Leyden, found a way to store static electricity charges. This "Leyden jar" made it even easier for scientists to investigate electricity. Finally, in 1784 Dr. van Marum of Holland (1750-1837) created an "electrostatic" machine with glass plates 65 inches (165 cm) across.*

read or tell

TEACHING TIP

Draw a timeline like the one shown below to illustrate this information.



TEACHING TIP

Advanced students may enjoy devising their own activity to show Benjamin Franklin's and others' experiments in this phase of FUDGE FACTORY. Less-advanced students may benefit from a teacher-led demonstration of this activity.

Do not evaluate hypotheses at this point. Accept all suggestions. Although the correct hypothesis will be obvious from the histories given in Phase 1, it is important to give students practice in applying the scientific method systematically.

TEACHING TIP

Explain that this experiment is only similar to what Franklin did. Franklin actually used his charged glass tube instead of a balloon and a metal wire on the other side of the "spider" to help it dance back and forth.

This experiment will work better in environments which are dry rather than humid. If your current weather includes high humidity your students may not be able to create much static electricity.

6. Distribute a Student Guide: Phase 1 to each student and direct students to read EUREKA! MOMENT 1 about Ben Franklin.

7. Discuss briefly.

8. Distribute EUREKA! ACTIVITY 1 and SCIENTIFIC METHOD to each student. Review the content of these handouts with the class. Make sure that students understand the objective and procedures. Use the following to guide students through the SCIENTIFIC METHOD form:
   Problem: Discuss the problem, which is often written in question form. Explain that this is what students want to find out. Have groups circle the word "Problem/Question" on their activity sheets.
   Hypothesis: This is an educated guess to answer the question stated in the problem. Have students circle the word "Hypothesis."
   Experiment: This is the procedure used to test the hypothesis. Have students circle the word "Experiment."
   Data: These are accurate records of the results of the experiment. Have students circle the word "Data."
   Conclusion: This is a summary of what the experimenter discovers (concludes) as a result of the experiment. Scientists compare their conclusions with the hypothesis recorded at the beginning of the activity. Have students circle the word "Conclusion."

9. Have students share what they think will happen during the experiment. After the discussion, have each student write his or her own hypothesis in the "Hypothesis" blank.
   Sample hypothesis: *The static electricity will make the paper spider move.*

10. Direct groups to perform the experiment. Ask that students record on their activity sheet what they observe as they conduct the experiment.

11. When groups have finished the experiment, ask them to share their results.
    Sample data: *The paper spider moved when the charged balloon was brought close to it. It danced for a longer time when we rubbed the balloon more.*

12. After the class discussion of the data, direct students to record their conclusions (as a result of their group's experiment) on their handouts.
    Sample conclusion: *The static electricity charge pushed away (repelled) the paper spider because the paper spider had a like charge. More rubbing meant more static electricity charge built up.*

13. Have students record what they have learned from this activity in their Science Journals. Compare results as a class. Explain that observing details is an important component to understanding science learning and applying the scientific method. For example, if they observe that rubbing the balloon for only thirty seconds in the experiment is not effective enough, they can then modify their approach until they succeed.

14. **Read or tell** the following information:
    All things are made of ***atoms****. Atoms are made of small parts called* ***particles****. Some particles of an atom are called* ***protons*** *and some other particles are called* ***electrons****. Protons have positive charges shown with a plus sign (+). Electrons have negative charges shown with a minus sign (–). Rubbing two items together can sometimes cause protons and electrons to move from one item to the other. When some protons and electrons move between two items, the charges can become unbalanced in each item.* ***Unbalanced charge*** *means that an object does not have an equal number of protons and electrons.*

    To start, both objects had a balance of protons (+) and electrons (–), but when rubbed, some electrons move from the wool to the balloon, upsetting the balloon's balance. Now the balloon's unbalanced charges ***attract*** *(pull toward each other), the spider's electrons or protons (it depends on what it needs), and the two stick together. This causes the spider's charges to become unbalanced. If the charges are the same, they will* ***repel*** *(push away from) each other, and the spider dances*

read or tell

TEACHING TIP

As an alternative, give each small group a copy of PROTONS AND ELECTRONS and read as a class.

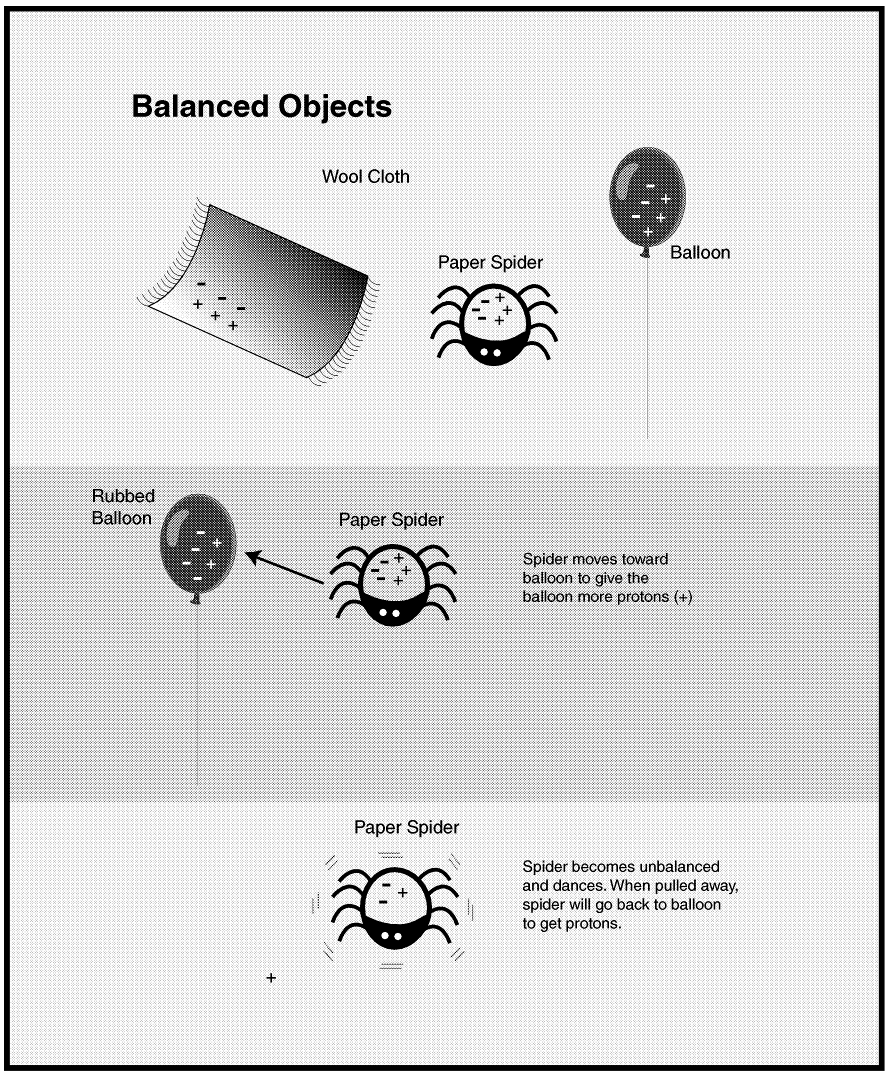
If your students do not know what the boldfaced terms are, direct them to the GLOSSARY or you may wish to list them on the chalkboard or an overhead transparency as you talk.

away from the balloon. Or gently pulled away, the spider will "dance" back and forth as the charges transfer from the balloon to the spider and back again.

The statement "Unlike charges attract each other, and like charges repel each other" is known as ***Coulomb's Law****, after Charles Coulomb (1736-1806), who first discovered and described this behavior in 1785. Scientists now measure electric charge in units called* ***coulombs****.*

TEACHING TIP

Draw the following diagram on the chalkboard or an overhead transparency.



15. Have students act out the parts of the protons, electrons, and their movement between objects.
    a. Divide your class into three equal groups. Designate one group as the "wool cloth," one as the "balloon," and one as the "spider."
    b. Within each group, give each student a 6" square symbol (+ or -) to mark him or her as a proton or electron. Make sure each "object" (group) starts with an equal number of protons and electrons.
    c. Re-read the description in step 14, directing the students to act out the transfers of electric charges.

16. Debrief students, discussing what they have learned today. Have students record what they think they have learned today in their Science Journals.

17. You may collect the Science Journals after class to check for student understanding. If you assign the Science Journal writing as homework, you may collect the journals at the beginning of the next science class period. Plan on checking Science Journals periodically throughout the unit. Encourage students to fill their journals with drawings, notes, observations, and any other relevant information.

18. You may collect the Student Guides at the end of each class, or have students keep them in their group folders.

19. Have students clean up for the day.

TEACHING TIP

As an alternative, have students come up with their own way of acting out the charge activity.

Estimated activity time
45 minutes

TEACHING TIP

You may provide thin pieces of zinc and copper then have advanced students design, record, and test a possible experiment to see if their voltaic battery produces electricity. Have them label the Problem, Hypothesis, Experiment (including a list of Materials), Data, and Conclusion to practice applying the SCIENTIFIC METHOD.

ANSWER KEY

EUREKA! MOMENT 2

Materials

- Student Guide: Phase 1 — *class set*
- Science Journals — *class set*
- EUREKA! ACTIVITY 2 — *class set*
- Eureka! Activity 2
  - Bowl of liquid (e.g., salt water, lemon juice) — *one per group*
  - Dimes or aluminum foil folded to dime-size — *five per group*
  - Paper towel (two-inch squares) — *nine per group*
  - Pencils — *class set*
  - Pennies — *five per group*

Procedure

1. If necessary, distribute the Student Guides and direct students to read EUREKA! MOMENT 2 about Luigi Galvani and Alessandro Volta.

2. Discuss briefly.

3. Distribute EUREKA! ACTIVITY 2 to each student.

4. Review the "Procedure" instructions.

5. Direct groups to perform the activity.

6. When groups have finished making their models, ask them to share their thoughts on what Volta must have faced as a scientific pioneer. Then have each student write his/her thoughts in his/her Science Journal.

7. Discuss the questions posed in the "Questions" section of EUREKA ACTIVITY 2.
   Sample answers
   (1) How is the structure of the voltaic pile like the structure of a modern battery? *It is layered.*
   (2) How is the structure of the voltaic pile different from the structure of the modern battery? *There are fewer layers in a modern battery than in a voltaic pile, and the modern battery is closed in, less messy, and more practical.*
   (3) Which battery would you prefer to use? Why? *Answers will vary.*

8. **Read or tell** the following information:

   Remember, this is just a model. An actual voltaic pile produces electricity if it is large enough and constructed of the right materials. For example, zinc might also work better than dimes (which now have copper in them), but it is not as readily available for classromm use.

   Volta's voltaic battery was an awkward arrangement, unlike our batteries today that can go anywhere from the ocean depths to Mars and beyond. But Volta's invention worked, and the steady current it created led to many more discoveries.

9. Debrief students, discussing what they have learned today. Allow time for students to record and reflect in their Science Journals.

10. Have students clean up for the day.

Estimated activity time
60 minutes

TEACHING TIP

Because the order in which students do each part does not matter, you might set up stations for half the class for each part of the activity. Have students complete one part at one type of station, undo their setups, then switch and complete the other part at the other type of station.

EUREKA! MOMENT 3

Materials

- Student Guide: Phase 1 — *class set*
- Science Journals — *class set*
- EUREKA! ACTIVITY 3 (Parts 1 and 2) — *class set*
- Eureka! Activity 3
  - Battery (D or lantern) — *one per group*
  - Compass — *one per group*
  - Insulated copper wire, 24-inch (61-cm) or longer with half-inch (1 cm) insulation stripped from each end — *one per group*
  - Insulated copper wire, 12-inch (30-cm) with half-inch (1 cm) insulation stripped from each end — *one per group*
  - Iron filings or small paper clips — *several per group*
  - Lightbulb — *one per group*
  - Lightbulb holder — *one per group*
  - Nail (long) — *one per group*
  - Pencils — *class set*
  - Tape (electrical or duct) — *one per group*

Procedure

1. If necessary, distribute the Student Guides and direct students to read EUREKA! MOMENT 3 about Hans Christian Oersted and Andre-Marie Ampère.

2. Discuss briefly.

3. Distribute EUREKA! ACTIVITY 3, Part 1 to each student.

4. Review the instructions and have each student record on his/her activity sheet what he/she thinks will happen during each part of the activity.

5. Direct groups to perform the activity.

6. When groups finish the activity, ask them to share their results. Then have each student record this information on his/her activity sheet.

7. Have groups determine and share their conclusions. Compare these to the hypotheses recorded at the beginning of the activity. Have each student write his/her conclusion on the activity sheet. Point out that students made a **galvanometer**.

8. Depending on the abilities of your students, you may guide their discussion with the following:
   Sample problem, Part 1: *Does electrical current produce magnetism?*
   Sample hypothesis, Part 1: *Electrical current will produce magnetism.*
   Sample data, Part 1: *The compass needle moved.*
   Sample conclusion, Part 1: *The electrical current produced magnetism, affecting the magnet on the compass.*

9. Distribute EUREKA! ACTIVITY 3, Part 2 to each student.

10. Review the instructions and have each student record on the activity sheet what he/she thinks will happen during each part of the activity.

11. Direct groups to perform the activity.

12. When groups finish the activity, ask them to share their results. Then have each student record this information on his/her activity sheet.

13. Have groups determine and share their conclusions. Compare these to the hypotheses recorded at the beginning of the activity. Have each student write his/her conclusion on the activity sheet. Point out that students made an **electromagnet.**

14. Debrief students, discussing what they have learned today. Allow time for students to record and reflect in their Science Journals.

15. Depending on the abilities of your students, you may guide their discussion with the following:
    Sample problem, Part 2: *Can you change electricity into magnetism?*
    Sample hypothesis, Part 2: *You can change electricity into magnetism.*
    Sample data, Part 2: *The nail was able to pick up the metal objects when an electric current was going through the wire.*
    Sample conclusion, Part 2: *The electricity flowing through the wires turned the nail into a magnet.*

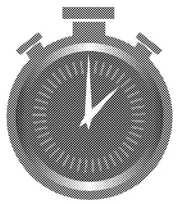
16. Have students clean up for the day.

TEACHING TIP

Part 1 Extension Idea: Discuss how a galvanometer might help us determine if electricity was flowing through a voltaic battery (see EUREKA! ACTIVITY 2).

TEACHING TIP

Part 2 Extension Idea: Ask, "What happens when you wrap the wire more or fewer times? Record your hypotheses, experiments, data, and conclusions in your Science Journal."



Estimated activity time
60 minutes

TEACHING TIP

It is important not to drop bar magnets as they may lose their effectiveness due to the jolt.

Once again, because the order in which students do each part does not matter, you may wish to set up stations for half the class for each part of the activity. Have students complete one part at one station, undo their setups, then switch and complete the other part at the other station.

EUREKA! MOMENT 4

Materials

- Student Guide: Phase 1 — *class set*
- Science Journals — *class set*
- EUREKA! ACTIVITY 4 (Parts 1 and 2) — *class set*
- Eureka! Activity 4
  - Bar magnet — *one per group*
  - Compass — *one per group*
  - Insulated copper wire, 30-inch (76-cm) or longer with half-inch (1 cm) insulation stripped from each end — *one per group*
  - Iron filings — *several per group*
  - Pencils — *class set*
  - Thin card (4" x 6" note card, large enough to cover force field bar magnet will create) — *one per group*

Procedure

1. If necessary, distribute the Student Guides and direct students to read EUREKA! MOMENT 4 about Michael Faraday.

2. Discuss briefly.

3. Distribute EUREKA! ACTIVITY 4, Part 1 to each student.

4. Review the instructions and have each student record on his/her activity sheet what he/she thinks will happen during each part of the activity.

5. Direct groups to perform the activity.

6. When groups finish the activity, ask them to share their results. Then have each student record this information on his/her activity sheet.

7. Finally, have groups determine and share their conclusions. Compare these to the hypotheses recorded at the beginning of the activity. Have each student write his/her conclusion on his/her activity sheet. Point out that students built a **dynamo** — except they must supply the power (muscle power).

8. Depending on the abilities of your students, you may guide their discussion with the following:
   Sample problem, Part 1: *Can you change magnetism into electricity?*
   Sample hypothesis, Part 1: *You can change magnetism into electricity.*
   Sample data, Part 1:
   (1) The compass needle moved.
   (2) The compass needle moved more.
   Sample conclusion, Part 1:
   (1) Magnetism can be turned into electricity.
   (2) Moving the magnet faster generated more electricity.

9. Distribute EUREKA! ACTIVITY 4, Part 2 to each student.

10. Review the instructions and have each student record on his/her activity sheet what he/she thinks will happen during each part of the activity.

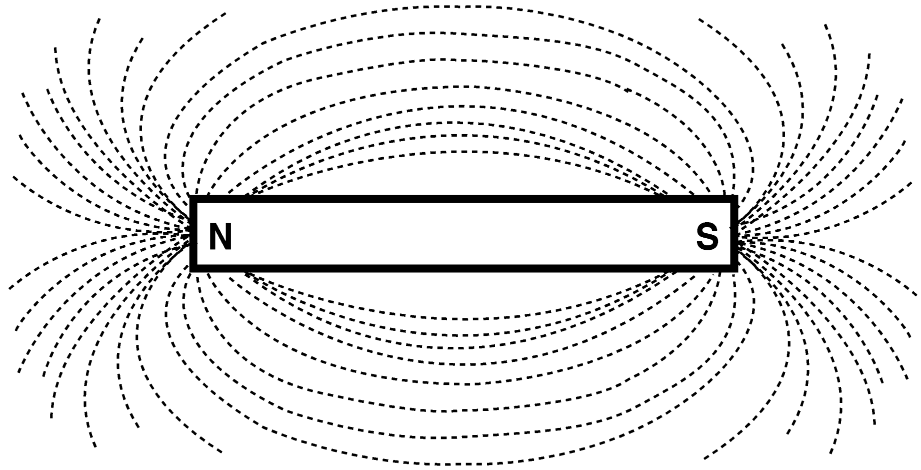
11. Direct groups to perform the activity.

12. When groups finish the activity, ask them to share their results. Then have each student record this information on his/her activity sheet.

13. Finally, have groups determine and share their conclusions. Compare these to the hypotheses recorded at the beginning of the activity. Have each student write his/her conclusion on his/her activity sheet.

14. Debrief students, discussing what they have learned today. Allow time for students to record and reflect in their Science Journals.

15. Depending on the abilities of your students, you may guide their discussion with the following:
    Sample problem, Part 2: *What kind of pattern will a force field create over a bar magnet?*
    Sample hypothesis, Part 2: *A force field creates a rounded/fanned pattern of iron filings over a bar magnet.*



Sample data, Part 2: *The iron filings formed curved lines on the card over the bar magnet (see diagram).*

Sample conclusion, Part 2: *A force field forms the pattern iron filings make over a bar magnet. The iron filings show where the force field is.*

16. Have students clean up for the day.

EUREKA! MOMENT 5

Materials

- Student Guide: Phase 1 — *class set*
- Science Journals — *class set*
- EUREKA! ACTIVITY 5 — *class set*
- Eureka! Activity 5
  - Art paper (12" x 18") — *for each group*
  - Markers, colored pencils or crayons — *class set*
  - Pencils — *class set*

Procedure

1. **Read or tell** the following:

   In this simulation, we have learned about the history of how people came to understand electricity, characteristics of electricity, and its usefulness and dangers. Today we will begin by exploring how inventions using electricity affect our lives and brainstorm how we might solve problems by inventing other uses for electricity.

2. If necessary, distribute the Student Guides. Direct students to read EUREKA! MOMENT 5 about Thomas Edison.

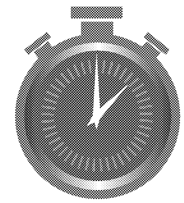
3. Discuss briefly.

4. **Read or tell** the following:

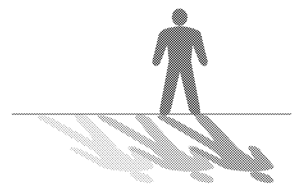
   As we saw in the information about Thomas Edison's work, an important part of applying the SCIENTIFIC METHOD is to only change one variable at a time in an experiment. That way, the scientist knows which change worked and which did not work. This is known as proper experimental design. We will need to keep proper experiment design in mind when working to solve the mystery in Phase 2 — or any other science mystery.

5. Distribute EUREKA! ACTIVITY 5 to each student.

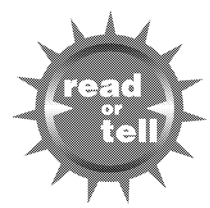
6. Read and discuss this information. Emphasize the CAUTION! given.



Estimated activity time 60 minutes plus time to create student inventions in class or as homework



Pairs or trios



To further demonstrate proper experimental design, have three students hide behind a partition or step out into the hall. Have each clap his or her hands in a steady beat. Have two more students ("variables") join the first three. Secretly let only one of these students know that he or she should clap while telling the other student to not clap.

