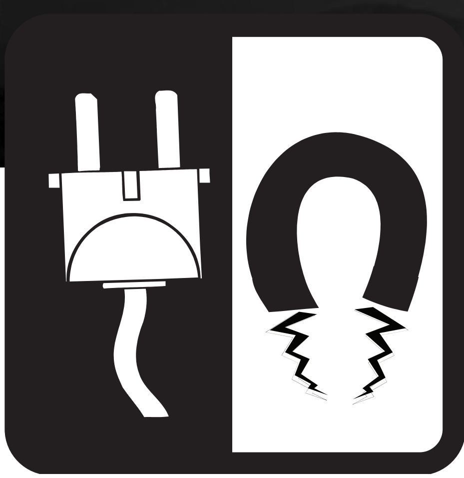
ElectroWorks
Teacher Guide

Hands-on activities and background information that explore basic concepts of atomic structure, electricity, magnets, electromagnets, batteries, and circuits.



Grade Level:

- Elem Elementary
- Int Intermediate

Subject Areas:

- Science
- Math
- Language Arts
- Technology

NEED
National Energy Education Development Project

Teacher Advisory Board

NEED Mission Statement

The mission of The NEED Project is to promote an energy conscious and educated society by creating effective networks of students, educators, business, government and community leaders to design and deliver objective, multi-sided energy education programs.

Teacher Advisory Board Statement

In support of NEED, the national Teacher Advisory Board (TAB) is dedicated to developing and promoting standards-based energy curriculum and training.

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Energy Data Used in NEED Materials

NEED believes in providing the most recently reported energy data available to our teachers and students. Most statistics and data are derived from the U.S. Energy Information Administration's Annual Energy Review that is published yearly. Working in partnership with EIA, NEED includes easy to understand data in our curriculum materials. To do further research, visit the EIA web site at www.eia.gov. EIA's Energy Kids site has great lessons and activities for students at www.eia.gov/kids.

NEED
National Energy Education Development

1.800.875.5029
www.NEED.org

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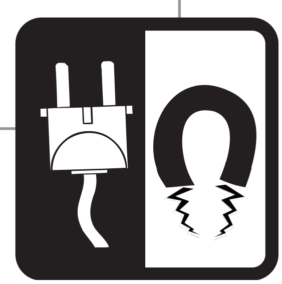


Standards Correlation Information

www.NEED.org/curriculumcorrelations

Next Generation Science Standards

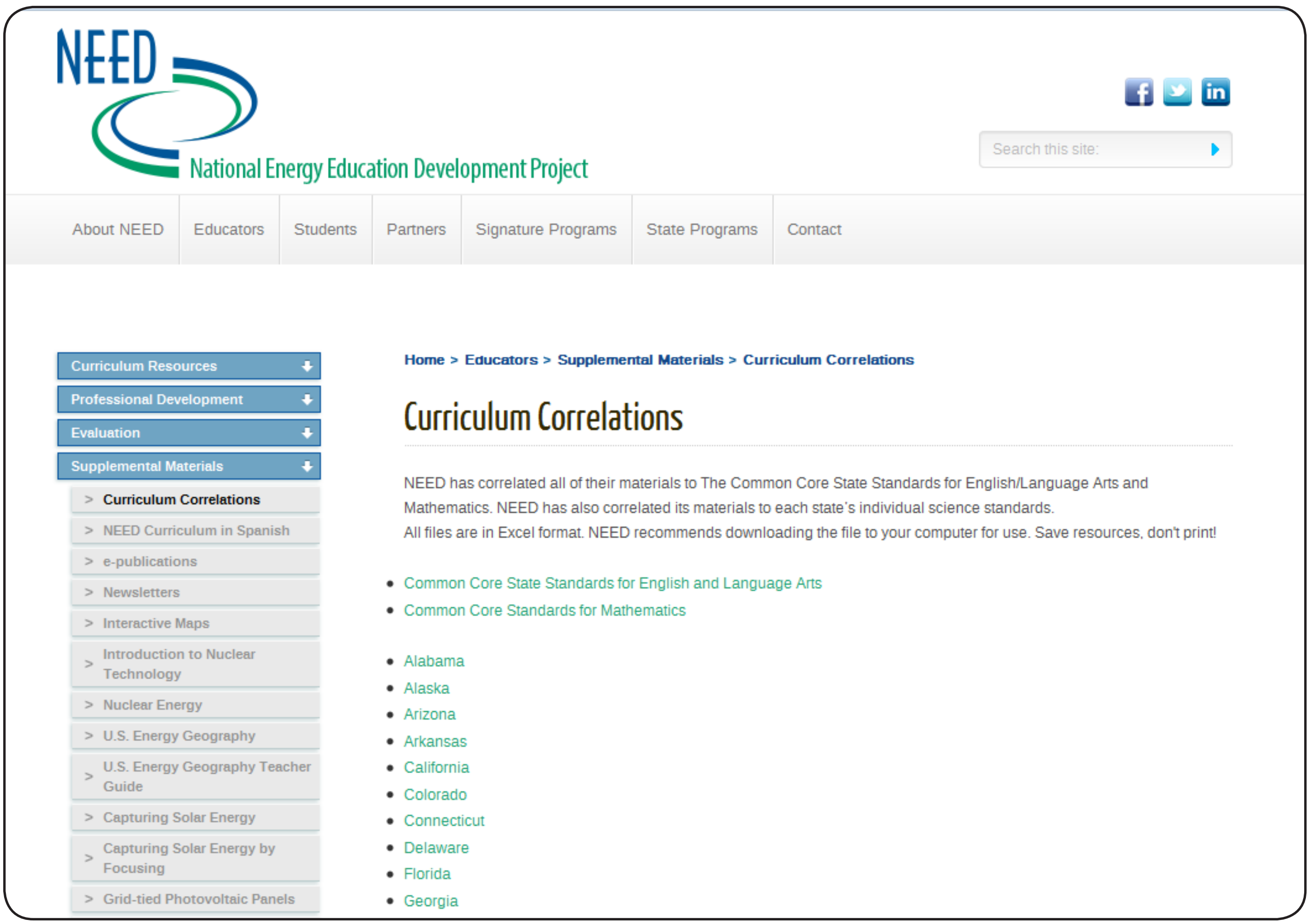
- This guide effectively supports many Next Generation Science Standards. This material can satisfy performance expectations, science and engineering practices, disciplinary core ideas, and cross cutting concepts within your required curriculum. For more details on these correlations, please visit NEED's curriculum correlations web site.

Common Core State Standards

- This guide has been correlated to the Common Core State Standards in both language arts and mathematics. These correlations are broken down by grade level and guide title, and can be downloaded as a spreadsheet from the NEED curriculum correlations web site.

Individual State Science Standards

- This guide has been correlated to each state's individual science standards. These correlations are broken down by grade level and guide title, and can be downloaded as a spreadsheet from the NEED web site.



Materials

ACTIVITY CENTER	MATERIALS NEEDED	
Center 1—Static Electricity	▪Electroscope ▪Balloons ▪Wool felt ▪Transparency film ▪Tape ▪Aluminum foil	▪Plastic marking pens ▪2 Pencils ▪Plastic rulers ▪2 Metal spoons ▪Scissors with plastic handle ▪Construction paper
Center 2—Batteries	▪5 D Batteries ▪2 Copper strips ▪2 Zinc strips (gray) ▪2 Alligator clips ▪1 Electrical meter	▪Salt ▪Aluminum foil ▪Beaker ▪Distilled water ▪Measuring cup
Center 3—Magnets and Magnetic Fields	▪2 Bar magnets ▪1 Horseshoe magnet ▪6 Ring magnets ▪4 Student compasses ▪1 Large sewing needle ▪1 Wooden disk ▪15 Small paper clips	▪1 Plastic bowl ▪1 Magnetic field demonstrator (box of iron filings in oil) ▪Tape ▪Water ▪Overhead projector ▪Pencil or straw
Center 4—Electromagnets	▪1 Piece of coated copper wire (1 meter long) ▪1 9-Volt battery ▪15 Small paper clips ▪1 Large iron nail ▪1 Small iron nail	▪1 D Battery ▪Wire stripper ▪Battery holder on circuit ▪Student compass ▪Tape
Center 5—Circuits 1	▪3 D Batteries ▪3 Battery holders with bulb sockets and switches ▪3 Light bulbs ▪1 Student compass ▪10 Pieces of coated copper wire (30 cm in length)	
Center 6—Circuits 2	▪3 D Batteries ▪3 Battery holders with bulb sockets and switches ▪3 Light bulbs ▪Colored pencils ▪12 Pieces of coated copper wire (30 cm in length)	

NOTE: An energy ball is also needed for the introduction to this unit on page 7. For more information on an energy ball or any of the items listed above, call NEED at 1-800-875-5029.

Teacher Guide

An introduction to the concepts of atomic structure, magnets, magnetic fields, batteries, electromagnetism, electricity, and circuits using informational text and center-based, hands-on explorations.

Grade Level

- Elementary: grades 4-5
- Intermediate: grades 6-7

Time

- Nine 45-minute class periods for grades 4-5.
- Six 45-minute class periods for grades 6-7.

Background

Students read a background article and work in groups to complete explorations at six centers that cover the following topics: static electricity, batteries, magnets, magnetic fields, electromagnets, and circuits.

