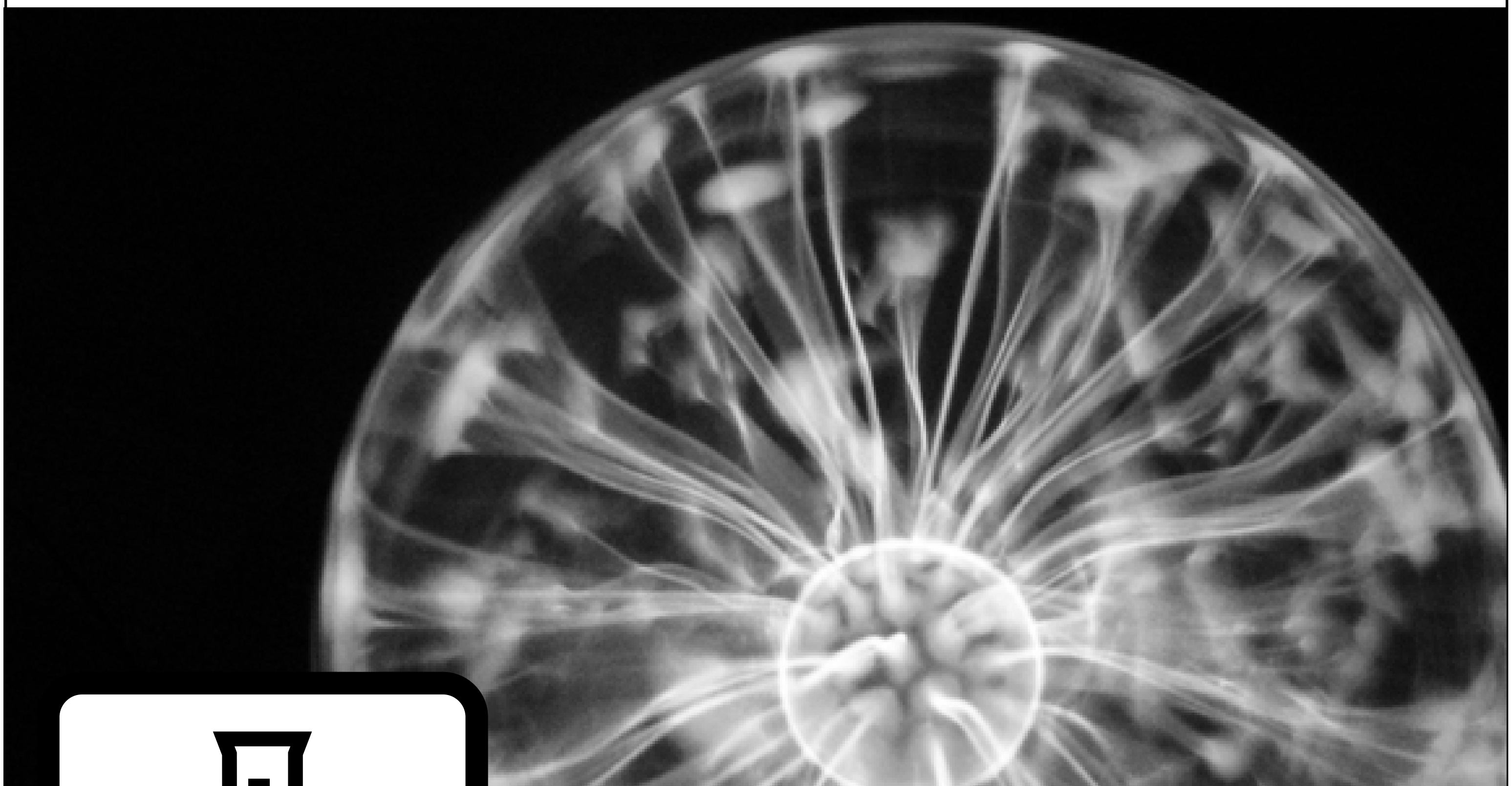
2019-2020

Secondary Science of Energy

Hands-on experiments and background information that allow students to explore the forms of energy and how they are transformed. Students master the various forms and their transformations, and then teach others what they have learned and how it can be visualized



Grade Level:

Sec Secondary

Subject Areas:

Science

Math

Language Arts

Public Speaking

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.

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Teacher Advisory Board

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

Energy Data Used in NEED Materials

NEED believes in providing teachers and students with the most recently reported, available, and accurate energy data. Most statistics and data contained within this guide are derived from the U.S. Energy Information Administration. Data is compiled and updated annually where available. Where annual updates are not available, the most current, complete data year available at the time of updates is accessed and printed in NEED materials. To further research energy data, visit the EIA website at www.eia.gov.

NEED
National Energy
Education Development

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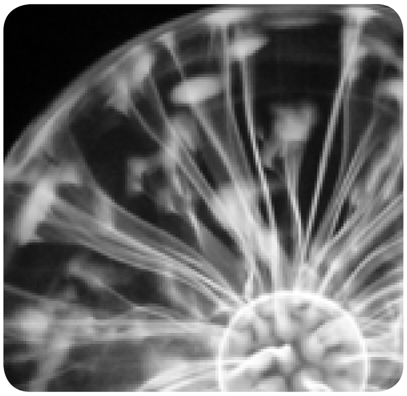

Secondary Science of Energy

Table of Contents

Secondary Science of Energy Kit

- 1 Secondary Science of Energy Guide (Grades 9-12)
- 1 9 -Volt Battery
- 2 Sets of alligator clips
- 10 Balloons
- 1 Battery holder
- 1 Bi-metal bar
- 1 Empty bottle (for vinegar)
- 1 Candle
- 1 Coated copper wire
- 1 Compass
- 1 Container of baking soda
- 1 Container of calcium chloride
- 2 Containers of sand (one full, one partially full)
- 1 Sealed plastic bag of iron oxide
- 2 Thick copper wires
- 1 Thin copper wire
- 1 D Battery
- 16 Hand warmers
- 8 Glow sticks
- 3 15 mL Measuring cups
- 1 Measuring tape
- 1 DC Microammeter
- 3 Motors (one disassembled)
- 1 Hand generated flashlight
- 6 Plastic bags
- 1 Radiometer
- 30 Rubber bands
- 1 Set of happy/sad spheres
- 1 Solar panel kit
- 1 Superball
- 3 Thermometers (metal)
- 4 Student thermometers (plastic)
- 1 Tin wire
- 2 Tongs
- 1 Toy car
- 2 Live wires (nitinol)
- 1 Yo-yo
- 2 Large nails
- 2 Small nails

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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 website.

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 website.

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 website.

Materials

STATION	MATERIALS IN KIT	ADDITIONAL MATERIALS NEEDED
Teacher Demo	▪2 Containers of sand ▪Thermometers (metal) ▪Hand generated flashlight	▪Safety glasses
Station One	▪Set of happy/sad spheres ▪Superball ▪Yo-yo ▪Toy car ▪Balloons ▪Measuring tape	▪Balance ▪Meter stick (optional) ▪Scissors ▪Drinking straw ▪String ▪Tape ▪Safety glasses
Station Two	▪Container of baking soda ▪Empty plastic bags ▪Thermometers (metal) ▪15 mL Measuring cups ▪Hand warmers ▪Sealed plastic bag of iron oxide ▪Container of calcium chloride ▪Empty bottle for vinegar	▪Balance ▪Scissors ▪Vinegar ▪Water ▪Safety glasses ▪50 mL Graduated cylinder
Station Three	▪Radiometer ▪Thermometers (plastic) ▪Solar panel with motor and fan blade	▪Tape ▪Piece of cardboard ▪Light source (bright sunlight, clamp light with halogen or incandescent bulb) ▪Protractor ▪C Battery ▪Black and white paper ▪Safety glasses ▪Stopwatch ▪Digital multimeter ▪Alligator clips ▪Meter stick
Station Four	▪Live wire ▪Bi-metal bar ▪Candle ▪Rubber bands ▪Tongs	▪Cup of hot water ▪Cup of ice water ▪Matches ▪4 Pieces of metal hanger (8” each) ▪Safety glasses
Station Five	▪Glow sticks ▪Small nail ▪Large nail ▪Thin copper wires ▪Thick copper wires ▪Tin wire ▪DC microammeter ▪Alligator clips	▪Cup of ice water ▪Cup of warm water ▪Apple ▪Metric ruler ▪Permanent marker ▪Safety glasses
Station Six	▪Hand generated flashlight from Teacher Demo ▪Motors (1 disassembled, 2 assembled) ▪9-volt Battery ▪Compass ▪Alligator clips ▪Battery holder ▪Large nail	▪Tape ▪Safety glasses

***Secondary Science of Energy* kits and additional consumable materials are available for purchase by calling 1-800-875-5029 or visit www.NEED.org for more information.**

Teacher Guide

Important Safety Notes

- All students should wear safety glasses while at any *Secondary Science of Energy* station.
- This kit contains latex balloons and rubber bands. Check to see if any of your students have latex allergies. If they do, the items should be removed from their stations.
- Station One, Four, and Five require hot water. Review with students proper procedures for handling hot water safely.
- The live wire in Station Four may spring out of the cup. Students should not peer directly over the demonstration, and should handle the live wire with tongs. Giving the students a clear glass or beaker to use in this demonstration may keep them from wanting to look directly over the cup.
- Thermometers in this kit do not contain mercury. These thermometers are made with alcohol spirits and are safe for classroom use. Should they break during the course of this unit, you can dispose of the thermometer and parts as you would anything else in your classroom.
- Hand out *Lab Safety Rules* and review with students prior to any investigation.

Background

The *Secondary Science of Energy* unit includes a teacher demonstration and six lab stations. Students are divided into six (or more, if needed) groups, with each group responsible for learning and teaching the other groups about the experiments in their assigned station. Instructions, guides, masters, and explanatory articles are provided for the teacher and students. Throughout this unit, students are encouraged to record their thinking in science notebooks.

Time

Secondary Science of Energy is designed to take as few as six class sessions of 45-60 minutes each. Teachers may choose to expand the time if their schedules allow.

DAY 1	DAYS 2-3	DAY 4	DAY 5	DAY 6
Introduction to Energy and Teacher Demonstration	Station Investigations	Present and Rotate	Present and Rotate	Energy Sources and Transformations

Possible Extended Schedule

DAY 1	DAYS 2-3	DAYS 4-5	DAYS 7	DAYS 8+
Introduction to Energy and Teacher Demonstration	Station Investigations and Plan Presentations	Present and Rotate	Energy Sources and Transformations	Science of Energy Extensions

Objectives

Upon completion of the *Secondary Science of Energy* unit, students will be able to:

- explain the main things energy enables us to do;
- differentiate between forms and sources of energy;
- describe how energy is stored in the major energy sources;
- list the forms of energy and give examples;
- explain energy transformations; and
- trace the energy flow of a system.

Unit Preparation

- Familiarize yourself with the equipment in the kit and procure the materials listed in the *Additional Materials Needed* section of the chart on page 5. Remove any materials not needed as the kit boxes may contain items used in the other *Science of Energy* units.

Science Notebooks

This unit refers to students using science notebooks to record their questions, hypotheses, data, observations, and conclusions as they work through each station. If your class does not already use science notebooks, there are templates on pages 26-27. Make enough copies of each page so that students have enough room to record observations at each of the six stations. These pages can be hole punched and placed in three-ring binders or bound with covers made from construction paper or card stock.

***NOTE:* For more information about energy, see the *Secondary Energy Infobook* available for download from www.NEED.org/energyinfobooks, or shop.NEED.org.**

Vocabulary

Listed below are terms in the *Secondary Science of Energy* unit that students will learn while going through each station. A glossary for the terms can be found on pages 83-84.

- absorb
- alternating current
- ampule
- atom
- catalyst
- Celsius
- chemical energy
- chemical reaction
- collision
- compress
- conduct
- contract
- conversion
- convert
- current
- direct current
- dissipate
- elastic energy
- electrical energy
- electricity
- electrode
- electrolyte
- electromagnet
- endothermic
- energy
- energy flow
- exothermic
- expand
- extrapolate
- Fahrenheit
- fission
- friction
- fusion
- generator
- gravitational potential energy
- heat
- hypothesis
- iron oxide
- kilowatt-hour
- kinetic energy
- Law of Conservation of Energy
- magnetic field
- mass
- molecular
- molecule
- neutralization
- nonrenewable
- nuclear energy
- oxidation
- phosphor
- photovoltaic cell
- potential energy
- prediction
- product
- radiant energy
- reactant
- reaction
- rebound
- reduction
- reflect
- renewable
- repel
- retention
- silicon
- surroundings
- system
- temperature
- thermal energy
- titanium
- transform
- transformation
- turbine
- vacuum

Activity One: Teacher Demonstration

Objective

- Students will be able to explain why shaking containers of sand causes the temperature of the sand to increase.

Materials

- 2 Containers of sand (one full, one approximately one-third full)
- 2 Thermometers
- *Thermometer* master, page 29
- *Fahrenheit/Celsius Conversion* master, page 30

Vocabulary

- Celsius
- convert
- energy
- Fahrenheit
- friction
- motion energy
- thermal energy

Preparation

- Create digital copies or make copies of the masters for projection.

NOTE: For this activity, it may make sense to collect data using degrees Fahrenheit. The degree increments are smaller on the Fahrenheit scale, and thus, may yield a more noticeable change in temperature for this actvity.

✔Procedure

1. Place the open containers of sand on a table to allow the temperature of the sand to stabilize.
2. Use the *Thermometer* master to review proper protocol for reading a thermometer, if necessary. Discuss or review how to convert Fahrenheit to Celsius and Celsius to Fahrenheit using the *Fahrenheit/Celsius Conversion* master.
3. Place one thermometer in each container. Compare the temperature reading of the two thermometers. Students should record the results in their science notebooks.
4. Ask students, "If we shake both of these containers in the same way, what will happen to the temperature of the sand? Will the temperatures of the sand in both containers be the same or different? If they will be different, which one will increase more?" Have students write one of three choices (same, full container greater, partially-full container greater) in their science notebooks.
5. Place the lids on each container tightly.
6. Introduce the activity to the students. Explain and model the shaking of the containers of sand. Each student should shake both containers ten times at the same time, one in his/her right hand and one in his/her left hand, then pass the containers to the next student. Discuss variables you might try to control.
7. While students are shaking the containers, ask them what they already think they know about energy. You may want to record their responses on the board. Ask students to name some moving objects and what sources of energy move them. If needed, prompt your students by asking, what moves a car? What moves a ball through the air? Explain that there are five main things energy helps us do: make things move, make things warm up, make light, make technology work (run electrical devices), and make things grow. Have students record these in their science notebooks and come up with examples of each.

CONTINUED ON NEXT PAGE

8. When all the students have shaken the containers, open the containers and place a thermometer in each. Have two students read the thermometers and record the results on the board. Everyone should record the results in their science notebooks. Discuss the difference and why students think the temperatures changed the way they did.
9. Review the results of the sand investigation. Ask the class if anyone made a correct prediction. Ask, "Based on the evidence presented in this demonstration, will you accept or reject your hypothesis? Record your answer in your notebook, and cite the evidence to support your conclusion." Use the information under *What Was Happening?* below to explain to students what was happening in the containers.

What Was Happening?

The energy we use is stored in different forms. Energy does not disappear, it just changes forms. This is the Law of Conservation of Energy. This law states that energy is neither created nor destroyed, and that the amount of energy in the universe remains constant.

There are two containers of sand, one filled about one-third of the way and the other filled to the top. Since they have been in the same environment, they should be the same temperature.

After each student has shaken the containers, the temperature was recorded. You should have seen a two to five degree Celsius increase with the less full container, and a smaller increase in the full container. The difference will be more apparent on the Fahrenheit scale since the increments are smaller on the Fahrenheit scale. A five-degree difference in Celsius equals a nine-degree difference in Fahrenheit.

Shaking the container, we moved the grains of sand, causing them to collide with each other. They rubbed against each other, causing friction between the particles and producing thermal energy. We transformed motion energy into thermal energy.

The increase in temperature was greater for the container that was only one-third full, because the partially full container has more space in it for the sand to move around. The grains of sand collide with each other with greater velocity. More velocity means more kinetic energy. In the container filled with sand, the grains of sand have little space to move. Temperature is a measure of the average kinetic energy of a substance. Since a similar amount of kinetic energy was transferred to the two containers of sand, the amount of energy transferred to each particle, on average, was higher in the container with less sand (fewer particles). There is more mass in the full container over which to spread the energy transferred. More energy must be transferred to a greater mass to cause the same temperature increase. Thermal energy is a result during most energy transformations.

Activity Two: Forms of Energy

Objective

- Students will be able to describe the forms of energy and give examples of each.

Materials

- *Forms of Energy* master, page 31

Preparation

- Create a digital copy of the master for projection, or prepare enough copies to distribute one to each student.

Vocabulary

- chemical energy
- elastic energy
- electrical energy
- gravitational potential energy
- kinetic energy
- molecule
- nuclear energy
- potential energy
- radiant energy
- thermal energy

✔Procedure

1. Introduce the concepts of potential and kinetic energy, explaining that potential energy is stored energy, and kinetic energy is energy of motion.
2. Introduce each form of energy to students and, if desired, have students highlight the *Forms of Energy* master in three different colors: one for the term; one for the definition; and one for an example. Substitute alternative names of each energy form in your discussion and convey to students that various educational texts and papers may substitute these terms depending on the context.
3. If time allows, student groups of 2-3 may be assigned one form of energy and asked to prepare a digital presentation about the energy form including its appropriate technical name, the definition, a source of the energy form, and a website and/or pictures illustrating or explaining the form.
4. Forms of energy can be introduced by creating a carousel of the forms, with students writing what they know about each form, adding to it after the lesson, and citing the source of the information.