Ask the rest of the class if they know which "variable" increased the sound. Point out that if only one student went out, the class could tell whether that variable was increasing the sound or not — all other factors being equal (that is, the original three students still clapping).

TEACHING TIP

Point out that students will not actually make a working model of their ideas in this exercise, only a detailed sketch.

You may also offer students the option of inventing safety devices for preventing electrical dangers or new ways to produce electricity.

7. Divide students into pairs or trios.

8. Offer the following challenge:
   A student who is blind wishes to play a ball game with the rest of the class. Design a solution for this problem, using electricity in some way.

9. Direct groups to follow steps 3-6 on the handout to meet this challenge.

10. When groups have completed the steps, have them share their plans and sketches with the class.

11. Explain that individual students will now choose their own problems to solve, then design and make a model of their "electrified" solution.

12. Tell and discuss the due dates. Have students fill in the due dates in the blanks provided at the bottom of their EUREKA! ACTIVITY 5 handout.

13. Review the CAUTION! information on EUREKA! ACTIVITY 5 again. It is imperative that students understand that electricity can be extremely dangerous and that students are not required to make working models of their inventions. Should they choose or be able to make a working model, it should use **battery power only**.

14. Debrief students, discussing what they have learned during Phase 1 of the simulation. Ask questions such as the following to stimulate students' thinking:
    - Which historical facts mentioned in the EUREKA! MOMENTS were your favorites? Why?
    - Which EUREKA! ACTIVITY was your favorite? Why?
    - With which historical person would you most like to spend an hour talking? Why?
    - How were the historical people we studied and their discoveries like your learning today? How were your experiences different from these scientists'?

TEACHING TIP

Direct students to keep their notes and handouts for reference in Phase 2.

15. Allow time for students to record and reflect about Phase 1 in their Science Journals.

16. Have students clean up for the day.

"Sparking Their Appetite" - Intro.

Materials

- Student Guide: Phase 2 — *class set*
- YOUR SCIENCE JOURNAL — *class set*
- MY SCIENCE JOURNAL — *class set*
- GLOSSARY — *class set*
- WHAT ARE T.E.A.M. ACTIVITIES? — *class set*
- INTRO. T.E.A.M. ACTIVITY — *one set of strips per group*
- INTRO. T.E.A.M. ACTIVITY RECORD — *one per group*
- Science Journals and Group Science Folders
  - Construction paper (11" x 17") — *class set + one per group*
  - Notebook paper — *10 sheets per student*
  - Pencils — *class set*
  - Stapler — *one per group*

Procedure

1. If you elected to skip Phase 1, divide your students into groups of four to six students each. These groups will work together throughout Phase 2. See **Setup Directions #4, Grouping Students**, for more information.

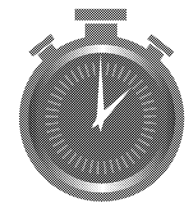
2. Distribute, read and discuss YOUR SCIENCE JOURNAL.

3. Distribute the MY SCIENCE JOURNAL cover and the GLOSSARY. Have students make their Science Journals as described in **Setup Directions #2**, **Science Journals**. Have students place the handouts inside their Science Journals.

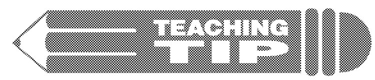
4. Distribute one sheet of construction paper to each group and have them make their group folder. Direct them to use their folder to store all important information gathered throughout Phase 2.

5. Distribute WHAT ARE T.E.A.M. ACTIVITIES? and have students read individually, within their groups or as a class.

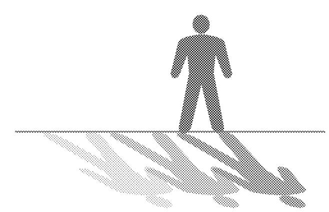
6. After students read about the T.E.A.M. activities, answer any questions they may have. Emphasize that students must ensure that every member of their group participates in each activity. Brainstorm ways to include everyone and appropriate ways to handle disagreements.



Estimated activity time
45 minutes



*If you elected to do Phase 1, students continue with their Science Journals. You will not need YOUR SCIENCE JOURNAL, MY SCIENCE JOURNAL or the GLOSSARY forms. Additionally, you will skip steps 2 and 3 of the **Procedure**.*



Groups of 4-6 students

If you elected to do Phase 1, then you may keep the same groups or divide your class into new groups at this time.

TEACHING TIP

If a group has fewer than six members, some students will need to handle more than one T.E.A.M. ACTIVITY strip.

read or tell

If desired, don't use the INTRO. T.E.A.M. ACTIVITY RECORD sheet; instead, have students cut apart the information on their strips and glue them to sheets of notebook paper, labeled "World of Medicine," "Safety First," Just for Fun," and "All for a Day's Work."

ANSWER KEY

If a group can make a reasonable case for placing one woman and her invention in another category, accept it. For example, Dr. Jagger's safety needle devices are for medical purposes, but could also be accurately listed under "Safety First."

7. Distribute the INTRO. T.E.A.M. ACTIVITY strips, one strip per student, one set per group. Distribute one INTRO. T.E.A.M. ACTIVITY RECORD to each group. Tell students that the purpose of this activity is to learn about several women inventors. Direct members of each group to share their information as described in WHAT ARE T.E.A.M. ACTIVITIES? Students classify the inventions of each of these women and record the answers on the INTRO T.E.A.M. ACTIVITY RECORD.

8. **Read or tell:**

   The early discoveries regarding electricity were made by men because society allowed and helped men get the education and resources they needed to use their creativity and intelligence to their fullest. Women, although just as smart, usually did not have a chance to develop their abilities in science as fully. The inventors explored today benefited from a changing society that allowed women to succeed.

9. After the activity, discuss the various women inventors. Allow students to share the ones they found the most interesting. Encourage them to explore the books about female inventors listed in the **Recommended Books** list found in this Teacher Guide.

10. **Answer Key** for INTRO. T.E.A.M. ACTIVITY
    World of Medicine — Dr. Gertrude Elion, drug; Jan B. Svochak, bifocal contact leanses; Dr. Janine Jagger, safety needle devices; Dr. Elizabeth Hazen and Dr. Rachel Brown, *Nystatin*; Dr. Mary Ann Moore, pain relief medication
    Safety First — Elena DeValdes, bottle stopper; Mary Walton, quieter elevated railway, antipollution device; Lori A. Cotrain, child car-restraint garment
    Just for Fun — Valerie Thomas, Illusion Transmitter; Ruth Handler, *Barbie* and *Ken Dolls*
    All for a Day's Work — Mary Jane Montgomery, improved locomotive wheel; Sarah Mather, combination submarine lamp and telescope; Alice Chatham, a space helmet and a space bed; Bette Graham, *Liquid Paper*; Mattie Knight, flat-bottomed paper bag folding machine; Rebecca Schroeder, *Glo Sheets*

11. Distribute a Student Guide: Phase 2 to each student. Direct students to read the three introductory news articles, examine the floor plan of the fudge factory, and read the following explanation. You may elect to read this material together as a class.

12. **Read or tell:**

    Ms. Faraday has asked for your help because she heard you are careful and hard-working scientific detectives. Time does not permit you and your classmates to stay at the Faraday Fudge Factory for long. You will begin your tour during our next science period. We hope to find enough clues to help you before you have to leave.

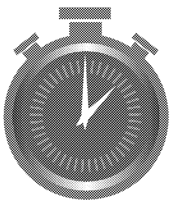
    To help you better understand how you can help Ms. Faraday, we will do science activities and experiments as we visit each part of the factory. Often, we will start with a T.E.A.M. group problem-solving activity like the one you did today. While we are exploring the Fudge Factory, each T.E.A.M. ACTIVITY will be related to solving the mystery, so pay special attention to what you learn all throughout the simulation.

13. Debrief students, discussing what they have learned today. Have students record what they have learned today in their Science Journals.

14. You may collect the Science Journals after class to check for student understanding. If you assign the Science Journal writing as homework, you may collect the journals at the beginning of the next science class period. Plan on checking Science Journals periodically throughout the unit. Encourage students to fill their journals with drawings, notes, observations, and any other relevant thoughts and information.

15. You may collect the Student Guides at the end of each class, or have students keep them in their group folders.

16. Have students clean up for the day.



Estimated activity time
45 minutes

TEACHING TIP

If you wish, include a poor wire connection instead of a dead battery. In such a case, adjust experiment answers accordingly.

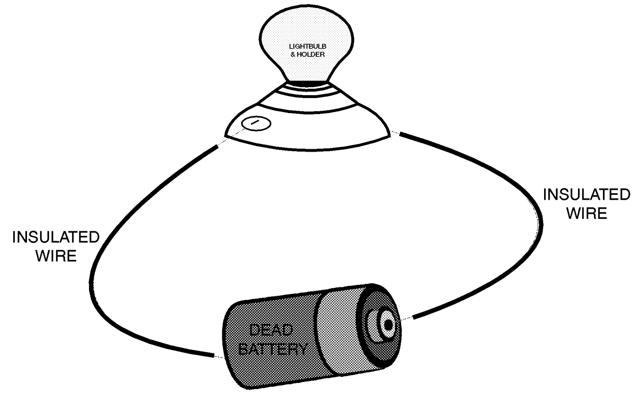
You may find it helpful to mount these setups on a piece of cardboard, taping down the components as you tape over the connections.

Room 1: The Office Suite

Materials

- Student Guide: Phase 2 — *class set*
- Science Journal
- T.E.A.M. ACTIVITY 1 — *one set of boxes per group*
- T.E.A.M. ACTIVITY 1 RECORD — *one per group*
- CLUE SEARCH 1 — The Office Suite — *class set*
- ELECTRICITY EXPLORATION 1 — *class set*
- SCIENTIFIC DETECTIVE RECORD FORM — *one per group and overhead transparency*
- T.E.A.M. ACTIVITY
  - Battery (size D) — *one per group*
  - Wire, eight-inch (20-cm) with half-inch (1-cm) insulation stripped from each end — *one per group*
  - Lightbulb — *one per group*
- Electricity Exploration 1
  - Faulty circuit setup — *one per group*
    - Battery (dead, size D) — *one per setup*
    - Lightbulb — *one per setup*
    - Lightbulb holder — *one per setup*
    - Tape (electrical or duct) — *one per group*
    - Wires, eight-inch (20-cm) with half-inch (1-cm) insulation stripped off each end — *two per setup*

Set up materials as shown here, but use a dead battery. Cover all connections with electrical or duct tape (not shown) so that students will have to check these more closely.



- Substitute circuit components:
  - Battery (working, size D) — *one per group*
  - Lightbulb — *one additional per group*
  - Lightbulb holder — *one additional per group*
  - Wires, eight-inch (20-cm) with half-inch (1-cm) insulation stripped from each end — *two additional per group*
- Stiff cardboard (optional) — *one piece per group*

Procedure

1. **Read or tell:**

   As we learn about electricity, I will record what we learn on an overhead transparency. Based on our discussions, I will add information to our list every day. Every day, you will record the same information in your Science Journals as well.

2. Distribute T.E.A.M. ACTIVITY 1, one box per student, one set per group. Give each group the materials listed at the beginning of this lesson under T.E.A.M. ACTIVITY. Distribute one T.E.A.M. ACTIVITY 1 RECORD to each group. Tell students that the objective of this activity is to learn about how simple circuits work. Direct each group to put together the circuits shown in each box and record its answers on its T.E.A.M. ACTIVITY 1 RECORD.

3. **Answer Key** for T.E.A.M. ACTIVITY 1:
   Works: circuit model numbers 1, 4, and 6
   Doesn't Work: circuit model numbers 2, 3, and 5

4. After the activity, discuss the situations described on the recording sheet and display the diagrams in the appropriate columns. Have students discuss why some setups worked and some didn't based on the materials they have to manipulate. Explain that the setups that worked were complete circuits and those that did not were incomplete circuits. Briefly discuss how incomplete circuits could be made complete. Have each group store this sheet in its group folder.

read or tell

TEACHING TIP

If a group has fewer than six members, some students will need to handle more than one T.E.A.M. ACTIVITY strip.

ANSWER KEY

Instead of the T.E.A.M. ACTIVITY RECORD sheet; you may have students cut apart the information on their strips and glue them to sheets of notebook paper, one labeled "Works" and one labeled "Doesn't Work."

You may do each T.E.A.M. ACTIVITY as a whole group exercise, using an overhead transparency to display answers.

read or tell

TEACHING TIP

Students writing on the map should use pencil and write small and neatly.

read or tell

TEACHING TIP

Although each ELECTRICITY EXPLORATION is a group activity, students will learn more if they can look at their own activity sheet and write in their own hypothesis, data, and conclusions.

Caution: Don't tell students what is "good" or "bad" concerning the materials.

Remind students to test one component at a time, going back to the original setup with the original materials before testing each new part.

5. **Read or tell:**

   Electrons move through complete circuits just as electrons move from object to object when static electricity is present. When a circuit is incomplete, the electrons cannot move through the circuit.

6. Distribute CLUE SEARCH 1 — The Office Suite to each student. Have students in each group study the information and list possible clues in the room marked "Office Suite" on the **Map of Faraday's Fudge Factory**, Student Guide: Phase 2, pp. 2-3. They should also record any possible clues from the Student Guides: Phase 1 and Phase 2 as well as from the Phase 1 EUREKA! ACTIVITIES on the map.

7. **Read or tell:**

   Ms. Faraday is hoping that we will be able to discover what is causing the shutdown of her factory. We will begin by examining the potential problems in the Office Suite. Your groups will perform an experiment to learn more about circuits. Be watching for any possible clues as you conduct this experiment.

8. Distribute one ELECTRICITY EXPLORATION 1 sheet to each *student* and one SCIENTIFIC DETECTIVE RECORD FORM to each *group*. Tell students that the objective of this activity is to determine why the circuit is not working. Explain that each group should follow the instructions on the ELECTRICITY EXPLORATION 1 sheet to help them answer the problem as stated (as a question) at the top of the page. Have students hypothesize about why they believe the lightbulb will not light and write each hypothesis in the column within the "Data" section on their activity sheet.

9. Give each group a circuit setup with a dead battery in it and the other materials. Direct students to perform and record the results of the activity.

10. **Sample Answers** for ELECTRICITY EXPLORATION 1:
Hypothesis: The lightbulb is burned out.

Data:

Part tested	Results
1. Wire connections	
a.	*no*
b.	*no*
c.	*no*
d.	*no*
2. Lightbulb	*no*
3. Battery	*yes*

Conclusion:

1. Why was the component a problem? *The battery must be dead. Our hypothesis was wrong.*
2. What made this a controlled experiment?*We only tested one component at a time and went back to the original setup with the original materials before testing each new part.*
3. What might you do to make it an "uncontrolled" experiment? *If we had tested more than one component at a time or had not gone back to the original setup before testing each new part, we would not have been able to pinpoint the exact problem. Controlled experiments have only one variable.*
4. How might an uncontrolled experiment harm your efforts to help Ms. Faraday solve her factory's problems? *We will not be able to pinpoint exact problems if we do not use controlled experiments.*

ANSWER KEY

TEACHING TIP

You may wish to refer students to EUREKA MOMENT 1 and 5 and the GLOSSARY regarding controlled experiments.

The sample answers will help you guide students into understanding the clues they should collect lesson by lesson.

Questions from SCIENTIFIC DETECTIVE RECORD FORM:
1. Problem Ms. Faraday has identified for room
2. Clues revealed through CLUE SEARCH
3. Clues uncovered through ELECTRICITY EXPLORATION
4. Other info. that applies to room's problems
5. Recommendations for Ms. Faraday

11. **Read or tell:**

    The battery in the circuit I gave you was indeed dead, making the circuit incomplete due to the fact that electrons will not flow out of and through dead batteries. However, many other problems could arise in using circuits in this mystery and in real life (e.g., each wire connection, the type of metal used in the wire, bulbs, power sources, and so on). This experiment has taught us how to systematically check a circuit to make sure it is complete and that its components are fully operational.

12. Direct each group to record their thoughts and findings on a SCIENTIFIC DETECTIVE RECORD FORM to give to Ms. Faraday. Make sure students note the definitions of **protons** and **electrons** and how **static electricity** may be related to the problems the factory is experiencing in the Office Suite. Collect the SCIENTIFIC DETECTIVE RECORD FORM from each group to give to Ms. Faraday.

13. **Sample Answers** for SCIENTIFIC DETECTIVE RECORD FORM (Office Suite):
    1. The computer is not working.
    2. The static electricity in the office suite is high.
    3. You can't just pull apart all the wires and know what caused the problem in an electrical circuit. You have to check one thing at a time.
    4. EUREKA! MOMENT 1 and 5 in Phase 1: Student Guide discusses controlled experiments and the article "LIGHTNING NEVER STRIKES TWICE?" in Student Guide: Phase 2 talks about the problems static electricity can cause for computers.
    5. Test the circuit components one at a time to pinpoint problems. Get rid of the wool sweater and the carpet to cut down on the static electricity in the room. Maybe the factory needs a lightning rod.

14. Allow groups to discuss and decide if ELECTRICITY EXPLORATION 1 helped them uncover any new clue(s). If so, they should each record it in the Office Suite on the **Map of Faraday's Fudge Factory**.

15. Have groups *review* the CLUE SEARCH 1: The Office Suite and T.E.A.M. ACTIVITY 1 RECORD sheet to see if they can spot and add any other possible clues to the map.

16. Using a blank transparency on the overhead do the following:
    a. Tell students that each day you will conduct a short debriefing session covering what they have learned.
    b. Ask students, "What have you learned today?"
    c. Note the ideas students share.

17. Encourage students to add these notes to their Science Journals. Any work the students have done today should go in their group folder.

18. Have students clean up for the day.

TEACHING TIP

Allow students to record clues in their Science Journals if they prefer.

TEACHING TIP

Suggested GLOSSARY review: static electricity, circuit, controlled experiment, variable.

Track clues that class consensus says are "Definitely Clues" and "Maybe Clues" on paper strips on a bulletin board. Move, add to, and discard clues as appropriate throughout Phase 2.

You may want to discuss safety issues related to current with your students. For example, the batteries used in these experiments use 1.5-6 volts whereas a typical home uses 115 volts. Students need to be aware of the dangers associated with home currents despite using current in these experiments.

Estimated activity time
90 minutes

TEACHING TIP

It is OK to use fewer types of materials than 12, but be sure to include fudge.
Students may test electrolytes — any substance that when dissolved in a liquid conducts electricity, such as vinegar, sugar water, salt water (compare each to distilled water). Use a powerful battery, such as a lantern battery, and test various solutions before offering substances for student exploration.

read or tell

You may wish to wear a simple prop each time you are assuming the persona of Ms. Faraday, such as a fancy hat.

Room 2: The Cooking Room

Materials

- Student Guide: Phase 2 — *class set*
- Science Journal
- T.E.A.M. ACTIVITY 2 — *one set of boxes per group*
- T.E.A.M. ACTIVITY 2 RECORD — *one per group*
- CLUE SEARCH 1 — The Office Suite — *for reference*
- CLUE SEARCH 2 — The Cooking Room — *class set*
- ELECTRICITY EXPLORATION 2 — *class set*
- SCIENTIFIC DETECTIVE RECORD FORM — *one per group and overhead transparency*
- Electricity Exploration 2
    - Items made from rubber, plastic, paper, cotton, copper, wood, fudge, steel, wool, aluminum, leather, nickel — *one of each per group*
    - Battery (any size) — *one per group*
    - Lightbulb — *one per group*
    - Lightbulb holder — *one per group*
    - Paper towels — *one wet and one dry per group*
    - Tape (electrical or duct) — *one per group*
    - Wires, eight-inch (20-cm) with a half-inch (1-cm) of the insulation stripped from each end — *three per group*

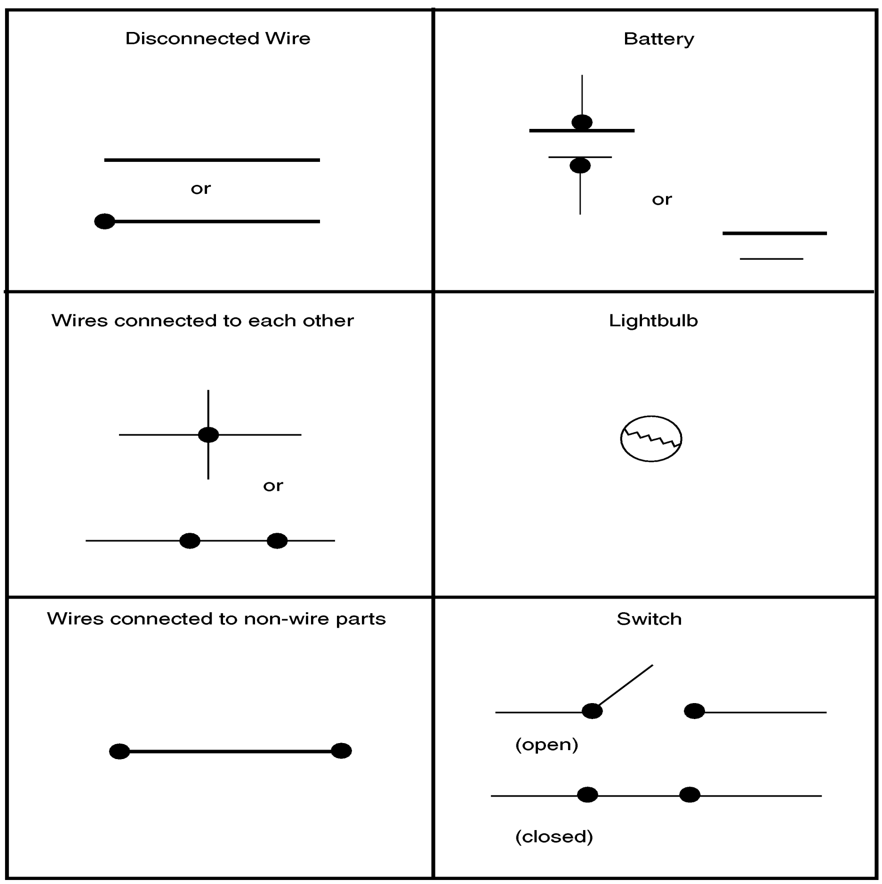
Procedure

1. Remind the students that they were just leaving the Office Suite.
   Read or tell:
   Ms. Faraday seems interested to see the results of your circuit testing. But she says, "I wonder if the information you gathered has anything to do with the problems my factory is experiencing. A little shock never hurt anybody and we have to take wires apart to find out what's wrong, don't we! You know what they say, you have to drop a few eggs on the floor to make an omelet!" There's a lot more of the factory to see. So you and your class move on to the Cooking Room, hoping you'll find more clues to help solve the mystery.