★ Concepts

- Atoms are the smallest particles that retain the characteristics of elements.
- Atoms are made of protons and neutrons in the nucleus, and electrons moving around the nucleus in energy levels.
- Neutral atoms have an equal number of protons and electrons. Protons carry a positive electrical charge equal to the negative charge of electrons. Neutrons have no charge.
- Some elements, such as metals, have electrons that are easily freed from their outer energy levels.
- When electrons spin, they make magnetic fields. In most substances, the magnetic fields cancel. However, in ferromagnetic elements, the magnetic fields align, forming tiny micromagnets or domains. When the domains of an object are aligned, the object is magnetic. The magnetic field moves away from the north pole and toward the south pole. The fields of two magnets can attract (N and S) because the fields are moving in the same direction, or repel (N and N) because they are moving in opposite directions.
- Electricity is moving electrons.
- Magnets can be used to induce an electric current. The electric current can be used to form magnetic fields.
- Chemical reactions can produce electricity in batteries.
- The flow of electrons can be measured, even though the electrons can't be seen.
- Electricity flows in closed loops, or circuits. Circuits can be connected in many ways.
- Electricity can be used to perform work. Devices that perform work in a circuit are called loads.

Science Notebooks

It is suggested that students keep science notebooks or journals over the course of the unit, as a place to record questions, hypotheses, observations, data, and conclusions. If you currently use notebooks or journals, you may have your students continue using these.

Depending on the level of your students' independence and familiarity with the scientific process, you may choose to use certain worksheets or the entire Student Guide for students to record their thoughts and observations. Or, as appropriate, you may choose to make copies of worksheets and have your students incorporate them into their existing notebooks.

Activity 1: Station Rotations

Preparation

- Become familiar with the Teacher and Student Guides. The Teacher Guide provides teacher versions of each of the student pages with different or more detailed background information, specific student objectives, preparation notes, and omits data tables and writing space. Please use the student guide pages for students.
- Obtain the materials needed on page 5. Make sure all of the materials are in working order.
- Make copies of any handouts, activities, or instructions needed from the Student Guides, if students are not to write in the guides.
- Cut one piece of coated wire to approximately one meter in length and 24 pieces of coated wire to approximately 30 cm in length. Strip both ends of each wire to a length of 1 cm with the wire stripper.
- Set up six centers in the room with the materials listed on page 5. Make copies of the instructions for each center found on pages 10, 12, 14, 17, 20, and 24 in the Teacher Guide. These will serve as station posters. You may choose to laminate these for multiple uses and durability.

  CENTER 1: Static Electricity

  CENTER 2: Batteries

  CENTER 3: Magnets and Magnetic Fields

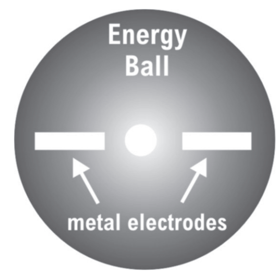
  CENTER 4: Electromagnets

  CENTER 5: Circuits 1

  CENTER 6: Circuits 2

- Prepare a copy of the *Circuits Master* on page 27 of the Teacher Guide to project and explain the components.

✔ Procedure



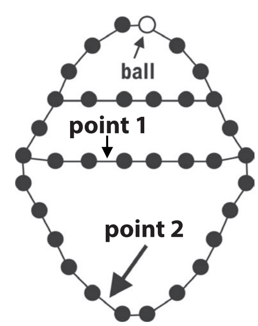
Introduction

1. Introduce the unit by discussing electricity, how it is found in nature, how we produce it, and how we use it. Use the Energy Ball to spark student interest.

   Have the students stand in a circle touching palms. Join the circle and hold the Energy Ball in one hand, making sure you touch one of the metal electrodes on the ball. Have the student next to you touch the other electrode on the ball. The ball will light and make noise. Discuss the term circuit.

   Experiment with opening and closing the circuit by having two students separate their hands. Discuss the terms open and closed circuits. Have the students touch just their index fingers together and observe the ball.

   Experiment with conductors and insulators by having one student touch a sleeve instead of a hand. Have two students hold different objects between them in the circuit, such as paper, glass, plastic, wood, and metal. Discuss the terms conductors and insulators. Discuss which objects are conductors and which are insulators. Ask students to identify the similar properties of all the conductors and insulators.

   Have the students connect in a configuration like in the diagram to the right. Have the students "break" the circuit at point one, then point two, as shown by the arrows. Discuss why the Energy Ball still lights and makes noise. Have a discussion about series and parallel circuits. Ask students what they think the terms mean. How is the ball different when the circuit is broken at the two different points?

2. Have the students read the informational text section, *Electricity,* and complete the *Key Words for Electricity* and *Atomic Structure* worksheets from the Student Guide. Review the answers as a class.
3. Divide the students into six groups and assign each group to a center.

   Grades 4-5: Explain that the groups will rotate through one center each day for the next six days. They should follow the instructions on each center poster.

   Discuss each of the centers with the students and answer any questions they have.

   Emphasize that students must put the centers back in order when they are finished, so that the next group can complete the activities.

   Grades 6-7: Explain that the groups will rotate through two centers each day for the next three days. They should follow the instructions on each center poster.

   Discuss all of the centers with the students, if necessary.

   Emphasize that students must put the centers back in order when they are finished so that the next group can complete the activities in the time allotted.

Student Groups Rotate Through Centers

1. Student groups rotate through the six centers, allowing the groups 30 minutes at each center (15 minutes for grades 6-7). Note that the groups who are beginning at both of the *Circuits* centers begin with the introductory *Circuits* activity on pages 23-24 of the Student Guide. Tell the students that that they do not need to complete the introductory *Circuits* activity again at the second circuits center they visit.
2. Monitor student work, answering questions and offering guidance, as needed.
3. Instruct the groups to make sure that all of the equipment is left as it was found, so that the next group can complete the experiments.

Activity 2: Measuring Electricity

Preparation

- Prepare a copy of the *Sample Electricity Calculations Answer Key* on page 33 of the Teacher Guide to project for the class.
- Make copies of the *Measuring Electricity,* and *Keywords for Measuring Electricity* worksheets on pages 9 and 39 of the Student Guide if you do not want students to write in the guides.

✔ Procedure

Introduction, Informational Text, Key Words, Calculations

1. Introduce this segment by discussing different units of measuring electricity: amperes, volts, watts, kilowatts, kilowatt-hours.
2. Have the students read the informational text section, *Measuring Electricity* on page 5 of the Student Guide, and complete the *Key Words for Measuring Electricity* worksheet on page 9.
3. Have the students turn to the *Sample Electricity Calculations* on page 38 of the Student Guide. Use the *Sample Electricity Calculations Answer Key* master to discuss the calculations.
4. Have the students complete the *Measuring Electricity* worksheet on page 39 of the Student Guide. Review.

☑Unit Review and Evaluation

1. Students should complete the *Review* worksheets on pages 36-37 of the Student Guide.
2. Evaluate the unit, using the *Evaluation Form* on page 37 of the Teacher Guide, and return to NEED.
3. Evaluate student performance using the students' science notebooks or Student Guides. A sample rubric for assessment is found on page 9.

Grading Rubric

Student Guide or Science Notebook Rubric

GRADE	SCIENTIFIC CONCEPTS	SCIENTIFIC INQUIRY	PRESENTATION
4	Student demonstrates thorough understanding of concepts through pictures, writing, and verbal communication.	Student is able to follow all steps of the scientific process: predicting, observing/recording data, and drawing a more complex conclusion related to his/her data. Student shows higher level thinking by asking his/her own questions.	Handwriting is legible. Pictures are realistic and include labels. All parts of the assignment are complete.
3	Student demonstrates understanding of concepts through pictures, writing, and/or verbal communication.	Student is able to predict, observe/record data, and draw a basic conclusion.	Handwriting is legible. Pictures are realistic and include most labels. All parts of the assignment are complete.
2	Student demonstrates a beginning understanding of concepts, may have a couple of lingering misconceptions.	Student is able to do two of the following: predict, observe/record data, draw conclusions.	Words and/or pictures may be hard to decipher at times. Pictures are present but are missing labels. The notebook has some missing components.
1	Student demonstrates confusion about concepts. Many misconceptions remain.	Student is able to do one or fewer of the following: predict, observe/record data, draw conclusions.	Words and/or pictures are hard to decipher. They may not be connected to the investigation. The notebook has many missing components.

Center 1: Static Electricity

1. Each student should examine the electroscope.
2. Each student should complete the *Static Electricity* exploration individually, recording his/her hypothesis and data.
3. Work in groups to answer the questions in the Conclusion section.
4. The group will put the materials back as they found them and clean up the center.

Static Electricity

Background

An electroscope is a device that demonstrates the presence of an electric charge on an object. An electric charge can be a build-up of electrons on an object, producing a negative (-) charge, or a loss of electrons, producing a positive (+) charge on an object. The electroscope in this experiment is a glass container with a rubber stopper holding a metal rod. At the bottom of the metal rod is a hook that holds two strips of foil. If an electrically charged object touches the metal ball at the top, the charge will flow down the metal rod, through the hook, and into the strips of foil. Both pieces of foil will develop the same charge and push away from each other. The electroscope can be used to to explore ways of producing electric charges.

Objective

- Students will be able to identify the kinds of materials that lose or attract electrons easily.

Materials

- Electroscope
- Piece of wool
- Piece of tape
- Wooden pencil
- Plastic marking pen
- Plastic ruler
- Piece of plastic transparency film
- Metal spoon
- Piece of construction paper
- Scissors with plastic handle
- Balloon
- Aluminum foil (in strips)

Teacher Preparation

- Cut aluminum foil into strips.