Activity Three: Station Investigations

Vocabulary

See Individual Station Guides

Objectives

- Objectives vary by station; students will be able to identify the forms of energy at various stages of a transformation, and explain what is happening within each.

Materials

- Station materials
- *Lab Safety Rules*, page 32
- *Units and Formulas* master, page 33
- *Station Presentation Planning Guide*, page 28 (optional)
- Safety glasses for each student
- Copies of *Station Guides* and *What Was Happening?* articles for each station

	STATION 1	STATION 2	STATION 3	STATION 4	STATION 5	STATION 6
Station Guide	36-42	45-49	54-58	61-63	66-68	71-72
What Was Happening?	43-44	50-53	59-60	64-65	69-70	73-74

Preparation

- Two different rotation schemes have been provided for your students to follow (see page 10). Decide which works best for your time constraints and group of students, or modify one of the schemes to best suit your needs.
- Organize your classroom into six stations. Station Three needs to be located near an electrical outlet. Make hot water accessible for those stations requiring it.
- Copy the *Station Guides* for each student assigned to that station.
- Make a copy of the *Units and Formulas* handout for each student.
- Make copies of each *What Was Happening?* article for each station. Do not pass these out until students are done with their learning-to-teach investigation.
- Read the specific notes regarding some of the stations, as you may want to go deeper into some of the content of the station depending upon your classroom content standards.
- Answer keys for the station investigations are provided on pages 18-24. These answer keys are simply provided as a reference. Students may reflect upon data and observations that are not suggested within the answers, but still accurate based on their use of the materials. It is suggested that teachers have a good familiarity with the stations for this purpose.

Important Information About Select Stations:

- **Station Two:** We suggest that you keep the contents of a hand warmer from this station exposed to the air for a week, and have the students periodically make observations about its appearance.
- **Station Three:** The proper way to measure voltage is across a load, and the proper way to measure current is through a load. As such, the most precise way to measure these is to do so simultaneously with two meters, as shown in NEED's *Exploring Photovoltaics* Student Guide, Solar 1 Activity. To keep the Station Three activity simple, however, students can get enough of a sense as to how power is affected by the angle of incidence of the sunlight as it strikes the PV panel by attaching one meter to the panel and switching from voltage to current. If you wish to use two meters to measure, download the *Exploring Photovoltaics* guide from shop.NEED.org for an example of how to set up the meters.

  When conducting radiant energy transformation activities, it is suggested that teachers attempt to use incandescent bulbs as available. Newer bulbs, like LEDs, will not produce enough thermal energy in a short time to produce the desired experimental results. Traditional incandescent, or energy saving halogen incandescent bulbs, are your best bet. However, a halogen incandescent bulb will not work as well with the PV cell in this station. The light from the halogen bulbs is of a slightly different wavelength. This wavelength of light will still operate the PV cell, but the cell itself may need to be held very closely to the bulb. Use caution in this case, so as to not melt the plastic. Sunlight and traditional incandescent bulbs will provide the best results for these activities.
- **Station Four:** The content of this station is much less complex than the other stations. If you are differentiating instruction, this is a good station for students who need simpler material to master.

CONTINUED ON NEXT PAGE

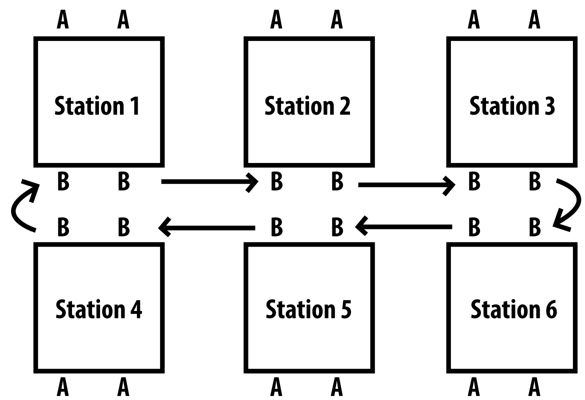
- **Station Five:** This station can be used to introduce half-cell potential to students, and is an excellent tie-in between energy and chemistry content standards.
- **Station Six:** This station requires the use of the hand generated flashlight from the teacher demonstration box.

Notes About Differentiating Instruction:

If more stations are needed to use with larger classes, several stations can be broken into parts. This can help those with pacing difficulties. Also, some stations, such as Station Four, are less challenging in content. Familiarize yourself with stations and assign stations to meet your students' needs.

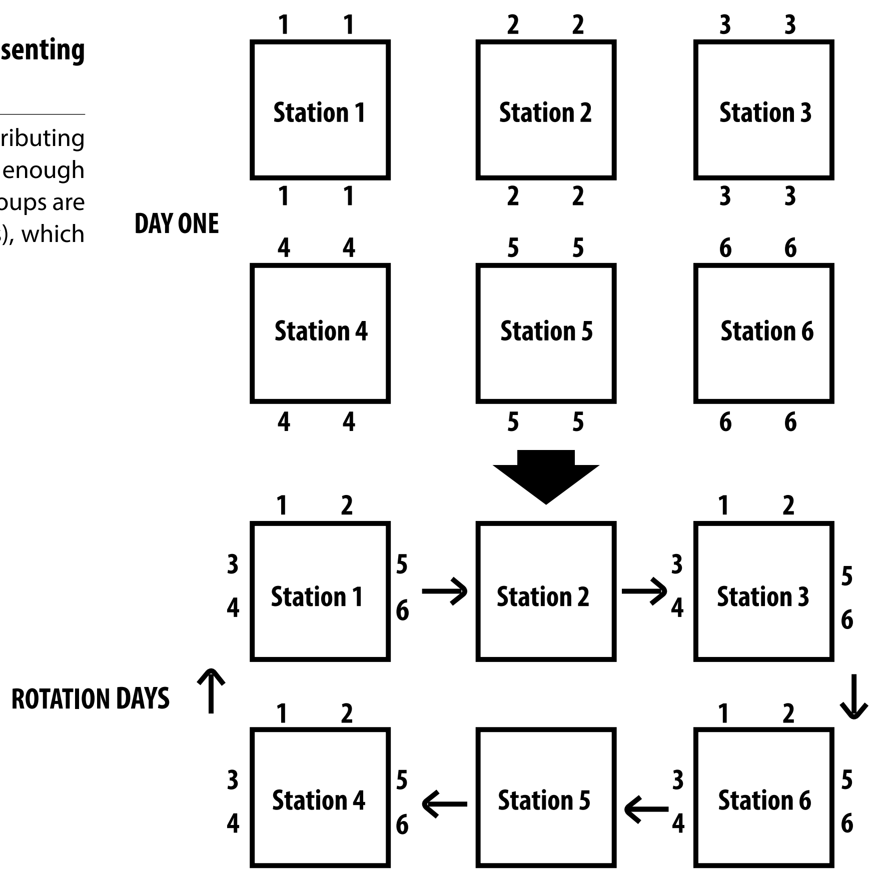
Rotation Scheme A/B (more time, students presenting in working pairs)

Students are assigned in groups of four; two of these students are "A" students, and two are "B" students. All four learn their stations well enough to guide the rest of the class. On the first set of rotations, the A students remain with their stations while the B students rotate. On the second set, the B students remain with their stations while the A students rotate.



Rotation Scheme Jigsaw (less time, students presenting individually)

Students are assigned to each of the six stations, distributing them as equally as possible, to learn their stations well enough to guide the rest of the class. On rotation days, new groups are formed, one from each station (groups of six students), which then rotate through the stations.



***IMPORTANT NOTE:** Regardless of the rotation scheme selected, the order of rotations will not matter or affect student learning, as all stations are independent of each other.

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✔ Procedure

1. Explain to students that over the next few days they will be investigating energy transformations in a variety of different systems. Each group will be assigned to a station. Everyone in the group is responsible for learning how to conduct and explain the energy transformations taking place at their station. On the first day, everyone will focus on learning their station. Once all groups have learned their stations they will split up to teach others what they learned.
2. Review the *Lab Safety Rules* with the class.
3. Assign students to their groups and give them the appropriate Station Guides. Students should read through the guides and write their hypotheses in their science notebooks.
4. Once everyone has written their hypotheses, give the groups their materials and let them start investigating. Remind students that they should be recording all observations and data in their science notebooks. Students should work in groups to learn their assigned stations. Students should be identifying the energy transformations, and explaining how and why the energy transformations occurred.
5. When students have finished their investigations, give each group the *What Was Happening?* article that goes with their station. Students should read the article and compare what they read to what they thought was going on. Without erasing their own conclusions, students should summarize the articles in their science notebooks. Students will need to understand what was happening at their station and be able to explain it to their peers as they rotate through.
6. Students should practice presenting their station. Let students know how much time they will have to present their stations so they can practice in that time frame. Use page 28 as an example of a planning guide.

Activity Four: Station Rotations

✪ Objective

- Students will be able to teach their peers about their assigned energy transformations.

Materials

- Materials per station
- Safety glasses per student
- Station Guides per station

Preparation

- Set out a fresh apple at Station Five.
- Make sure each station has adequate consumable supplies.
- Have a supply of ice and hot water available.

✔ Procedure

1. Students will rotate through stations for as many days as needed (usually at least two) for all groups to complete the investigations, according to the scheme you have selected or modified.
2. In the A/B rotation scheme, half of the group will stay at the station to present the energy transformations, while the others rotate through the stations. The next day everyone will switch roles. In the Jigsaw scheme, one person from each station is in a group (six students per group) and the groups rotate from station to station.
3. At each station, the students who learned the energy transformations will coach or guide their peers through the activities, answering questions as needed. As students complete the activities, the group members who are "experts" on the station will be responsible for ensuring their group members understand the forms of energy throughout the initial, intermediate, and final stages of the transformation. Students should all be recording data and observations as indicated by the Station Guides in their notebooks.

Activity Five: Energy Sources and Transformations

✪ Objectives

- Students will be able to identify the forms of energy in the sources of energy we use.
- Students will be able to define renewable and nonrenewable sources of energy and identify each source as renewable or nonrenewable.
- Students will be able to construct an energy flow showing transformations that occur in a process such as riding a bike or operating a computer.

Materials

- *Energy Transformations* master, page 34
- *Forms and Sources of Energy* worksheet, page 35
- Hand generated flashlight

Preparation

- Make copies or prepare a copy of the *Energy Transformations* master for projection. If desired, deconstruct the energy flow by cutting it apart and gluing each piece onto an index card.
- Make copies of *Forms and Sources of Energy* worksheet for each student.

A Note About Your Hand Generated Flashlight

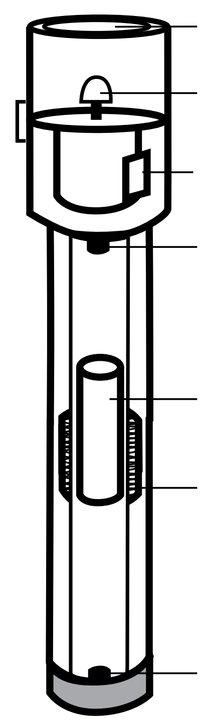
This flashlight stores energy using a NiMH (Nickel Metal Hydride) rechargeable battery. This battery will hold a charge for approximately two hours. For demonstration purposes, teachers may wish to “drain” the charge on the battery by turning on the flashlight and allowing it to remain lit for some time, in order to show the flashlight starting from zero to generate light. If the light is mostly drained and faint, students will immediately be able to see the light brightening as they shake and add energy. From this point, however, it may take extended amounts of shaking to fully recharge the battery and to emit a bright light. Refer to the charging instructions on the box for more information regarding recharging the battery.

Hand Generated Flashlight

A hand generated flashlight works by converting motion into electrical energy. Electricity is powering the light and charging the capacitor or battery for use when not shaking.

Inside of the flashlight is a stationary coil of wire, there is also one magnet that passes through the coil of wire when the flashlight is gently shaken, this magnet is called the "charging" magnet. At each end of the inner housing is sometimes an additional magnet. These magnets are oriented to repel the charging magnet so it moves smoothly through the coil of wire. This is called a magnetic repulsion recoil system. There may also be rubber bumpers, rather than magnets, that cause the central magnet to recoil.

As the flashlight is shaken, electricity is generated as the charging magnet passes back and forth through the coil of wire. The electricity is stored in a capacitor or battery. When the flashlight is turned on, the capacitor or battery delivers electricity to a light emitting diode (LED). The light will stay on as long as the capacitor or battery is charged.



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✔ Procedure

1. Hold up the hand generated flashlight from the teacher demo instruction box.
2. Demonstrate how the flashlight works, describing all the parts inside.
3. Ask students the forms of energy being transformed in the flashlight.
4. Have students identify the form(s) of energy that are the product(s) of the transformation.
5. Show the *Energy Transformations* master. Identify the form(s) of energy at each stage of the flow.
6. Direct students to the *Forms and Sources of Energy* worksheet. Explain what renewable and nonrenewable energy sources are, and give a brief description of each energy source. The glossary includes definitions to use, if needed. Have students identify the form of energy found in each source listed and write it on the line.
7. Instruct students to calculate the percentage of total energy acquired from each form of energy listed and from renewable and nonrenewable sources, using the statistics listed in the diagram.
8. Go back to the *Energy Transformations* master. Explain to students that with each transformation step, significant amounts of energy are transformed into a non-desired form. Explain that while some efficiencies can be calculated, such as the amount of energy from the sun that reaches the surface of the Earth, others cannot be easily calculated, such as the efficiency with which the human body uses the energy from food.
9. Have the students choose another process, such as riding a bike or operating a computer. Instruct them to work backward through the energy transformations, ultimately arriving at some source of nuclear energy as the very first energy form in the energy flow. Students who choose a process involving electricity may choose whichever source of electric power they like, or you can have students research the most used source for your geographical area.
10. If desired, have students arrange the index cards containing the deconstructed energy flow into the proper order. Alternatively, you may have students deconstruct their own energy flows to exchange with a partner.

Unit Extensions

- Invite other classes of all ages to rotate through the stations and have your class teach others about energy transformations.
- Have students brainstorm new investigations using the materials included in the kit. Allow students to plan their own experiment, test their ideas, collect data, and form new conclusions related to energy and their investigations. Some sample ideas include:
    a. Experiment with the spheres in Station One and explore how exposing the spheres to varied temperatures affects bounce height.
    b. Experiment with the superball in Station One and how varying the drop height affects bounce height.
    c. Calculate the average speeds of the toy cars and balloons in Station One in order to calculate the kinetic energy in them.
    d. Calculate the angular speed of the radiometer in Station Three by counting revolutions visually or with a strobe light.
    e. Substitute various fruits and vegetables to find the best electrolytic cell in Station Five.
    f. Use various probewear attachments to calculate data and enhance explorations.
- Have students play *Science of Energy Bingo* (pages 15-16) or *Forms of Energy in the Round* (page 17). These are designed to get students up and moving around, interacting with each other, and utilizing forms of energy vocabulary in a fun way.

☑Unit Assessment and Evaluation

There are multiple options for evaluating student learning in this unit.

- Evaluate students on their group work including: their ability to work as a team to learn the material and prepare their experiment; their ability to teach students from other teams about their experiment; and their ability to handle equipment properly and safely. Devise your own rubric and share it with the class.
- Assess students' science notebooks for developing science process skills and their understanding of the concepts covered at each station. A sample rubric is provided below.
- Have students create a *Secondary Science of Energy Brochure* using the rubric on page 76.
- Use the *Secondary Science of Energy Assessment* on pages 77-78.

Science Notebook Rubric

This is a sample rubric that can be used with science notebooks. You may choose to only assess one area at a time, or look at an investigation as a whole. It is suggested that you share this rubric with students and discuss the different components ahead of time.

	SCIENTIFIC CONCEPTS	SCIENTIFIC INQUIRY	DATA/OBSERVATIONS	CONCLUSIONS
4	Written explanations illustrate accurate and thorough understanding of scientific concepts.	The student independently conducts investigations and designs and carries out his or her own investigations.	Comprehensive data is collected and thorough observations are made. Diagrams, charts, tables, and graphs are used appropriately. Data and observations are presented clearly and neatly with appropriate labels.	The student clearly communicates what was learned and uses strong evidence to support reasoning. The conclusion includes application to real life situations.
3	Written explanations illustrate an accurate understanding of most scientific concepts.	The student follows procedures accurately to conduct given investigations, begins to design his or her own investigations.	Necessary data is collected. Observations are recorded. Diagrams, charts, tables, and graphs are used appropriately most of the time. Data is presented clearly.	The student communicates what was learned and uses some evidence to support reasoning.
2	Written explanations illustrate a limited understanding of scientific concepts.	The student may not conduct an investigation completely, parts of the inquiry process are missing.	Some data is collected. The student may lean more heavily on observations. Diagrams, charts, tables, and graphs may be used inappropriately or have some missing information.	The student communicates what was learned but is missing evidence to support reasoning.
1	Written explanations illustrate an inaccurate understanding of scientific concepts.	The student needs significant support to conduct an investigation.	Data and/or observations are missing or inaccurate.	The conclusion is missing or inaccurate.

Science of Energy BINGO Instructions

Get Ready

Duplicate as many *Science of Energy Bingo* sheets (found on page 79) as needed for each person in your group. In addition, decide now if you want to give the winner of your game a prize and what the prize will be.