2. Distribute T.E.A.M. ACTIVITY 2, one box per student, one set per group. Distribute one T.E.A.M. ACTIVITY 2 RECORD to each group. Tell students that the objective of this activity is to learn the symbols used in real life to show a circuit diagram. Direct each group to allow each student to share and discuss the circuit diagram he or she was given. Encourage students to compare the circuits that do work and those that don't to deduce which symbol means what. Then tell students to draw the symbol for each component on the RECORD and recheck their decisions by reviewing the circuits given.

3. When groups finish the activity, discuss their results, defining the symbols and talking about how they went about figuring out which was which.

4. **Answer Key** for T.E.A.M. ACTIVITY 2:



TEACHING TIP

Assure students that the lightbulbs and other components are in good working order and that all connections are good—unlike in ELECTRICITY EXPLORATION 1.

ANSWER KEY

DAILY DIRECTIONS
PHASE 2: FARADAY'S FUDGE FACTORY

TEACHING TIP

Note: In Clue Search 2 the vats are unplugged from the wall outlet and the bottom. This is done as a safety precaution, as the vats are similar to a crockpot. Students should be aware of unplugging all connections to a power source before beginning work.

Ensure that students do not touch wires together and incorrectly conclude that an insulator is a conductor. This mistake is more likely with the fudge.

5. Distribute CLUE SEARCH 2 — The Cooking Room to each student and allow each group time to read and discuss the information. Have each group record possible clues on the **Map of Faraday's Fudge Factory**.

6. Distribute ELECTRICITY EXPLORATION 2.

7. Have students perform this experiment. Guide them into understanding the definitions of a **conductor** and an **insulator**. Stimulate your students' thinking by asking the following questions:
   - Which types of materials seem to conduct electricity? *Metals.*
   - Why do you suppose these types of materials conduct electricity so well? *They complete the circuit because they allow electrons to move through them.*
   - Which types of materials do not conduct electricity at all? *Plastic, wood, etc.*
   - Why do you suppose these materials are insulators? *Electrons cannot move through them.*

8. When groups have finished the activity, help students discern and summarize what types of materials fit each category, reviewing the terms **conductor** and **insulator**. Tell your students that this information should help them better understand the behavior of electricity.

ANSWER KEY

9. **Answer Key** for ELECTRICITY EXPLORATION 2:
   Conductors: *copper, steel, aluminum, nickel*
   Insulators: *plastic, paper, cotton, wood, rubber, leather, wool, fudge*
   Conclusion: Why do you think some materials conduct electricity and others do not? *Some allow electrons to flow while others do not.*

10. Allow groups to discuss and decide if the ELECTRICITY EXPLORATION 2 and T.E.A.M. ACTIVITY 2 uncovered any new clues. If so, they should record it in the Cooking Room on the **Map of Faraday's Fudge Factory**.

11. Suggest that groups *review* CLUE SEARCH 2 — The Cooking Room to see if they can spot and add any other possible clues.

12. Have each group prepare a SCIENTIFIC DETECTIVE RECORD FORM, based on what they have learned in this lesson to give to Ms. Faraday.

13. **Sample Answers** for SCIENTIFIC DETECTIVE RECORD FORM (The Cooking Room):
    1. Some of the vats had not been heating up before the electricity went out.
    2. Many of the electrical connections on the cooking vats have some burned substance on them. Each outlet uses doubling and tripling devices.
    3. Electricity won't flow through certain types of materials, including fudge. ELECTRICITY EXPLORATION 2 helped us see which materials electricity might or might not flow through.
    4. T.E.A.M. ACTIVITY 1 and ELECTRICITY EXPLORATION1 helped us learn how to check a circuit for problems.
    5. The electrical connections on the cooking vats need to be cleaned and kept clean. The room should be rewired so that doubling and tripling devices don't need to be used at the outlets.

14. **Read or tell** (as Ms. Faraday):

    "Humpf! So electricity can't flow through fudge. That might come in handy some day. But still, you young'ns are right. We're going to have to keep those connections clean from now on!"

15. Debrief today's activities, noting on an overhead transparency ideas students share about what they have learned today. Encourage students to add these notes to their Science Journals.

16. Have students clean up for the day.

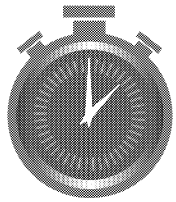
ANSWER KEY

Questions from SCIENTIFIC DETECTIVE RECORD FORM:
1. Problem Ms. Faraday has identified for room
2. Clues revealed through CLUE SEARCH
3. Clues uncovered through ELECTRICITY EXPLORATION
4. Other info. that applies to room's problems
5. Recommendations for Ms. Faraday

TEACHING TIP

Suggested GLOSSARY review: conductor, insulator, electron.

If you set up a bulletin board to track clues as a class, update that now.



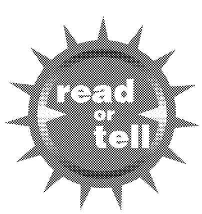
Estimated activity time
90 minutes

Room 3: The Refrigeration Room

Materials

- Student Guide: Phase 2 — *class set*
- Science Journal
- T.E.A.M. ACTIVITY 3 — *one set of strips per group*
- T.E.A.M. ACTIVITY 3 RECORD — *one per group*
- CLUE SEARCH 1 — The Office Suite and CLUE SEARCH 2 — The Cooking Room — *for reference*
- CLUE SEARCH 3 — The Refrigeration Room — *class set*
- ELECTRICITY EXPLORATION 3 — *class set*
- SCIENTIFIC DETECTIVE RECORD FORM — *one per group and overhead transparency*
- SCIENTIFIC METHOD — *from Phase 1*
- Electricity Exploration 3
  - Battery (C or larger) — *two* per group*
    ***do not distribute second battery until students build a parallel circuit (see last question in Procedure, step 7 - *Optional*)**
  - Lightbulbs — *two per group*
  - Lightbulb holders — *two per group*
  - Tape (electrical or duct)— *one per group*
  - Wires, eight-inch (20-cm) with a half-inch (1-cm) of insulation stripped from of each end — *six* per group*
    ***do not distribute two of the wires for the original experiment. Distribute these additional wires when students build a parallel circuit (see last question in Procedure, step 7 - *Optional*)**

Procedure



1. Remind the students that they were just leaving the Cooking Room. **Read or tell:**

   Your stomach is rumbling from the thought of fudge; you leave the Cooking Room and move onto the Refrigeration Room, hoping to find more clues.

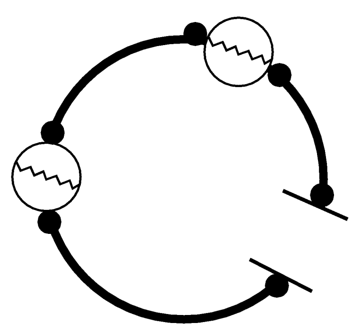
2. Distribute one copy of CLUE SEARCH 3 — The Refrigeration Room to each student and allow each group to read and discuss the information. Have groups record any clues they find in the Refrigeration Room on the **Map of Faraday's Fudge Factory.**

3. Distribute T.E.A.M. ACTIVITY 3 strips and one T.E.A.M. ACTIVITY RECORD to each group. Explain that the purpose of this activity is to learn about two types of electrical circuits to help them solve the mystery in the Refrigeration Room. As a result of completing this activity, students will also be able to draw a diagram of each circuit on the T.E.A.M. ACTIVITY 3 RECORD sheet. Students will also use these diagrams to complete ELECTRICITY EXPLORATION 3 successfully. Direct each group to listen to each member offer information from their strips. Then have each group diagram its findings on their T.E.A.M. ACTIVITY 3 RECORD sheet.

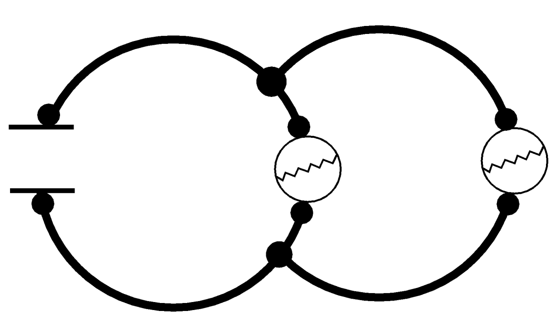
4. After the activity, discuss the differences between the two types of circuits. Display correct diagrams of each type of circuit. Tell or ask students the true names of the types of circuits and have them add this information to their diagrams and other recorded information. (Type 1 is a **series circuit**; Type 2 is a **parallel circuit**.) They should also make any corrections in their drawings at this time.

5. **Answer Key** for T.E.A.M. ACTIVITY 3:

   Type 1 is a Series Circuit:



   Type 2 is a Parallel Circuit:



TEACHING TIP

You may have your students draw the diagrams of the circuits in their Science Journals instead of on a T.E.A.M. ACTIVITY 3 RECORD sheet.

Encourage or tell students to use the circuit symbols they learned in T.E.A.M. ACTIVITY 2 to draw their diagrams.

ANSWER KEY

read or tell

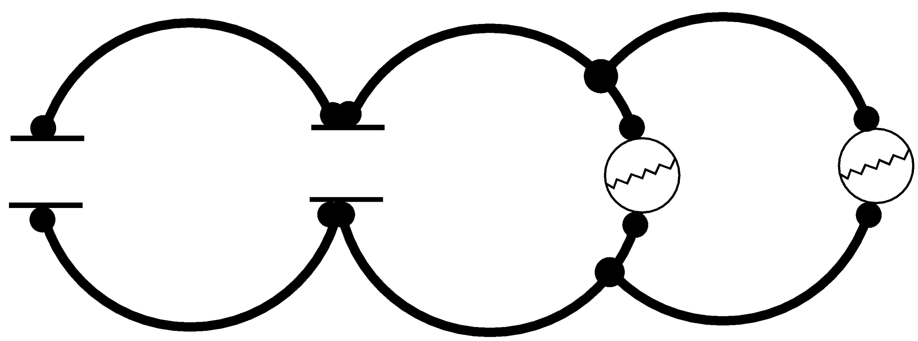
TEACHING TIP

Suggest to students that they might not need each item listed under "Materials" on the ELECTRICITY EXPLORATION 3 sheet for each circuit. For example, they might not need as many wires as listed.

6. **Read or tell:**

   Ms. Faraday is interested to hear about each type of circuit, but feels you need to do more investigation before you can help her with the Refrigeration Room problem.

7. Distribute and have groups do ELECTRICITY EXPLORATION 3. Ask questions such as the following to stimulate your students' thinking:
   - Were the diagrams you drew in T.E.A.M. ACTIVITY 3 accurate? If not, how did you have to change them to get the lightbulbs to light? *Answers will vary.*
   - If you remove one lightbulb, in which type of circuit will the other lightbulb go out? *Series.*
   - If you remove one lightbulb in the parallel circuit, what happens? Why? *The other lightbulb stays lit because the electricity can still get to it; the circuit isn't broken.*
   - ***Optional* - Distribute a second battery and two more wires to each group**. How might you build a parallel circuit with two batteries connected in parallel? S*ee drawing below.*



8. Encourage each individual student to also make his/her own drawing of each type of circuit in his/her Science Journal.

9. **Sample Answers** for ELECTRICITY EXPLORATION 3:
Hypothesis: A Type 2 circuit is more practical.
Data:
   1. What happened when you removed one bulb from the series circuit? *The other lightbulb went out when we removed one lightbulb from the serires circuit.*
   2. What happened when you removed one bulb from the parallel circuit? *The other lightbulb stayed lit when we removed one lightbulb from the parallel cicuit.*

   Conclusion:
   1. Which type of circuit is usually going to be more practical? *A parallel circuit is usually more practical.*
   2. Why do you think this is true? *Because it keeps functioning as a complete circuit even when one bulb is not working.*

10. Suggest that groups *review* the CLUE SEARCH 3 — The Refrigeration Room sheet to see if they can now spot and add any other possible clues.

11. Have students record any possible clues they think T.E.A.M. ACTIVITY 3 and ELECTRICITY EXPLORATION 3 suggest for solving the mystery in the Refrigeration Room on their **Map of Faraday's Fudge Factory**. Then encourage them to record their personal thoughts in their Science Journals.

12. Have each group prepare a SCIENTIFIC DETECTIVE RECORD FORM, based on what they have learned in this lesson to give to Ms. Faraday.

13. **Sample Answers** for SCIENTIFIC DETECTIVE RECORD FORM (The Refrigeration Room):
    1. Nothing—Ms. Faraday is proud of this room.
    2. There is frayed wiring. When you unplug one refrigerator, they all stop working.
    3. A parallel circuit is more practical.
    4. The Phase 2: Student Guide article "HOUSE FIRE IN BURLINGTON DUE TO BAD WIRING" says that frayed wiring is dangerous.
    5. The room needs to be rewired on a parallel instead of a series circuit. All the wiring that is frayed should be replaced.

ANSWER KEY

ANSWER KEY

Questions from SCIENTIFIC DETECTIVE RECORD FORM:
1. Problem Ms. Faraday has identified for room
2. Clues revealed through CLUE SEARCH
3. Clues uncovered through ELECTRICITY EXPLORATION
4. Other info. that applies to room's problems
5. Recommendations for Ms. Faraday

14. **Read or tell** (as Ms. Faraday):
Go figure! Can't understand that there fridge system. Must be something wrong with the design. Have to talk to Fred soon. Let's move on to the Packaging Room. I'm more anxious than a fudgesicle on a hot day to get this problem over with! I can hear my workers gossiping in the Packaging Room. Let's get moving. There is no time to waste before the school bus comes to take you back to school. Besides, we're running out of rooms, so I sure hope you young'ns can solve this mystery soon. Hold that bus! she shouts to a worker.

15. Debrief today's lesson, recording student comments on an overhead transparency. Encourage students to record these comments in their Science Journals.

16. Have students clean up for the day.

TEACHING TIP

Suggested GLOSSARY review: parallel circuit, series circuit.

Track clues that class consensus says are "Definitely Clues" and "Maybe Clues" on paper strips on a bulletin board. Move, add to, and discard clues as appropriate throughout Phase 2.

Room 4: The Packaging Room

Materials

- Student Guide: Phase 2 — *class set*
- Science Journal
- CLUE SEARCH 1 — The Office Suite and
  CLUE SEARCH 2 — The Cooking Room and
  CLUE SEARCH 3 — The Refrigeration Room — *for reference*
- CLUE SEARCH 4 — The Packaging Room — *class set*
- ELECTRICITY EXPLORATION 4A — *class set*
- ELECTRICITY EXPLORATION 4B — *class set*
- SCIENTIFIC DETECTIVE RECORD FORM — *one per group and overhead transparency*
- Electricity Exploration 4A
  - Base (such as a plastic or Styrofoam cup) — *one per group*
  - Battery (D-cell) — *one per group*
  - Dowel, half-inch (1-cm) or other round object — *one per group*
  - Magnet (strong, but small) — *one per group*
  - Magnet wire, 12-inch (30-cm), enamel-coated, 32 gauge (or thinner) — *one per group*
  - Paper clips (uncoated) — *two per group*
  - Rubber band (thick) — *one per group*
  - Sandpaper — *one piece per group*
  - Tape (electrical or duct) — *one per group*
- Electricity Exploration 4B
  - Battery (D-cell) — *one per group*
  - Lightbulb — *one per group*
  - Lightbulb holder — *one per group*
  - Semiconductor diode (400v) — *one per group*
  - Tape (electrical or duct) — *one per group*
  - Wire, eight-inch (20-cm) with half-inch (1-cm) insulation stripped from each end — *three per group*

Procedure

1. Remind students that they were just leaving the Refrigeration Room. Explain that today students will do two ELECTRICITY EXPLORATIONS instead of one T.E.A.M. ACTIVITY and one ELECTRICITY EXPLORATION.

Estimated activity time two 45-60 minute class periods depending on how much setup you do and how much students do for ELECTRICITY EXPLORATION 4A.

TEACHING TIP

Depending on your students, set up the motors as described and shown on ELECTRICITY EXPLORATION 4A and simply have students do Steps 9 and 10 under "Experiment" and answer the questions under "Data" and "Conclusion." Or, depending upon the maturity level, age, and experience of your students, it may be wise to do this activity as a demonstration only. ***Use your best judgment to prevent burns.***

You may sand the ends of the wire ahead of time. You need to remove about 1 inch (2.5 cm) of the enamel from each end so it will conduct electricity. This is a simple procedure.

TEACHING TIP

You may want to review the following before your discussion: electromagnet (GLOSSARY term) and the "Motors Have Magnetic Attraction" article (Student Guide).

2. Distribute CLUE SEARCH 4 — The Packaging Room to each student. Allow groups time to read and discuss this latest information. Have groups record any possible clues in the Packaging Room on the **Map of Faraday's Fudge Factory**.

3. Distribute one ELECTRICITY EXPLORATION 4A per student. Explain to students that the objective of this activity is to explore the relationships among electricity, magnetism, and motors. Direct each group to record their findings on their activity sheets as they perform the experiment.

Caution students to only touch the still-enameled part of the magnet wire once the loop is set in the paper clips as the wire will get hot!

4. Ask questions such as the following to stimulate student thinking:
   - What might go wrong with a motor? *An electrical connection may be bad so that the electromagnet is not created, a permanent magnet or other part of the structure might not be lined up correctly, motion may not be transferred to the drive shaft because of friction or other interference, parts may be too worn, and so on.*
   - How many magnets are involved in the motor in Experiment Step 9? *Two, the magnet sitting on the battery and the magnet wire.*
   - Why do you suppose the magnet wire loop is moving? *The electricity flowing through the magnet wire magnetizes it, making it an electromagnet, and the magnetism of the other (permanent) magnet repels and attracts it, making the loop spin.*
   - In a real motor, how might such motion be harnessed? *A drive shaft extending from the motor transfers the motion to where it's needed to make the machine work. See article titled "Motors Have Magnetic Attraction" Student Guide: Phase 2.*
   - On this simple model of a motor, where might a drive shaft be attached? *From either straight end of the magnet wire loop structure.*
   - What happens when you remove the permanent magnet in Experiment Step 10? *The motor doesn't work.* Why? *Because the electromagnet (wire loop) does not have anything to attract and repel it.*

5. After the activity, discuss the results of ELECTRICITY EXPLORATION 4A. Have students support their answers with the data they gathered and the motors they constructed.

6. **Sample Answers** for ELECTRICITY EXPLORATION 4A:
   Hypothesis: Magnets will attract and repel each other, making motion.
   Data:
   1. What does the wire loop do in Step 9 above when lined up horizontally? *The wire loop spun around, making motion.*
   2. What does the wire loop do in Step 10 when lined up horizontally? *The wire loop did not move.*

   Conclusion:
   1. Why does the wire loop act as it does in Step 9? *The wire loop became an electromagnet because electricity was flowing through it, and, when lined up right with the per manent magnet, the permanent magnet attracted and repelled it, creating motion.*
   2. Why does the wire loop act as it does in Step 10? *The wire loop did not have a magnet to attract and repel it to create motion.*

7. Allow groups time to discuss and decide if ELECTRICITY EXPLORATION 4A has given them any new clue(s) to help them solve the mystery. If so, direct them to record this information in the Packaging Room on the **Map of Faraday's Fudge Factory**.