Student Preparation

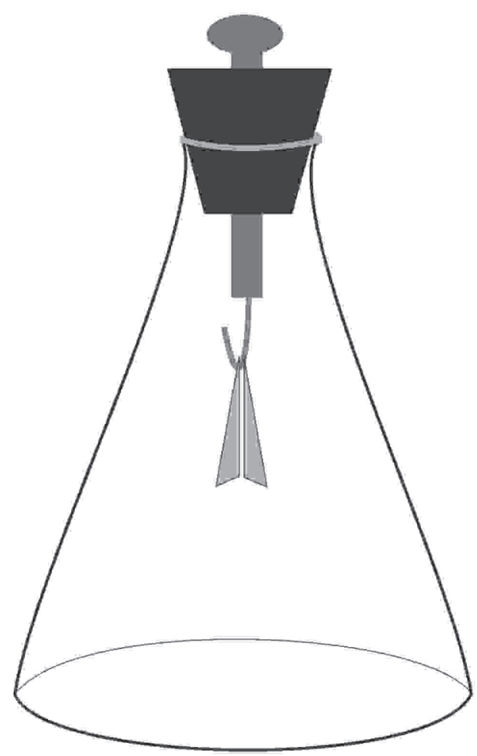
- Blow up the balloon and tie it.
- Roll the construction paper into a tube and tape it.

Hypothesis

Read the procedure and record your hypothesis.

Procedure

1. Look at the list of objects in the data table (page 12 of the Student Guide). Check the first column if you think it will hold a charge.
2. Test each object by rubbing it quickly with the piece of wool, then holding it close to the ball on the electroscope.
3. Check the second column for each object that produces a charge on the electroscope.
4. Produce a charge on the electroscope and touch your finger to the ball. Observe the foil strips.



Data

Record your observations.

Conclusion

1. Were you surprised by any of the objects that produced an electric charge?
2. Why did you rub the objects with a piece of wool? Would a piece of aluminum foil produce the same results? Try it and see.
3. Describe how the aluminum foil affected the charge on the objects.
4. Why did the foil strips stay charged when you touched the electroscope? How long did the charge stay on the electroscope?

Center 2: Batteries

1. **Each student should individually record his/her hypothesis and data.**
2. **Each student should individually conduct the D battery exploration in the first step under Procedure.**
3. **Work in groups to complete steps 2-5 under Procedure (see diagram 2).**
4. **Work in groups to answer the questions in the Conclusion section.**
5. **The group will put the materials back as they found them and clean up the center.**

Make a Battery

Background

Batteries produce electricity to power many devices. Batteries usually have two kinds of metal placed in chemical solutions like acids. The solutions undergo chemical reactions with the metals, freeing electrons. One metal loses electrons more easily than the other. The metal that loses electrons is the positive (+) terminal of the battery. The other metal is the negative (-) terminal of the battery. If we make a closed circuit with the battery, we can produce electricity. When electrons flow through a wire, heat is produced. We can sometimes feel that heat in battery operated devices. We can also measure the flow of electricity with an ammeter, which measures electric current.

Objectives

- Students will be able to explain how to make a battery.
- Students will be able to explain how to produce electricity using a battery.

Materials

- 2 Zinc electrodes
- 2 Copper electrodes
- 6 D Batteries (1 per group)
- 2 Alligator clips
- 1 Measuring cup
- 1 Electrical meter (ammeter)
- 1 Beaker of distilled water
- Aluminum foil
- Salt

Teacher Preparation

- Cut 50 x 6 cm pieces of aluminum foil.

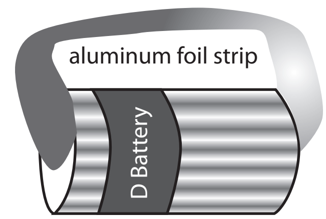


Diagram 1

Student Preparation

- Fold the piece of aluminum foil several times lengthwise to make a thick foil strip. Cut this foil strip in half, so that you have two 25 cm strips. Cut one again so that you have a 10 cm and a 15 cm strip.

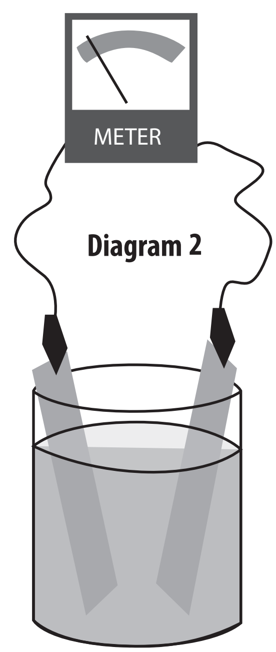
Hypothesis

Read the procedure and record your hypothesis.

Procedure

1. Attach the 10 cm strip to the terminals (ends) of the battery with tape, as shown in Diagram 1. Hold the strip in your fingers for 15 seconds. Observe any change in the temperature of the strip. Attach the 15 cm strip to the battery and feel the strip. Do the same thing with the 25 cm strip.
2. Attach the alligator clips to the leads on the meter. Attach the clip with the red label to a zinc electrode and the other clip to a copper electrode. Observe the meter. Place the electrodes in the beaker of water so they are NOT touching (Diagram 2). Observe the meter. Remove the electrodes.
3. Add 5 cm^3 of salt to the water and stir. Place the electrodes in the salt water so they are NOT touching and observe the meter. Add another 5 cm^3 of salt, stir, and observe the meter. Touch the electrodes together and observe the meter.
4. Place two copper electrodes on one clip and two zinc electrodes on the other in the salt solution and observe the meter.
5. Place one copper electrode on each clip and observe the meter.

NOTE: 1 cm^3 = 1 mL



Data

Record your observations.

Conclusion

1. Using the D battery, could you feel any heat produced by the electricity in the foil strips? Which length of foil got hotter? Why?
2. Did the metal electrodes produce electricity before they were placed in water? Was this apparatus a battery? Did the metal electrodes produce electricity when they were placed in water? In salt water? Was this apparatus a battery? Which solution made a better battery? What happened when the metal electrodes were touching in the salt solution?
3. How did increasing the amount of metal affect the meter? What happened when both electrodes were made of the same metal? Why?

Center 3: Magnets and Magnetic Fields

1. Each student should individually record his/her hypothesis and data.
2. Work in groups to complete the *Magnets and Compasses* exploration.
3. Work in groups to complete the *Magnetic Fields* exploration.
4. Work in groups to answer the questions in the Conclusion sections.
5. The group will put the materials back as they found them and clean up the center.

Magnets and Compasses

Background

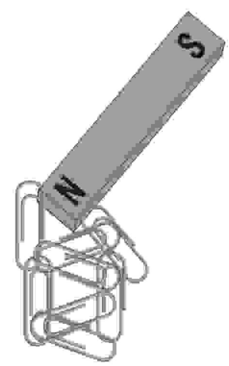
The Earth is a giant magnet. The Earth has north and south poles just like a magnet has north and south poles. The Earth has a magnetic field around it. The needle of a compass always points to the north because the needle is a magnet, too. An ordinary needle can be made into a magnet by stroking it with a magnet, rearranging the electrons in the needle. You can demagnetize the needle by dropping or striking it several times.

Objectives

- Students will be able to explain how a compass works.
- Students will be able to list several properties of magnets.

Materials

- 2 Bar magnets
- 1 Horseshoe magnet
- 6 Ring magnets
- 1 Student compass
- 1 Large sewing needle
- Wood disk
- Paper clips
- Tape
- Bowl of water
- Pencil or straw

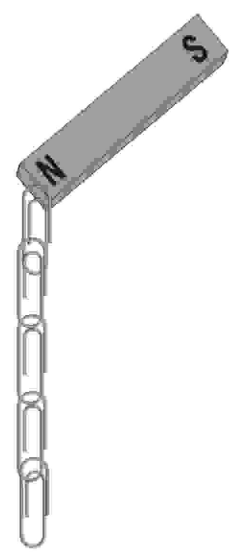


Hypothesis

Read the procedure and record your hypothesis.

Procedure

1. Hold the needle firmly on the end with the eye. Hold one end of a bar magnet with your other hand. Stroke the needle with the magnet from the eye end to the pointed end—in one direction only—about 25 times.
2. Tape the needle to the wood disk and float it in the water with the needle on top. Observe the direction that the needle points. Compare it to the direction of the needle of the compass. The compass will always point north.
3. Examine the two bar magnets. Try to push the north (N) poles of the bar magnets together, then the two south (S) poles. Now place the N pole of one magnet next to the S pole of the other. Observe how the magnets attract and repel each other.
4. Examine the horseshoe magnet. Observe how it is different from the bar magnets. Determine the N and S poles of the horseshoe magnet using a bar magnet.
5. Examine the ring magnets. See if you can determine their N and S poles. Stack the ring magnets on a pencil or straw so that they repel each other.
6. Put the paper clips in a pile on the table. See how many paper clips the N pole of a bar magnet can lift. Now try the S pole. Try the other bar magnet to determine if it has the same magnetic force as the first. See if a magnet can lift as many paper clips end to end—in a line—as it can if they are bunched together.
7. Place both bar magnets together N pole to S pole. See how many paper clips the magnets together can lift.
8. See how many paper clips the horseshoe magnet and the ring magnets can lift.

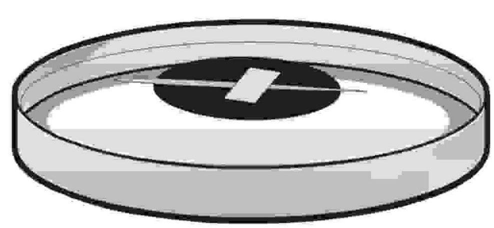


Data

Record your observations.

Conclusion

1. Which end of the needle is the N pole? If you stroked the needle in the other direction, would the N pole be on the needle's other end? Write your answer, then test it out.
2. Which magnet was the most powerful? How do you know?
3. Do you think the paper clips became magnetized to lift other paper clips? What evidence supports your answer?



Magnetic Fields

Background

Every magnet produces a magnetic field around it. This magnetic field attracts certain materials, such as iron. It can also affect the direction of a compass needle. A magnetic field demonstrator holds small pieces of iron suspended in oil.

Objective

- Students will be able to draw and describe the magnetic fields of magnets.