Get Set

Pass out one *Science of Energy Bingo* sheet to each member of the group.

Go

PART ONE: FILLING IN THE BINGO SHEETS

Give the group the following instructions to create bingo cards:

- This bingo activity is very similar to regular bingo. However, there are a few things you'll need to know to play this game. First, please take a minute to look at your bingo sheet and read the 16 statements at the top of the page. Shortly, you'll be going around the room trying to find 16 people about whom the statements are true so you can write their names in one of the 16 boxes.
- When I give you the signal, you'll get up and ask a person if a statement at the top of your bingo sheet is true for them. If the person gives what you believe is a correct response, write the person's name in the corresponding box on the lower part of the page. For example, if you ask a person question "D" and he or she gives you what you think is a correct response, then go ahead and write the person's name in box D. A correct response is important because later on, if you get bingo, that person will be asked to answer the question correctly in front of the group. If he or she can't answer the question correctly, then you lose bingo. So, if someone gives you an incorrect answer, ask someone else! Don't use your name for one of the boxes or use the same person's name twice.
- Try to fill all 16 boxes in the next 20 minutes. This will increase your chances of winning. After the 20 minutes are up, please sit down and I will begin asking players to stand up and give their names. Are there any questions? You'll now have 20 minutes. Go!
- During the next 20 minutes, move around the room to assist the players. Every five minutes or so tell the players how many minutes are remaining in the game. Give the players a warning when just a minute or two remains. When the 20 minutes are up, stop the players and ask them to be seated.

PART TWO: PLAYING BINGO

Give the class the following instructions to play the game:

- When I point to you, please stand up and in a LOUD and CLEAR voice give us your name. Now, if anyone has the name of the person I call on, put a big "X" in the box with that person's name. When you get four names in a row—across, down, or diagonally—shout "Bingo!" Then I'll ask you to come up front to verify your results.
- Let's start off with you (point to a player in the group). Please stand and give us your name. (Player gives name. Let's say the player's name was "Joe.") Okay, players, if any of you have Joe's name in one of your boxes, go ahead and put an "X" through that box.
- When the first player shouts "Bingo," ask him (or her) to come to the front of the room. Ask him to give his name. Then ask him to tell the group how his bingo run was made, e.g., down from A to M, across from E to H, and so on.

***Science of Energy Bingo* is a great icebreaker for a NEED workshop or conference. As a classroom activity, it also makes a great introduction to an energy unit.**

Preparation

- 5 minutes

Time

- 45 minutes

Bingos are available on several different topics. Check out these resources for more bingo options! All are available for free download at shop.NEED.org.

- Biomass Bingo—*Energy Stories and More*
- Change a Light Bingo—*Energy Conservation Contract*
- Coal Bingo—Coal guides
- Energy Bingo—*Energy Games and Icebreakers*
- Energy Efficiency Bingo—*School Energy Experts* and *School Energy Managers*
- Hydropower Bingo—Hydropower guides
- Hydrogen Bingo—*H_2 Educate*
- Nuclear Energy Bingo—Nuclear guides
- Oil and Natural Gas Bingo—Oil and Natural Gas guides
- Solar Bingo—Solar guides
- Transportation Bingo—Transportation guides
- Wind Energy Bingo—Wind guides

- Now you need to verify the bingo winner's results. Ask the bingo winner to call out the first person's name on his bingo run. That player then stands and the bingo winner asks him the question which he previously answered during the 20-minute session. For example, if the statement was "can name two renewable sources of energy," the player must now name two sources. If he can answer the question correctly, the bingo winner calls out the next person's name on his bingo run. However, if he does not answer the question correctly, the bingo winner does not have bingo after all and must sit down with the rest of the players. You should continue to point to players until another person yells "Bingo."

SCIENCE OF ENERGY BINGO ANSWERS

A. Knows what type of reaction releases thermal energy

B. Knows the form of energy that comes from the sun

C. Knows one way to store energy

D. Knows the form in which our bodies store energy

E. Knows the force responsible for the attraction between the Earth and nearby masses

F. Knows why rubbing your hands together makes them warm

G. Can name a form of kinetic energy

H. Has visited a thermal power plant

I. Knows where most energy on Earth originates

J. Knows what type of reaction absorbs thermal energy

K. Has used a radiant clothes dryer

L. Knows what form of energy is stored in most energy sources

M. Knows how an electric generator works

N. Knows what device turns energy from the sun directly into electricity

O. Can name a form of potential energy

P. Knows what energy can be transformed into

A exothermic	**B** radiant	**C** battery, chemical, in a spring, etc.	**D** chemical
E gravity	**F** motion energy is transformed into thermal energy through friction	**G** radiant, thermal, motion (kinetic), sound, electrical	**H** Anyone who has visited a nuclear, coal, natural gas power plant has visited a thermal power plant
I the sun	**J** endothermic	**K** Anyone who has hung wet clothes on a line outside has used a radiant clothes dryer	**L** chemical
M Coils of wire surround a magnet. The magnet(s) rotate inside the wire, inducing electric current in the wire. The coils can also rotate inside magnets.	**N** photovoltaic cell, PV cell	**O** chemical, nuclear, elastic, gravitational	**P** any other form of energy

Forms of Energy in the Round Instructions

Get Ready

- Copy one set of the *Forms of Energy in the Round Cards* on pages 80-82 on card stock and cut into individual cards.
- Have a class set of the *Secondary Energy Infobooks* available for quick reference.

Get Set

- Distribute one card to each student. If you have cards left over, give some students two cards so that all of the cards are distributed.
- Have the students look at their bolded words at the top of the cards. Give them five minutes to review the information about their words using the *Secondary Energy Infobooks*.

Go

- Choose a student to begin and give the following instructions:
  - Read the question on your card. The student with the correct answer will stand up and read the bolded answer, "I have _____."
  - That student will then read the question on his/her card, and the round will continue until the first student stands up and answers a question, signaling the end of the round.
- If there is a disagreement about the correct answer, have the students listen to the question carefully looking for key words (forms versus sources, for example) and discuss until a consensus is reached about the correct answer.

ANSWER KEY

STARTING WITH CHEMICAL ENERGY'S CLUE:

NUCLEAR FUSION
POTENTIAL ENERGY
CONDUCTOR
RADIANT ENERGY
LAW OF CONSERVATION OF ENERGY
MOTION
PHOTOSYNTHESIS
EXOTHERMIC PROCESS
ELECTRICAL ENERGY
CHEMICAL CHANGE
THERMAL ENERGY
ENERGY
PHOTOVOLTAIC CELL
KINETIC ENERGY
INERTIA
ELASTIC ENERGY
GRAVITY
NUCLEAR FISSION
NUCLEAR ENERGY
INSULATOR
CONVECTION
GENERATOR
SOUND
REFLECTION
FRICTION
PHYSICAL CHANGE
ENDOTHERMIC PROCESS
VISIBLE LIGHT
CONDUCTION
CHEMICAL ENERGY

***Forms of Energy in the Round* is a quick, entertaining game to reinforce information about energy sources, forms of energy, and general energy information from the *Secondary Energy Infobook*.**

Preparation

- 10 minutes

Time

- 20–30 minutes

Alternative Instructions

- Give each student or pair a set of cards.
- Students will put the cards in order, taping or arranging each card so that the answer is directly under the question.
- Have students connect the cards to fit in a circle or have them arrange them in a column.

"In the Rounds" are available on several different topics. Check out these resources for more, fun "In the Round" examples! All are available for free download at shop.NEED.org.

- Coal in the Round—*Exploring Coal*
- Conservation in the Round—*School Energy Experts* and *School Energy Managers*
- Hydrogen in the Round—*H_2 Educate*
- Oil and Natural Gas Industry in the Round—*Fossil Fuels to Products, Exploring Oil and Natural Gas*
- Uranium in the Round—Nuclear guides
- Solar Energy in the Round—*Energy From the Sun*
- Transportation Fuels in the Round—Transportation guides

Station Investigation Answer Keys

Station One

Part One

1. The pie charts for all spheres should follow the same progression through each position. With position one containing 100% GPE, position two containing 50% GPE and 50% KE, position 3 containing 100 % KE, and postion 4 containing 100% GPE.
2. Student answers may vary based on the accuracy of their masses recorded. The black spheres should each have a mass of approximately 10 grams, while the superball should have a mass of approximately 20 grams. Students should assume *g* to be 9.8 m/s².

Superball Sample Calculation

Mass = 19 g = 0.019 kg

Position 1 GPE = 0.1862 J

Position 2 GPE = 0.0931 J

KE = 0.0931 J

Position 3 GPE = 0 J

KE = 0.1862 J

Position 4 GPE = 0.140

%Energy Recovered = 75.2% (Expect %ER to be 70% or higher)

Happy Sphere Sample Calculation

Mass = 10 g = 0.010 kg

Position 1 GPE = 0.098 J

Position 2 GPE = 0.049 J

KE = 0.049 J

Position 3 GPE = 0 J

KE = 0.098 J

Position 4 GPE = 0.071 J

%Energy Recovered = 72% (Expect %ER to be around 70% or less)

Sad Sphere Sample Calculation

Mass = 10 g = 0.010 kg

Position 1 GPE = 0.098 J

Position 2 GPE = 0.049 J

KE = 0.049 J

Position 3 GPE = 0 J

KE = 0.098 J

Position 4 GPE = 0.001568

%Energy Recovered = 1.6% (Expect %ER to be 5% or less)

3. The superball was most efficient at transforming energy because it bounced the highest.
4. The height in position 4 is less than the height in position 1. Some of the energy from position 1 was dissipated to the surroundings as sound and thermal energy.
5. Answers will vary based upon the student.

Part Two

1 and 2. Both the car and the balloon have the same transformation of energy. The pie charts for both toys should follow the same progression through each position. At position 1 the toys will have 100% elastic energy. At position 2, the toys will have a small amount of sound and thermal energy, and the remainder of the energy will be evenly distributed between elastic energy and motion or kinetic energy. At position 3, the amount of sound and thermal energy should be larger than in position 2, with the remaining energy being kinetic or motion energy. Finally at position 4, 100% of the energy will be dissipated as sound and thermal energy.

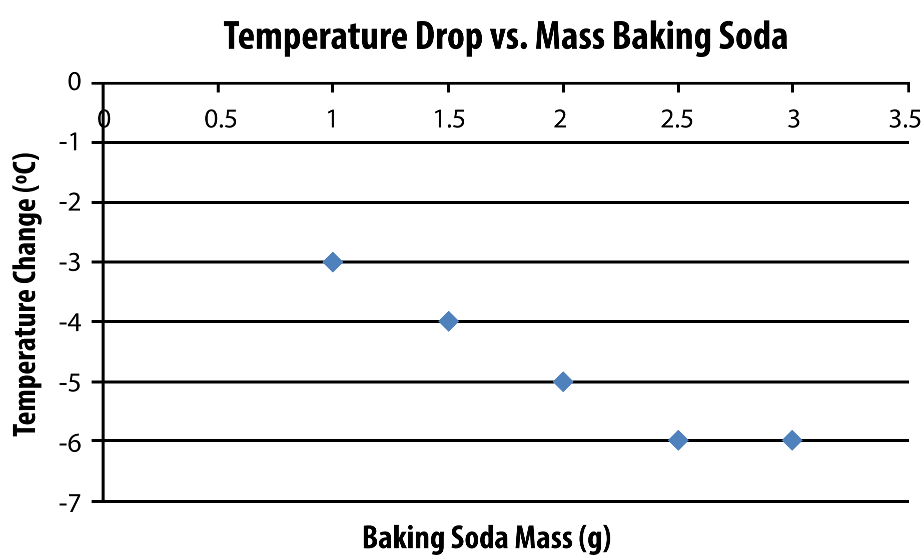
For the yo-yo, the pie charts will be slightly different. At position 1, the yo-yo has 100% GPE. At position 2, it will have a very small amount of sound and thermal energy, but most of its energy will be split between GPE and motion or kinetic energy. At position 3, there will be slight bit more sound and thermal energy dissipated, but the majority of the system will be motion or kinetic energy. At position 4, the system will have 100% GPE.

3. Some of the original energy dissipated as sound and thermal energy to the surroundings.
4. The energy dissipated as sound and thermal energy to the surroundings.
5. Answers will vary based upon the student.

Station Two

Part One

1. The following is a sample of data that could be obtained by a student doing this activity. Individual student data will vary, but should show a steady decrease until 2.5 grams of baking soda are used, at which point the temperature will not drop any more due to the vinegar being used up (limiting reagent).



2. The more reactant used, the greater the temperature change.
3. The temperature change will still be -6 degrees Celsius because the vinegar will be used up before the baking soda will be, as in the scenarios using 2.5 g and 3.0 g baking soda.
4. Using more vinegar will cause a greater temperature change until it is all consumed.
5. This process is endothermic, because the temperature of the surroundings goes down.
6. Answers will vary based upon the student.
7. Answers will vary based upon the student.

Part Two

1. Answers will vary based upon the student.
2. The temperature of the water increased.
3. This process is exothermic, because the temperature of the surroundings increased.
4. Answers will vary based upon the student.

Part Three

1. This process is exothermic, because the temperature of the surroundings increased.
2. Answers will vary based upon the student.
3. The temperature should have increased slightly with the bag closed, but not nearly as much as with it open. The reason is that the oxygen supply to the hand warmer contents was limited when the bag was closed. Oxygen was used up (limiting reagent) and no more thermal energy could be released.
4. Answers will vary by student, but should include oxidations and combustions such as candles, gasoline, etc.
5. The same amount of thermal energy would be released, but at a much slower rate, and the temperature increase would not be noticeable. Less surface area of the iron would be exposed to, and available for reaction with oxygen.

Station Three

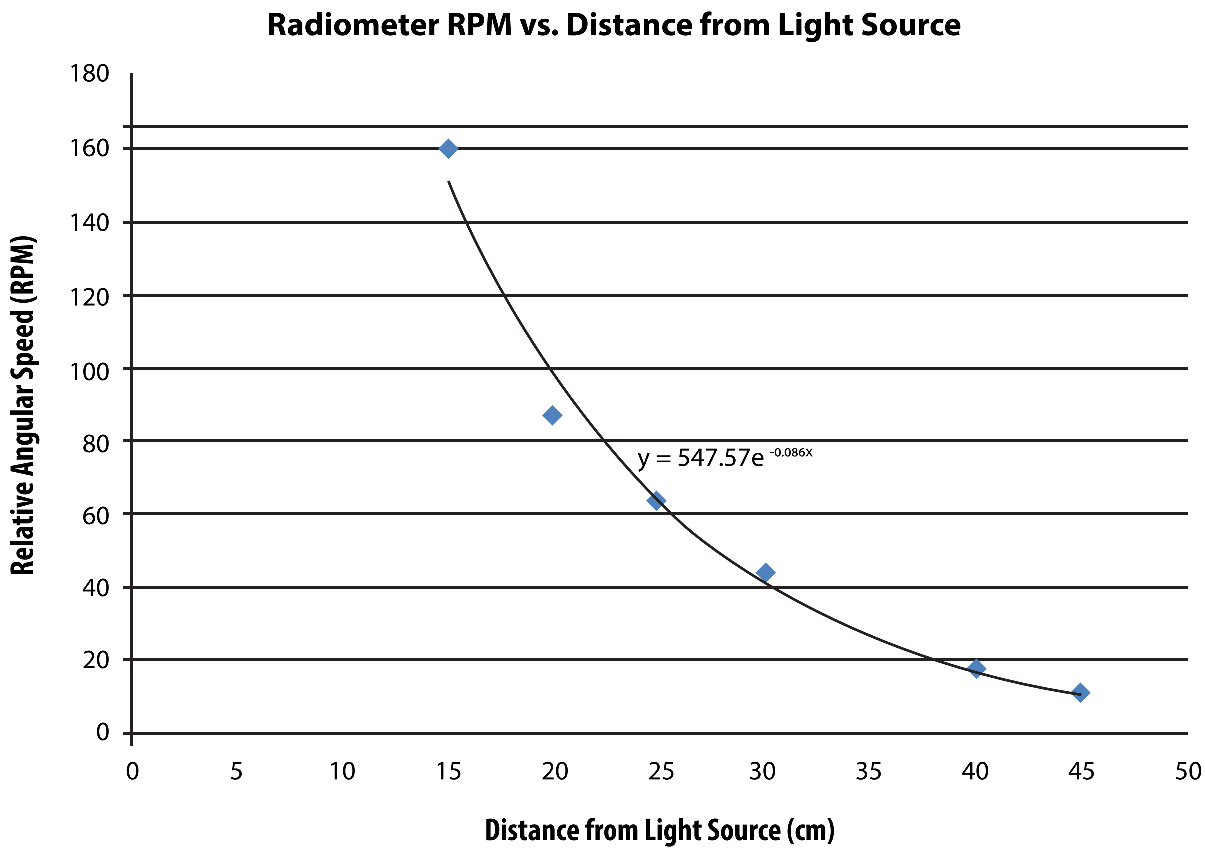
Part One

Graph – The thermometers exposed to the light source or sunlight should show a steady increase in temperature, with the thermometer on the dark paper increasing more than the thermometer on the white paper. The thermometers on the shady side might increase a degree or two in temperature, but shouldn't increase much at all.

1. The temperature on the illuminated side of the cardboard should have increased; the temperature on the shady side of the cardboard should have remained nearly unchanged.
2. The air temperature on both sides of the cardboard is the same.
3. The black paper thermometer on the illuminated side should have increased more than the white paper on the illuminated side, but there would be little difference between the papers on the shady side.
4. Answers will vary based upon the student.
5. Radiant energy is transformed into thermal energy.
6. Answers will vary by student but should represent the concept that temperature of an object in direct light can be changed when the color of the item is altered.