8. **Read or tell:**
   You look at the motor's Operating Manual and put the permanent magnet back where it should be. Then you close the outer casing securely and hook up the generator to see if the motor works now. Nothing! Something else must be wrong. Real life problems are not always controlled experiments, but if you deal with one problem at a time, eventually, you will systematically get the motor running.

   Ms. Faraday returns from the Office Suite looking as grumpy as ever. "Sure could use some good news today!" she sputters. Disappointed to see that the

ANSWER KEY

Data — Some groups may only be able to get the wire loop to swing back and forth. This is acceptable under classroom conditions. Simply explain that it is difficult to line the apparatus up just right to produce complete rotation. In addition, point out that in a real motor, the loop would not spin completely around. Instead, a second permanent magnet placed opposite the first would make the loop swing back and forth creating motion.

TEACHING TIP

Depending on your schedule, you may wish to stop for the day at this point and continue next class.

read or tell

motor is still not working, she grumbles, "Maybe this doo-hicky is causing trouble again!" She touches a small cylinder-shaped part of the wiring. "It's called a semi truck die-road or some such nonsense. Anyways, it's supposed to help direct the current. I turned it around while I was tinkering with this here contraption. Try this experiment and see what you find out."

9. **Read or tell:**
   Here is the experiment that Ms. Faraday gave you. Let's check this circuit and see if we can finally get that motor running!

10. Distribute ELECTRICITY EXPLORATION 4B. Explain to students that the objective of this activity is to see how a **semiconductor diode** affects a circuit. Direct each group to record their findings on their activity sheets as they perform the experiment.

11. As students work through the experiment, ask questions and make statements such as the following to stimulate students' thinking:
    - Whose setup lit the bulb and whose didn't?
    - Have you checked each connection to make sure it's not loose?
    - If your lightbulb is not lighting, see if it does without the diode. What might this tell you about the diode? *It's damaged; it's not placed in the circuit correctly.*
    - Remember, none of the components is faulty. Change one thing at a time to determine what is wrong.

12. After the activity, discuss the results of ELECTRICITY EXPLORATION 4B. Have students support their answers with the data they gathered and the circuits they constructed.

TEACHING TIP

Assure students that all components are in good working order. Review and discuss all helpful GLOSSARY terms at this time.

Monitor groups closely to ensure they continue to use the setup shown on the activity sheet and that they are not creating other problems for themselves, such as loose connections.

13. **Sample Answers** for ELECTRICITY EXPLORATION 4B:
    Hypothesis: *The diode will need to be in the right position to work.*
    Data:
    1. What happened when you first completed the circuit? Answer should be *The bulb lit or The bulb did not light.*
    2. If the lightbulb did **not** light on your first try, what did you try until it worked? Answers will vary, but may include: *We pressed the wires more firmly into the diode* or *We turned the diode around* or *We wrapped the wire around the diode* and so on. If the lightbulb **did** light on your first try, what did you try until it did **not** work? *We turned the diode around.*

    Conclusion:
    1. Why did the lightbulb **light** or **not** light in Experiment Step 4? Answer should be *The diode needed to be turned around* or *The diode was in the right position on our first try.*
    2. What does this experiment tell you about diodes? *Diodes only allow electricity to flow in one direction.*

14. Allow groups time to discuss and decide if ELECTRICITY EXPLORATION 4B has given them any new clue(s) to help them solve the mystery. If so, direct them to record this information in the Packaging Room on the **Map of Faraday's Fudge Factory**.

15. **Read or tell:**

    This experiment showed you that diodes only allow electricity to flow in one direction. If your bulb did not light, turning the semiconductor diode around solved the problem.

    How might this help in a motor? ***It's safer: electricity can't flow in the wrong direction, overheating a motor part or anything else connected to it by going the wrong way.***

Examine your working circuit more closely. The colored band on one end of the diode shows which direction the electricity will flow toward.

*How does the positioning of the diode correspond to the **positive** and **negative** terminals (ends) on the battery? **The positive (+) of the diode is turned in the same direction as the positive (+) on the battery; in other words, if the battery's positive terminal is pointing clockwise along the circuit, so should the diode's, or vice versa. The thin colored band on the diode is always positive.***

After repairing the motor, all the conveyor belts begin rumbling. Seeing that you have the conveyor belts running again, Ms. Faraday exclaims in delight, 'Well, you young'ns are the greatest things since sliced fudge! Thank you, thank you! How did you ever do it?'

16. Encourage students to *review* CLUE SEARCH 4 — The Packaging Room and add any other clues they can spot to the **Map of Faraday's Fudge Factory**.

17. Have each group complete a SCIENTIFIC DETECTIVE RECORD FORM for Ms. Faraday.

18. **Sample Answers** for the SCIENTIFIC DETECTIVE RECORD FORM (Packaging Room):
    1. One conveyor belt motor has needed repair recently.
    2. All the conveyor belts are running roughly. One conveyor belt motor stops working. Then all the conveyor belts stop.
    3. A motor needs at least two magnets to work. The diode must be placed correctly to send the electricity in the right direction.
    4. Since all the conveyor belts stopped working when one motor had a problem then started to run again when we fixed that one, they must be on a series circuit like the refrigerators were (like in the Refrigerator Room). The article "Motors Have Magnetic Attraction" in the Student Guide: Phase 2 helped too.
    5. Put the magnet back into the motor. Make sure all diodes are placed the right way. Stop using series circuits!

19. Using a blank overhead transparency, debrief what students share they have learned today. Encourage students to add these notes to their Science Journals.

20. Direct students to clean up for the day.

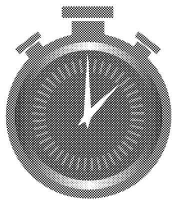
ANSWER KEY

Questions from SCIENTIFIC DETECTIVE RECORD FORM:
1. Problem Ms. Faraday has identified for room
2. Clues revealed through CLUE SEARCH
3. Clues uncovered through ELECTRICITY EXPLORATION
4. Other info. that applies to room's problems
5. Recommendations for Ms. Faraday

Students may reasonably make other suggestions, too, such as the sample answers listed for the questions in Steps 4 and 11 of this lesson.

Suggested GLOSSARY review: electromagnet, electromagnetism, dynamo, semiconductor diode.

If you set up a bulletin board to track clues as a class, update that now.



Estimated activity time
45-60 minutes

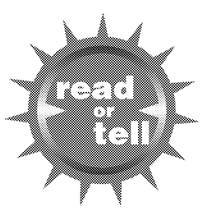
Room 5: The Boiler Room

Materials

- Student Guide: Phase 2 — *class set*
- Science Journal
- CLUE SEARCH 1 — The Office Suite and
  CLUE SEARCH 2 — The Cooking Room and
  CLUE SEARCH 3 — The Refrigeration Room
  CLUE SEARCH 4 — The Packaging Room — *for reference*
- CLUE SEARCH 5 — The Boiler Room — *class set*
- ELECTRICITY EXPLORATION 5 — *class set*
- SCIENTIFIC DETECTIVE RECORD FORM — *one per group and overhead transparency*
- Electricity Exploration 5
  - Battery (lantern) — *one per group*
  - Brads (one-inch or long enough to go through the cardboard) — *two per group*
  - Clay — *two lumps per group*
  - Corrugated cardboard, 2" x 3" (5 x 7 cm) — *one per group*
  - Insulated copper wire, eight-inch (20-cm) with half-inch (1-cm) insulation stripped from each end — *four per group*
  - Lightbulb — *one per group*
  - Lightbulb holder — *one per group*
  - Nichrome wire (#32) 2-3-inch (5-7.5-cm) — *one per group*
  - Paper clips (uncoated) — *three per group*

Procedure

1. Remind students that they were just leaving the Packaging Room. Explain that today students will complete an ELECTRICITY EXPLORATION and solve the mystery.



2. **Read or tell** (as Ms. Faraday):
   Well, if you folks can fix a motor, maybe you can figure out this cantankerous boiler of ours! Let's move as fast as a melted chocolate mountain river and see what you can do.

3. Distribute CLUE SEARCH 5 — The Boiler Room to each student. Allow groups time to read and discuss this information. Have groups record any possible clues in the Boiler Room on the **Map of Faraday's Fudge Factory**.

4. **Read or tell:**
   As the bus rumbles along on the way back to school, you and your group mates discuss what you saw in the Boiler Room.

5. **Read or tell:**
   Most of you are probably wondering about the fuses in the Boiler Room. Ms. Faraday has sent an activity to show how a fuse works in the hopes that this will help you solve the mystery.

6. Distribute ELECTRICITY EXPLORATION 5 to each student.

7. Explain to students that the objective of this activity is to explore how a fuse works and why it works as it does.
   Caution students strongly not to touch the nichrome wire once the circuit is closed.
   Direct each group to record answers in the spaces provided on the ELECTRICITY EXPLORATION 5 sheet as they perform the experiment.

8. After the activity, discuss the results of ELECTRICITY EXPLORATION 5.

9. **Sample Answers** for ELECTRICITY EXPLORATION 5:
   Hypothesis: The fuse wire will melt.
   Data: The fuse wire got hot and broke.
   Conclusion: The fuse wire had too much electricity in it. It overheated and broke, which kept the rest of the circuit from overloading.

10. Have students record their personal thoughts in their Science Journals.

11. Allow groups time to discuss and decide if ELECTRICITY EXPLORATION 5 has given them any new clue(s) to help them solve the mystery. If so, direct them to record this information in the Boiler Room on the **Map of Faraday's Fudge Factory**.

Remind students that it was Thomas Edison who invented fuses when he was trying to bring electricity into people's homes. See EUREKA! MOMENTS 5 in Student Guide: Phase 1.

TEACHING TIP

Depending on the maturity level, age, and experience of your students, it may be wise to do this activity as a demonstration only. ***Use your best judgment to prevent burns.***

ANSWER KEY

ANSWER KEY

Questions from SCIENTIFIC DETECTIVE RECORD FORM:
1. Problem Ms. Faraday has identified for room
2. Clues revealed through CLUE SEARCH
3. Clues uncovered through ELECTRICITY EXPLORATION
4. Other info. that applies to room's problems
5. Recommendations for Ms. Faraday

12. Have students *review* CLUE SEARCH 5 — BOILER ROOM to see if they can spot any more clues to add to the **Map of Faraday's Fudge Factory**.

13. Then have each group complete a SCIENTIFIC DETECTIVE RECORD FORM to fax to Ms. Faraday with the latest information.

14. **Sample Answers** for the SCIENTIFIC DETECTIVE RECORD FORM (The Boiler Room):
    1. She's not sure if the boiler is causing problems in the factory or not.
    2. The pressure gauge is stuck at a dangerously high reading. The boiler is old, and the factory is wired with (burned out) fuses instead of circuit breakers.
    3. Fuses melt, breaking a circuit when the circuit is overloaded.
    4. The Student Guide: Phase 2 article on the house fire explains how fuses and circuit breakers work. ELECTRICITY EXPLORATION 5 showed how a fuse works.
    5. The power from the boiler could not get to the factory because the fuses were blown. Ms. Faraday should switch to circuit breakers because they are more convenient to reset, and she should never leave the boiler operating without using its power or it might explode. The boiler might need to be replaced if it is overloading the system. When the diesel-powered generators were hooked up, the fuses (or circuit breakers) should not be by-passed because they are important for safety.

15. **Read or tell:**

    With all the information you have collected, including today's information, you should be able to solve the electricity mystery by the end of today's class.

16. Using a blank overhead transparency, debrief students, recording what they share they have learned today. Encourage students to add these notes to their Science Journals.

17. Allow students extra time to write more on their "fax" to Ms. Faraday, with their group recommendations, based on all the clues they have gathered.

18. Congratulate your students on a job well done. Remind them of how important these investigative skills are in real life.

19. Direct students to clean up.

If you set up a bulletin board to track clues as a class, update that now.

TEACHING TIP

They can use the back of the SCIENTIFIC DETECTIVE RECORD FORM if they need more space.

There is no one "right" answer to the mystery, except to say that the wiring and machinery of Faraday's Fudge Factory is very outdated and the fuses were probably blown from being overloaded by the aging boiler. Encourage groups to make detailed recommendations, based on the observations they made as they "toured" the factory and conducted the experiments and activities.

TEACHING TIP

For any of these events, you may wish to serve fudge as a treat. If you have a student who is allergic to chocolate, find out if carob "fudge" is an acceptable dietary substitute for this individual, or provide another treat.

TEACHING TIP

(for Re-enactments) Unless you are specifically teaching and assessing oral communication, be sensitive to the fact that some students prefer to have non-speaking roles in skits, such as working on simple props, scenery, and sound effects.

You may choose from any of these activities to extend your students' learning through this simulation. Consider inviting parents, other classes, administrators, and local media to your class's big event.

1. **Presentation to Ms. Faraday**
   Have groups present their recommendations to a "Ms. Faraday," the Owner of Faraday's Fudge Factory (school principal, yourself, or other dignitary).

2. **Challenge Projects**
   Assign or allow students to choose from the list of CHALLENGE PROJECTS listed on page 69. You may also wish to have students present these projects to "Ms. Faraday" and other visitors.

3. **Electrified Inventions Day**
   You may wish to require formal displays as in a science fair. SCIENCE FAIR, another Interact simulation, offers specific guidelines for preparing an attractive science display.

4. **Women Inventors**
   Have students research more information about women inventors. Require them to make and present attractive displays about an individual's life and work, similar to those suggested for ELECTRIFIED INVENTIONS. Each student could make a simple model of an item their inventor created to go with his/her display.

5. **Eureka! Moment Re-enactments**
   You may wish to have each small group select a moment in history explored in PHASE 1 to re-enact for Ms. Faraday and other visitors. Encourage students to use simple props, such as the experiment materials. If desired, use the rubric on page 68 to guide your assignment and assessment of this activity.

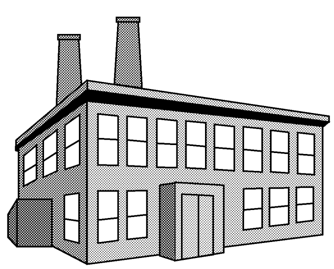
Scientists and Detectives Scientists are really detectives who work diligently to solve a problem. Like detectives who work for the police department, scientists have tools they use to solve mysteries. For example, both scientists and detectives keep notebooks (or journals). Here they carefully document what they find, observe, question, or believe to be a possible solution to the mystery they are attempting to solve.

Keeping a Journal As you work through the FUDGE FACTORY mystery, you will keep a journal, just as a real scientist or a real detective does. This Science Journal will be important because in it you will record *everything* you learn!

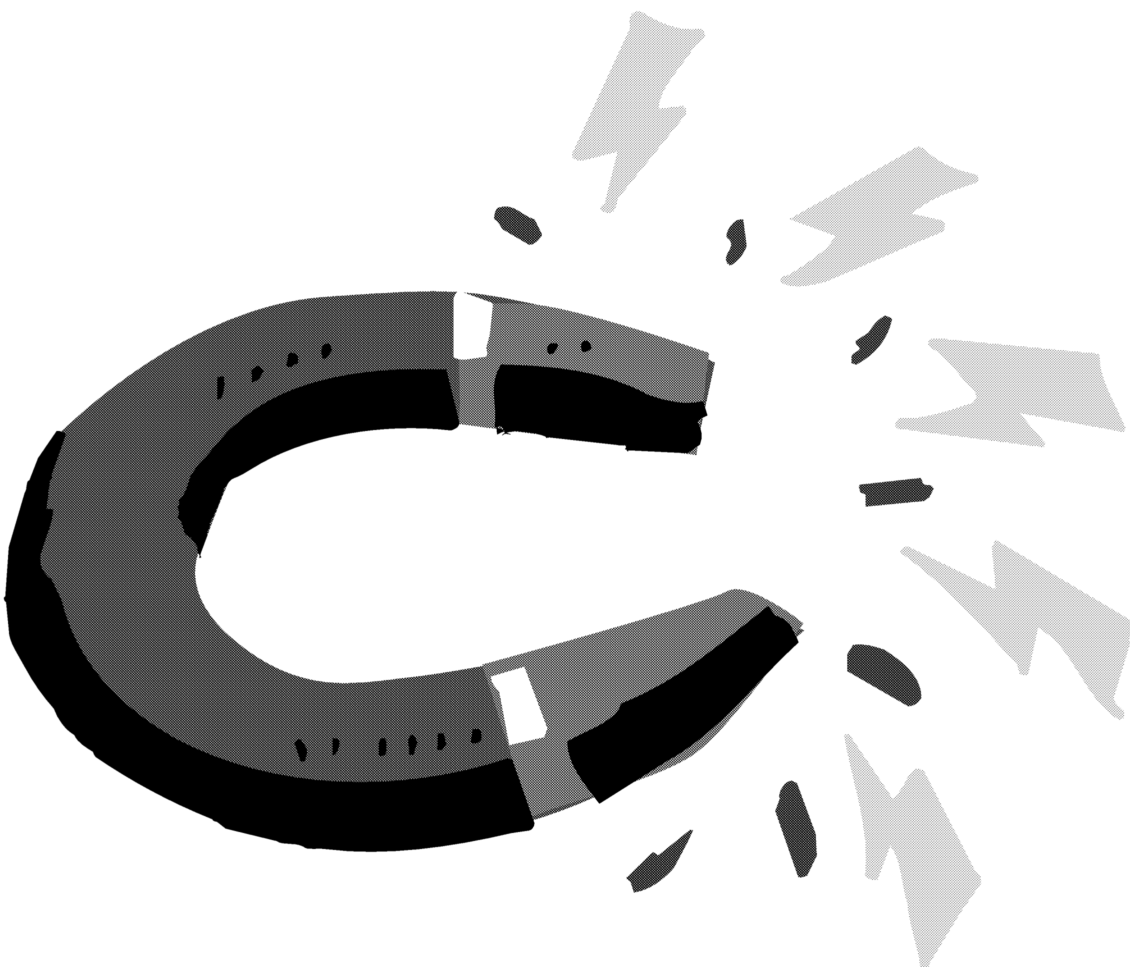
Making an Authentic Journal To keep an authentic—that is, a real and worthwhile—Science Journal, you should include the following elements:

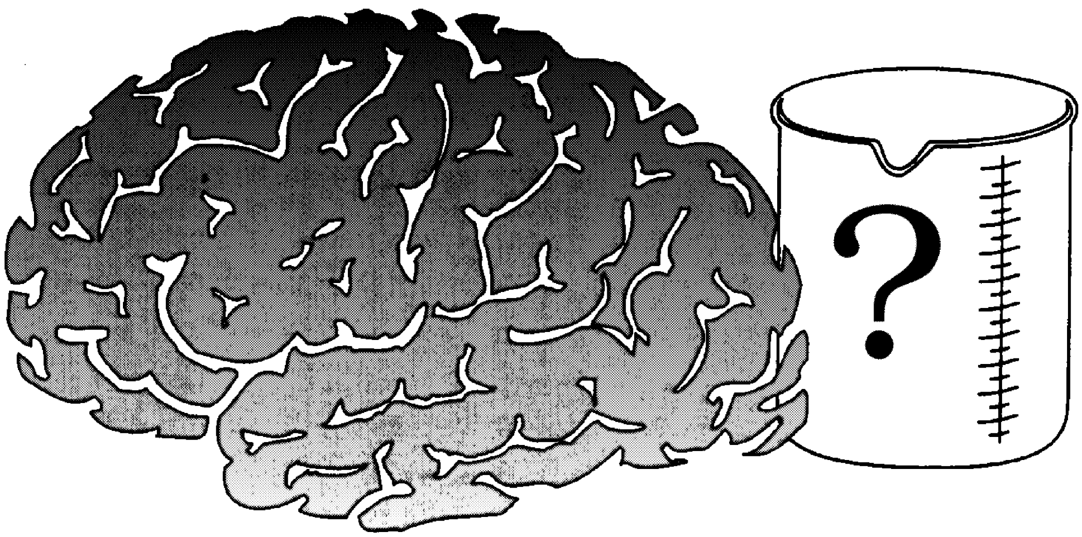
1. **Dates** Every time you write in you SCIENCE JOURNAL, you *must* include the date! This date will help you keep track of when you did activities and experiments and made observations.
2. **Complete Descriptions** Descriptions of all activities, experiments, and observations must be very complete so that someone with no knowledge of the activities and experiments you did could pick up your journal, read it, and understand *exactly* what you did.
3. **Illustrations** Have you heard the expression, “A picture is worth a thousand words?” Illustrations will help someone reading your journal to understand even more than they would from words alone. Illustrations do not have to be complex: they can be simple diagrams or sketches. These illustrations will not only help someone reading your journal; they will also help you when you look back at your notes. Scientists often take pictures at different points in their experiments. If you have a camera, you may also take pictures as you work through this FUDGE FACTORY mystery.
4. **Important Questions** Scientists use their journals to record carefully any questions that occur to them as they are working. These questions help them determine what would be studied further. You should include questions you may have in your Science Journal as you work through this mystery.
5. **Possible Solutions** Scientists are always thinking about the solution to the problem troubling them. In their journals, they record possible solutions whenever one comes to mind. Do the same thing in your Science Journal.