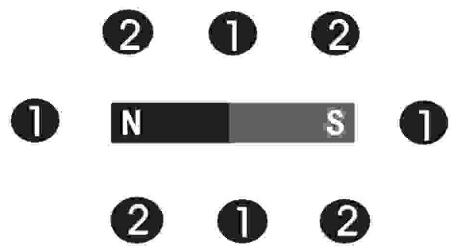
Materials

- 2 Bar magnets
- 1 Horseshoe magnet
- 1 Ring magnet
- 4 Student compasses
- 1 Magnetic field demonstrator (MFD)
- Overhead projector

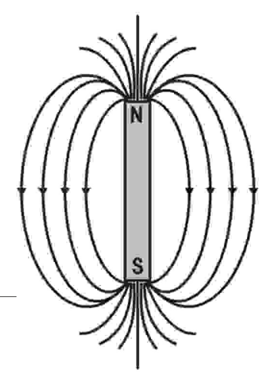
Hypothesis

Read the procedure and record your hypothesis.

✔ Procedure



1. Arrange four compasses around a bar magnet, as shown in the diagram to the right. Place them at the positions marked as 1, far enough away from the magnet so that the compasses don't move toward the magnet. Make a diagram of the magnet and compasses, showing the N and S poles of the magnet and the direction that each compass needle points. Do the same placing the compasses at the 2 positions.
2. Arrange compasses first around the horseshoe magnet, then around a ring magnet, and make diagrams of these, too.
3. Shake the magnetic field demonstrator (MFD). Place a bar magnet on the projector and place the MFD on top of it. Observe the pattern of the iron filings. Make a diagram of the magnetic field of the magnet, as shown by the iron filings.
4. Shake the MFD. Place both bar magnets together on the projector with N and S poles together. Place the MFD on top of the magnets. Make a diagram of the magnetic field produced by the two magnets.
5. Shake the MFD and place it on the horseshoe magnet. Make a diagram of its magnetic field.
6. Shake the MFD and place it on the ring magnet. See if the magnetic field changes if you turn the ring magnet over. Draw a diagram of the magnetic field of the ring magnet.



Data

Draw what you observed.

Conclusion

1. Do your diagrams of the compasses and the iron filings for each shape of magnet give you the same information? Compare them and see what you discover.
2. Which magnet has a magnetic field most like that of the Earth? Draw a diagram showing what the magnetic field of the Earth might look like.

Center 4: Electromagnets

1. **Each student should individually record his/her hypothesis and data.**
2. **Work in groups to complete the *Electromagnets 1* exploration.**
3. **Work in groups to complete the *Electromagnets 2* exploration.**
4. **Work in groups to answer the questions in the Conclusion sections.**
5. **The group will put the materials back as they found them and clean up the center.**

Electromagnets 1

Background

Moving electrons create a magnetic field around them. If we move electrons through a wire, the wire has a magnetic field around it. We can use this electricity to make a magnet. This kind of magnet is called an electromagnet.

Objective

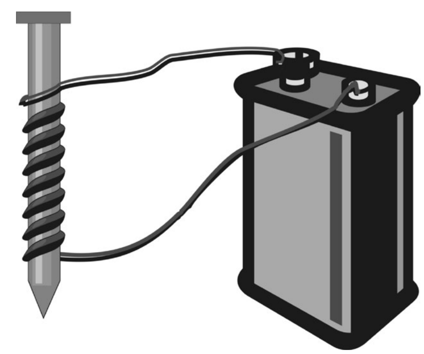
- Students will be able to explain how to make an electromagnet.

Caution

If the wire begins to feel hot, detach it from the battery and allow it to cool before resuming the experiments. Only connect while testing batteries, not indefinitely. Batteries will get hot.

Materials

- 1 Piece of coated copper wire (1 meter long)
- 1 Large iron nail
- 1 9-Volt battery
- 1 Compass
- Paper clips
- Tape



Student Preparation

- Check to see if the nail is magnetized by moving it over the compass. Does the needle of the compass move? If it moves, tap the nail on the floor several times and recheck.

Hypothesis

Read the procedure and record your hypothesis.

Procedure

1. Move the wire over the compass. Observe any movement of the compass needle. Does the compass detect a magnetic field around the wire?
2. Wrap the middle of the wire around the nail 10 times, as shown in the picture above. Do not let the wires cross or touch each other; wrap the wire as if it were a spring.
3. Wrap the ends of the wire around the metal contacts on top of the battery to make a circuit, and tape in place like in the picture above.
4. Move the compass near the wire wrapped nail. Observe the movement of the compass needle. Does the wrapped nail act like a magnet? Has the wrapped nail become an electromagnet?
5. Place a pile of paper clips on the table. Touch the nail to the paper clips and lift. See how many paper clips the nail can lift.
6. Carefully remove the nail from the coil of wire. See if the coil of wire can lift paper clips without the nail inside. Is the coil of wire an electromagnet?
7. Disconnect the coil of wire from the battery after observations are completed.
8. Move the compass over the nail. Did the nail become magnetized?

Data

Record your observations.

Conclusion

1. When you wrapped the wire around the nail, you intensified the magnetic field of the electrons flowing through the wire. Did the nail also become a magnet while it was in the wire?
2. Is the coiled wire an electromagnet without the nail inside? What experimental evidence supports your answer?

Electromagnets 2

Background

We have discovered that moving electrons have a magnetic field around them. In this experiment, we will investigate the variables that affect the force of electromagnets.

Objective

- Students will be able to identify and describe factors that affect an electromagnet.

Caution

If the wire begins to feel hot, detach it from the battery and allow it to cool before resuming the experiments. Only connect while testing batteries, not indefinitely. Batteries will get hot.

Materials

- 1 Piece of coated copper wire (1 meter long)
- 1 Large iron nail
- 1 Small iron nail
- 1 9-Volt battery
- 1 1.5-Volt battery (D battery)
- Paper clips
- Battery holder on circuit

Hypothesis

Read the procedure and record your hypothesis.

Procedure

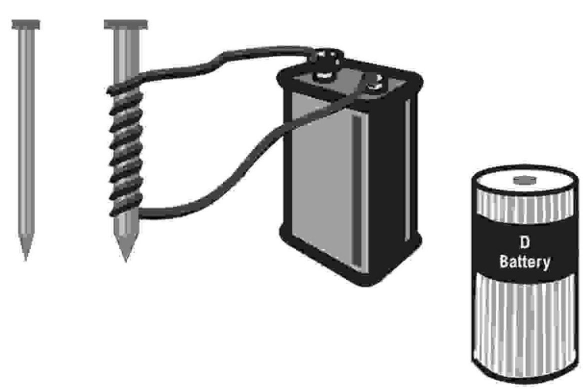
1. Insert the large nail back into the coil of wire from the last experiment. Make sure there are 10 coils of wire on the nail, that they are not crossing or touching, and reattach the wire to the 9-volt battery.
2. How many paper clips can the electromagnet lift?
3. Wrap the wire around the nail 10 more times, so that you have 20 coils of wire on the nail.
4. How many paper clips can the electromagnet lift?
5. Remove the ends of the wire from the 9-volt battery. Have someone hold the ends of the wire to the ends of the 1.5-volt battery.
6. How many paper clips can the electromagnet lift?
7. Carefully remove the large nail and insert the small nail into the coil of wire. Tighten the coils around the nail.
8. How many paper clips can the electromagnet lift?
9. Connect to the 9-volt battery.
10. How many paper clips can the electromagnet lift?
11. Remove 10 coils from the small nail so that there are only 10 coils of wire around it.
12. How many paper clips can the electromagnet lift?

Data

Record your observations.

Conclusion

1. How does the number of coils affect the strength of an electromagnet? How do you know?
2. How does the voltage of the battery affect the strength of an electromagnet? How do you know?
3. How does the size of the nail in the coil affect the strength of the electromagnet? How do you know?
4. What would you do to build a very strong electromagnet?



Center 5: Circuits 1

1. Each student should individually record his/her hypothesis and data.
2. Work in groups to complete the *Circuits* exploration and the *Series Circuits 1* and *2* explorations.
3. Work in groups to answer the questions in the Conclusion sections.
4. The group will put the materials back as they found them and clean up the center.

Circuits

Background

For electrons to flow through a wire, the wire must make a complete path or circle. This path is called a circuit. A battery produces electricity when it is part of a circuit. You can add a switch to a circuit to open and close the path. You can also add a load to the circuit so that the electricity can do work as it flows through the circuit. A light bulb is an example of a load.

Objective

- Students will be able to make a circuit and identify the power source, the switch, and the load in their circuit.

Materials

- 1 Battery holder with switch and light socket
- 1 D Battery
- 1 Light bulb
- 1 Student compass
- 3 Pieces of wire or alligator clips

Diagram 1

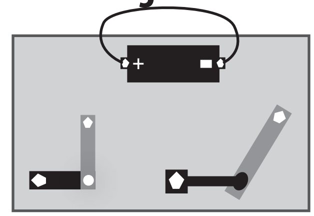
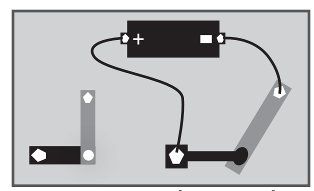
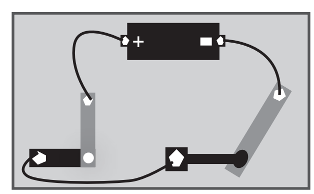


Diagram 2



circuit with switch

Diagram 3



circuit with switch and load

Hypothesis

Read the procedure and record your hypothesis.