Part Two

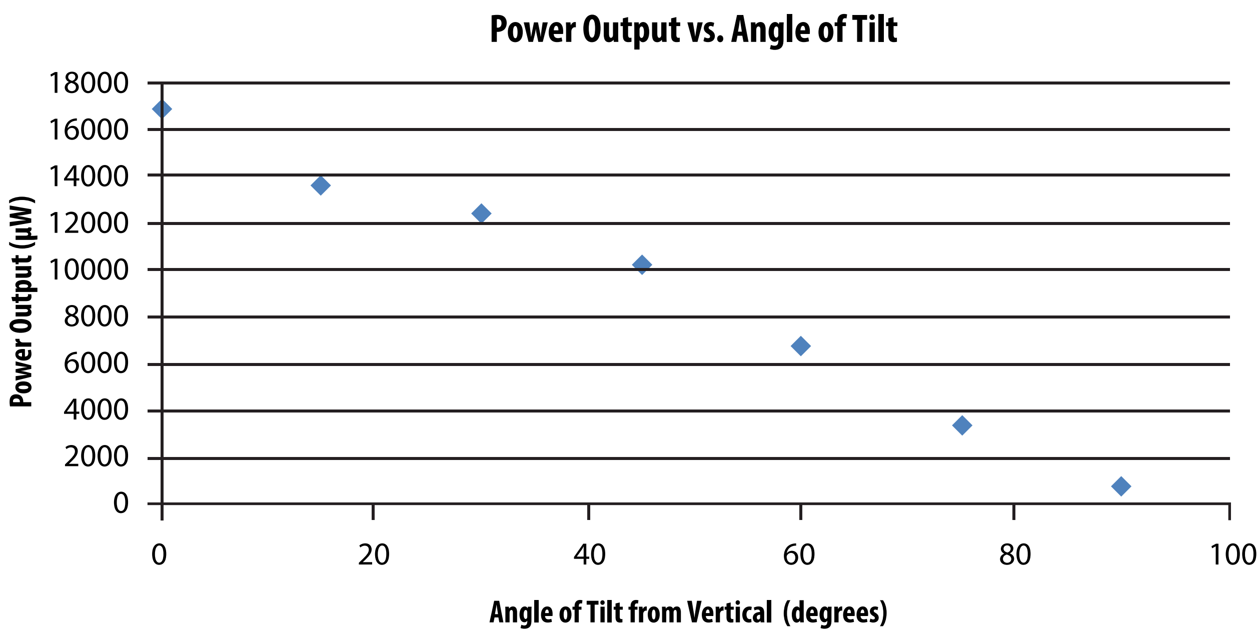
Graph – A sample graph is shown below, including a line of best fit generated by computer and its equation. Students' data will vary but should demonstrate exponential decrease as distance from the light source increases.



1. As the distance from the light increases, the speed of the radiometer decreases.
2. Answers will vary based upon the student.
3. Radiant energy is being transformed into kinetic or motion energy.
4. The black vanes on the radiometer move more than the white side, which causes the entire apparatus inside to spin. The black vanes absorbed more radiant energy than the white sides of the vanes, just like the dark paper in Part One absorbed more energy and got hotter than the white paper on the illuminated side of the cardboard. The air molecules surrounding the black vanes heat up because the black vanes are absorbing more energy. These heated air molecules bump back into the black vanes and push them, dragging the white vanes along for the ride.

Part Three

Graph - A sample graph is shown below that represents output vs. tilt. Students should be able to show that as the angle increases the output decreases.



1. As the solar panel is tilted away from the light source, the power output decreases.
2. The power output changed nearly the same for each 15-degree interval, as demonstrated by the nearly linear relationship of the data points.
3. Answers will vary based upon the student.
4. The radiometer graph shows exponential decrease, while the solar panel graph shows linear decrease.
5. As the distance or angle away from a light source increases, the amount of energy available from that light source decreases.

Station Four

Part One

1. Thermal energy is transformed into kinetic or motion energy.
2. Students' drawings should indicate that stainless steel is on the outside of the bend when heated, and that nickel is on the inside of the bend when heated. This is because stainless steel's coefficient of expansion is higher than that of nickel.
3. Gaps are left between sections of rail to allow the metal to expand and contract without distorting its shape or position as the weather gets warmer and cooler.
4. Answers will vary by student, but should reference the data obtained in the exploration.
5. Answers will vary based upon the student.

Part Two

1. Kinetic or motion energy was transformed into thermal energy at the site of bending.
2. Bending the hanger piece and the bi-metal bar bending are the reverse of each other. The hanger was bent and got warmer, while the bi-metal bar got warmer and bent.
3. Answers will vary based upon the student.

Part Three

1. When stretched, kinetic or motion energy is transformed into thermal energy. When relaxed, thermal energy is absorbed back into the rubber.
2. The movement of the rubber band causes it to get warmer, while warming the bi-metal bar causes it to move. They also are opposites of each other, as with the hanger pieces.
3. Answers will vary based upon the student.

Part Four

1. The wire quickly moved back into its original straight shape when warmed by the hot water.
2. The live wire transformed thermal energy into kinetic or motion energy.
3. Answers will vary by student, but should reference the data obtained in the exploration.
4. Answers will vary based upon the student.

Station Five

Part One

Data recorded by students will vary according to the size of the apple and the amount of oxidation that may be present on the wires and nails. The large zinc nail and thick copper wire should yield the highest reading on the meter in the first part, and the reading on the meter should increase as the depth of the wires in the apple increases in the second part.

1. Chemical energy was transformed into electrical energy.
2. The best combination of metals should be the thick copper wire with the large zinc nail; they should produce the highest reading on the meter.
3. The optimal depth for the pieces of metal should be 4 cm, which will produce the highest reading on the meter.
4. Answers will vary based upon the student.

Part Two

1. Chemical energy is transformed into radiant energy.
2. A glow stick uses a chemical reaction between hydrogen peroxide and an ester to release energy. The energy is absorbed and re-released by a phosphorescent dye that varies by color of the glow stick.
3. As the temperature of the glow stick's surroundings increases, the brightness of the glow stick also increases, indicating the reaction is proceeding at a faster rate.
4. Changing the temperature of the unbroken glow stick does not change it because no chemical reaction is taking place inside the glow stick.
5. Refrigerating batteries will slow down the rate of reaction in the battery, thus extending its life.
6. Answers will vary based upon the student.

Station Six

Part One

1. The electric current induced a magnetic field in the wire when it passed through the wire.
2. The two poles of a magnet are labeled North and South.
3. Students' answers will vary according to the direction (clockwise or counterclockwise) they wound the wire and to which terminal of the battery each end of the wire was connected.
4. Electric current flows through a wire, which induces a magnetic field around the wire. Because the wire itself is wrapped around the nail, the magnetic field lines around the wire are in alignment, causing a straight-line magnetic field through the nail and then wrapping around the outside of it, similar to the way the magnetic field wraps around the Earth.
5. Answers will vary based upon the student.

Part Two

1. The motor transforms electrical energy into kinetic energy. When used as a generator, a motor transforms kinetic energy into electrical energy.
2. The direction of the motor's motion reverses direction when the terminals of the battery are swapped. This is because the direction of the current through the wires inside the motor is reversed.
3. Changing the direction of the turn on the first motor will cause the direction of the second motor to also change direction. This is because the induced electric current in the wires changes direction.
4. Answers will vary based upon the student.

Answer Keys

Forms and Sources of Energy, page 35

NONRENEWABLE
Petroleum - chemical
Coal - chemical
Natural Gas - chemical
Uranium - nuclear
Propane - chemical

RENEWABLE
Biomass - chemical
Hydropower - motion
Wind - motion
Solar - radiant
Geothermal - thermal

- Chemical - 85.00%, Nuclear - 8.61%, Motion - 5.23%, Radiant - 0.79%, Thermal - 0.21%*
- Nonrenewables - 88.41%, Renewables - 11.54%*

*Total does not equal 100% due to independent rounding.

Secondary Science of Energy Assessment, pages 77-78

1. The ball will not return to its original height, because some of the gravitational potential energy is dissipated to the ball's surroundings as sound and thermal energy, and is not available to push the ball back up in the air.
2. Answers will vary.
3. Iron rusting is an exothermic reaction. This is evident in a hand warmer, where the temperature of the contents of the warmer increases as the reaction progresses. When a system of chemical reactants releases thermal energy into its surroundings, it is an exothermic reaction.
4. Increasing the amount of reactants increases the rate of the reaction, which increases the amount of energy absorbed or released, and therefore causes the change in temperature to be greater.
5. The black vanes inside the radiometer absorb more radiant energy, transforming it into thermal energy. The warmer, black vanes affect the air molecules beside them more than the cooler, white vanes, and the air molecules bounce off of and push the black vanes, causing the entire apparatus to spin. Radiant energy is transformed into kinetic energy.
6. Photovoltaic systems will produce the most electricity when they are exposed to the maximum amount of sunlight. Therefore, the panels must be installed at an angle such that the sunlight is reaching them as directly as possible, and must be installed where no shadows will fall across them during the day.
7. The reason the bi-metal bar bends in the candle flame is because the two metals expand differently when heated. If two metals with very similar coefficients of linear expansion were used, the bar would not bend very much, if at all.
8. A bi-metal bar is a sandwich of two layers of two different metals, while the nitinol wire is an alloy, or mixture, of two metals in a specific lattice configuration. Heating the bi-metal bar causes it to move, while heating the nitinol wire gives it the energy to move back into its original shape. Both provide examples of how thermal energy can be transformed to move objects.
9. If a glow stick is cooled, the reaction will slow, and the stick will be dimmer. If the stick is warmed, the reaction will speed up, and the stick will be brighter. This is because the increase or decrease in temperature changes the thermal energy of the reactants, and changes the likelihood that the molecules in the reaction will collide and react.
10. A fresh apple will produce more electric current than an apple that has been used for a while, because the amount of malic acid in the fresh apple is greater. Also, the metals being used will affect how much current is generated, as metals with significantly different potentials will yield the best batteries. Finally, increasing the amount of substance in the apple, either by mass of metal (thickness of wire) or by surface area (depth of insertion) will increase the amount of electric current generated because the chemical reaction can take place at a faster rate.
11. Moving the magnet through the coil of wire induces electric current in the flashlight. The electrical energy is transformed into radiant energy in the LED inside the flashlight.
12. Motors and generators both contain coils of wire and magnets. A motor takes in electrical energy and produces kinetic energy through turning the shaft of the motor. A generator takes in kinetic energy, which turns the coils and produces electrical energy.
13. In the sun, nuclear energy is transformed to radiant energy through nuclear fusion. The radiant energy travels through space to Earth in electromagnetic waves, where it is absorbed by plants and transformed into chemical energy via photosynthesis. We eat the plants, and use the chemical energy in respiration to produce kinetic energy in the movement of our muscles. The bike changes the linear motion of our muscles into the rotational motion of the tires, and we ride the bike. Thermal energy can also result in each of the steps in the transformation.

TITLE:

QUESTION:

HYPOTHESIS:

OBSERVATIONS AND DATA:

CONCLUSION:

NEXT, READ THE 'WHAT WAS HAPPENING?' ARTICLE. SUMMARIZE THE ARTICLE BELOW:

REAL WORLD APPLICATION:

Station #______ Presentation Planning Guide

PRESENTATION ELEMENTS	WHO IS RESPONSIBLE?
Present the question.	
Demonstration: What will you do?	
Ask the group to identify the energy transformations.	
Explain what was happening at your station.	

Thermometer

A thermometer measures temperature. The temperature of a substance is a measure of the average amount of kinetic energy in the substance.

This thermometer is a long, glass tube filled with colored alcohol. Alcohol is used in many thermometers because it expands in direct proportion to the increase in kinetic energy or temperature.

Temperature can be measured using many different scales.

The scales we use most are:

- **Celsius**

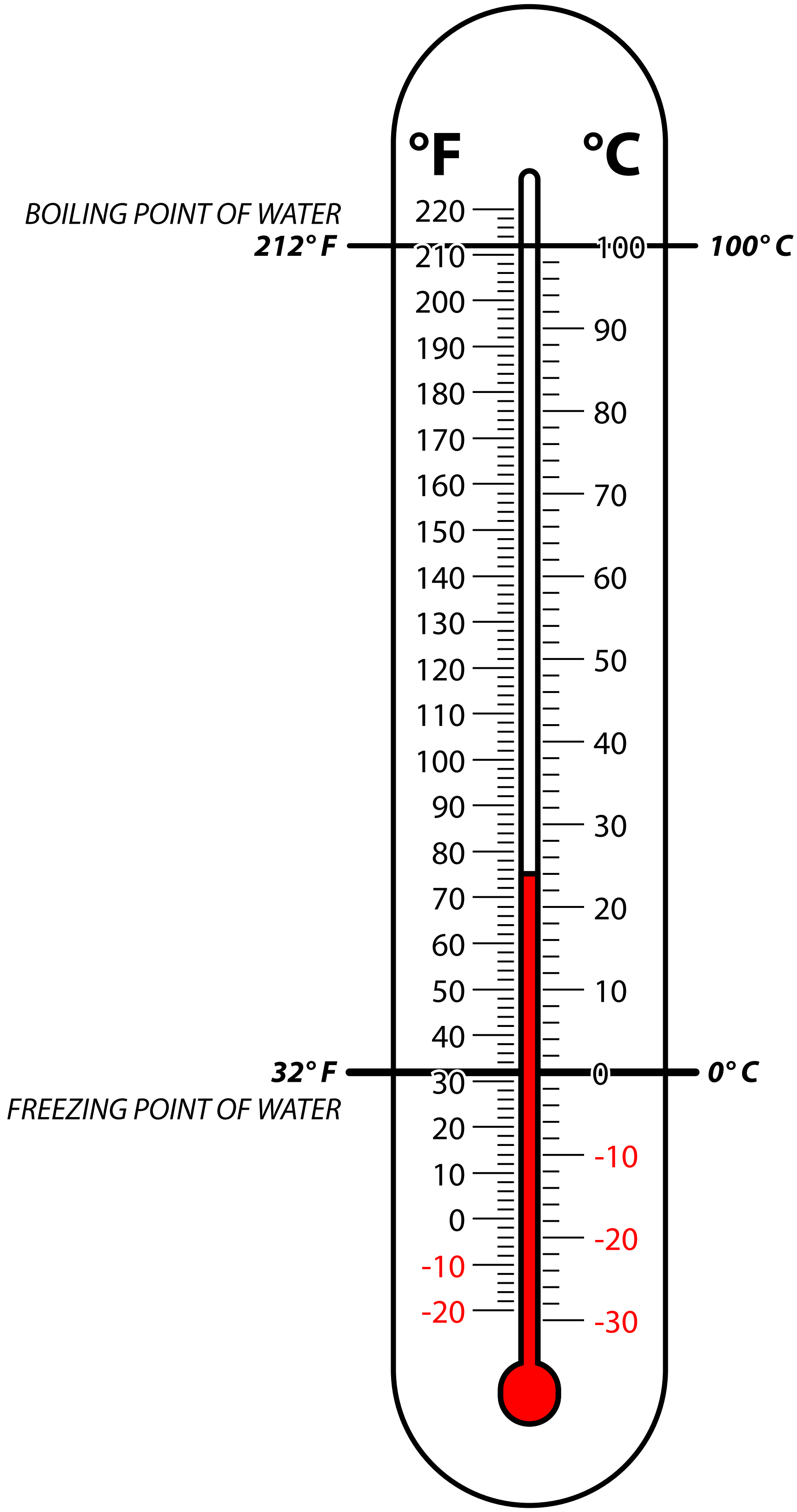
The **Celsius (C)** scale uses the freezing point of water as 0°C and the boiling point of water as 100°C.

- **Fahrenheit**

The **Fahrenheit (F)** scale uses the freezing point of water as 32°F and the boiling point of water as 212°F.

In the United States, we usually use the Fahrenheit scale in our daily lives, and the Celsius scale for scientific work. People in most countries use the Celsius scale in their daily lives as well as for scientific work.

Notice the numerical difference between the freezing and boiling points of water are different on the two scales. The difference on the Celsius scale is 100, while the difference on the Fahrenheit scale is 180. There are more increments on the Fahrenheit scale because it shows less of an energy change with each degree.



Fahrenheit/Celsius Conversion

On the Fahrenheit scale, the freezing point of water is 32° and the boiling point of water is 212°.

On the Celsius scale, the freezing point of water is 0° and the boiling point of water is 100°.

To convert from Celsius to Fahrenheit, multiply the C number by $\frac{180}{100}$ or $\frac{9}{5}$, then add 32, as shown in the formula below.

$$F = \left(C \times \frac{9}{5}\right) + 32$$

If C = 5

$$F = \left(5 \times \frac{9}{5}\right) + 32$$

$$F = 9 + 32$$

$$F = 41$$

To convert from Fahrenheit to Celsius, subtract 32 from the F number, then multiply by $\frac{100}{180}$ or $\frac{5}{9}$ as shown in the formula below.

$$C = (F - 32) \times \frac{5}{9}$$

If F = 50

$$C = (50 - 32) \times \frac{5}{9}$$

$$C = 18 \times \frac{5}{9}$$

$$C = 10$$

Forms of Energy

All forms of energy fall under two categories:

POTENTIAL

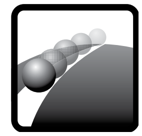
Stored energy and the energy of position (gravitational).