   Good luck with your Science Journal. It will help you keep track of most of your thoughts and actions as you solve this intriguing mystery.



My Science Journal





Using your brain in sequential steps

1. **Problem/Question:** What do you wish to find out?

2. **Hypothesis:** What do you think the answer is?

3. **Experiment:** Design a procedure (experiment) to test your hypothesis.

4. **Data:** Conduct the experiment and keep accurate records of your results. Repeat the experiment a number of times. Record the information you collect (data) in a Science Journal. (You may also put some information on a graph.)

5. **Conclusion:** Summarize what you have discovered (concluded) as a result of doing this experiment.

Attract—pull toward.

Atom—the smallest part of a material that can exist either alone or combined with something else.

Capacitor—a device in which to collect and store electricity.

Circuit Breaker—a switch that automatically stops the flow of too much electricity to protect electric circuits against overheating and damage.

Conductor—a material that allows electricity to flow through it, such as copper.

Controlled Experiment—an experiment that has only one variable.

Coulomb's Law—unlike charges attract each other, and like charges repel each other; named after Charles Coulomb (1736-1806), who first discovered and described this behavior in 1785.

Coulombs—a practical unit of measurement of the quantity of electric charge.

Current—the movement or flow of electric charges.

Diode—see semiconductor diode.

Discharge—to let go of electrical energy.

Dynamo—machine that produces electricity, also called a generator.

Electromagnet—a metal rod changed into a magnet by being surrounded by a wire carrying an electric current.

Electromagnetism—magnetism created by an electrical current as with an electromagnet.

Electron—negatively charged particle in an atom. Shown with a minus sign (–).

Force Field—the space in which electricity and magnetism operates.

Fuse—a safety device for stopping an electrical current if the electrical circuit becomes overloaded.

Galvanometer—a tool used to detect or measure electricity in a magnetic field.

Insulator—a material that does not conduct electricity, such as rubber, plastic, or wood.

Lodestone—a natural magnet made of the mineral magnetite; has north and south poles.

Parallel Circuit—an electrical current circuit in which the energy source (e.g., a battery or generator) is connected by wires to more than one component (e.g., lightbulb) along (many) paths, so that if one component fails to work, the circuit will still conduct electrical current.

Particles—small parts that make up atoms.

Patent—a legal document giving an inventor the right to be the only person to make, use, or sell her or his invention for a set period of years.

Phonograph—the first machine that could save sounds and replay them; An early type of record player.

Proton—positively charged particle in an atom. Shown with a plus sign (+).

Repel—push away from.

Semiconductor—any of a certain group of solids that conducts electricity more than an insulator but less than a conductor.

Semiconductor Diode—an electronic device that restricts current flow chiefly to one direction.

Series Circuit—an electrical current circuit in which the energy source (e.g., a battery or generator) is connected by wires to more than one component (e.g., lightbulb). The same current passes through each component without being diverted, so that if one component fails to work, the circuit will not continue to conduct electrical current.

Static Electricity—isolated electrical charges that do not move through a circuit.

Technology—applying knowledge in practical ways.

Unbalanced Charge—an object does not have an equal number of protons and electrons.

Variable—a part of an experiment. It should be the *only* thing that changes in tests of a hypothesis.

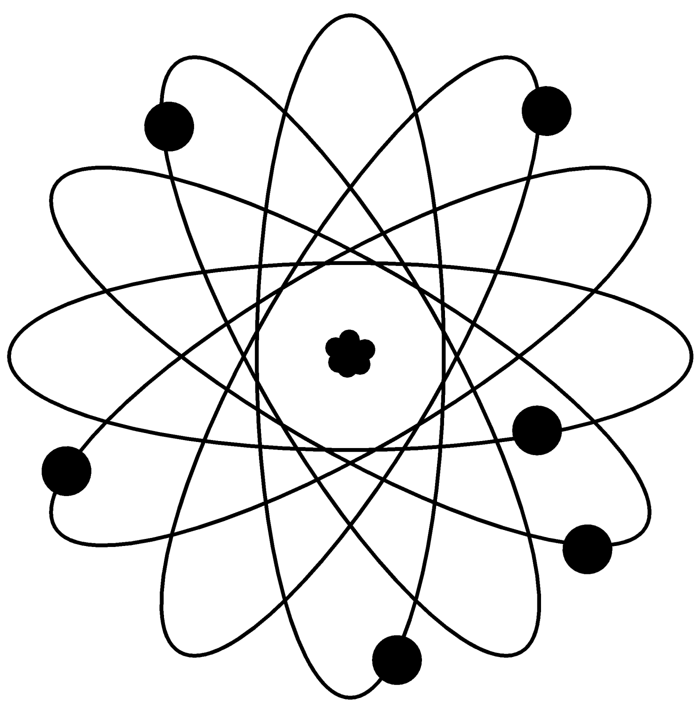
Volt—an electrical unit of measurement.

Please read the following information about protons and electrons. When you have completed the reading, come up with your own way of acting out the charge activity described.

All things are made of **atoms**. Atoms are made of small parts called **particles**. Some particles of an atom are called **protons** and some other particles are called **electrons**. Protons have positive charges shown with a plus sign (+). Electrons have negative charges shown with a minus sign (-). Rubbing two items together can sometimes cause protons and electrons to move from one item to the other. When some protons and electrons move between two items, the charges can become unbalanced in each item. **Unbalanced charge** means that an object does not have an equal number of protons and electrons.

To start, both objects have a balance of protons (+) and electrons (-), but when rubbed, some electrons move from the wool to the balloon, upsetting the balloon's balance. Now the balloon's unbalanced charges **attract** (pull toward each other), the spider's electrons or protons (it depends on what it needs), and the two stick together. This causes the spider's charges to become unbalanced. If the charges are the same, they will **repel** (push away from) each other, and the spider dances away from the balloon. Or gently pulled away, the spider will "dance" back and forth as the charges transfer from the balloon to the spider and back again.

The statement "Unlike charges attract each other, and like charges repel each other" is known as **Coulomb's Law**, after Charles Coulomb (1736-1806), who first discovered and described this behavior in 1785. Scientists now measure electric charge in units called **coulombs**.



SCIENTIFIC DETECTIVE RECORD FORM

Names of Detectives: ____

____

Search Number: ______________ **Name of Factory Room:** ______________________

1. According to Ms. Faraday, what problem does this room in the factory have?

2. What clues did the CLUE SEARCH reveal in this room?

3. What clues did the ELECTRICITY EXPLORATION uncover?

4. What other information have you learned so far in FUDGE FACTORY that may apply to this room's problems?

5. What are your recommendations to Ms. Faraday about how she can correct the problem and get her factory back in operation again?

Eureka! Moment Re-enactment Rubric

Names ______________________________ Date _____________________________________

Title of presentation ____

	Excellent (5)	Very Good (4)	Good (3)	Fair (2)
Historical accuracy				
Creativity				
Teamwork				
We could hear you in the back of the room				
			Total Points	

Teacher may score between levels.
Circle one choice, depending on your teacher's instructions:
These projects are **optional.** **required.**

If required, you must complete ________ project(s) by ____.

1. Choose a woman inventor to research. Either use the information you find to write a simulated newspaper article and present it in newspaper form or write and deliver a simulated TV news report about this woman.

2. Design another experiment related to this simulation. Make sure it only has one variable. Test it with some friends.

3. Design a game that reviews the information you learned in this simulation. Play it with your classmates.

4. Write a fictional diary entry from the point of view of a person we studied in EUREKA! MOMENTS (Phase 1) of this simulation. Describe what a day in your life is like.

5. Research, write, and illustrate a book for younger students about electricity naturally occurring in animals.

6. List at least 10 modern uses of magnets. Make a poster showing the things they're used in and how they're used.

7. Once people had electricity in their homes, they began to think of many new ways to use it. Make a timeline that shows the dates, names, and creators of at least 15 inventions related to electricity.

8. Write a simulated e-mail message to Thomas Edison. Tell him how people have improved upon three of his inventions. Then write a simulated e-mail answer from Mr. Edison.

9. Design an experiment to define a "resistor," showing how it is different from a conductor and an insulator.

10. After receiving your teacher's approval, develop any project related to this topic that interests you.

11. Demonstrate your experiment to your class.

ELECTRIC SPIDER — Franklin's Experiment

GLOSSARY words: **static electricity, attract, repel, discharge, proton, electron, lodestone**

Problem After reading the experiment directions, write a question that this activity will answer:

____

Your Hypothesis ____

Materials

- Balloon (inflated)
- Paper spider (see directions below)
- Scissors
- Stopwatch or clock with a second hand
- String or yarn (12" -14" long [30 - 35 cm])
- Wool cloth

Prepare the spider

1. Carefully cut out the spider.
2. Tie a knot in one end of the string.
3. Carefully poke a hole through the X marked on the spider's body.
4. Thread the unknotted end of the yarn through the hole until the knot rests right underneath the spider's body.
5. Fold the legs downward.

Experiment

1. Have one group member hold the spider by the yarn so that it is dangling in the air.
2. Hold the balloon about four inches (10 cm) from the spider and record your observations in the "no rubbing" data section below.
3. Have another group member rub the balloon vigorously with the wool cloth for 30 seconds to give it a static electricity charge.
4. Hold the balloon about four inches (10 cm) from the spider and record your observations in the "30 seconds of rubbing" data section below.
5. Repeat steps 3 and 4 to see if rubbing the balloon for 60 seconds has a different effect.

Data Record your observations in the chart:

Situation	What You Saw
No rubbing	
30 seconds of rubbing	
60 seconds of rubbing	

Conclusions Record why you think each situation caused what you saw in the chart:

Situation	Why
No rubbing	
30 seconds of rubbing	
60 seconds of rubbing	

MODEL OF A VOLTAIC BATTERY — Volta's Work

GLOSSARY words: **volt, voltaic pile**

With this activity, you can make a simple model of Volta's "voltaic pile." It will not generate electricity, but you will see the general idea of how Volta put his primitive battery together.

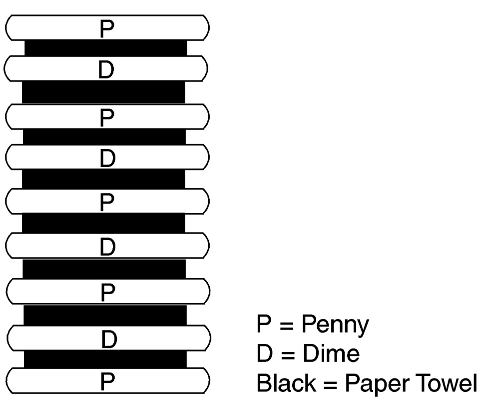
Materials

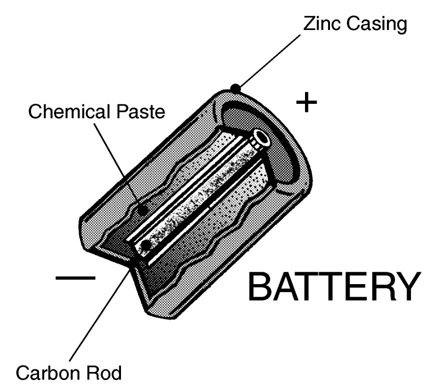
- Bowl of liquid (e.g., salt water or lemon juice)
- Dimes or aluminum foil folded to dime-size — *five*
- Paper towels (two-inch squares) — *nine*
- Pennies — *five*

Procedure

1. Fold the paper towel squares in half twice to make thicker, one-inch squares.
2. Soak the paper towel squares in the liquid.
3. Place a penny on the table. Place a soaked paper towel square on top of the penny. Place a dime on top of this pile. Keep alternating penny, paper towel, dime, paper towel, penny, and so on, until you use all your supplies. (See Model of Voltaic Pile)
4. Look carefully at this diagram of the inside of a modern battery.

Model of Voltaic Pile





Questions

1. How is the structure of the voltaic pile like the structure of a modern battery?
   ____

2. How is the structure of the voltaic pile different from the structure of a modern battery?
   ____

3. Which battery would you prefer to use? ________________________________

   Why? ____

ELECTROMAGNETISM — Oersted's Experiment

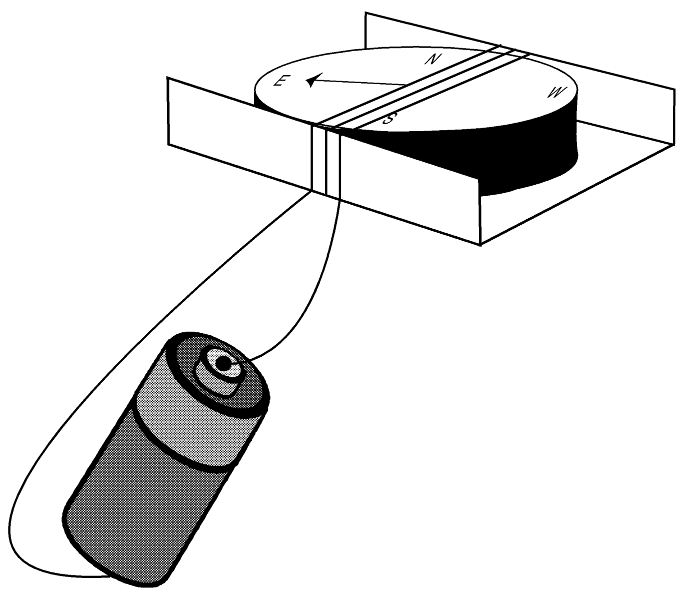
GLOSSARY words: **electromagnetism, galvanometer**

Problem Does electrical current produce magnetism?

Your Hypothesis ____________________

Materials
- Battery (D or lantern)
- Compass
- Insulated copper wire, 24-inch (61-cm) or longer with half-inch (1 cm) stripped from each end
- Tape

Experiment
1. Leave 6 inches (15 cm) of the wire free at one end. Wrap the wire around the compass three times.
2. Tape one bare end of the wire to each end of the battery.



Data
What happens? ____________________

Conclusion
Why does this happen? ____________________

____

ELECTROMAGNETISM — Ampère's Experiment

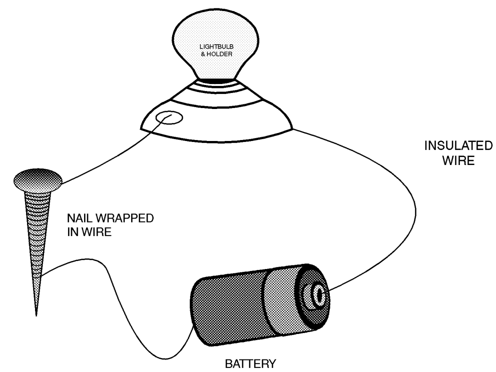
GLOSSARY word: **electromagnet**

Problem Can you change electricity into magnetism?

Your Hypothesis ____

Materials

- Battery (D or lantern)
- Insulated copper wire, 24-inch with half-inch stripped from each end
- Insulated copper wire, 12-inch with half-inch stripped from each end
- Iron filings or paper clips
- Lightbulb
- Lightbulb holder
- Nail
- Tape



Experiment

1. Leave 6 inches (15 cm) of the long wire free at one end. Wrap the wire around the nail 20 times.
2. Use the tape to attach one bare end of the long wire (already wrapped around the nail) to one end of the battery. Attach the other bare end of the long wire to the lightbulb holder. Place the lightbulb securely in the holder.
3. Bring the tip of the nail close to the iron filings or paperclips.
4. Complete the circuit: Use the tape to attach one bare end of the short wire to the free end of the battery and the other bare end to the free side of the lightbulb holder (see diagram).
5. Bring the tip of the nail close to the iron filings or paperclips.

Data

1. What happens in Step 3? ____
2. What happens in Step 5? ____

Conclusion

1. In Step 3 why did this happen?____

____

2. In Step 5 why did this happen?____

____

FIRST GENERATOR — Faraday's Invention

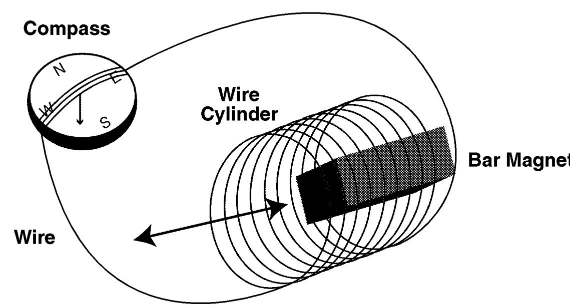
GLOSSARY word: **dynamo**

Problem Can you change magnetism into electricity?

Your Hypothesis ____

Materials
- Bar magnet
- Compass
- Insulated copper wire, 30-inch (76-cm) or longer with half-inch (1 cm) insulation stripped off each end

Experiment
1. Leave about 6 inches (15 cm) of wire free at one end. Wrap the wire loosely around three of your fingers 10 times. Remove your fingers, carefully protecting this wire cylinder.
2. Leave about 6 inches (15 cm) of wire free at the other end. Wrap the wire loosely around the compass three times.
3. Connect the two bare ends of the wire by twisting them together securely.
4. Push and pull the magnet in and out of the hollow of the wire cylinder.
5. Push and pull the magnet much faster than you did in Step 4.



Data
1. What happens to the needle on the compass? ____
____
2. What happened to the needle when you moved the magnet faster? ______________________________
____

Conclusion
1. Why does this happen (Data 1)? ____
____
2. Why does this happen (Data 2)? ____
____

MAGNETS — Faraday's Discovery

GLOSSARY word: **force field**

Problem What happens when iron filings are brought near a bar magnet?

Your Hypothesis ____

Materials

- Bar magnet
- Iron filings
- Thin card large enough to cover the bar magnet completely

Experiment

1. Place the card over the bar magnet.
2. Sprinkle the iron filings onto the card.

Data

Draw what the iron filings do in the space below:

Conclusion

Why do you think the iron filings did this? ______________________________

____

ELECTRIFIED INVENTIONS — Edison's Work

GLOSSARY words: **technology, controlled experiments, phonograph, variable, fuse, patent**

This project gives you an opportunity to learn from Edison by designing and making a model of an invention that uses electricity in some way.

CAUTION! You are not required to create a working model of your invention. If you do, use ***battery power only!*** Current from wall plugs is ***extremely dangerous!***

Materials

- Art paper
- Markers, colored pencils, or crayons
- Pencil
- Science Journal

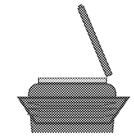
Procedure

1. **Brainstorm** a list of problems that need to be solved. Is there something an electrical device could solve? Watch for problems to solve. Record these in your Science Journal.
2. **Circle** the problem you think will be the most interesting to solve on your list.
3. **Brainstorm** again to come up with ideas to help you solve the problem you selected. Anything goes! Write each idea in your Science Journal without judging them.
4. **Choose** one solution idea, or combine two or more other ideas to make one better idea. Take time to think about this—several days if you can.
5. **Sketch** your solution. Show what the final product should look like. Label its specific features. List the dimensions (size) of what you think the finished product should be.
6. **Keep thinking** about your idea. Try to make your idea better. Record these ideas in your Science Journal. If necessary, make a new drawing.
7. **Make** a model of your invention, using scrap materials. ***Caution!*** **This does not need to be a working model. Remember, electricity can be extremely dangerous. It's okay to ask an adult to use adults-only tools and help you construct your model as long as the ideas are yours.**
8. **Prepare** a display of your ELECTRIFIED INVENTIONS project according to your teacher's instructions.

Due date for steps 1-4: ________________________

Due date for steps 5-7: ________________________

Due date for step 8: ___________________________



The Office Suite

Ms. Faraday ushers you in to a suite of offices. You pause to read a plaque on the waiting room wall:

FARADAY'S FUDGE FACTORY
1922
FARRELL M. FARADAY, FOUNDER

Old photographs of the factory and a painting decorate the room. Ms. Faraday brags, “My grandfather built this factory. It is as solid as that picture of Mount Fudge, my Granny Faraday’s imaginative painting! Haven’t had to replace a thing—we just add equipment when necessary to increase production. Only minor repairs, too.” Another sign declares, *Chocolate Solves Everything!* “Our motto,” Ms. Faraday informs you.

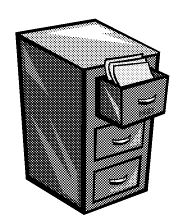
You walk down a darkened, carpeted hallway past several offices, with frustrated workers sifting through papers by window-light. “I found the Ripley account!” shouts one worker to another. “Good,” comes the reply, “but I don’t know how long we’ll survive without our computers!”

As you continue down the crowded hallway, your hand accidentally brushes against a doorknob, and you receive a nasty shock. Soon you and your class crowd into Ms. Faraday’s office. She pulls a sweater off a rack. Crackle! Spark! It was stuck to another sweater. “I’ll need this in the Refrigeration Room,” she says, then adds, “Oh, yeah, that room won’t be so cold today; anyway, wool always makes me itch.”

The wool carpet is grooved from years of Ms. Faraday, her father, and her grandfather before her, rolling a desk chair across it. A computer brain lies open on her desk. “Been trying to fix this durned new-fangled contraption since early this morning,” she reports, “now I’m using this generator to test it, because we need this computer to coordinate factory operations. I wonder if it was those thunderstorms last night.