Procedure

1. Place the battery in the battery holder. Using one wire, attach the ends of the wire to the terminals on the sides of the battery holder, as shown in Diagram 1. Use the compass to determine if you have completed a circuit. Are there electrons flowing through the wire? Disconnect.
2. Add a switch to the circuit. Unhook one end of the wire from the battery holder and attach it to one of the terminals of the switch, as shown in Diagram 2. Attach a second wire to the other end of the switch and to the other end of the battery holder.
3. Place the compass under one of the wires. Close the circuit by pushing on the switch until it touches the metal under it. Open and close the switch several times, observing the movement of the compass needle.
4. Add a load to the circuit. Attach the light bulb to the circuit as shown in Diagram 3. You will need three wires. One wire is attached to the battery holder and the light bulb holder. The second wire is attached to the light bulb holder and the switch. The third wire is attached to the other terminal of the switch and the battery holder.
5. Close the switch. Have you made a circuit? Does the light bulb glow?

Data

Record your observations.

Conclusion

1. In conductors, electrons are loosely bound and therefore easy to move. In insulators, electrons are tightly bound and therefore hard to move. Examine the switch. It is made of plastic and metal.
   Which material is a better conductor?
   Which material is an insulator?
2. Why do you think the copper wire is covered in a plastic coating?

Series Circuits 1

Background

There are many different ways to make circuits. You might want to connect several loads or power sources in one circuit. In a series circuit, the electricity flows through all of the parts of the circuit in one loop. If multiple loads are wired in series, the amount of work each load can do will decrease.

Objective

- Students will be able to describe what happens when loads are wired in series circuits.

Materials

- 3 Battery holders with switches and light sockets
- 1 D Battery
- 3 Light bulbs
- 5 Pieces of wire or alligator clips

Hypothesis

Read the procedure and record your hypothesis.

Procedure

1. Make a simple circuit with one power source, one switch, and one load as shown in Diagram 1. Observe the brightness of Light Bulb 1 when you close the switch.
2. Make a series circuit with one power source, one switch, and two loads, as shown in Diagram 2. Connect the parts in this order: battery to switch; switch to Light Bulb 2; Light Bulb 2 to Light Bulb 1; Light Bulb 1 to battery.
3. When you close the switch, observe how the light bulbs glow. Do they both glow as brightly as one bulb did? Does one bulb glow more brightly than the other?
4. Make a series circuit with one power source, one switch, and three loads, as shown in Diagram 3. Connect the parts in this order: battery to switch; switch to Light Bulb 2; Light Bulb 2 to Light Bulb 3; Light Bulb 3 to Light Bulb 1; Light Bulb 1 to battery.
5. When you close the switch, observe how the light bulbs glow.

Data

Record your observations.

Conclusion

1. What happened to the brightness of the light as you added loads to the circuit, but kept only one battery for the power source?
2. If you unscrew one of the light bulbs in a series circuit, what happens to the circuit? Try it and see. Explain what happens.

Diagram 1

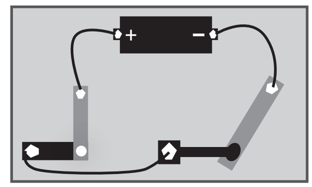


Diagram 2

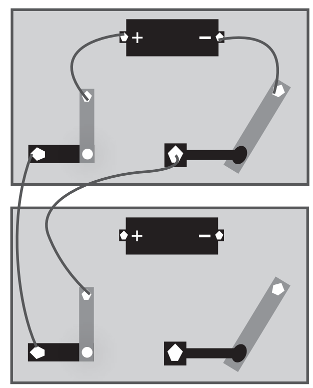
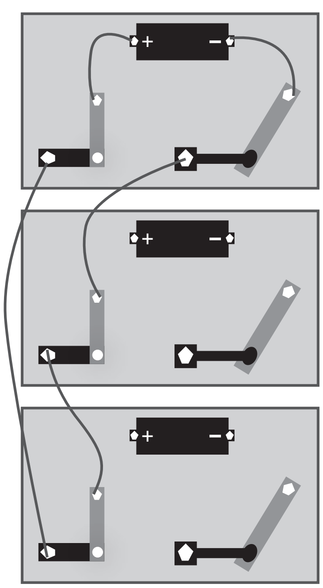


Diagram 3



Series Circuits 2

Background

Adding power sources (batteries) to the series circuit allows for the loads to receive more power. The light bulbs will be brighter with each power source added to the series circuit.

Objective

- Students will be able to describe how series circuits are changed by adding power sources.

Materials

- 3 Battery holders with switches and light sockets
- 3 D Batteries
- 3 Light bulbs
- 7 Pieces of wire or alligator clips

Hypothesis

Read the procedure and record your hypothesis.

Procedure

1. First, close the switch in the circuit you made in Diagram 3 of *Series Circuits 1*. Observe the brightness of the bulbs.
2. Make a series circuit with two power sources, one switch, and three loads, as shown in Diagram 4. Connect the parts in this order: Battery 1 (-) to Battery 2 (+); Battery 2 (-) to Switch 2; Switch 2 to Light Bulb 2; Light Bulb 2 to Light Bulb 3; Light Bulb 3 to Light Bulb 1; Light Bulb 1 to Battery 1 (+). Make sure you connect the negative end of Battery 1 (-) to the positive end of Battery 2 (+).
3. When you close the switch, observe the brightness of the bulbs. Did their brightness change when you added another power source as compared to Diagram 3 of *Series Circuit 1* (step 1 above)?
4. Make a series circuit with three power sources, one switch, and three loads, as shown in Diagram 5. Connect the parts in this order: Battery 1 (-) to Battery 2 (+); Battery 2 (-) to Battery 3 (+); Battery 3 (-) to Switch 3; Switch 3 to Light Bulb 3; Light Bulb 3 to Light Bulb 2; Light Bulb 2 to Light Bulb 1; Light Bulb 1 to Battery 1 (+). Make sure you connect the negative end of one battery to the positive end of the other.
5. When you close the switch, observe the brightness of the bulbs. Did their brightness change when you added another power source?

Diagram 4

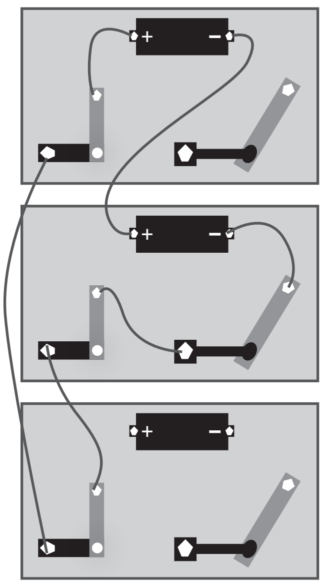
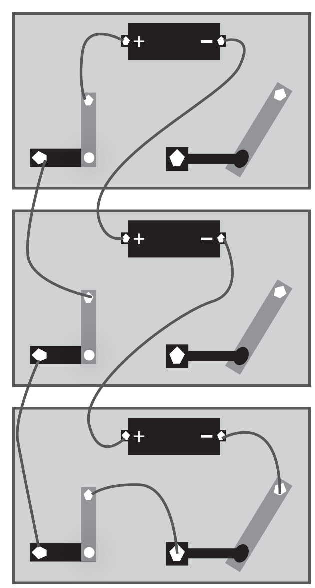


Diagram 5



Data

Record your observations.

Conclusion

1. What happened to the brightness of the light as you added batteries to the circuit?
2. Did adding power sources to the series circuit increase the power to the loads? (power = voltage x current)

Center 6: Circuits 2

1. **Each student should individually record his/her hypothesis and data.**
2. **Work in groups to complete the *Circuits, Parallel Circuits,* and the *Mixed Circuits* explorations.**
3. **Work in groups to answer the questions in the Conclusion sections.**
4. **Each student should individually complete the *Circuit Worksheets 1*, *2*, and *3*.**
5. **The group will put the materials back as they found them and clean up the center.**

Circuits

Background

For electrons to flow through a wire, the wire must make a complete path or circle. This path is called a circuit. A battery produces electricity when it is part of a circuit. You can add a switch to a circuit to open and close the path. You can also add a load to the circuit so that the electricity can do work as it flows through the circuit. A light bulb is an example of a load.

Objective

- Students will be able to make a circuit and identify the power source, the switch, and the load in their circuit.

Materials

- 1 Battery holder with switch and light socket
- 1 D Battery
- 1 Light bulb
- 1 Student compass
- 3 Pieces of wire or alligator clips

Diagram 1

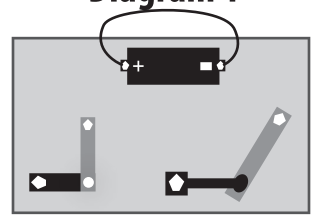
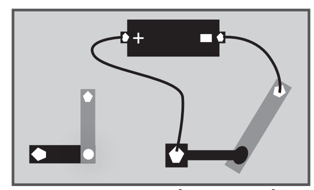
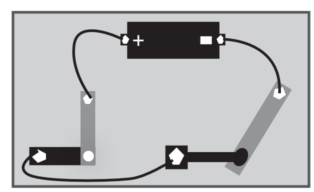


Diagram 2



circuit with switch

Diagram 3



circuit with switch and load

Hypothesis

Read the procedure and record your hypothesis.

Procedure

1. Place the battery in the battery holder. Using one wire, attach the ends of the wire to the terminals on the sides of the battery holder, as shown in Diagram 1. Use the compass to determine if you have completed a circuit. Are there electrons flowing through the wire? Disconnect.
2. Add a switch to the circuit. Unhook one end of the wire from the battery holder and attach it to one of the terminals of the switch, as shown in Diagram 2. Attach a second wire to the other end of the switch and to the other end of the battery holder.
3. Place the compass under one of the wires. Close the circuit by pushing on the switch until it touches the metal under it. Open and close the switch several times, observing the movement of the compass needle.
4. Add a load to the circuit. Attach the light bulb to the circuit as shown in Diagram 3. You will need three wires. One wire is attached to the battery holder and the light bulb holder. The second wire is attached to the light bulb holder and the switch. The third wire is attached to the other terminal of the switch and the battery holder.
5. Close the switch. Have you made a circuit? Does the light bulb glow?

Data

Record your observations.