CHEMICAL ENERGY is the energy stored in the bonds of atoms and molecules. Gasoline and a piece of pizza are examples.

NUCLEAR ENERGY is the energy stored in the nucleus of an atom – the energy that holds the nucleus together. The energy in the nucleus of a plutonium atom is an example.

ELASTIC ENERGY is energy stored in objects by the application of force. Compressed springs and stretched rubber bands are examples.

GRAVITATIONAL POTENTIAL ENERGY is the energy of place or position. A child at the top of a slide is an example.



KINETIC

The motion of waves, electrons, atoms, molecules, and substances.

RADIANT ENERGY is electromagnetic energy that travels in transverse waves. Light and x-rays are examples.

THERMAL ENERGY is the internal energy that causes the vibration or movement of atoms and molecules in substances. Liquid water has more thermal energy than solid water (ice).

MOTION ENERGY is the energy present in the movement of a substance from one place to another. Wind and moving water are examples.

SOUND ENEGRY is the movement of energy through substances in longitudinal waves. Echoes and music are examples.

ELECTRICAL ENERGY is the movement of electrons. Lightning and electricity are examples.

Lab Safety Rules

Eye Safety

- Always wear safety glasses when performing experiments.

Fire Safety

- Do not heat any substance or piece of equipment unless specifically instructed to do so.
- Be careful of loose clothing. Do not reach across or over a flame.
- Keep long hair pulled back and secured.
- Do not heat any substance in a closed container.
- Always use tongs or protective gloves when handling hot objects. Do not touch hot objects with your hands.
- Keep all lab equipment, chemicals, papers, and personal effects away from the flame.
- Extinguish any flame as soon as you are finished with the experiment and move it away from the immediate work area.

Heat Safety

- Always use tongs or protective gloves when handling hot objects and substances.
- Keep hot objects away from the edge of the lab table, in a place where no one will accidentally come into contact with them.
- Remember that many objects will remain hot for a long time after the heat source is removed or turned off.

Glass Safety

- Never use a piece of glass equipment that appears cracked or broken.
- Handle glass equipment carefully. If a piece of glassware breaks, do not attempt to clean it up yourself. Inform your teacher.
- Glass equipment can become very hot. Use tongs if glassware has been heated.
- Clean glass equipment carefully before packing it away.

Chemical Safety

- Do not smell, touch, or taste chemicals unless instructed to do so.
- Keep chemical containers closed except when using them.
- Do not mix chemicals without specific instructions.
- Do not shake or heat chemicals without specific instructions.
- Dispose of used chemicals as instructed. Do not pour chemicals back into containers without specific instructions to do so from your teacher.
- If a chemical accidentally touches your skin, immediately wash the affected area with water and inform your teacher.
- Do not allow spatulas or foreign objects to remain in containers.

MSDS Safety Sheets are included for all chemicals in the kits as well as the products of all chemical reactions.

Glow Stick Safety: The solutions contained in the glow sticks are non-toxic and will not cause injury to the skin or eyes. Eye contact may cause temporary discomfort similar to that produced by soaps or shampoos. Should a glow stick rupture, rinse the affected area thoroughly with water, then repeat the process. The solutions can soften or mar paint and varnish, and can stain fabric. If you have any concerns about possible allergic reactions or sensitivities, please speak with Omniglow's customer service at 1-866-783-3799.

Units and Formulas

MEASUREMENT	STATION WHERE USED	UNIT	UNIT SYMBOL
Coefficient of linear thermal expansion	4	per degree Celsius	/°C
Electric current	5	microampere, ampere	μA, A
Electric potential	6	volt	V
Electric resistance	6	ohm	Ω
Energy	1	joule	J
Length	1, 3, 5	meter, centimeter	m, cm
Mass	1, 2	gram, kilogram	g, kg
Power	3, 6	megawatt, watt, microwatt	MW, w, μW
Temperature	2, 4	degree Celsius	°C
Time	1, 3	second, minutes	s, min
Volume	2	milliliter, cubic centimeter	mL, cm^3

Mathematical Relationships used in SOE

Station One Relationships

Gravitational potential energy in joules = (mass in kg)(acceleration due to gravity m/s^2)(height in m)

GPE = $m \times g \times h$ (the value of g is always 9.8 m/s^2)

Kinetic energy in joules = (½)(mass in kg)$(\text{velocity in } m/s)^2$

KE = $\frac{1}{2} \times m \times v^2$

Station Three Relationships

Voltage in volts = (current in amperes)(resistance in ohms)

$V = I \times R$

Power in watts = (current in amperes)(voltage in volts)

$P = I \times V$

Station Four Relationship

Change in length in meters = (initial length in meters)(coefficient of linear expansion in per degree Celsius)(change in temperature in degrees Celsius)

$\triangle L = L \times \alpha \times \triangle T$

Common Metric Energy Prefixes

giga = 10^9

mega = 10^6

kilo = 10^3

base unit (meter, gram, watt, amp)

centi = 10^{-1}

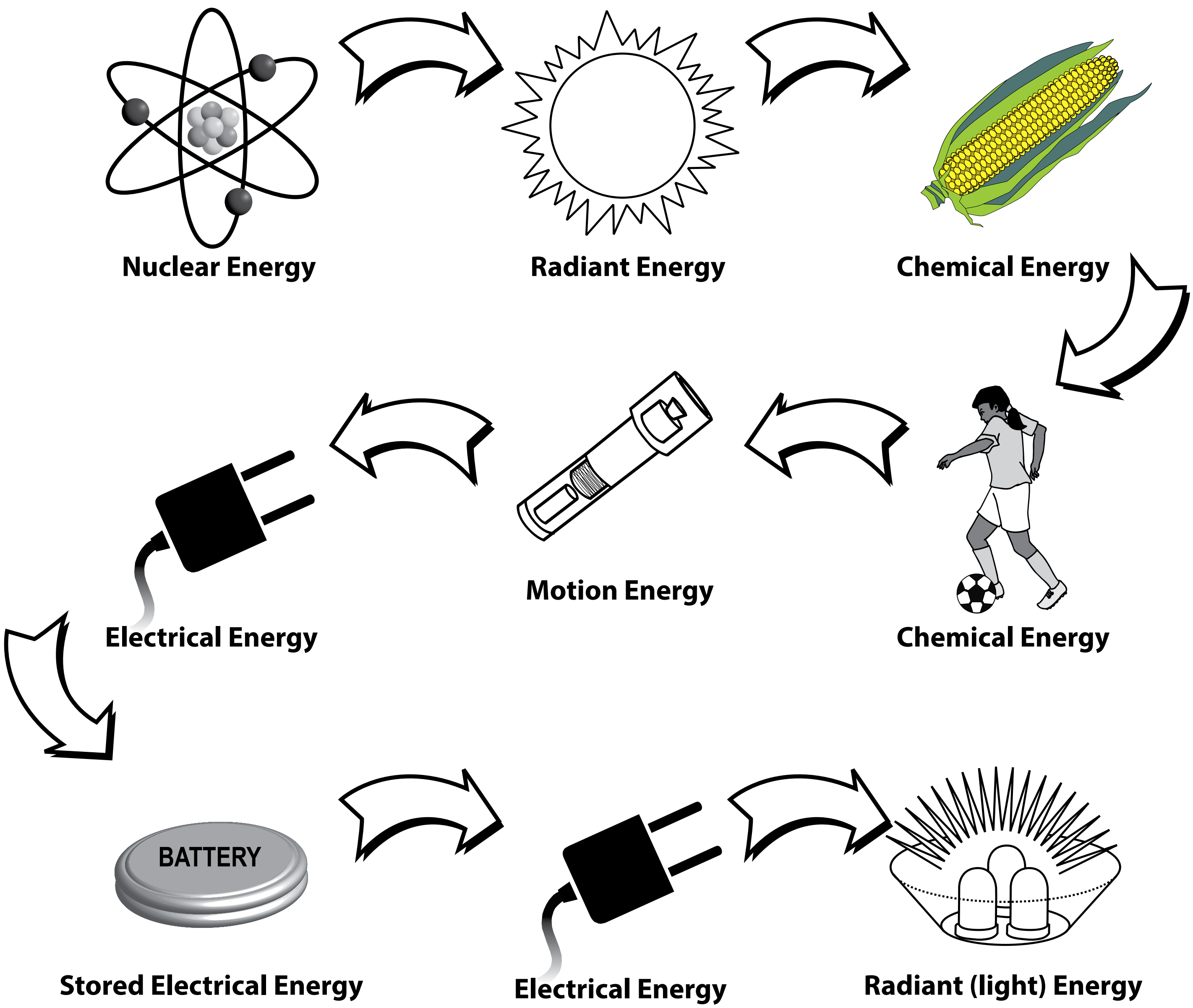
milli = 10^{-3}

micro = 10^{-6}

nano = 10^{-9}

Energy Transformations

Hand Generated Flashlight



Forms and Sources of Energy

In the United States we use a variety of resources to meet our energy needs. Use the information below to analyze how each energy source is stored and delivered.

1 Using the information from the *Forms of Energy* chart and the graphic below, determine how energy is stored or delivered in each of the sources of energy. Remember, if the source of energy must be burned, the energy is stored as chemical energy.

NONRENEWABLE

Petroleum ____________________

Coal ____________________

Natural Gas ____________________

Uranium ____________________

Propane ____________________

RENEWABLE

Biomass ____________________

Hydropower ____________________

Wind ____________________

Solar ____________________

Geothermal ____________________

2 Look at the U.S. Energy Consumption by Source graphic below and calculate the percentage of the nation's energy use that each form of energy provides.

What percentage of the nation's energy is provided by each form of energy?

Chemical _____

Nuclear _____

Motion _____

Radiant _____

Thermal _____

What percentage of the nation's energy is provided

by nonrenewables? ______

by renewables? ______

U.S. Energy Consumption by Source, 2017

NONRENEWABLE

PETROLEUM 36.99% *
Uses: transportation, manufacturing - includes propane

NATURAL GAS 28.66% *
Uses: heating, manufacturing, electricity - includes propane

COAL 14.15%
Uses: electricity, manufacturing

URANIUM 8.61%
Uses: electricity

PROPANE
Uses: heating, manufacturing

*Propane consumption figures are reported as part of petroleum and natural gas totals.

RENEWABLE

BIOMASS 5.20%
Uses: heating, electricity, transportation

HYDROPOWER 2.83%
Uses: electricity

WIND 2.40%
Uses: electricity

SOLAR 0.79%
Uses: heating, electricity

GEOTHERMAL 0.21%
Uses: heating, electricity

**Total does not add up to 100% due to independent rounding.
Data: Energy Information Administration

Station One Guide

Part One: Spheres

Question

- How does the composition of material in a sphere affect the dissipation of energy in transformations when dropped?

Hypothesis

In your science notebook, write a hypothesis stating how you think the material in a sphere affects how it dissipates energy when dropped.

Materials

- 1 Set of happy and sad spheres
- Balance
- Hard surface such as a table or tiled floor
- Measuring tape or meter stick
- Safety glasses
- String
- Superball

Vocabulary

- absorb
- collision
- dissipate
- elastic energy
- friction
- gravitational potential energy
- kinetic energy
- potential energy
- rebound
- surroundings
- system
- thermal energy

✔ Procedure

1. Use the balance to determine the mass of the superball and record it in the data table.
2. Drop the superball onto a hard surface from a height of one meter.
3. Record how high the superball rebounds and any other observations in your science notebook.
4. Repeat steps 2-3 two more times for a total of three trials. Calculate the average, and record it in the data table.
5. Use the balance to determine the mass of one black sphere and record it in the data table.
6. Drop the first black sphere onto a hard surface from a height of one meter.
7. Record how high the sphere rebounds and any other observations in your science notebook.
8. Repeat steps 6-7 two more times for a total of three trials. Calculate the average, and record it in the data table.
9. Use the balance to determine the mass of the second black sphere and record it in the data table.
10. Drop the second black sphere onto the hard surface from a height of one meter.
11. Record how high the sphere rebounds and any other observations in your science notebook.
12. Repeat steps 10-11 two more times for a total of three trials. Calculate the average, and record it in the data table.

Data

Make this table in your science notebook:

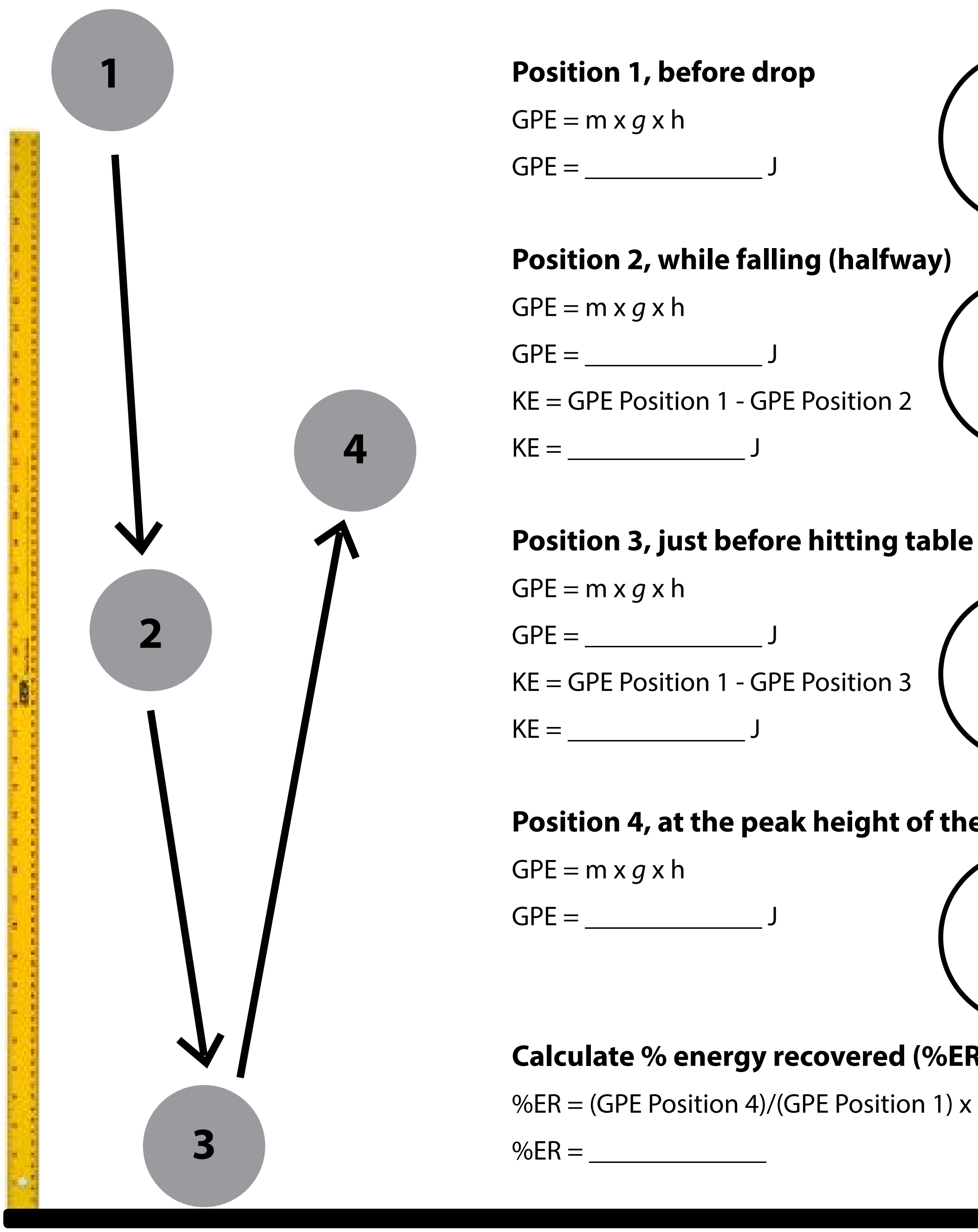
1 METER	MASS (g)	TRIAL 1 (m)	TRIAL 2 (m)	TRIAL 3 (m)	AVERAGE (m)
SUPERBALL					
BLACK SPHERE 1					
BLACK SPHERE 2					

Station One Guide

⁂ Part One Conclusion

1. Copy the diagrams on pages 37-39 into your science notebook. In the first diagram on the left-hand side, label the form(s) of energy present at each of the stages, 1-4. Use the pie charts on each diagram to show the approximate proportion of each form of energy present at each stage. Label the pie chart with the form(s) of energy being represented. It may be helpful to use different colors for labeling and shading potential and kinetic energy.
2. Use the average bounce height and the mass of each sphere to determine the amount of energy represented in each stage shown in the appropriate diagram. Complete the calculations in each diagram using the relationships listed.
3. Which sphere was most efficient at transforming kinetic energy back into gravitational energy? Cite the experimental evidence that supports your answer.
4. What do you notice about position 1's GPE and position 4's GPE? Where did the energy transfer?
5. Will you accept or reject your hypothesis? Cite experimental evidence that supports your answer.