“I also pulled apart all the wiring in this computer to see if a connection was loose. Now let me see here . . . I just have to put them all back together in the right order!” She continues to work on the computer, forgetting about you.

After a few minutes, you clear your throat politely, and Ms. Faraday looks up, “Well, there’s nothing really to see here. Let’s see what you young’ns can find in the factory.”



The Cooking Room

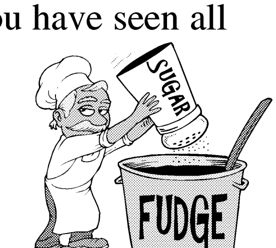
You and your class soon arrive in the Cooking Room. Dozens of giant vats stand in even rows. “Like chocolate soldiers sweating cocoa on Parade Day!” says Ms. Faraday. “Some of these vats had stopped heating up even before the electricity went out,” she mentions. Giant electric mixers sit silent, powerless to stir the fudge that isn’t there. Empty bags of sugar and cocoa powder are scattered throughout the room. The smell of rancid butter fills the air. As far as you can see, all of the vats need washing—inside and out. Factory workers are scrubbing the vats feverishly. “Don’t wanna have rats move into Fudge Heaven,” mutters Ms. Faraday, “Pumped off what liquid we could and sent it to Mr. Ficklebee’s Fudge Emporium so it wouldn’t be wasted. Humph! Never thought I’d give the likes of *him* anything! Oh, well. As Ben Franklin always said, ‘Waste not, want not.’”

Ms. Faraday continues to mutter as you squat down and take a closer look at how each vat is connected to its electricity supply. It seems to be a connection like that on the bottom of a crockpot, and sure enough, Ms. Faraday explains, “There is a hidden heating element in the bottom of each vat to provide an even source of heat. Finest sort of setup for fudge-making. Paid more’n a pretty fudge-soaked check for these babies!”

A groupmate unplugs one vat from its outlet and then unplugs it from under the vat. She notices it has three holes into which three prongs on the bottom of the vat receptor fit. You and the rest of your group do the same to the other vats, inspecting each connection. A friend gives a shout, and you rush to look. A dry, flaky brown substance clings to the prongs on one vat. Another shout—another set of prongs caked with this brown substance. Then another! You try to get close enough to smell the substance. Then you ask permission to scrape some off. The flakes smell like burned cookies. You decide it might be unsafe to try to taste it, since, as an experienced scientist, you know you should only taste things you already know are safe.

Ms. Faraday says, “Now let’s hurry along, my fine young scientists. Can’t be slower than trying to melt fudge in an icehouse—or we’ll never solve this mystery and get the factory up and running again!” You and your groupmates quickly search for frayed wiring and find none. Each outlet opening, though, has at least two and sometimes three plugs in it with doubling or tripling devices.

Finally, you reluctantly begin to follow Ms. Faraday, hoping you have seen all you need to see in the Cooking Room.



The Refrigeration Room

Trailing behind the rest of your class, you enter the Refrigeration Room last. You see three strange square tunnels, made of several eight-foot-long sections. The sections are connected by cords, plugging the sections together. The room itself is long and narrow; it leads to the Packaging Room, Ms. Faraday informs you. “Each tunnel is made of several specially designed refrigerators. My daughter Freda designed them herself,” she reports proudly. “Fudge cools on the way from the Cooking Room to the Packaging Room on the conveyor belts.” She points at the conveyor belt inside one of the tunnels. “This tunnel on the other side of the room brings boxes back from the Packaging Room to be put in cool storage until they are loaded onto trucks at the dock.” She points at a door labeled “TO DOCK.” “We use those big refrigerators along that wall for storage,” she finishes, pointing at the wall behind you.

You and your groupmates have just started to look around for clues when a young man enters and tells Ms. Faraday that the emergency generators are in place.

“Good Fudge-y Heavens!” Ms. Faraday exclaims. “Get them runnin’ pronto, son!”

Shortly, the hum of the refrigerators fills the room. With Ms. Faraday’s permission, you and your groupmates push and pull one storage fridge away from the wall. You gasp at the frayed wiring. After asking permission, you unplug it. The hum stops. All the storage refrigerators have stopped running! You plug the one refrigerator back in, and all the refrigerators start running again. The same thing happens when you disconnect one section on a fridge tunnel.

You look around a few more minutes, not seeing anything more that concerns you.

Now the clank-clunk of the conveyor belts draws your attention. You pull a classmate off one belt and eagerly head toward the Packaging Room to continue your search for clues.

The Packaging Room

You enter the Packaging Room through a door between two refrigeration tunnels. Just inside the room, the conveyor belt that is designed to bring fudge from the Refrigeration Room ends above another conveyor belt. The fudge drops onto the lower belt and continues its journey into the Packaging Room.

Workers stand along the conveyor belt, waiting for fudge that isn't coming any time soon. "Machines box up the fudge and workers pack the boxes in bigger boxes," Ms. Faraday says, waving at contraptions above the conveyor belt. "Go on down to the Cooking Room and help clean up," she orders the workers, "I'm not paying you to stand around trading fudge recipes!" The workers leave, one grumbling that Ms. Faraday is going into "Fudge Addiction Withdrawal." "Chocolate *is* the problem—not the solution," mumbles another.

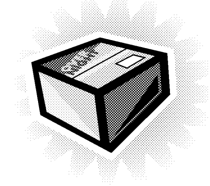
You and your classmates begin to look for clues. You all notice that the conveyor belts don't move smoothly. The one you're standing near is making terrible grinding noises. It suddenly stops working, and the room falls silent. All the conveyor belts in the Packaging Room have stopped working. Right away, you know what caused them all to stop working, but you're more concerned with the motor on the one that caused the problem. "Durn it!" Ms. Faraday gripes, "I thought I had that motor fixed! I worked on it three hours last Thursday."

She opens up the motor and starts pulling pieces out of it. "Wait!" you say politely, "It's better to look at one thing at a time." But it's too late. "Here," says Ms. Faraday, "You young'ns take my toolbox and fix it. I can't take another fudge-filled disaster today!"

You and most of your classmates gather around the battered and torn owners manual. A few of your classmates start to take apart the motor, after rummaging through the toolbox. "Wait!" you shout, "We have to unplug everything before working on anything electrical!"

The public address system crackles, and a secretary calls Ms. Faraday away to the Office Suite, leaving your class to fix the conveyor belt's motor.

As you pick up a piece of the motor, you notice that other metal bits are sticking to it. "A magnet!" you exclaim.



The Boiler Room

Proud that you could help fix the conveyor belt motor, you hurry after Ms. Faraday as she leads the way to the Boiler Room. You enter a hot and steamy room. Standing in the center of the room is a large, round metal contraption. “Bronson Boiler Co. Inc. Fire-Tube Boiler, Model no. 436, Patent Pending” is imprinted across one side. “This here boiler was the finest that could be had when we built this here factory. Works as good as ever!” declares Ms. Faraday.

She continues, explaining how it works, “We burn coal in the combustion chamber at the bottom of the boiler. Inside the main part of the boiler is a tube curving back and forth. The tube has hot gases in it. These gases escape through the flue going up the side, like smoke up the chimney on your fireplace. Water surrounds the tube. As the water is heated by the hot tube, steam rises. Steam makes the turbine go, making electricity for the factory.”

You ask her if the boiler had quit working when the electricity outage began. “No, it kept chugging away. We just couldn’t figure what went wrong that nothing worked in the factory, so we brought in the diesel-powered generators to see if they made a difference. Hooked them up over there past the fuse box.” She waves at a panel of small, round fuses. “But, boy, this room sure is hotter and steamier than melted fudge. Better shut it down ‘til we find out more,” she finishes.

You look closely at the gauge on the boiler. It is stuck at 260 pounds of pressure per square inch. A corroded sign under the gauge warns, “CAUTION! Keep pressure between 150-250 pounds per square inch for safe and effective power supply.”

Now you nervously move to the wall to examine the fuse box. Ms. Faraday explains, “Them round thingamabobs are fuses.” Some of them have a clear glass cover, but the glass on several of them looks smoky and charred.

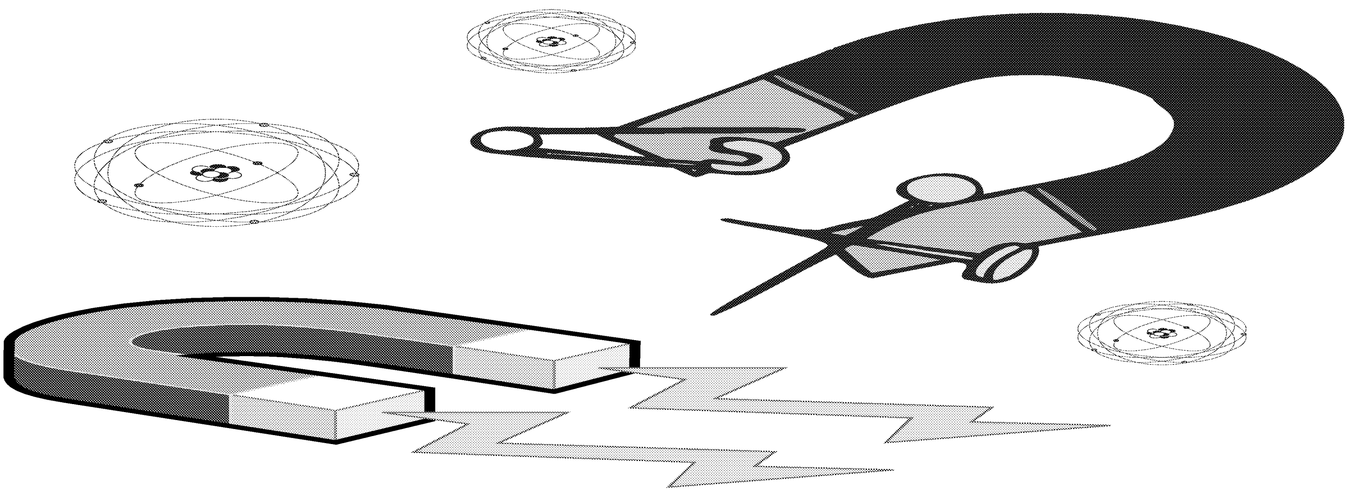
“Beep, beep!”

“That’s our bus!” you all moan. It’s a long walk back to your school, so quickly you leave the factory, wishing you could stay longer.

WHAT ARE T.E.A.M. ACTIVITIES?

For the next few days you will be doing T.E.A.M. ACTIVITIES with your group members. T.E.A.M. stands for **T**ogether **E**veryone **A**ccomplishes **M**ore. Each T.E.A.M. ACTIVITY gives you important information about science that you will need to solve the mystery; it will also give you the opportunity to work together with other group members to solve a problem. As you do each activity, you will discover two things: that everyone in the group has something to offer, and that many brains working together help tremendously when you are trying to solve a problem.

TEAM



HOW DO YOU DO T.E.A.M. ACTIVITIES?

1. Your team's goal is to solve the problem presented to the group.
2. Each group member will receive some special information that no one else in your team has.
3. Each group member will share all the information (clues) to solve the problem.
4. Each group member will share information only one way — *orally*.
5. No one may take or look at another group member's clues.
6. Each group member will participate!
7. Once all members have individually shared their clues, each group member should continue to contribute in solving the activity. (Of course, clues may be repeated orally, if needed.)
8. Each group member will take a turn to talk and give ideas or opinions.
9. And what is the most important skill all group members must practice? *Listening!* It is very important that everyone listen carefully while other members of the group are talking since we can all learn from one another.

Good luck on your T.E.A.M. ACTIVITIES!

You will enjoy uncovering the information each day and then using what you learn to solve the FUDGE FACTORY mystery.

Cut this sheet into strips along dotted lines. Give each team member a different strip.

In 1864, Mary Jane Montgomery received a patent for creating a way to improve locomotive wheels.

In 1913, Elena DeValdes invented the bottle stopper, an early type of tamper-proof packaging.

Dr. Gertrude Elion began gaining patents in 1954 when she was granted a patent for a disease-fighting drug. By 1994, she held 45 patents.

In 1980, Valerie Thomas invented the Illusion Transmitter, which creates a three-dimensional image that looks like it's in the room with you.

In 1845, Sarah Mather invented a combination submarine lamp and telescope, which aided ocean exploration.

In 1994, Jan B. Svochak patented bifocal contact lenses and the method for making them.

In 1982, Alice Chatham patented a space helmet and a space bed.

In 1881, Mary Walton invented a quieter elevated railway—a challenge Thomas Edison had not been able to meet. Walton also invented an antipollution device for factory smokestacks.

In 1992, Lori A. Cotrain invented a car-restraint garment so that a child can be kept safe with a regular seat belt instead of a child car seat.

Cut this sheet into strips along dotted lines. Give each team member a different strip.

In 1956, Bette Graham, a secretary, invented "Mistake Out" to paint over her typing mistakes. This product is now called *Liquid Paper.*

In the 1990s, Dr. Janine Jagger gained several U.S. patents for safety needle devices for medical use.

In 1892, Harriet Tracy patented an important safety device to keep elevators from falling fast and crashing at the bottom of the shaft. She was best known, however, for the several sewing machine patents she received.

In the late 1950s, Ruth Handler invented the *Barbie Doll*, named after her daughter, who preferred dolls that were more adult-like. The *Ken Doll* is named after Handler's son.

In the 1870s, Mattie Knight's paper bag folding machine created paper bags that had flat bottoms. Until then, such bags had had to be made by hand. Knight earned at least 22 patents in her lifetime.

In the 1940s, Dr. Elizabeth Hazen and Dr. Rachel Brown developed a drug called *Nystatin* to kill fungus diseases in people.

In 1973, at the age of 12, Rebecca Schroeder was granted a U.S. patent for *Glo Sheets*, which provide light from phosphorescent paint so nurses, military personnel, and others can write in the dark on a regular sheet of paper placed over the *Glo Sheet*.

A patent is a written document that gives an inventor the legal right to be the only one to make, use, or sell an invention for a period of time.

In 1979, Dr. Mary Ann Moore invented a pain relief medication and the method of preparing it.

WORLD OF MEDICINE

SAFETY FIRST

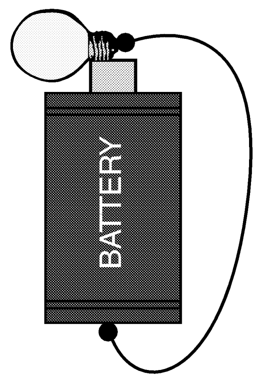
JUST FOR FUN

ALL FOR A DAY'S WORK

T.E.A.M. ACTIVITY 1

Cut this sheet into the individual boxes. Give each team member a different box.

1



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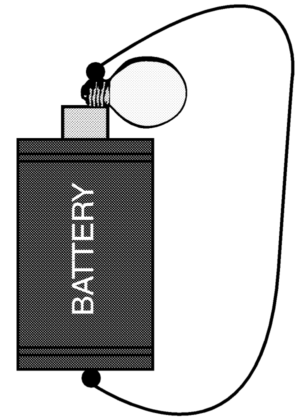

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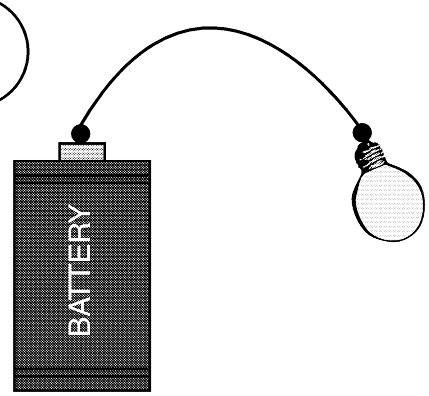

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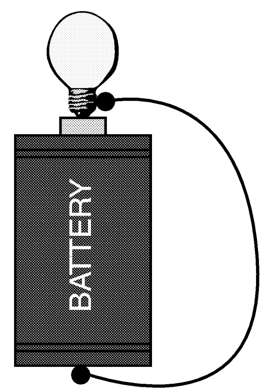

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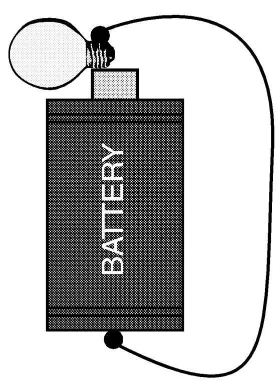

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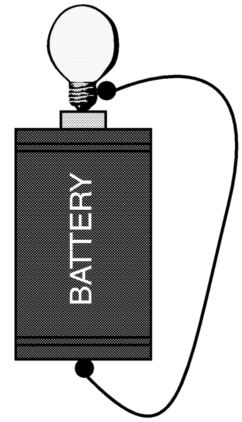


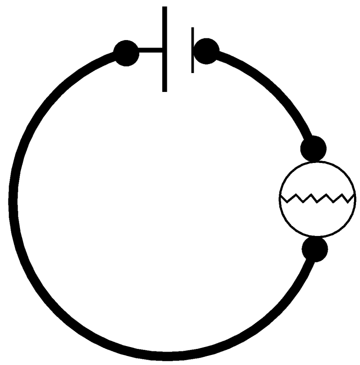
T.E.A.M. ACTIVITY 1 RECORD

Using the diagrams in the T.E.A.M. ACTIVITY 1 boxes, write down the numbers of those circuits that will work and those that will not in the appropriate spaces.

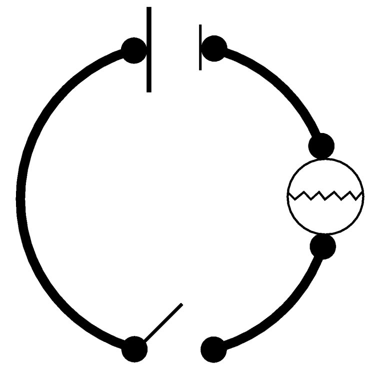
WORKS	DOESN'T WORK

T. E. A. M. ACTIVITY 2

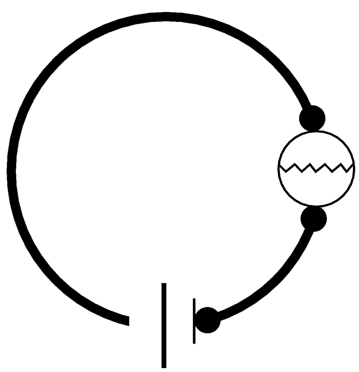
Cut this sheet into the individual boxes. Give each team member a different box.



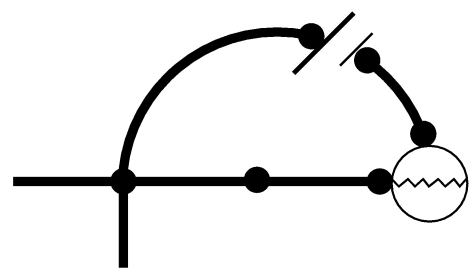
1. The lightbulb lights in this circuit.



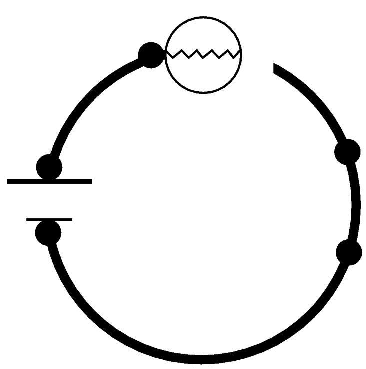
2. The lightbulb will not light in this circuit.



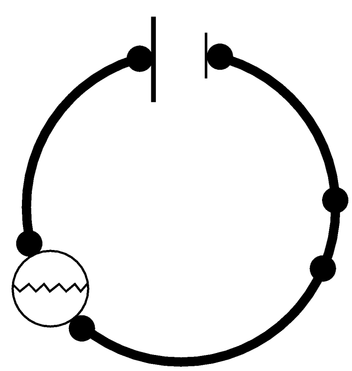
3. The lightbulb will not light in this circuit.



4. The lightbulb lights in this circuit.



5. The lightbulb will not light in this circuit.



6. The lightbulb lights in this circuit.

T.E.A.M. ACTIVITY 2 RECORD

Based on the information you have been given, draw the symbol for each part of a circuit in the correct box.

Disconnected Wire	**Battery**
Wires connected to each other	**Lightbulb**
Wires connected to non-wire parts	**Switch**

T . E . A . M . A C T I V I T Y 3

Cut this sheet into strips along dotted lines. Give each team member a different strip.

In a **Type 1 circuit**, if one lightbulb breaks or is removed, all the bulbs in the entire circuit go out.

A **Type 2 circuit** has at least two paths for the electricity to travel along.

A model **Type 2 circuit** might have two wires laid alongside each other, connecting one lightbulb to another lightbulb.

Each lightbulb in a **Type 1 circuit** and a **Type 2 circuit** must be placed all the way into the lightbulb holder for electricity to flow through the lightbulb.

A model **Type 1 circuit** might have a separate wire taped to each end of a battery.