Conclusion

1. In conductors, electrons are loosely bound and therefore easy to move. In insulators, electrons are tightly bound and therefore hard to move. Examine the switch. It is made of plastic and metal.
   Which material is a better conductor?
   Which material is an insulator?
2. Why do you think the copper wire is covered in a plastic coating?

Parallel Circuits

Background

In series circuits, electricity flows through all parts of the circuit in one loop. In parallel circuits, there are separate circuits within the larger circuit. If there is one power source and more than one load, each of the loads is connected to the power source separately. Part of the power goes to each load.

Objective

- Students will be able to describe what happens when loads are wired in parallel circuits.

Materials

- 3 Battery holders with switches and light sockets
- 1 D Battery
- 9 Pieces of wire or alligator clips
- 3 Light bulbs

Hypothesis

Read the procedure and record your hypothesis.

✔ Procedure

1. First, make a simple circuit as shown in Diagram 1. Observe the brightness of Light Bulb 1 when you open and close the switch.
2. Make a parallel circuit with one power source, two switches, and two loads, as shown in Diagram 2. Leave the first circuit as it is. Make a parallel circuit by connecting Battery 1 (-) with a second wire to Switch 2; Switch 2 to Light Bulb 2; Light Bulb 2 to Battery 1 (+).
3. Close Switch 1 and observe the brightness of the light. Close Switch 2 and do the same. Now close both switches at the same time. Observe the brightness of the light bulbs.
4. Make a parallel circuit with one power source, three switches, and three loads, as shown in Diagram 3. Leave the first two circuits as they are. Make a parallel circuit by connecting Battery 1 (-) with a third wire to Switch 3; Switch 3 to Light Bulb 3; Light Bulb 3 to Battery 1 (+).
5. Close Switch 1 and observe the brightness of the light. Close Switches 1 and 2 and do the same. Now close all three switches at the same time. Observe the brightness of the light bulbs.

Diagram 1

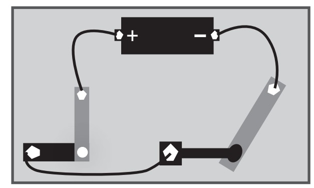


Diagram 2

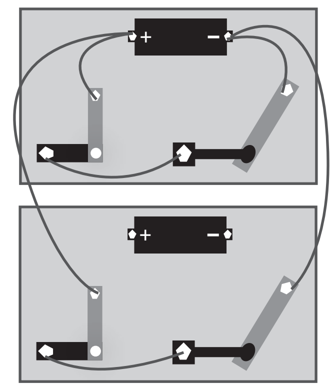
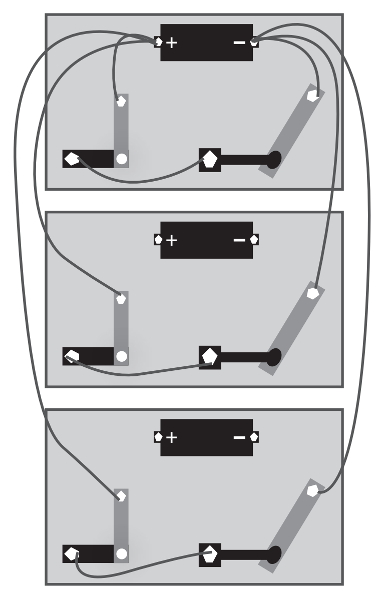


Diagram 3



Data

Record your observations.

Conclusion

1. If one of the light bulbs is unscrewed, will the other bulbs glow? Try it and see. Explain your observations.
2. Do you think the battery would last as long with three circuits as with one?

Mixed Circuits

Background

A mixed circuit contains circuits that have both series and parallel connections. The power sources are wired in series circuits and the loads in parallel circuits.

Objective

- Students will be able to describe the difference between series and parallel circuits.

Materials

- 3 Battery holders with switches and light sockets
- 3 D Batteries
- 12 Pieces of wire or alligator clips
- 3 Light bulbs
- Colored pencils

Hypothesis

Read the procedure and record your hypothesis.

Procedure

1. Make a mixed circuit with two batteries in series and two bulbs in parallel, as shown in Diagram 1. Connect the negative end of Battery 1 to the positive end of Battery 2. Connect the positive end of Battery 1 to both light bulbs. Connect the negative end of Battery 2 to Switch 2. Connect the other end of Switch 2 to both light bulbs at the unused connection point. Do not connect anything to Switch 1.
2. Close Switch 2 and observe the brightness of the bulbs. Unscrew one of the bulbs and observe the brightness of the remaining bulb.
3. Make a mixed circuit by connecting three batteries in series and three bulbs in parallel, as shown in Diagram 2. Connect the positive end of Battery 3 to the negative end of Battery 2, and the positive end of Battery 2 to the negative end of Battery 1. Connect the positive end of Battery 1 to Switch 1. Connect the other end of switch 1 to all three bulbs. Connect the unused connections of all three bulbs to Switch 3. Connect the negative end of Battery 3 to the unused end of Switch 3. Switch 2 will not be used. Close only Switch 3, leaving switch 1 open. Observe.
4. Close Switch 1 and observe the brightness of the bulbs. Unscrew one bulb and observe the brightness of the other two bulbs. Unscrew one of the remaining bulbs and observe the last bulb's brightness.

Diagram 1

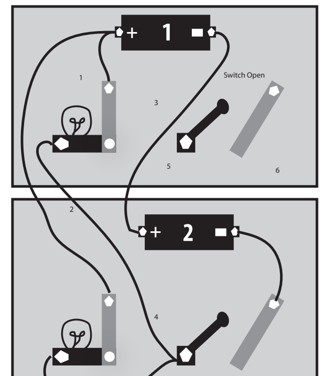
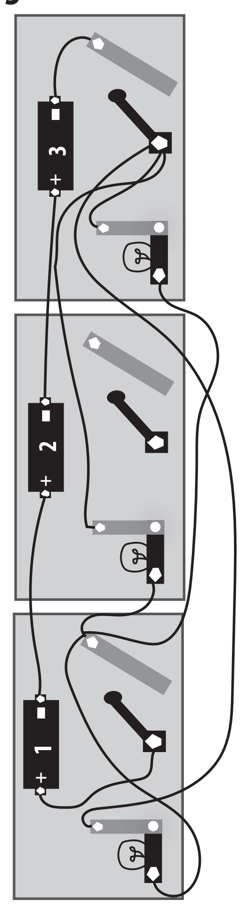