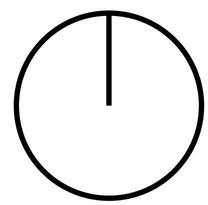
SUPERBALL DIAGRAM



Position 1, before drop

GPE = m x *g* x h

GPE = ______________ J



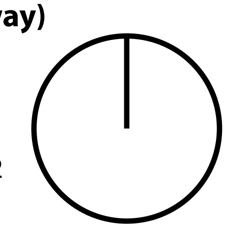
Position 2, while falling (halfway)

GPE = m x *g* x h

GPE = ______________ J

KE = GPE Position 1 - GPE Position 2

KE = ______________ J



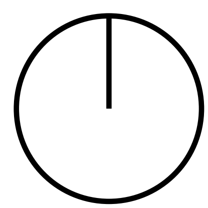
Position 3, just before hitting table top (0m)

GPE = m x *g* x h

GPE = ______________ J

KE = GPE Position 1 - GPE Position 3

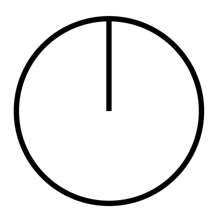
KE = ______________ J



Position 4, at the peak height of the bounce

GPE = m x *g* x h

GPE = ______________ J



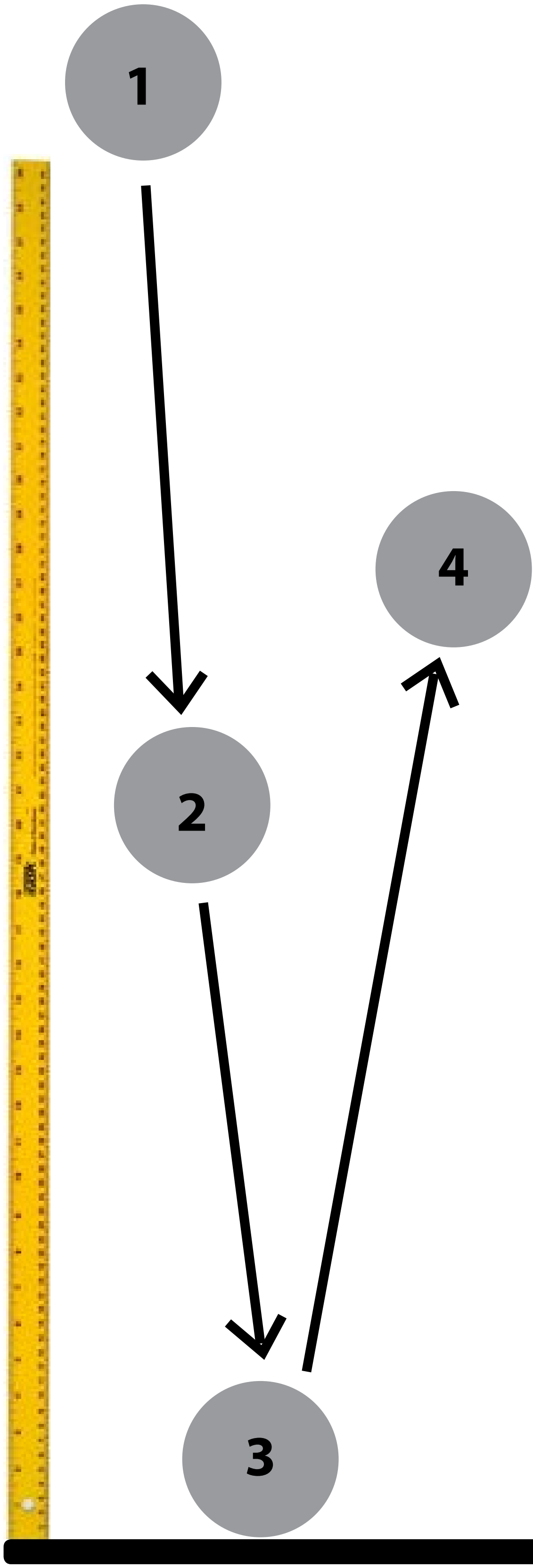
Calculate % energy recovered (%ER)

%ER = (GPE Position 4)/(GPE Position 1) x 100

%ER = ______________

Station One Guide

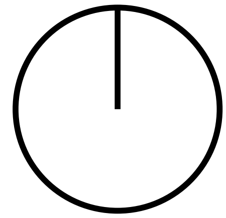
BLACK SPHERE 1 DIAGRAM



Position 1, before drop

GPE = m x *g* x h

GPE = ______________ J



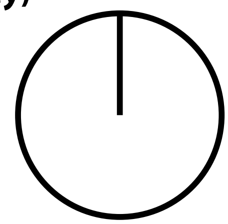
Position 2, while falling (halfway)

GPE = m x *g* x h

GPE = ______________ J

KE = GPE Position 1 - GPE Position 2

KE = ______________ J



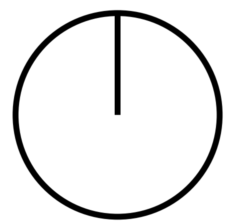
Position 3, just before hitting table top (0m)

GPE = m x *g* x h

GPE = ______________ J

KE = GPE Position 1 - GPE Position 3

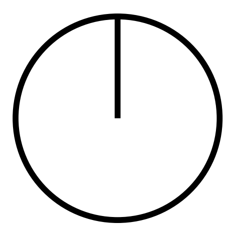
KE = ______________ J



Position 4, at the peak height of the bounce

GPE = m x *g* x h

GPE = ______________ J



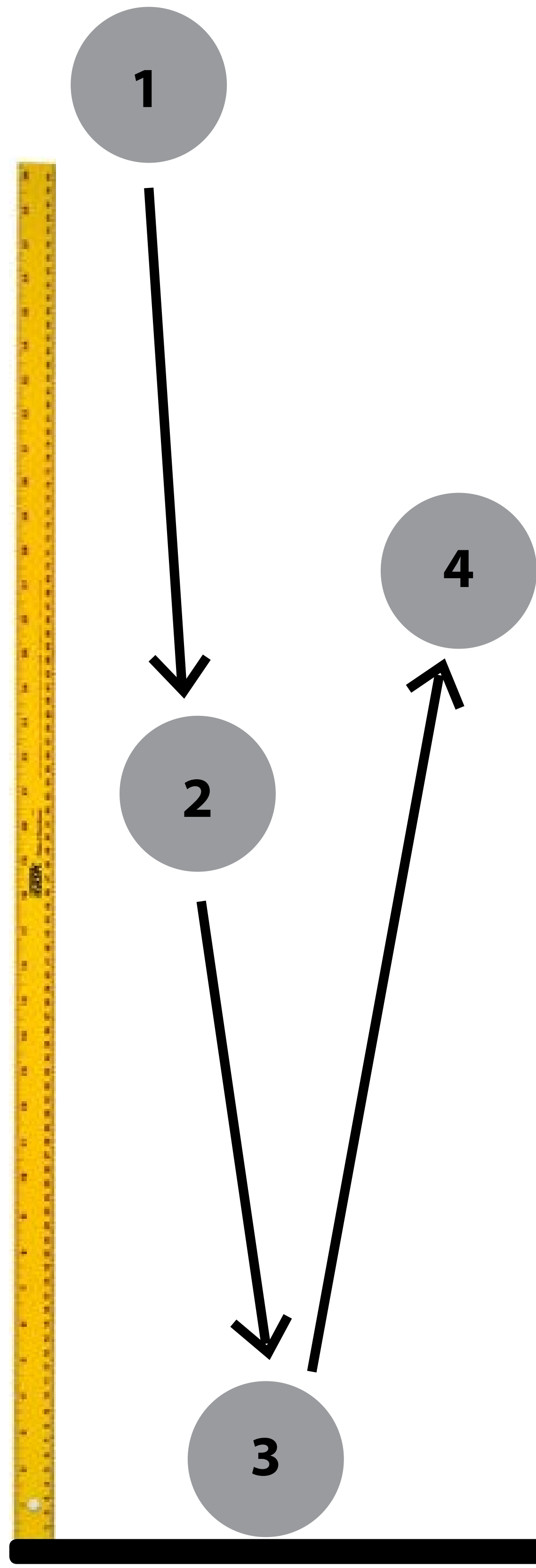
Calculate % energy recovered (%ER)

%ER = (GPE Position 4)/(GPE Position 1) x 100

%ER = ______________

Station One Guide

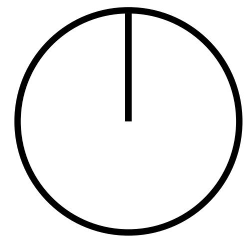
BLACK SPHERE 2 DIAGRAM



Position 1, before drop

GPE = m x *g* x h

GPE = ______________ J



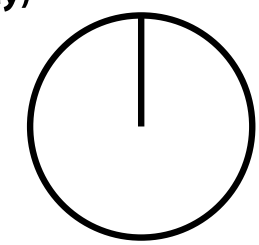
Position 2, while falling (halfway)

GPE = m x *g* x h

GPE = ______________ J

KE = GPE Position 1 - GPE Position 2

KE = ______________ J



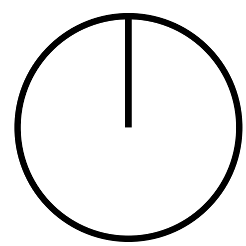
Position 3, just before hitting table top (0m)

GPE = m x *g* x h

GPE = ______________ J

KE = GPE Position 1 - GPE Position 3

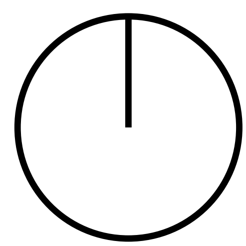
KE = ______________ J



Position 4, at the peak height of the bounce

GPE = m x *g* x h

GPE = ______________ J



Calculate % energy recovered (%ER)

%ER = (GPE Position 4)/(GPE Position 1) x 100

%ER = ______________

Station One Guide

Part Two: Toys

Caution

This activity uses a balloon made of latex. If you have a latex allergy, you should not handle the balloon.

Question

- Which form(s) of energy are transformed in some common toys?

Hypothesis

In your science notebook, write one hypothesis for each toy, stating which form(s) of energy you think are being transformed in each.

Materials

- Balloon
- Drinking straw
- Scissors
- String
- Tape
- Toy car
- Yo-yo
- Meter stick
- Hard surface such as a table or tiled floor

Vocabulary

- compress
- contract
- conversion
- elastic energy
- friction
- kinetic energy
- potential energy

✔ Procedure

Car

1. Set the toy car on a long, hard surface, such as a long table or tiled floor.
2. Carefully push down as you pull back on the car.
3. Release the car and allow it to move until it comes to a stop.
4. Record observations in your science notebook, describing the car's appearance as it was traveling the fastest, and when it started to slow down.

Balloon

1. Tear one or two strips of tape that are about 10 cm long.
2. Cut a 5 cm length of the drinking straw.
3. Inflate the balloon almost as far as possible. Take care not to overinflate the balloon.
4. While holding the balloon stem pinched shut, work with a partner to tape the straw to the top of the balloon such that it runs parallel to the long axis of the balloon stem.
5. Thread 5-10 m of string through the straw.

6. Working with a partner, hold the string very taut between you, and push the balloon all the way to the end of the string as shown.
7. Release the balloon and allow it to travel along the string until it stops on its own.
8. Record observations in your science notebook, such as when it traveled the fastest, what happened when the balloon was deflated, etc.

Station One Guide

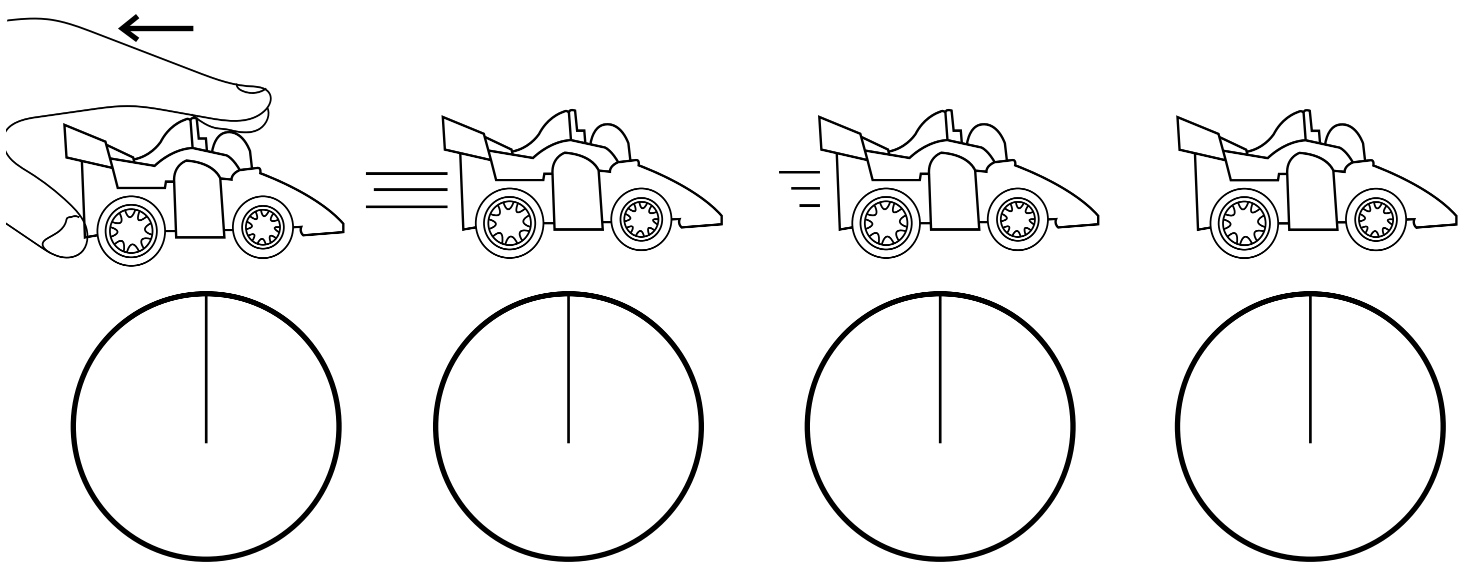
Yo-yo

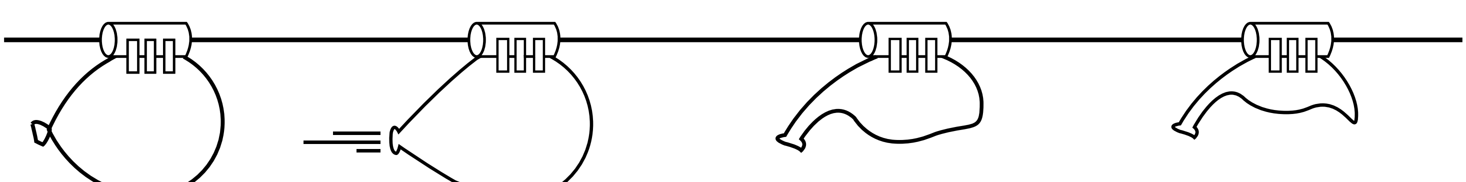
1. Fully unwind the yo-yo and measure the length of the string. Record this measurement in your science notebook.
2. Wrap all of the yo-yo string around it, leaving only the loop protruding from the yo-yo.
3. Slip the yo-yo string loop over your finger. Hold the yo-yo in your hand.
4. Turn your hand over so that the yo-yo is under your hand while holding onto it. Align a meter stick such that the "0" mark is even with the palm of your hand.
5. Release the yo-yo. Do not push down on the yo-yo in any way. Measure the height to which the yo-yo rebounds.
6. Repeat steps 2-5 two more times for a total of three measurements.
7. Record observations in your science notebook, such as the way the yo-yo was moving its entire trip down.

⁂ Part Two Conclusion

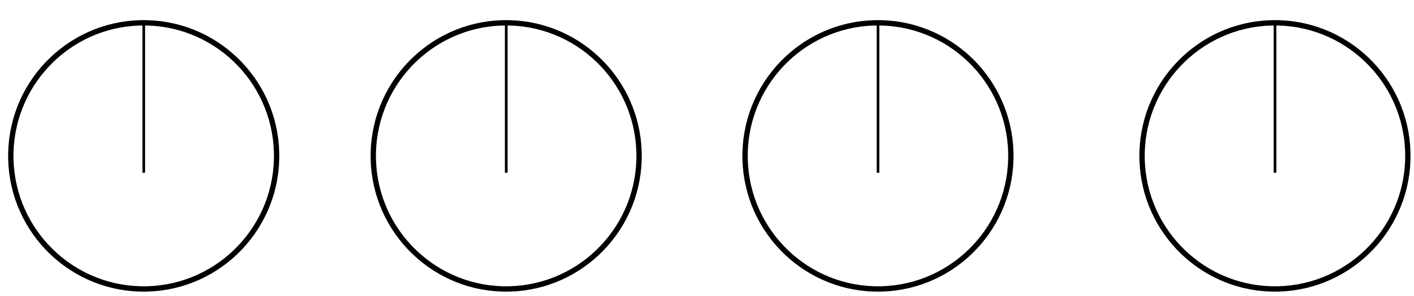
1. Copy the diagrams below and on page 42 into your science notebook.
2. For each toy used in Part Two, identify the form(s) of energy present at each stage shown. Use the pie charts to show the approximate proportion of each form of energy at each stage. Label the portions of the pie chart with the form of energy being represented.