Strings of Christmas tree lights used to be wired in **Type 1 circuits**, but now they are wired in **Type 2 circuits**. Why do you suppose this change was made?

One meaning of the **Type 1 circuit** is “a number of things coming one after another in a sequence.”

A model **Type 2 circuit** might use two lightbulbs, each in a lightbulb holder.

If the lights in your house are wired in a **Type 1 circuit**, turning off the light in your bedroom will turn off all the other lights in the house.

T . E . A . M . ACTIVITY 3

Cut this sheet into strips along dotted lines. Give each team member a different strip.

A model **Type 1 circuit** might have two lightbulb holders, one connected to each wire attached to each end of a battery.

In both a **Type 1 circuit** and **a Type 2 circuit**, each wire must be securely connected to the other items in the circuit by its bare copper ends for electricity to flow through the circuit.

One meaning of the **Type 2 circuit** is "lines going in the same direction alongside each other, never crossing."

If the lights in your house are wired in a **Type 2 circuit**, turning off the light in your bedroom will not turn off any of the other lights in the house.

A model **Type 1 circuit** might have two lightbulb holders connected to each other with one wire.

A model **Type 2 circuit** might have a separate wire connected to each end of a battery.

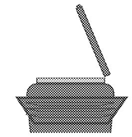
A **Type 1 circuit** has only one path for the electricity to travel along.

A model **Type 2 circuit** might use two lightbulbs, each in a lightbulb holder.

A model **Type 2 circuit** might have two wires laid alongside each other, connecting the battery to a lightbulb holder.

T.E.A.M. ACTIVITY 3 RECORD

Draw a Diagram of a Type 1 Circuit	Draw a Diagram of a Type 2 Circuit



ELECTRICITY EXPLORATION 1

Problem Why won't the lightbulb in the circuit light?

My Hypothesis ____

Materials

- Circuit setup (from your teacher)
- Battery — *one extra*
- Lightbulb — *one extra*
- Lightbulb holder — *one extra*
- Wires — *two extra*

Experiment

1. Test each part of the circuit and record the results in the chart under "Data."
2. Go back to the **original circuit setup** with the original components before testing each new part.

Data

Part tested	Results
1. Wire connections a.	
b.	
c.	
d.	
2. Lightbulb	
3. Battery	

Conclusion

1. Why was the component a problem?

   ____

2. What made this a controlled experiment?

   ____

3. What might you do to make it an "uncontrolled" experiment?

   ____

4. How might an uncontrolled experiment harm your efforts to help Ms. Faraday solve her factory's problems?

   ____

Write any possible clues in the Office Suite on the Map of Faraday's Fudge Factory. As a group, complete a SCIENTIFIC DETECTIVE RECORD FORM based on the information you have learned doing this activity and give it to Ms. Faraday.

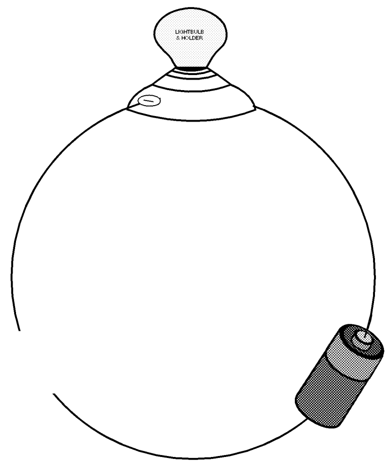
ELECTRICITY EXPLORATION 2

Problem Which types of materials allow electricity to flow (which are **conductors**)? Which do not allow any electricity to flow (which are **insulators**)?

My Hypothesis for Each Item Record each in the chart below, under "Hypothesis."

Materials

- Items made from materials listed on the chart below
- Battery
- Lightbulb
- Lightbulb holder
- Paper towels — *1 wet, 1 dry*
- Eight-inch (20 cm) wires with a half-inch (1 cm) of the insulation stripped off each end — *three*
- Tape



Experiment

1. Make a circuit as shown, using the tape to help hold the wire ends to the battery. Leave an opening in the circuit as shown (see above).
2. Test each type of item listed in the chart by touching both free wire ends to each item (**be sure you don't connect the two wires directly**). Note: After testing a liquid, use the wet paper towel to clean the wires and the dry paper towel to dry the wires.

Data

	An item made of	Hypothesis	Data (Results)
1.	Rubber	e.g., *Conductor*	e.g., *Insulator*
2.	Plastic		
3.	Paper		
4.	Cotton		
5.	Copper		
6.	Wood		
7.	Fudge		
8.	Steel		
9.	Wool		
10.	Aluminum		
11.	Leather		
12.	Nickel		

Conclusion Why do you think some materials conduct electricity and others do not?

Write any possible clues in the Cooking Room on the Map of Faraday's Fudge Factory. As a group, complete a SCIENTIFIC DETECTIVE RECORD FORM based on the information you have learned doing this activity and give it to Ms. Faraday.

ELECTRICITY EXPLORATION 3

Problem Which circuit is more practical?

My Hypothesis ____

Materials

- Battery
- Lightbulbs — *two*
- Lightbulb holders — *two*
- Tape
- Eight-inch (20-cm) wires with a half-inch (1 cm) of insulation stripped off of each end — *four*

Experiment

1. Use some or all of the materials listed above to construct a model of a series circuit.
2. Do the lightbulbs light up? If not, correct your model series circuit. Make sure all connections are good.
3. Remove one lightbulb in this circuit. Record what happens under "Data" question 1 below.
4. Take apart the series circuit and use some or all of the materials listed above to construct a model of a parallel circuit.
5. Do the lightbulbs light up? If not, correct your model parallel circuit. Make sure all connections are good.
6. Remove one lightbulb in the parallel circuit. Record what happens under "Data" question 2 below.

Data

1. What happened when you removed one bulb from the series circuit?

   ____

2. What happened when you removed one bulb from the parallel circuit?

   ____

Conclusion

1. Which type of circuit is usually going to be more practical?

   ____

2. Why do you think this is true?

   ____

Write any possible clues in the Refrigeration Room on the Map of Faraday's Fudge Factory. As a group, complete a SCIENTIFIC DETECTIVE RECORD FORM based on the information you have learned doing this activity and give it to Ms. Faraday.

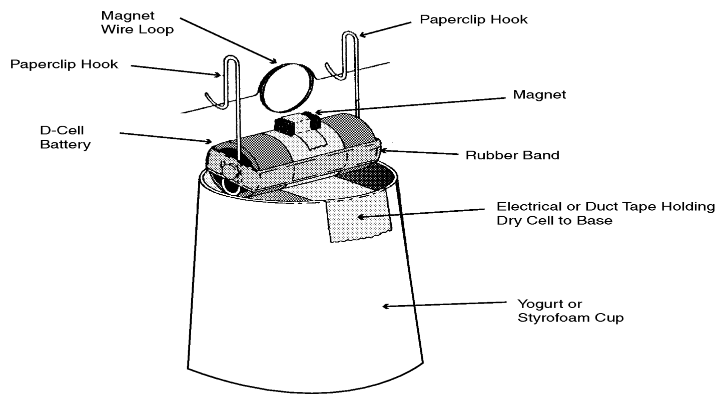
ELECTRICITY EXPLORATION 4A

Problem How does magnetism help a motor run?

My Hypothesis ____

Materials

- Base (such as a plastic or Styrofoam cup)
- Battery
- Dowel or other round object
- Magnet
- Magnet wire, enamel-coated
- Paper clips (uncoated) — *two*
- Rubber band
- Sandpaper
- Tape



Experiment

1. Tape the battery to the base.
2. Bend the paper clips as shown and use the rubber band to hold a paper clip to each end of the battery.
3. Use the sandpaper to rub the enamel off the ends of the magnet wire (remove about one-inch [2.5 cm] of the enamel from each end).
4. Wrap the magnet wire around the dowel four times. Carefully pull this magnet wire loop off the dowel and bend the ends straight out as shown in the diagram.
5. Place the magnet on the top side of the battery. Tape in place if necessary.
6. Set the magnet wire onto the paper-clip hooks.
   CAUTION! This wire will get hot fast. Only touch it on the enamel-coated loop!
7. Carefully raise or lower the paper clips so that the wire loop is just above, but not touching, the magnet set on the battery.
8. Touching only the enamel part of the wire loop, stop any motion to begin with, then remove your finger.
9. Carefully wiggle the paper clips so that the wire loop is horizontal. Patiently experiment until you see motion. Record what happens under "Data" question 1.
10. Remove the magnet set on the battery and make sure the wire loop is horizontal and still. Record what happens under "Data" question 2.

Data

1. What does the wire loop do in Step 9 above when lined up horizontally?

   ____

2. What does the wire loop do in Step 10 when lined up horizontally?

   ____

Conclusion

1. Why does the wire loop act as it does in Step 9?

   ____

2. Why does the wire loop act as it does in Step 10?

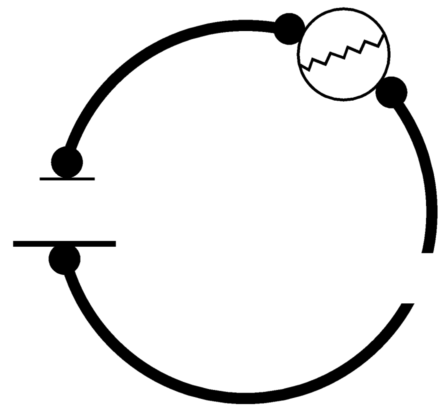
   ____

Write any possible clues in the Packaging Room on the Map of Faraday's Fudge Factory. As a group, complete a SCIENTIFIC DETECTIVE RECORD FORM based on the information you have learned doing this activity and give it to Ms. Faraday.

Problem How does a diode affect a circuit?

My Hypothesis ____

Materials



- Battery
- Lightbulb
- Lightbulb holder
- Semiconductor diode
- Tape
- Eight-inch (20-cm) pieces of wire (half-inch [1 cm] insulation stripped off each end) — *three*

Experiment

1. Set up a circuit as shown, leaving two wires disconnected, and the semi conductor diode nearby.
2. Check the circuit by touching the two disconnected wires together. If the bulb does not light, find and correct the problem before continuing with Step 3.
3. Now close the circuit by touching one loose wire to each end of the diode.
4. If the bulb does **not** light, experiment with the diode until the bulb **lights**. If the bulb **lights**, experiment with the diode until the bulb does **not** light.

Data

1. What happened when you first completed the circuit (Step 3)? ______________________________

   ____
2. If the lightbulb did not light on your first try, what did you try until it worked (list all attempts)? If the lightbulb did light on your first try, what did you try until it did not work (list all attempts)'

   ____

   ____

Conclusion

1. Why did the lightbulb light or not light in Experiment Step 4? ______________________________

   ____
2. What does this experiment tell you about diodes? ______________________________

   ____

Write any possible clues in the Packaging Room on the Map of Faraday's Fudge Factory. As a group, complete a SCIENTIFIC DETECTIVE RECORD FORM based on the information you have learned doing this activity and give it to Ms. Faraday.

Problem How does a fuse protect a circuit?

E L E C T R I C I T Y E X P L O R A T I O N 5

My Hypothesis ____

Materials

- Insulated copper wire, half-inch insulation stripped off each end — *four*
- Battery (lantern)
- Clay — *two lumps*
- Lightbulb
- Nichrome wire (#32)
- Brads — *two*
- Corrugated cardboard, 2" x 3" (5 x 7 cm)
- Lightbulb holder
- Paper clips (uncoated) — *three*

Experiment

1. Push the brads through the cardboard with one end through one paper clip. Make sure the brads are close enough for the paper clip to reach across. Flatten the brads underneath. Leave the paper clip up. This is your switch (see Diagram 1).
2. Open the other two paperclips and set each in a lump of clay.
3. Connect these two paper clips with the nichrome wire. The nichrome wire acts as a fuse would.
4. Set up a circuit as shown in Diagram 2. The lightbulb acts as an appliance would.

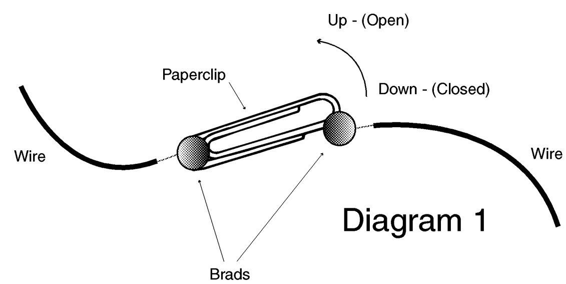


Diagram 1

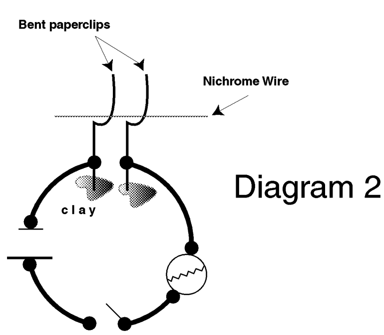


Diagram 2

5. Close the switch. - **CAUTION! Do not touch the nichrome wire once the switch is closed!**

Data What happened when you closed the switch?

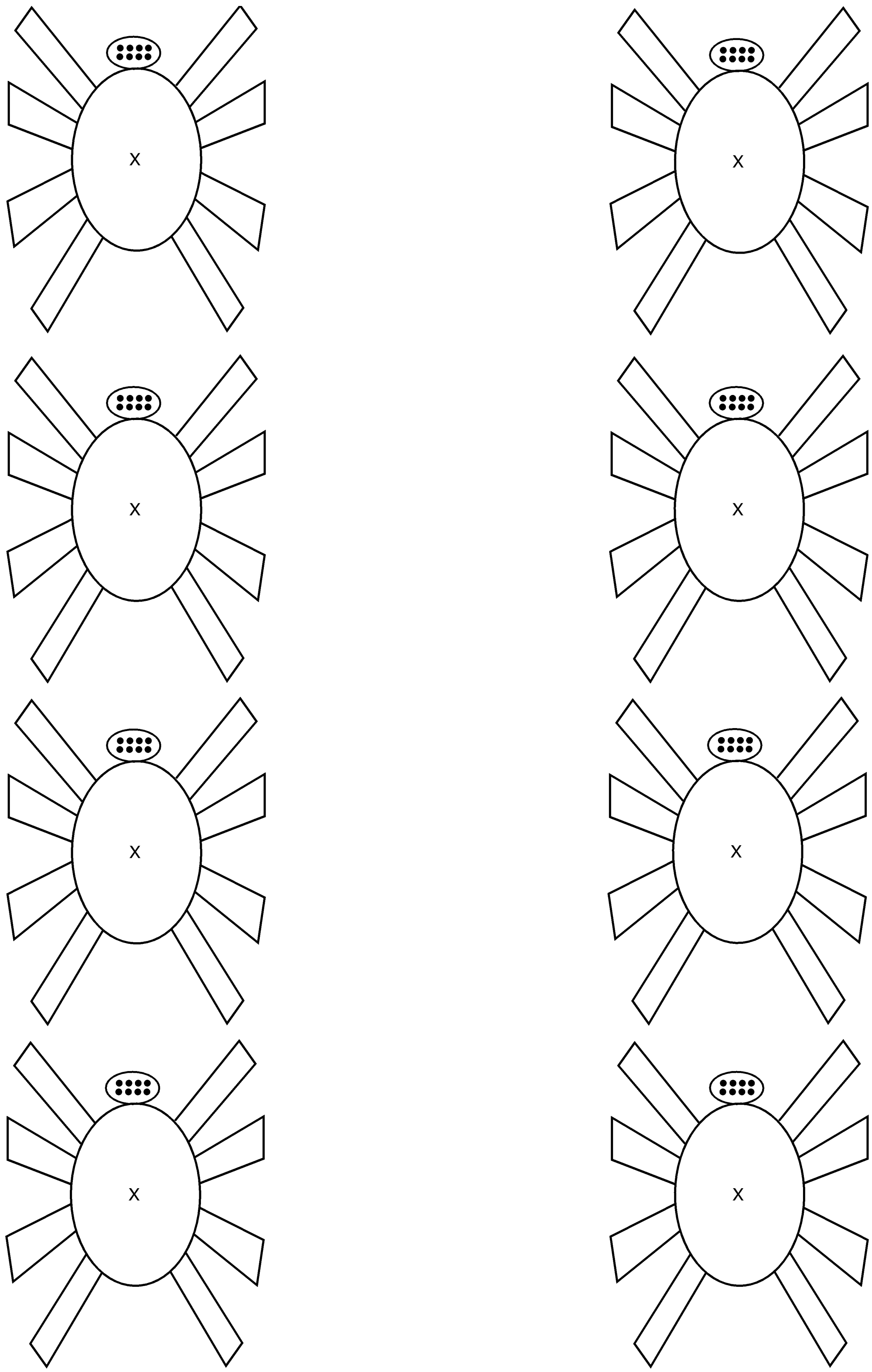
____

Conclusion Why did this happen?

____

Write any possible clues in the Boiler Room on the Map of Faraday's Fudge Factory. As a group, complete a SCIENTIFIC DETECTIVE RECORD FORM based on the information you have learned doing this activity and give it to Ms. Faraday.

Use lightweight paper to ensure a more responsive spider.



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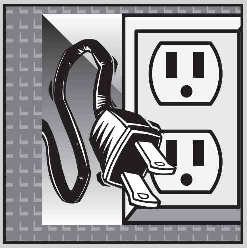


FUDGE FACTORY

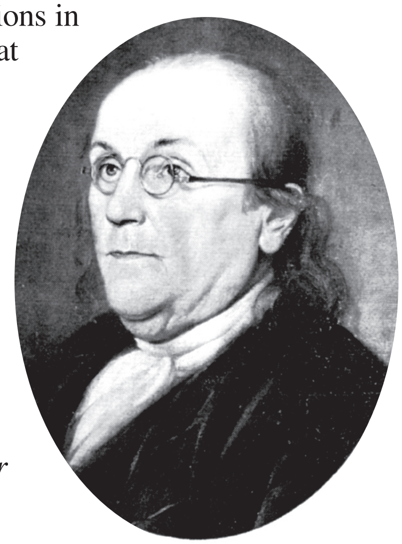
STUDENT GUIDE

PHASE 1

Much of scientific discovery is the result of endless hours of careful observation, deep thought, and tireless persistence—with a large helping of genius. Indeed, Thomas Edison said, "Genius is one percent inspiration and ninety-nine percent perspiration." In this phase of FUDGE FACTORY, you will learn some of the exciting professional and personal details of the people who sought to explain the science of electricity. Through accompanying **Eureka! Activities**, you will see for yourself how their perseverance provided humankind with truths we take for granted today.

EUREKA! MOMENT 1—BENJAMIN FRANKLIN, 1706–1790

The Leyden jar, a capacitor, and the study of electricity fascinated Ben Franklin—printer, statesman, and scientist (among other things). Ben performed many experiments to explore the nature of electricity. In the 1740s, English scientist Mr. P. Collinson sent him a glass tube with instructions for using it to produce electricity. Franklin practiced the experiments and also tried new ways to show that electricity exists. In fact, his work brought so many people to his house, he was embarrassed. To get rid of the crowds, he set a neighbor up with the apparatus needed to perform the experiments. This man toured the Colonies, making a living performing the experiments.



Meanwhile, Ben continued his own experiments. Ben mentions in his first letter to Mr. Collinson that a charged object would at first be **attracted** to an uncharged object. Then, it would be **repelled** after the two objects had touched each other. He called the **discharge** an "*electric wind*." Additionally, he demonstrated that an electric spark could light a candle and that electricity could cause objects to move. For example, he made a "*spider*" (a cork with thread legs) and added a "*grain or two of lead...*" to the spider, "*to give him more weight.*"[1] Ben was able to make the spider "dance" with static electricity. In another fun experiment, Ben invented the "*electric kiss*." To perform an electric kiss, a man and woman stood on wax. Then, the instructions read, "*Give one of them the electrised phial [tube] in hand; let the other take hold of the wire; there will be a small spark; but when their lips approach, they will be struck and shocked.*"[2]

Franklin began to investigate the relationship between electricity and lightning in late 1749. By 1750, he was suggesting the use of lightning rods on the tops of buildings to conduct the electricity safely into the ground, preventing fires. In June 1752, Ben is said to have set up his most famous experiment. The story goes that he flew a kite in a thunderstorm. When he noticed the threads on the string standing up, he touched a knuckle to a key tied on the end of the string—and zap! However, if this story were true it would have killed him. If he had, in fact, conducted such an experiment, he probably knew enough to attach a Leyden jar to the string to collect the static electricity more safely. Still, standing out in a thunderstorm is dangerous!

End notes:

1. Dunsheath, P. 1967. *Giants of Electricity.* New York: Thomas Y. Crowell, pp.9–10.
2. Dunsheath, P. 1967. *Giants of Electricity.* New York: Thomas Y. Crowell, p.9.