Diagram 2



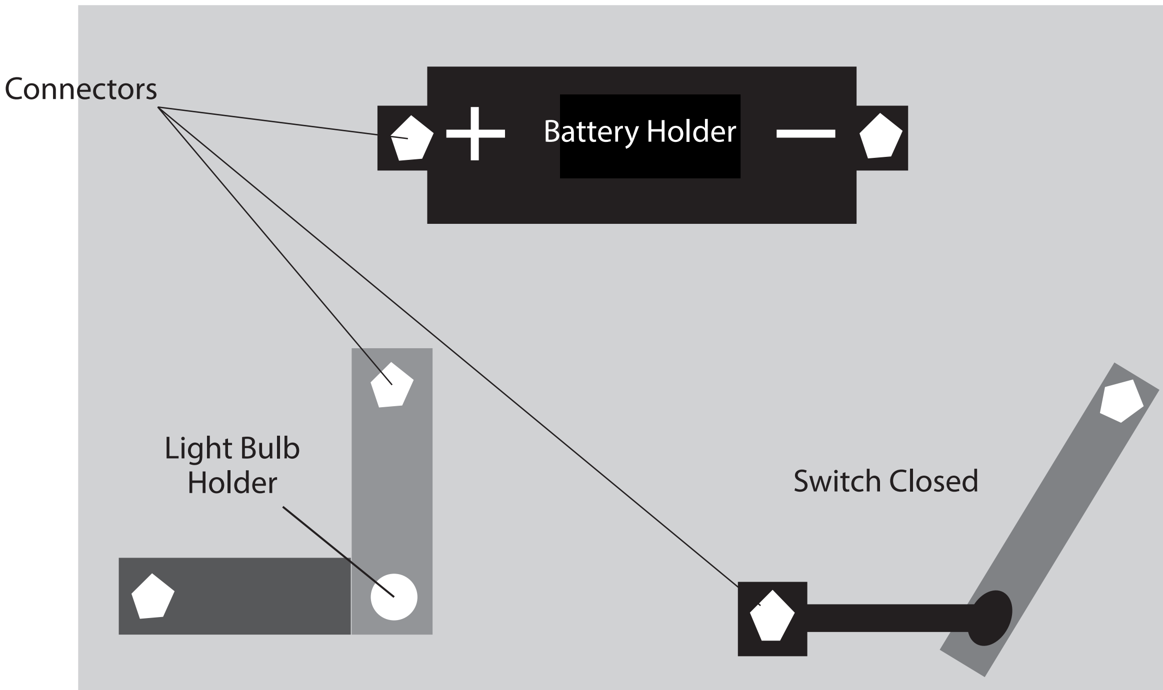
Data

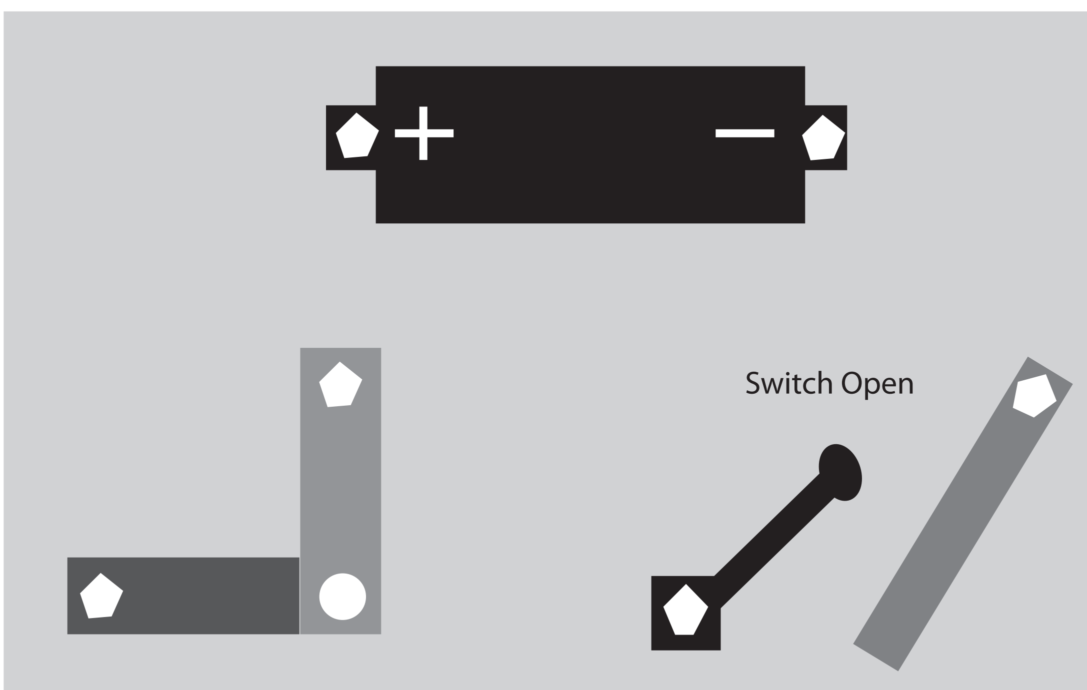
Record your observations.

Conclusion

1. Could you tell that the power from the batteries was divided in the parallel circuits? What experimental evidence supports your answer?
2. If you wanted a string of lights to keep working if one of the bulbs burned out, would you wire the lights in series or parallel? Why?

Circuits Master





Key Words Answer Keys

Electricity

1. element
2. nucleus
3. battery
4. north pole
5. neutrons
6. attract
7. load
8. electricity
9. electrical charges
10. outer energy level
11. static electricity
12. protons
13. south pole
14. repel
15. turbine
16. electrons
17. circuit
18. generator
19. atoms
20. magnet

Measuring Electricity

1. resistance
2. watts
3. current
4. Ohm's Law
5. amperes
6. resistor
7. watt-hours
8. voltage
9. load
10. power
11. ohms
12. pressure
13. volts
14. current
15. voltage
16. power
17. electrical energy
18. current
19. load

Atomic Structure Answer Key

Below is a model of an atom of magnesium (Mg). Magnesium is a silvery white metal that has 12 protons, 12 electrons, and 12 neutrons in its most stable isotope. Number the words on the left with the correct part of the atom in the diagram.

proton **2**

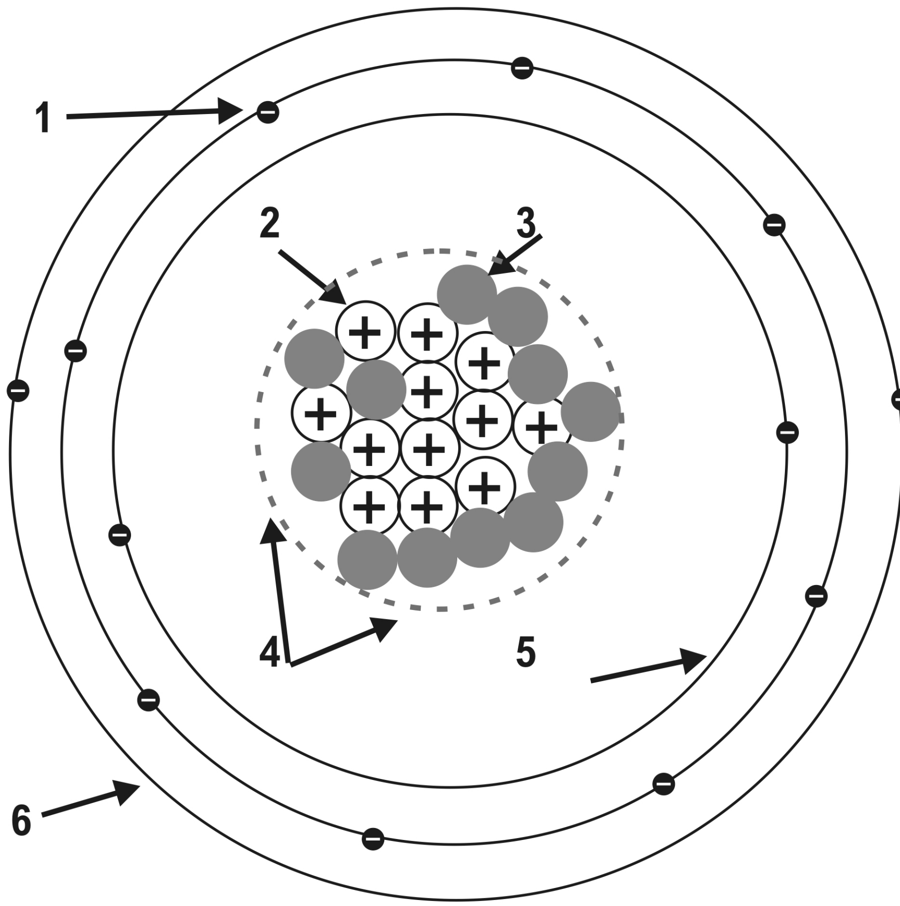
electron **1**

neutron **3**

inner energy level **5**

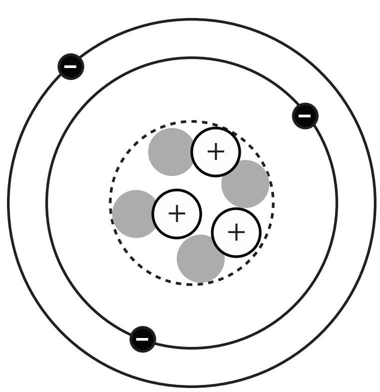
nucleus **4**

outer energy level **6**

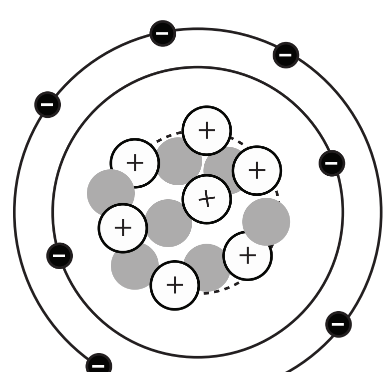


Magnesium–24

Draw the protons, neutrons, and electrons on the atoms below. Be sure to put the electrons in the correct energy levels. Lithium has three protons and four neutrons. Nitrogen has seven protons and seven neutrons.



Lithium–7

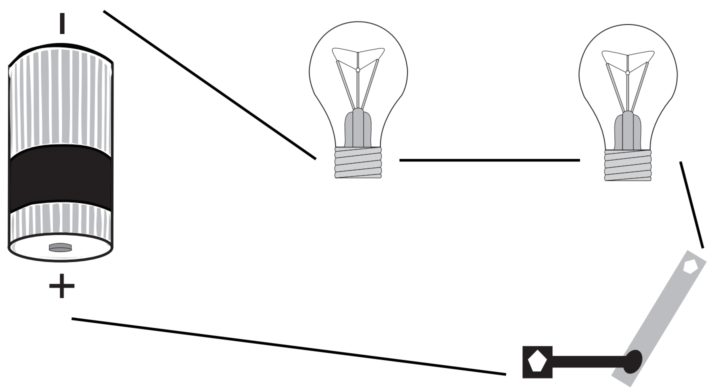


Nitrogen–14

Circuits Answer Keys

Circuit Worksheet 1

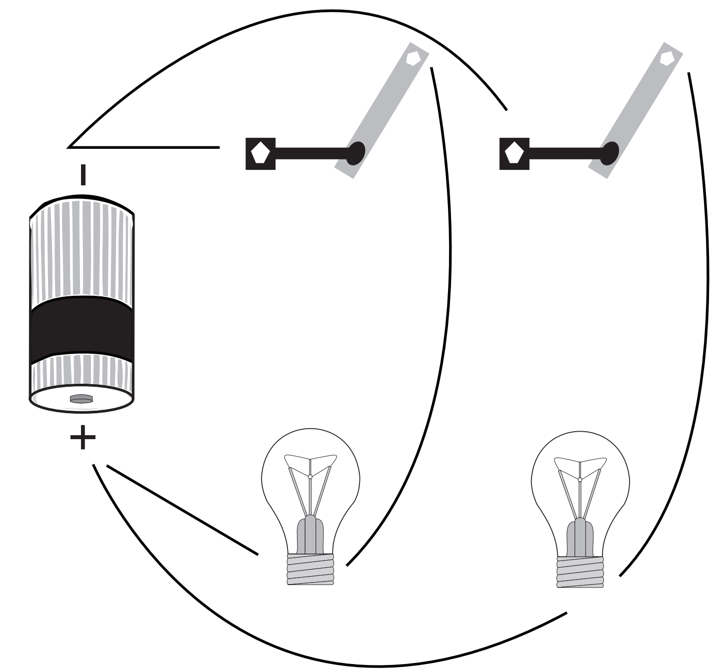
Instructions: Draw wires between all of the parts below to make a series circuit. Use different colored pencils to draw the different wires.*



*Notes: Any connection is valid as long as only one pathway for electricity exists.