1. Fully Compressed, Pulled Back **2. Partially Compressed, Moving** **3. Mostly Released, Moving** **4. Fully Released, Stopped**

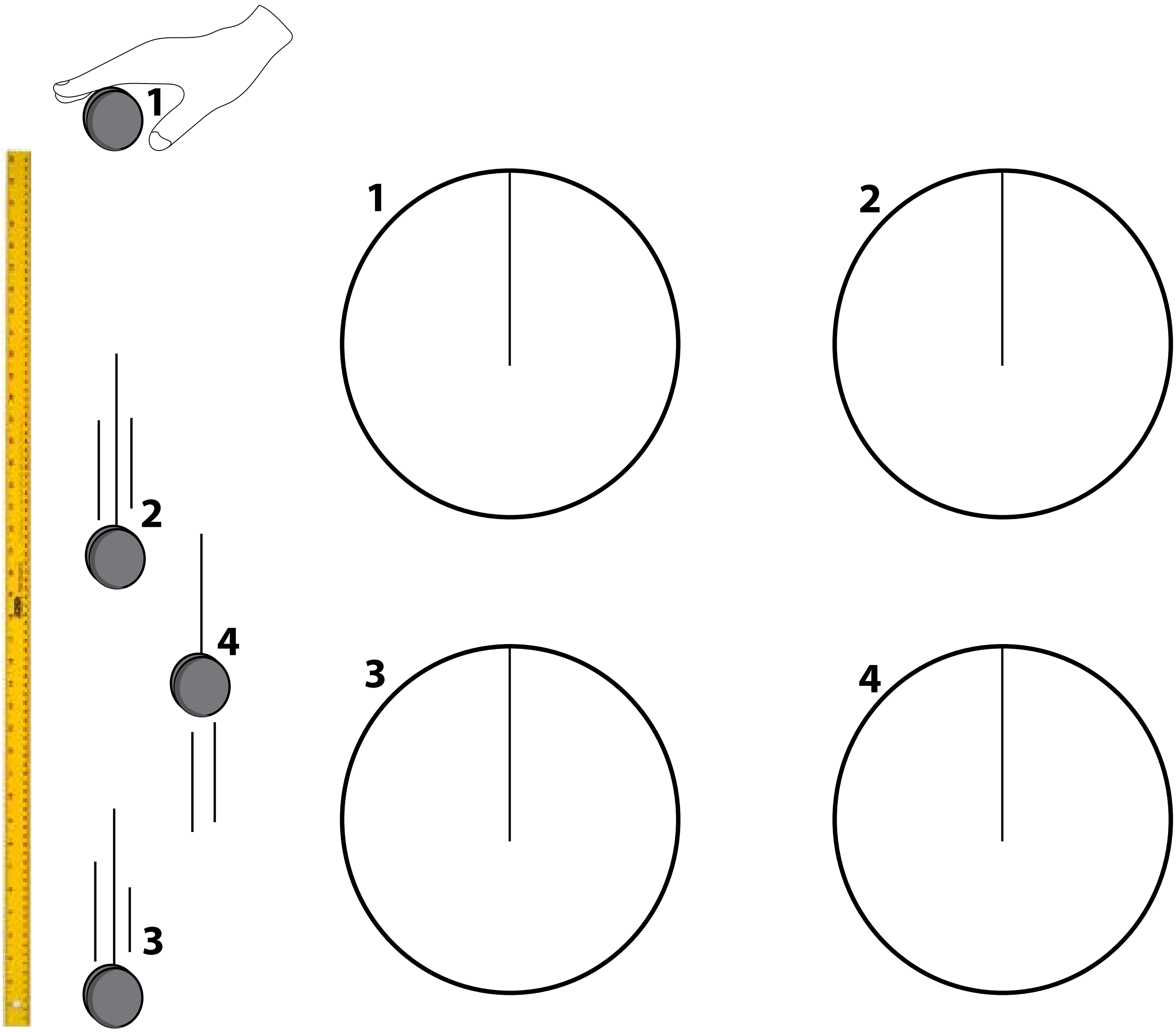




1. Fully inflated, not yet released **2. Partially deflated, moving** **3. Mostly deflated, still moving** **4. Fully deflated, stopped**



Station One Guide



3. Explain why the spheres in Part One and the yo-yo don’t return to their original positions.
4. When the yo-yo was dropped, some of the energy was recovered, and some was not. What happened to the energy that was not recovered?
5. Will you accept or reject your hypotheses about each of the toys? Cite the experimental evidence that supports your answers.

⁂Station One: Read

Read the *Station One: What Was Happening?* article. Do not erase your original conclusions, but compare what you read to what you thought was going on. Summarize the article in your science notebook.

Station One: What Was Happening?

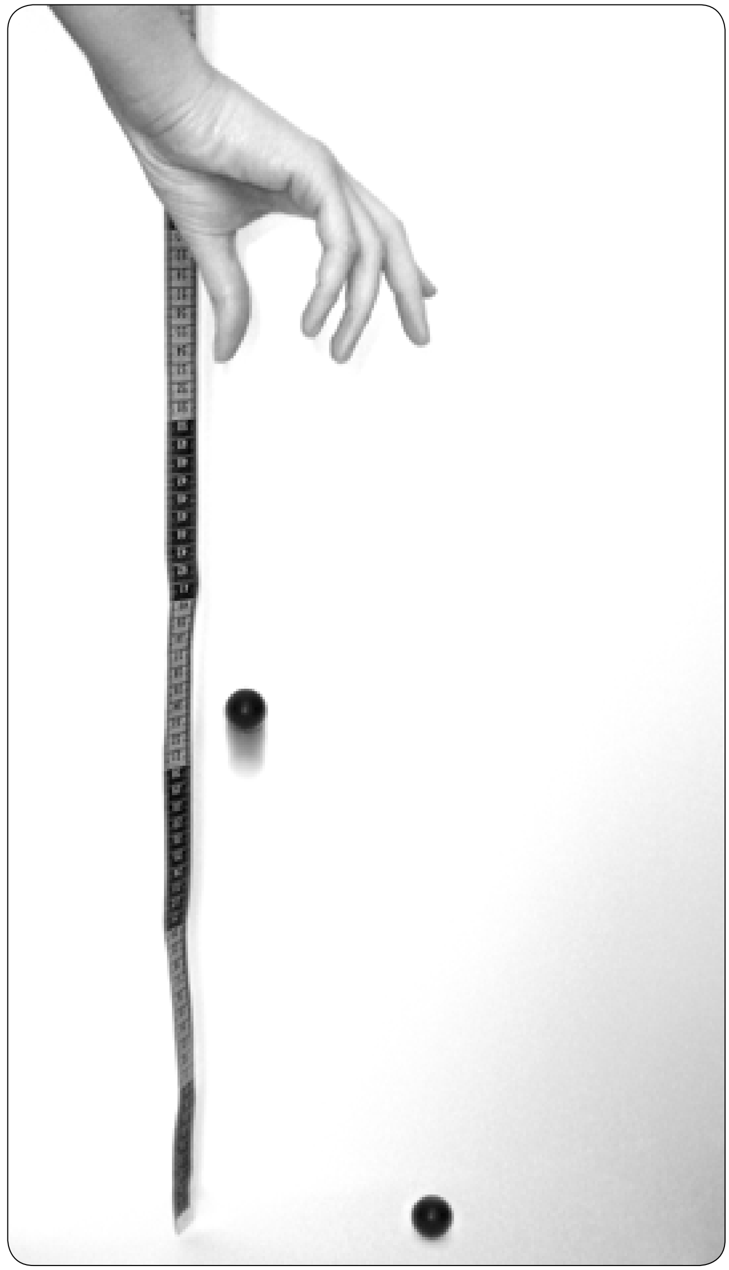
Spheres

Kinetic energy can take many forms, so can potential energy. When an object is moving, it has kinetic energy. When an object is elevated, it has gravitational potential energy. If a rock is placed at the top of a steep hill, it has gravitational potential energy. When a force is applied to the rock, it will begin to roll downhill. As it moves, the gravitational potential energy is transformed into kinetic energy. However, the conversion is not 100% efficient; in all energy transformations, some of the input energy form is dissipated as thermal energy and often also as sound. When the rock reaches the bottom of the hill, it will slow down and come to a stop, and all of the energy that was stored as gravitational potential energy will have been transformed to kinetic energy, then dissipated as thermal or sound energy, or in deforming the ground or rock.

Dropping an object from a position elevated above the floor works similarly to a rock rolling downhill. However, when the object, in this case a sphere, reaches the floor, it bounces. This is because some of the kinetic energy can be stored as elastic energy. The bouncing action is caused by the elastic energy being transformed back into kinetic energy, but this time in the opposite direction. Some materials are very efficient at transforming elastic energy into kinetic energy. The elasticity of an object depends upon the structure of the compounds making the object. Some materials, like a block of ice, will not bounce well. Very elastic compounds, like rubber, will bounce well.

A dropped object will not bounce to the same height as that from which it was dropped. Why is this? It is because some of the energy stored when the object was elevated is dissipated to the object's surroundings as thermal energy or sound, or deformation of the material. No energy transformation is 100% efficient to do work. Some of the energy transfers into the surroundings and cannot be recovered to do work. If you were to bounce the superball repeatedly, over the course of an extended period of time, the temperature of the superball would increase.

The black spheres, called "happy" and "sad" spheres, look very similar. However, they did not behave the same when dropped from the same height. One bounced much higher than the other, which is why it is nicknamed "happy." The material in the happy sphere is neoprene rubber. The other sphere did not bounce much, if at all; isn't that sad? The material in the sad sphere is polynorborene. Even though the size of the spheres is the same, and the densities are almost the same, there is a distinct difference in the elasticity of the two materials. Polynorborene is softer, and is able to absorb and dissipate energy better than neoprene. Therefore, it does not bounce as high as the neoprene sphere. Both spheres stored almost the same amount of gravitational potential energy; however, what they did with that energy when they hit the surface of the table or floor was different.



The happy sphere (left) keeps more of its energy, allowing it to rebound higher than the sad sphere (right). More of the energy in the sad sphere is transferred into heat and sound.

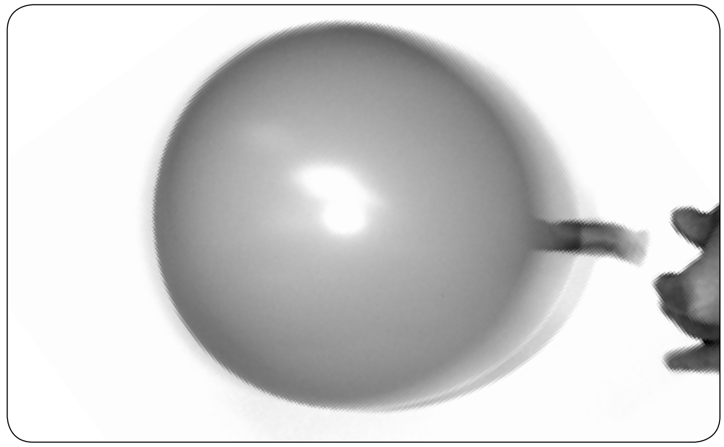
Toys

▪ Toy Car

The toy car contains a spring, and when the car is depressed and pulled backwards, the spring is compressed, storing elastic energy. Releasing the car allows the spring to transform the elastic energy into kinetic energy, and the car moves. When the spring is fully relaxed, the car still moves. Why? All objects in motion have momentum—the more massive the object, or the higher its velocity, the greater distance the object will continue to travel. The kinetic energy of a moving object is always being dissipated as thermal energy and sound because of the resistance it encounters. Without additional potential energy being transformed into kinetic energy, eventually all of the kinetic energy is transformed into thermal and sound energy, and the car comes to a stop.

▪ Balloon

Inflating a balloon pushes compressed air inside, stretching the rubber. When the rubber is stretched, it stores elastic energy, and the balloon pushes back against the air inside the balloon. As long as the balloon stem is held shut, the air inside pushes back with equal pressure against the walls of the balloon. However, when the balloon is released, the elastic energy of the balloon pushes the air out. Because of Newton's Third Law of Motion, when the air moves out of the balloon, the balloon moves forward in the air. Using the straw and string simply marks a pathway for the balloon to move. In this way, the balloon transforms elastic energy into kinetic energy.



What happens when the pressure inside the balloon and outside the balloon are equalized? The balloon has momentum, just like the toy car did, so it continues to move. However, because there is no more transformation of stored energy occurring, the resistance that the balloon encounters from the string and from the air ahead of it cause the kinetic energy of the balloon to be dissipated as thermal and sound energy, and the balloon comes to a stop.

▪ Yo-yo

A yo-yo behaves similarly to a dropped object, and takes the gravitational potential energy stored by holding it at an elevated position and converts it into kinetic energy. However, the behavior of the yo-yo at the bottom of the string is different than an object bouncing back because of elastic energy. As a yo-yo falls and unwinds the string, the yo-yo rotates. The movement of the yo-yo causes it to build momentum, and when it reaches the end of the string, its momentum causes it to continue rotating in its original direction. The result is that the yo-yo rewinds itself up the string, but in the opposite direction. For example, if the string was originally wound clockwise, the rebound would wind the string counterclockwise on the yo-yo.

As was the case with the spheres, the yo-yo will not rebound all the way to the height from which it was dropped. At the bottom of the string, the rotating yo-yo encounters some friction as it spins within the loop of the string. Some of the kinetic energy is dissipated to the yo-yo's surroundings as thermal energy and a small amount of sound energy; therefore the yo-yo will not climb the string all the way up to your hand if it is simply released. If you want the yo-yo to return to your hand, you must snap your wrist when you initially release it, and add additional energy beyond the gravitational potential energy imparted by the yo-yo's position.

Station Two Guide

Part One: Baking Soda and Vinegar

Question

- How does the amount of reactants present before a reaction affect the temperature of the products after the reaction?

Hypothesis

In your science notebook, write a hypothesis stating how you think the amount of reactants will affect the temperature of the products after the reaction.

Materials

- 50 mL Graduated cylinder
- Baking soda
- Balance
- Plastic bags
- Safety glasses
- Thermometer
- Vinegar

Vocabulary

- chemical reaction
- endothermic
- exothermic
- expand
- kinetic energy
- potential energy
- product
- reactant
- temperature
- thermal energy

✔ Procedure

1. Measure out 1.0 g of baking soda.
2. Use the graduated cylinder to measure 25 mL of vinegar and pour it into a plastic bag.
3. Place the thermometer into the bag of vinegar so the bulb of the thermometer is suspended in the vinegar. Record the temperature of the vinegar.
4. Carefully add the baking soda to the vinegar.
5. Closely and continuously watch the temperature and record the lowest temperature reached in degrees Celsius.
6. Record qualitative observations in the data table before, during, and after the reaction. Was there any residue left over in the bag? Describe the contents of the bag.
7. Empty, rinse, and dry the plastic bag.
8. Repeat steps 2-7 for each additional amount of baking soda listed in the data table.
9. Calculate the change in temperature ($\triangle$T) for each amount of baking soda used.

Data

Make this table in your science notebook:

VOLUME VINEGAR	MASS BAKING SODA	TEMPERATURE OF VINEGAR (°C)	TEMPERATURE OF VINEGAR AND BAKING SODA (°C)	CHANGE IN TEMPERATURE ($\triangle$T)	OBSERVATIONS
25 mL	1.0 g				
25 mL	1.5 g				
25 mL	2.0 g				
25 mL	2.5 g				
25 mL	3.0 g				

Station Two Guide

⁂ Part One Conclusion

1. Copy the graph section below into your science notebook or create a digital graph of your data. Construct a line graph for your data, appropriately labeling the independent and dependent variables. Identify the units for each axis, and give your graph an appropriate title.
2. What does your graph show about the relationship between change in temperature and amount of reactant used?
3. What do you think would happen to the temperature of the mixture if you used 3.5 g of baking soda? Support your answer with data from your experiment.
4. What do you think would happen if you increased the amount of vinegar? Support your answer with data from your experiment.
5. Would you identify this process as endothermic or exothermic? Use the data from your experiment to support your answer.
6. Will you accept or reject your hypothesis? Upon what experimental evidence are you basing your conclusion?
7. Why do some trials of this experiment leave a residue in the bottom of the plastic bag? What would happen if you added some vinegar to the residue?

Station Two Guide

Part Two: Calcium Chloride and Water

Question

- How does the addition of calcium chloride affect the temperature of water?

Hypothesis

In your science notebook, write a hypothesis stating how you think calcium chloride will affect the temperature of water. Sketch a graph of your prediction, showing how the temperature would change with varying amounts of calcium chloride added.

Materials

- Calcium chloride
- Measuring cup
- Plastic bag
- Safety glasses
- Thermometer
- Water

Vocabulary

- chemical reaction
- endothermic
- extrapolate
- exothermic
- potential energy
- temperature
- thermal energy

Procedure

1. Pour 10 mL of water into an empty plastic bag.
2. Place the thermometer in the bag. Make sure the bulb of the thermometer is suspended in the water. Record the temperature of the water in your science notebook. Leave the thermometer in the bag.
3. Carefully pour 4 cm^3 of calcium chloride into the water and gently mix.
4. Wait 30 seconds and record the temperature again. Wait another 30 seconds and take at least 1 more measurement to see if the temperature has increased more. Calculate the total difference in temperature and record in your science notebook.
5. Remove the thermometer from the bag and carefully zip the bag closed.
6. Record and illustrate your observations in your science notebook.

Data

Make this table in your science notebook:

	WATER ONLY	WATER + CALCIUM CHLORIDE			TOTAL CHANGE IN TEMPERATURE
TEMPERATURE		30 sec.	1 min	1 min 30 sec.	

Part Two Conclusion

1. Will you accept or reject your hypothesis? Upon what experimental evidence are you basing your conclusion?
2. How was the temperature of the water affected when combined with calcium chloride?
3. Would you identify this process as endothermic or exothermic? Use the data from your experiment to support your answer.
4. Go back to the sketched graph you made before doing this activity. Would you change it? Why?

Station Two Guide

Part Three: Hand Warmers

Question

- What energy change would you expect when iron is exposed to oxygen?