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EUREKA! MOMENT 2
LUIGI GALVANI, 1737–1798, and ALESSANDRO VOLTA, 1745–1827

In 1786 **Luigi Galvani** was a professor of anatomy at the University of Bologna (Italy). He noticed that the leg muscles of a dissected frog twitched when a nearby electrical machine was operating. He embarked on years of experiments to prove that animal tissue could generate a significant amount of electricity. Although he failed to prove this without a doubt, he managed to uncover some other helpful information about electricity. For example, he found that different metals had differing abilities to conduct electricity. These differences encouraged electricity to flow from one metal to the other. Unfortunately, he did not understand the reasons for these differences. He instead credited them to "*animal electricity*."

Alessandro Volta, an Italian physics professor, believed that he knew why Galvani's frog leg muscles twitched. He thought the differences in the metals Galvani used caused most of the current; the animal tissue mainly added the fluid needed. Volta applied his theory to designing the first continuous electric current. In 1800, he presented his "*voltaic pile*" to the scientific community, the world's first "*battery*." He made it with stacks of alternating metals, such as copper and zinc, copper and zinc. In between each layer of metal he placed a pad soaked with a liquid, such as salt water. Having a continuous source of current electricity made it easier for scientists to further explore the nature and uses of electricity. The **volt**, an electrical unit of measurement, honors Volta's contributions to our understanding of electricity.

EUREKA! MOMENT 3—HANS CHRISTIAN OERSTED, 1777–1851

In about 1819, **Hans Christian Oersted**, a Danish physicist, established a definite relationship between electricity and magnetism. He noticed that a magnetic needle (like on a compass) reacted to a voltaic battery current. No one knows if his discovery was an accident or not, but he knew it was important. Others had suspected a relationship between electricity and magnetism; Oersted proved it. This became known as **electromagnetism**. The reason a magnetic needle responds to a wire carrying electric current near it, Oersted correctly suggested, is that the current-carrying wire has a circular magnetic field around it. So, electrical current *produces* magnetism, which affects the magnetism of the needle. Oersted's work paved the way for a new wave of progress in understanding and using electricity for many scientists to come.

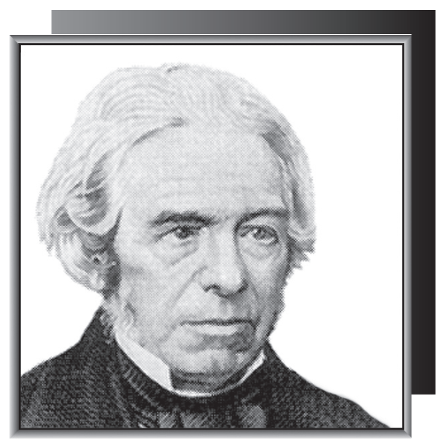
EUREKA! MOMENT 3—ANDRE-MARIE AMPÈRE, 1775–1836

Andre-Marie Ampère, a French mathematician, used his knowledge of math to help improve upon Oersted's work. He took a magnetic needle and wrapped a current-carrying wire around it, producing a stronger change in the needle's behavior. The more times he wrapped the wire around the needle, the stronger the change. He called his invention a **galvanometer**, a tool to detect or measure electricity in a magnetic field.

Ampère also showed that an iron rod could be magnetized by inserting it in the center of a coil of current-carrying wire. This **electromagnet** could attract other iron pieces until the current was turned off. Ampère was the first to suggest that messages might be sent by electric current and received by electromagnetism. Eventually, these ideas led to the invention of the first practical electric telegraph in 1837 by Joseph Henry and Samuel Morse.

EUREKA! MOMENT 4—MICHAEL FARADAY, 1791–1867

Oersted and Ampère showed how to turn electricity into magnetism. **Michael Faraday**, an English chemist, worked on the opposite process—changing magnetism into electricity. He began by carefully studying the work of Oersted, Ampère, and others. Then he set out to see if he could produce movement using magnetism.

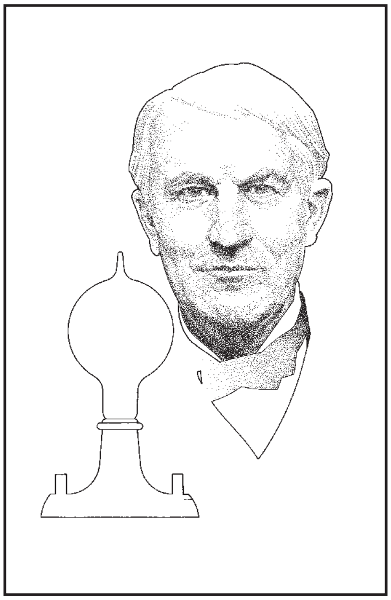


Faraday experimented and experimented. Most of his experiments failed. Finally—success! Faraday designed the first electric generator. He made it out of eight 27.5-foot lengths of copper wire wrapped to form a hollow cylinder. He hooked the wire to a galvanometer. To generate electricity, he pushed and pulled a bar magnet into and out of the hollow area. This motion caused the needle of the galvanometer to move, showing that he had made electricity.

His next task was to design a generator that would move the magnet for him. Once again he experimented and experimented. Eventually, he built the first direct-current **dynamo**.

Meanwhile, he wondered about the exact relationship between electricity and magnetism. For one series of experiments he did to solve this puzzle, he studied the pattern iron filings make over an electrified wire and over a bar magnet. This led to his theory that electromagnetism was not created by electric or magnetic "*particles*" but by the space in which they operated—the **force field**. Knowledge of this force field spread throughout the study of electricity, helping even today's scientists put electricity to use.

EUREKA! MOMENT 5—THOMAS EDISON, 1847–1931



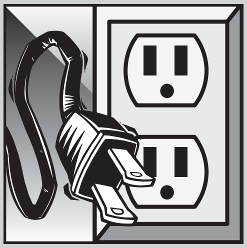
Thomas Edison was a curious boy who could not sit still in school. At home, he was always experimenting. Once he put goose and chicken eggs in the same nest and sat on them to see what would happen. All he managed to do was break the eggs and ruin his pants! At 12, he took a job selling candy on a train. In his spare time, he did experiments in the baggage car—until he accidentally set it on fire. When he was 15, he saved a little boy from being killed by a runaway boxcar. The boy's grateful father taught Thomas how to operate a telegraph. He worked as a telegraph operator and became skillful at fixing and improving the equipment. This started him on a lifelong adventure in developing new **technology**.

In 1876, he set up a large laboratory in Menlo Park, New Jersey to work on his many inventions. He hired dozens of people to help him test his countless ideas. Edison became known as the "*Wizard of Menlo Park*." In 1877, he and his workers improved Alexander Graham Bell's telephone and invented the **phonograph**. The phonograph was the first machine that could save sounds and replay them.

The next year, he began looking for a way to use electricity in practical ways. He wanted to find a way to bring it safely to businesses and homes. He is most famous for his invention of the electric light bulb in 1879, the result of thousands of carefully **controlled experiments**. Each time he designed a new test to find a material that would burn reliably, he only changed one thing, or **variable**. That way, he would know exactly what worked and what did not.

Thomas wired the homes of Menlo Park with electric lights to show the world his triumph. Meanwhile, he worked to develop ways to control electricity, including ways to wire homes safely, bring electricity to the homes, and measure the electricity each home used. He also invented safety devices, such as the electrical **fuse**, which stopped the flow of electricity when a circuit became dangerously overloaded.

Eventually, Thomas invented the movie camera and projector, a powerful storage battery and many other machines. He was issued an amazing 1,093 **patents!** He died on October 18, 1931, at the age of 84.



STUDENT GUIDE

PHASE 2

FUDGE FACTORY

The following newspaper articles were written from information gathered across the country and around the world. Read them carefully. Take note of their common theme—electricity. Then consider the following question: How do electricity and related ideas affect our lives? When you have read the two articles, examine the **Map of Faraday's Fudge Factory** on pages 2 and 3, and the additional information on page 4. As you will see, in this simulation, you each will become a "science detective" and work with an investigative team to solve the mystery of Faraday's Fudge Factory.

LIGHTNING NEVER STRIKES TWICE?

Boise, ID—Don't tell that to Ray Sullivan. A retired park ranger, he's been hit by lightning seven times! Each second more than a hundred bolts of lightning strike the earth—24 hours a day, 365 days a year.

Electric charges build up in thunderclouds as warm and cool air "rub" against each other. The flash a lightning bolt makes is brighter than ten million one-hundred watt lightbulbs.

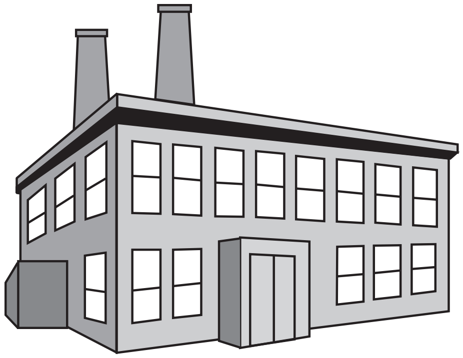
Lightning is static electricity, the same thing created by scuffing your feet on carpet and discharged when you then touch a metal object.

Lightning can start fires, causing great damage. Static electricity seems harmless enough, but it too can cause problems. For example, computers are very sensitive to static electricity charges. It is wise to wear an acrylic sweater when tinkering with the insides of a computer, rather than wool. This is because wool transfers electrical charges more readily.

HOUSE FIRE IN BURLINGTON DUE TO BAD WIRING

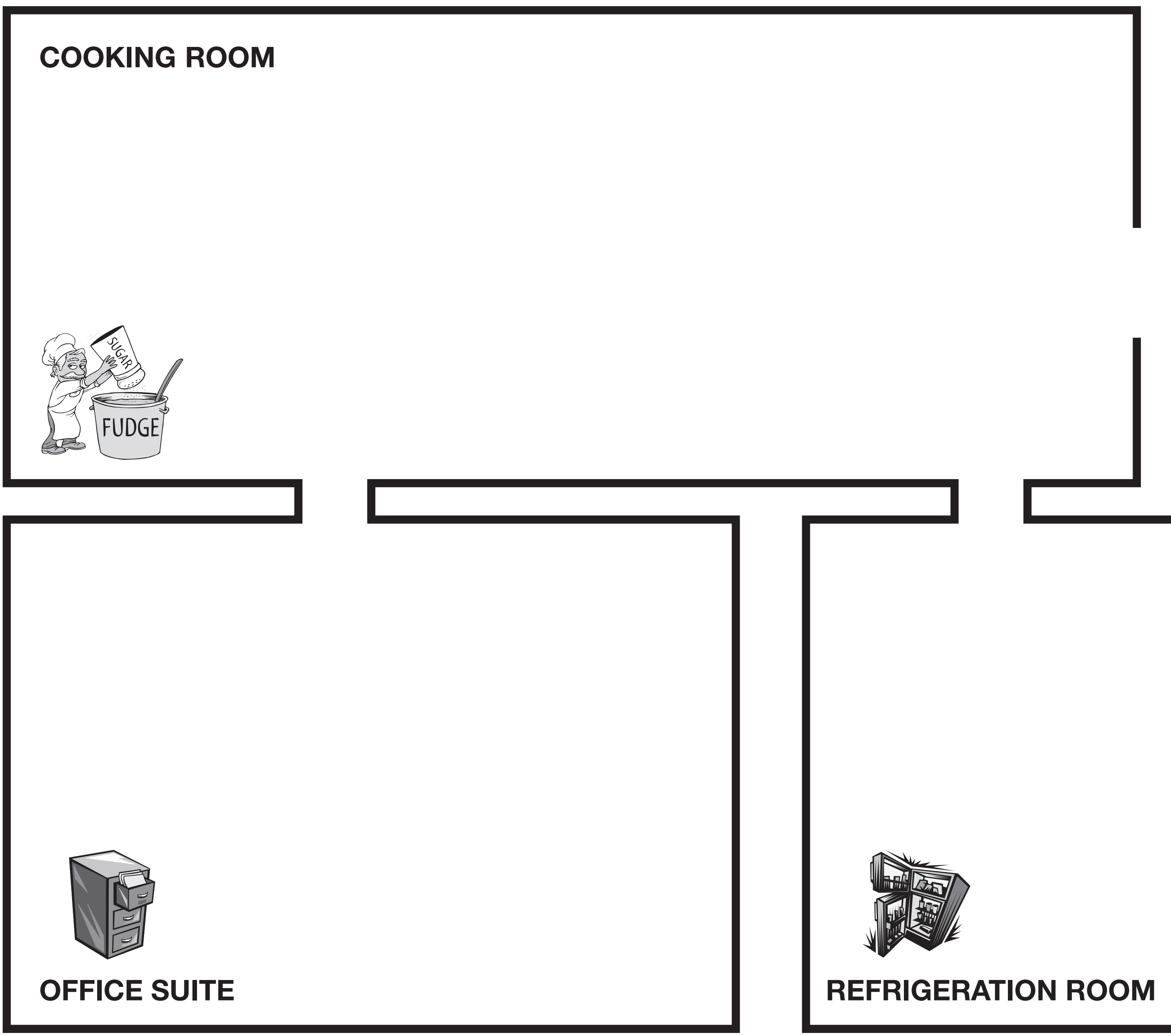
Burlington, VT—Fire officials in Burlington believe the fire last night at 617 Pine St. was caused by faulty and outdated wiring. The fire destroyed most of the house. Inspectors could see in the remaining parts of the house that wiring was frayed.

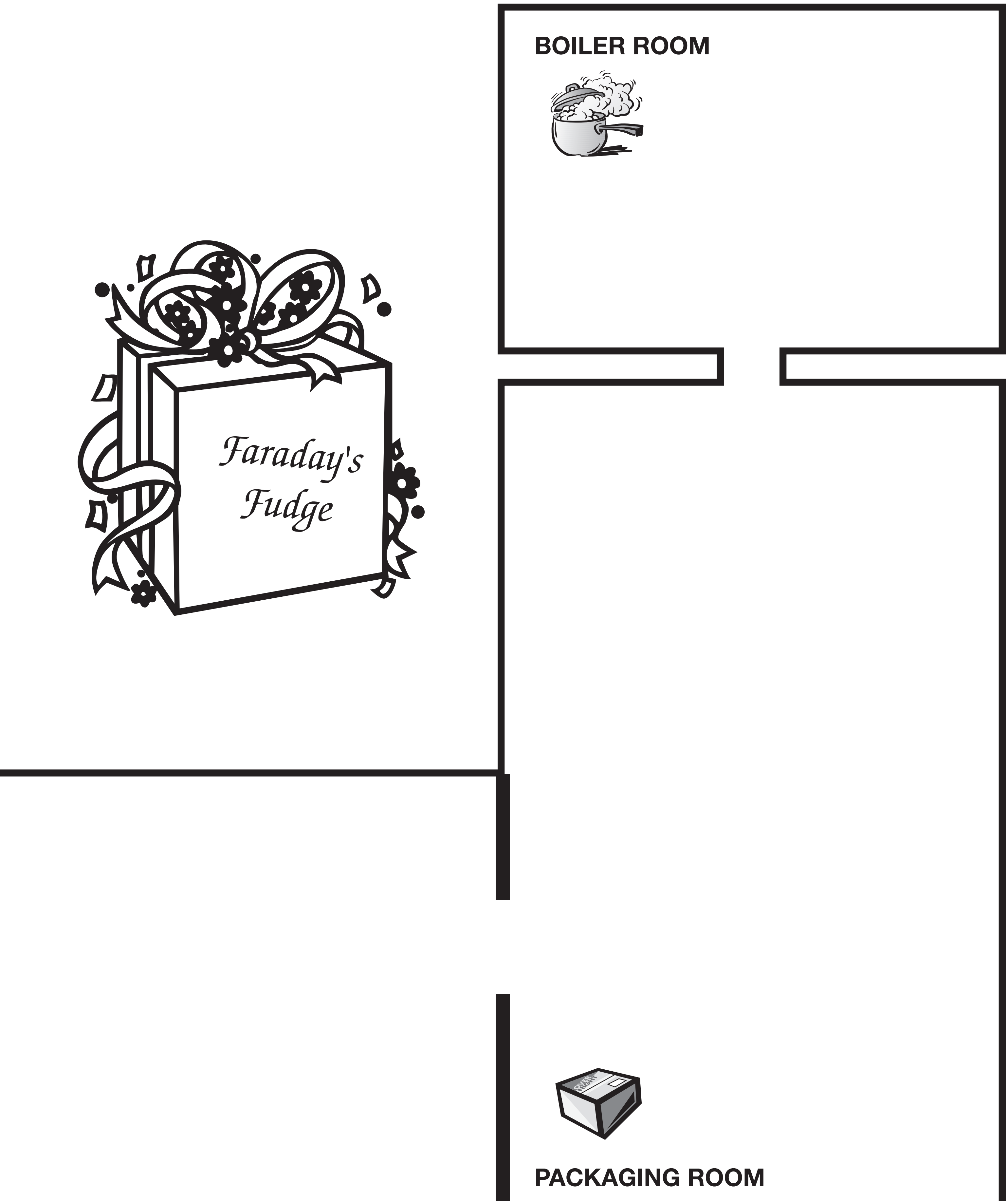
They also found a fuse box in the basement that was original to the 70-year old house. Fuses burn out when too much current goes through electrical wires. The wire in a fuse is sensitive to heat and melts to break the circuit. This stops the current from overloading the system. However, circuit breakers are now used because they are more convenient. They only need to be reset, not replaced like fuses. Fire Chief Henders said, however, that "The use of fuses shows the wiring in the house is outdated. A closer inspection will probably reveal other problems, such as having too many electrical devices plugged into one socket."



MAP OF FARADAY'S FUDGE FACTORY

This map shows the main rooms of Faraday's Fudge Factory in which you will be collecting clues. In each room, use a pencil and neat and small writing to record the possible clues as you uncover them. Be thinking of solutions to each room's electrical problems as you collect clues.



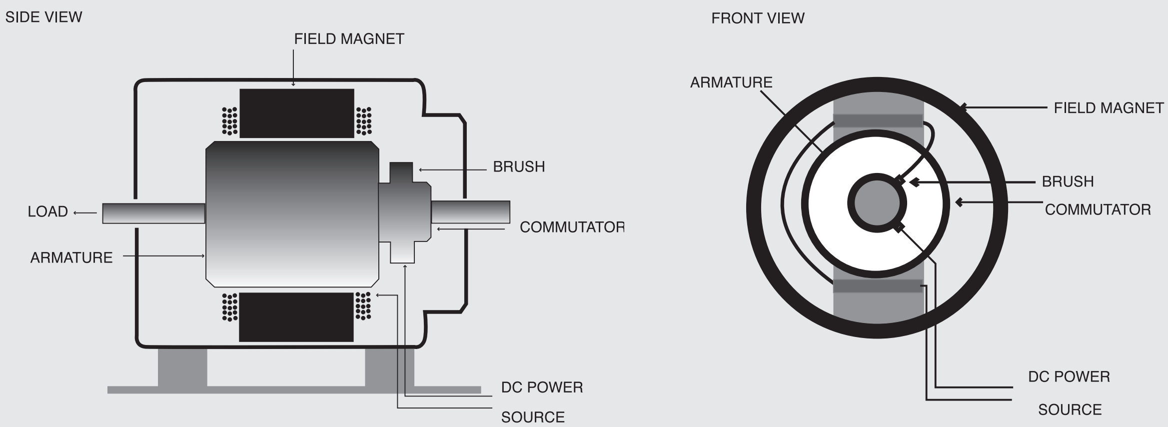

BOILER ROOM
Faraday's Fudge
PACKAGING ROOM

MOTORS HAVE MAGNETIC ATTRACTION

Detroit, MI—Motors change electrical energy into mechanical energy to do work. Electricity and magnetism work together to produce motion.

An electric motor works based on these ideas: First, an electric current creates a magnetic field. This is called an electromagnet. There is also a permanent fixed magnetic field. Second, the direction of the current determines where the magnet's poles are (North and South). Third, the magnetic poles of the permanent and electromagnet attract and repel each other.

This attraction and repelling creates motion. The motion makes a drive shaft move, making the machine work. The diagram shows a simple electric motor.



Now that you have read the newspaper articles and examined the **Map of Faraday's Fudge Factory**, please read the following information. Then ask yourself, "How can we help Ms. Faraday?"

On a field trip to learn about the chemistry used at Faraday's Fudge Factory, you and your classmates are looking forward to the box of fudge you will each receive at the end of the tour. As you arrive, however, a large truck pulls away. Ms. Faraday herself stands on the front steps of the factory, frowning.

As you approach, Ms. Faraday clears her throat and says, "I'm sorry, class, but we're in a fudge-covered pickle this morning! My entire factory is shut down due to power troubles. We can't even refrigerate our stockpile of Famous Fabulous Faraday Fudge, so we have had it all hauled away in refrigerated trucks to our distributors before it spoils. It's a good thing we have paper copies of our shipping plan, because our computers are shut down, too. I have heard what fine scientists you all are, and I was hoping your class would help us figure out what the problem is—before we go out of business! The way I see it, we have about a week before our creditors come pounding on the door, thinking we're fudging on our accounts."

You begin your tour, **Science Journals** in hand, looking for clues. It seems you are going to learn about electricity—not chemistry!