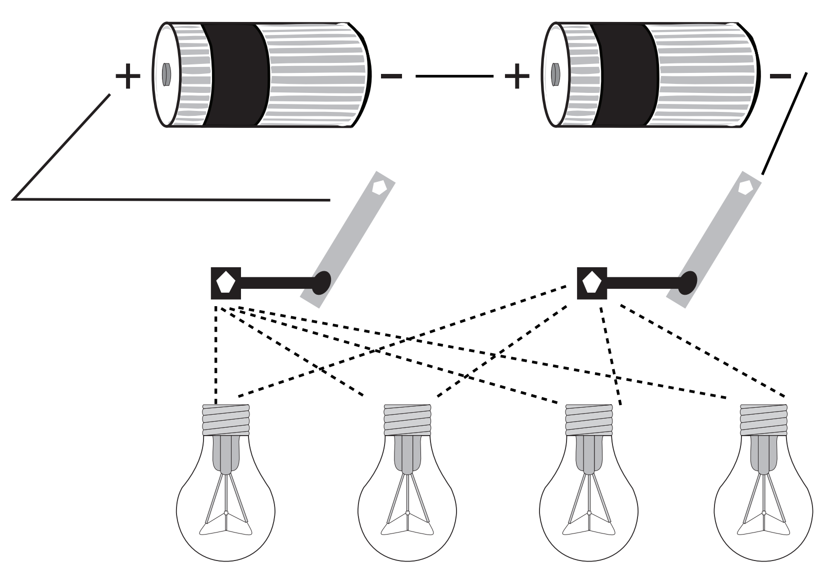
Circuit Worksheet 2

Instructions: Draw wires between all of the parts below to make parallel circuits. Use different colored pencils to draw the different wires.



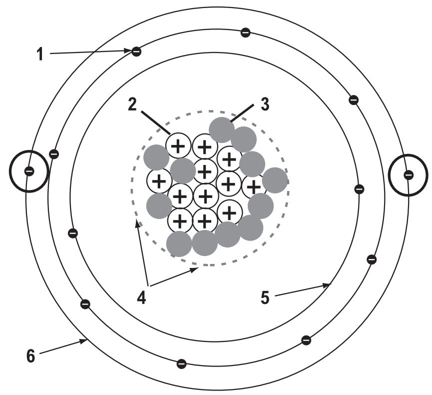
Circuit Worksheet 3

Instructions: Draw wires with different colored pencils to connect the batteries in series and the lights in parallel circuits.



Review Answer Key

1. Identify this atom, which has 12 protons, 12 electrons, and 12 neutrons. Circle the electrons that are loosely held and write numbers to identify the following parts of the atom:



What is this atom? Magnesium

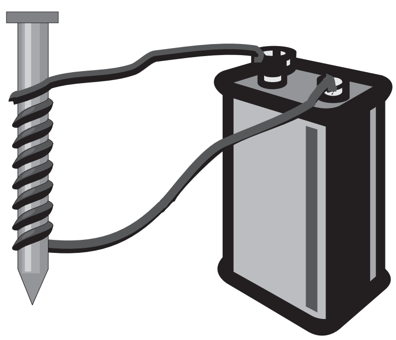
electron	1
neutron	3
proton	2
nucleus	4
outer energy level	6
inner energy level	5

2. Circle the correct answer for each set of magnets below.

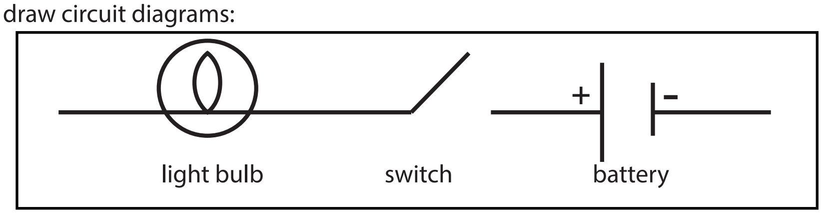
attract or repel

attract or repel

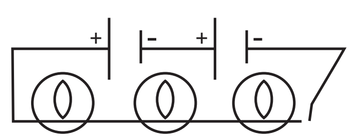
3. Explain what the device pictured below does. ***It is an electromagnet—behaves like a magnet.***



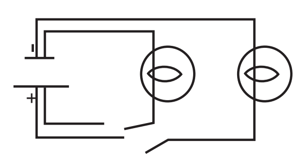
Use these symbols to draw circuit diagrams:



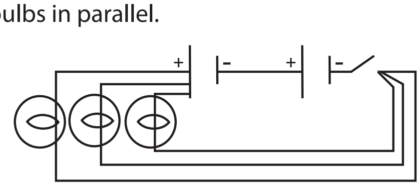
4. Draw a series circuit with two batteries, one switch, and three light bulbs.



5. Draw a parallel circuit with a battery, two switches, and two light bulbs.



6. Draw a circuit with two batteries and one switch in series, and three light bulbs in parallel.



Sample Electricity Calculations Answer Key

Example 1: Calculating Voltage

If household current is 6 amps and the resistance of an appliance is 20 ohms, calculate the voltage.
To solve for voltage, use the following equation: voltage = current x resistance (V = I x R).

Voltage = 6 A x 20 Ω
V = 6 A x 20 Ω = 120 V

Example 2: Calculating Current

The voltage of most residential circuits is 120 V. If we turn on a lamp with a resistance of 60 ohms, what current would be required?
To solve for current, use the following equation: current = voltage / resistance (I = V / R).

Current = 120 V / 60 Ω
I = 120 V / 60 Ω = 2 A

Example 3: Calculating Resistance

A car has a 12-volt battery. If the car radio requires 0.5 amps of current, what is the resistance of the radio?
To solve for resistance, use the following equation: resistance = voltage / current (R = V / I).

Resistance = V / A
R = 12 V / 0.5 A = 24 Ω

Example 4: Calculating Power

If a 6 V battery pushes 2 A of current through a light bulb, how much power does the light bulb require?
To solve for power, use the following equation: power = voltage x current (P = V x I).

Power = V x A
P = 6 V x 2 A = 12 W

Example 5: Calculating Voltage

If a 3 A blender uses 360 W of power, what is the voltage from the outlet?
To solve for voltage, use the following equation: voltage = power / current (V = P / I).

Voltage = W / A
V = 360 W / 3 A = 120 V

Example 6: Calculating Current

If a refrigerator uses power at a rate of 600 W when connected to a 120 V outlet, how much current is required to operate the refrigerator?
To solve for current, use the following equation: current = power / voltage (I = P / V).

Current = W / V
I = 600 W / 120 V = 5 A

Example 7: Calculating Electrical Energy and Cost

If a refrigerator uses power at a rate of 600 W for 24 hours, how much electrical energy does it use?
To solve for electrical energy, use the following equation: electrical energy = power x time (EE = P x t).

Electrical Energy = W x t
EE = 600 W x 24 h = 14,400 Wh/1000
14,400 Wh/1000 = 14.4 kWh

If the utility charges $0.12 a kilowatt-hour, how much does it cost to run the refrigerator for 24 hours?
To calculate cost, use the following equation: cost = electrical energy x price.

Cost = 14.4 kWh x $0.12/kWh = $1.73

Measuring Electricity Answer Key

TABLE 1

VOLTAGE	=	CURRENT	X	RESISTANCE
1.5 V	=	**0.5 A**	x	3 Ω
12 V	=	3 A	x	4 Ω
120 V	=	4 A	x	**30 Ω**
240 V	=	**20 A**	x	12 Ω

TABLE 2

POWER	=	VOLTAGE	X	CURRENT
27 W	=	9 V	x	**3 A**
180 W	=	120 V	x	1.5 A
45 W	=	**15 V**	x	3 A
240 W	=	120 V	x	2 A

TABLE 3

APPLIANCE		POWER	=	VOLTAGE	X	CURRENT
TV		180 W	=	120 V	x	**1.5 A**
COMPUTER		40 W	=	120 V	x	**0.33 A**
PRINTER		120 W	=	120 V	x	**1 A**
HAIR DRYER		1,000 W	=	120 V	x	**8.33 A**

TABLE 4

POWER	x	TIME	=	ELECTRICAL ENERGY (kWh)	X	PRICE	=	COST
5 kW	x	100 h	=	**500 kWh**	x	$ 0.12	=	**$ 60.00**
25 kW	x	4 h	=	**100 kWh**	x	$ 0.12	=	**$12.00**
1,000 W	x	1 h	=	**1,000 Wh = 1 kWh**	x	$ 0.12	=	**$ 0.12**

Youth Awards for Energy Achievement

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

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

What's involved?

Students and teachers set goals and objectives, and keep a record of their activities. If students like, they can combine their planning materials and activities into a binder or portfolio that highlights their goals, outreach opportunities, and their evaluation of the activities. Students will then use this binder or portfolio to help them create a digital project to submit for judging. In April, digital projects should be uploaded to the online submission site.

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

ElectroWorks
Evaluation Form

State: ____________ Grade Level: ____________ Number of Students: ___________

1. Did you conduct the entire unit?	❑ Yes	❑ No
2. Were the instructions clear and easy to follow?	❑ Yes	❑ No
3. Did the activities meet your academic objectives?	❑ Yes	❑ No
4. Were the activities age appropriate?	❑ Yes	❑ No
5. Were the allotted times sufficient to conduct the activities?	❑ Yes	❑ No
6. Were the activities easy to use?	❑ Yes	❑ No
7. Was the preparation required acceptable for the activities?	❑ Yes	❑ No
8. Were the students interested and motivated?	❑ Yes	❑ No
9. Was the energy knowledge content age appropriate?	❑ Yes	❑ No
10. Would you teach this unit again?	❑ Yes	❑ No

Please explain any 'no' statement below.

How would you rate the unit overall?	❑ excellent	❑ good	❑ fair	❑ poor
How would your students rate the unit overall?	❑ excellent	❑ good	❑ fair	❑ poor

What would make the unit more useful to you?

Other Comments:

Please fax or mail to: **The NEED Project**
P.O. Box 10101
Manassas, VA 20108
FAX: 1-800-847-1820

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