Hypothesis

In your science notebook, write a hypothesis stating what kind of energy change you would expect when iron is exposed to oxygen.

Materials

- Hand warmers
- Plastic bag
- Safety glasses
- Scissors
- Sealed plastic bag of expired hand warmer contents
- 2 Thermometers

Vocabulary

- catalyst
- chemical reaction
- endothermic
- exothermic
- iron oxide
- oxidation
- thermal energy

✔ Procedure

1. Remove the hand warmer from the plastic wrap. Cut open the packet.
2. Pour the contents of the hand warmer into an empty plastic bag. This will be called the "new packet." Record the temperature immediately then leave the bag open for three minutes. Air should be able to freely enter the bag.
3. While waiting, observe the bag with the contents of an old hand warmer. Record your observations. Put a thermometer in the bag and record the temperature of the contents in the bag.
4. Put a thermometer back in the bag with the new packet contents and measure the temperature. Record your observations.
5. Seal the new packet to prevent oxygen from entering the bag and set it aside.
6. After three additional minutes, measure the temperature of the new packet. Are there any changes to the temperature?
7. Put a thermometer back into the old packet. Record the temperature.

***Do not discard the old packet. You will use this packet during the presentations.**

Data

Make this table in your science notebook:

	OLD PACKET		NEW PACKET		
	START	END	IMMEDIATELY AFTER OPENING	AFTER 3 MINUTES, OPEN	AFTER 3 ADDITIONAL MINUTES, SEALED
TEMPERATURE					

Part Three Conclusion

1. Would you identify this process as endothermic or exothermic? Use the data from your experiment to support your answer.
2. Will you accept or reject your hypothesis? Upon what experimental evidence are you basing your conclusion?
3. What was the difference between the temperature of the new packet after three minutes with the bag open and after three minutes with the bag closed? Were the temperatures different? Explain why.
4. What other reactions do you know that use oxygen that are also exothermic?
5. How would the hand warmer function differently if the iron inside of it was a solid piece instead of finely ground? Justify your answer.

Station Two Guide

Extension

- Search the internet for a recipe for a homemade hand warmer. Design an experiment using iron of varying sizes (powdered, filings, nail, etc.) and investigate reaction rates. Determine the optimum size of the iron for the fastest reaction rate, and the longest-lasting hand warmer.

Station Two: Read

Read the *Station Two: What Was Happening?* article. Do not erase your original conclusions, but compare what you read to what you thought was going on. Summarize the article in your science notebook. As a final conclusion, describe how chemical bonding causes change in temperature in a chemical process. Also, explain why calcium chloride *does not* fit with the other two processess in producing temperature change, being sure to include ionization in your explanation. Record your answer in your science notebook, citing evidence and reasoning from your experimental observations and reading.

Station Two: What Was Happening?

Baking Soda and Vinegar

Chemicals go through changes we call chemical processes. Some of these processes involve changes that create new products. These processes are chemical reactions. Not all processes, however, are chemical reactions. Chemical reactions occur when bonds between atoms are being broken and new bonds are being formed. The result is a new substance or group of substances that hadn't been present before the reaction took place.

All chemical processes involve the transfer of energy. Often the energy transferred is thermal energy, but other forms of energy, like radiant and electrical energy, can be transferred. Some processes absorb energy and some release it.

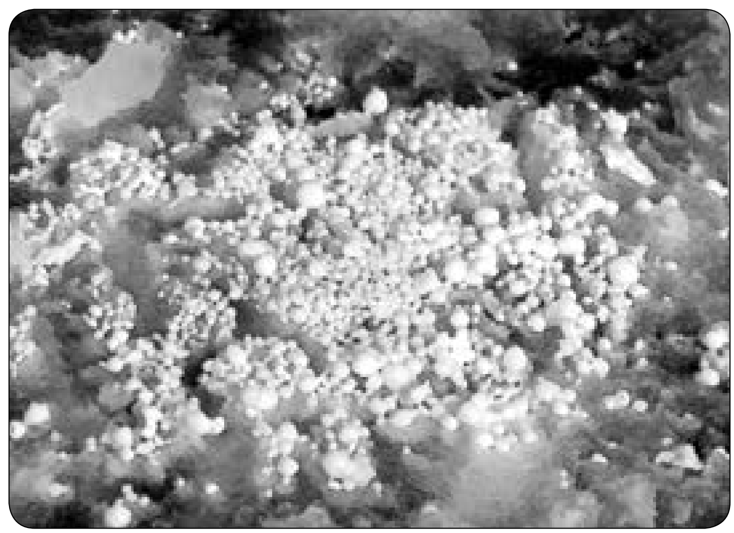
An exothermic process releases or emits thermal energy. *Exo-* means out and *thermal* means heat. The system of chemical reactants in an exothermic process releases energy and their surroundings become warmer. *Endo-* means in; endothermic processes absorb energy into the chemical bonds and their surroundings become cooler. In Station Two you saw both types of processes.

The reaction between baking soda and vinegar is endothermic – it absorbed energy and made the surroundings feel cold. Vinegar is the common name for a dilute solution of acetic acid, and baking soda is the common name for sodium bicarbonate. Combining acetic acid and sodium bicarbonate made other chemicals: water, carbon dioxide, and sodium acetate. The chemical reaction is:

$$CH_3COOH\,(aq) + NaHCO_3\,(s) + \text{Thermal Energy} \rightarrow H_2O\,(l) + CO_2\,(g) + CH_3COONa\,(aq)$$

In all chemical processes, energy is required to break bonds, and energy is released when bonds are formed. If the energy required to break bonds is greater than the energy released when new bonds are formed, the reaction or process will be endothermic. The additional energy needed will be absorbed from the surroundings, causing them to become cooler. The opposite is true of exothermic processes.

An endothermic process occurred when you combined vinegar and baking soda.



Calcium chloride (the small, round spheres) is commonly used to melt ice on driveways and sidewalks. When mixed with water (ice), it releases heat that can melt the ice.

Calcium Chloride and Water

When calcium chloride comes into contact with ice or water, it dissolves, and the calcium chloride ionizes or separates into calcium ions and chloride ions. This process is not a chemical reaction but a chemical process that requires energy. The attraction forces between those ions and water molecules releases a greater amount of energy than what was required to dissociate them, leading to an overall exothermic process.

Adding electrons to an atom increases its energy. Removing electrons from an atom requires energy. When ions form, energy can be released or absorbed. Sometimes ionic compounds form a crystal structure. Crystal structures are very ordered patterns, or symmetrical patterns of molecules in a substance. Many salts, like $CaCl_2$, have a crystal structure. Energy is needed to maintain that structure. Sometimes a crystal structure is very stable, and breaking it requires energy. However, some crystal structures actually release energy when dissolved. This is the case in calcium chloride. Dissolving calcium chloride causes energy to be released into the water and other parts of the surroundings. There are also many other factors that contribute to the dissolution of calcium chloride being exothermic that are beyond the scope of this activity. Since exothermic processes release thermal energy, the temperature of the solution increased.

A common use for calcium chloride is driveway ice melt. You can buy driveway ice melt at your local hardware store to melt the ice on your driveway or sidewalk during the winter. The ionization process is:

$$CaCl_2(s) + H_2O(aq) \rightarrow Ca^{2+} + 2Cl^- + H_2O(aq) + \text{Thermal Energy}$$

Hand Warmers

Hand warmers contain powdered iron. They are sealed in plastic to prevent oxygen and water in the air from reaching the iron. The old packet is made of iron that had been open for several weeks. When the iron was left in an open plastic bag, oxygen in the air was able to come in contact with the surface area of the iron. This chemical process is an example of a chemical reaction. The oxygen chemically reacted with the iron to form a new product, iron oxide, or rust. This process is an example of an oxidation reaction.

As was the case with baking soda and vinegar, energy was transferred in the reaction of iron with oxygen. However, energy was released, showing that the energy needed to break the bond in oxygen was less than the energy released when rust was formed. Therefore, the process was exothermic, and the temperature of the surroundings increased. The chemical reaction is:

$$\textbf{Fe(s) + O}_2\textbf{(g)} \rightarrow \textbf{2FeO(s) + Thermal Energy}$$

The rate of a chemical reaction is how quickly a product appears, or a reactant disappears, over time. The rate of a reaction can be affected by many factors; some of these factors include concentration, surface area, catalysts, and temperature. A few of these factors apply to this experiment.

Decreasing the concentration of a reactant effectively slows down or stops the reaction. With the hand warmer, sealing the bag caused the supply of oxygen to be cut off, effectively decreasing the amount of oxygen (concentration) available to the iron in the bag.

Increasing the amount of surface area of a solid in a reaction allows more atoms or molecules of that reactant to be available to react. A solid piece of iron takes a long time to rust completely. However, powdered iron oxidizes quickly. The same amount of energy is released when equal masses of iron rust, but powdered iron releases the energy faster because there is more surface area of the iron exposed to air.

Some of the ingredients in the hand warmer act as catalysts. A catalyst is a substance that changes the rate of reaction by creating conditions for the reactants that favor the production of products in a chemical reaction without the catalyst actually being consumed.

When exposed to oxygen, iron filings will turn into iron oxide.

Endothermic Processes

Vinegar: CH_3COOH

Acetate: CH_3OO^-

Hydrogen: H^+

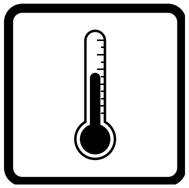
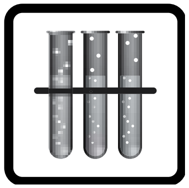
Baking Soda: $NaHCO_3$

Sodium: Na^+

Bicarbonate: HCO_3^-

Neutralization Reaction

$$\underset{\text{Acetic Acid}}{CH_3COOH\ (aq)} + \underset{\text{Sodium Bicarbonate}}{NaHCO_3\ (s)} + \text{Thermal Energy} \longrightarrow \underset{\text{Water}}{H_2O\ (l)} + \underset{\text{Carbon Dioxide}}{CO_{2\ (g)}} + \underset{\text{Sodium Acetate}}{CH_3COONa\ (aq)}$$

Exothermic Processes

Oxidation Reaction

$$2\,Fe\,(s) + O_2\,(g) \longrightarrow 2\,FeO\,(s) + \text{Thermal Energy}$$

Iron	Oxygen		Iron Oxide (rust)	

Calcium Choride and Water - Dissolution

$$CaCl_2\,(s) \xrightarrow{H_2O} Ca^{+2}\,(aq) + 2Cl^{-}\,(aq) + \text{Thermal Energy}$$

Calcium Chloride		Calcium	Chloride	

When calcium chloride and water are mixed in a solution, there is not a chemical reaction occurring, but rather the ionization of the calcium chloride. Thermal energy is released due to heat exchange from the ionization of the calcium chloride.

Station Three Guide

Part One: Sunlight and Shade

Question

- How much do direct sunlight and its absorbance affect the temperature of an object?

Hypothesis

Write a hypothesis stating how you think sunlight and its absorbance affect the temperature of an object in your science notebook.

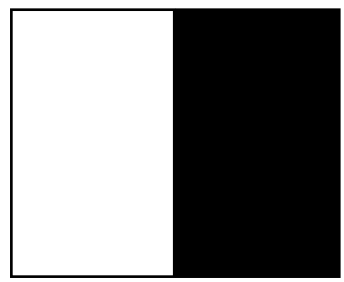
Materials

- 4 Thermometers
- Cardboard
- Light source
- Safety glasses
- Tape
- Black and white construction paper
- Stopwatch

Vocabulary

- absorb
- radiant energy
- reflect
- thermal energy
- transform

✔Procedure



1. Attach a half-sheet of black paper and a half-sheet of white paper side-by-side, as shown. Do this on both sides of the cardboard.
2. Tape one thermometer onto each color of paper. Do this on both sides of the cardboard so that all four thermometers are used. Label one side of the cardboard "sunny" and the other side "shaded". Record the starting temperatures on both sides of the cardboard.
3. Place the cardboard so that the sunny side is facing the sunlight (or alternate light source) and the shaded side is facing away.
4. Record the temperature of each thermometer every three minutes. Continue with the other parts of Station Three while passing the time.

Data

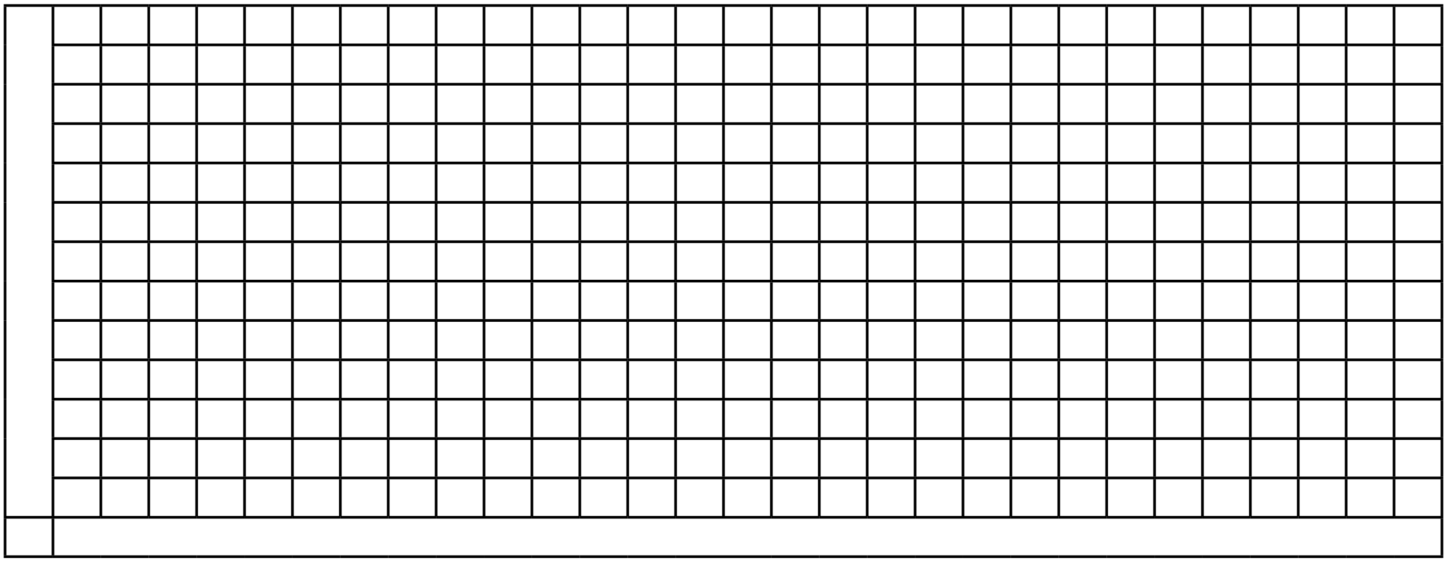
Make this table in your science notebook:

TIME	TEMPERATURE OF "SUNNY" SIDE		TEMPERATURE OF "SHADED" SIDE	
	BLACK PAPER	WHITE PAPER	BLACK PAPER	WHITE PAPER
STARTING (0 MINUTES)				
3 MINUTES				
6 MINUTES				
9 MINUTES				
12 MINUTES				
15 MINUTES				

Station Three Guide

Part One Conclusion

Copy the graph section below into your science notebook or create a digital graph of your data. Plot your data using a different color for each line, and provide a legend for your data plots.



1. How did exposure to the light change the temperature registered by the thermometer?
2. Compare the *temperature of the air* on the shady side of the cardboard with the temperature of the air on the sunny side of the cardboard. Think carefully before you answer.
3. Was there a difference between the temperatures on the black paper vs. on the white paper? Was this effect seen on both sides of the cardboard? Explain your answer.
4. Will you accept or reject your hypothesis? Upon what experimental evidence are you basing your conclusion?
5. What is the energy transformation that is occuring?
6. Explain how this energy transformation can be applied in everyday life. Describe two ways it can be useful and two ways it can be harmful.

Part Two: Radiometer

Question

- How does the intensity of a light source affect the movement of a radiometer?

Hypothesis

Write a hypothesis stating how you think the intensity of a light source affects the movement of a radiometer in your science notebook.

Materials

- Light source
- Meter stick
- Radiometer

Vocabulary

- absorb
- expand
- intensity
- kinetic energy
- molecule
- radiant energy
- reflect
- thermal energy
- transform
- vacuum

Station Three Guide

✔ Procedure

1. Lay a meter stick on the table.
2. Place the light so the edge of the light bulb is aligned with the "0" mark on the meter stick.
3. Place the radiometer on the table so the pin in the center of it is aligned with the 10 cm mark.
4. Turn the light on. Wait 3 minutes for the temperature of everything to come to equilibrium.
5. Observe the movement of the radiometer. Write a qualitative description of the radiometer's rotational speed in your science notebook.
6. Move the radiometer out to the 15 cm mark and let it sit for 3 minutes again.
7. Record observations about the relative speed of the radiometer at 15 cm as compared to 10 cm.
8. Repeat steps 6-7, each time moving the radiometer another 5 cm, until it is 50 cm from the light. At this distance, depending on the intensity of the light, the radiometer may not move at all, or it may move very slowly. Record your observations of its movement.
9. Using the graph area provided, make a sketch of how the radiometer's movement changes as it is moved farther from the light.

Data

Copy the graph section below into your science notebook. Make a sketch of the movement of the radiometer vs. the distance from the light source.

⁂ Part Two Conclusion

1. Describe how the distance from the light affects the speed of the radiometer.
2. Will you accept or reject your hypothesis? Upon what experimental evidence are you basing your conclusion?
3. What energy transformations are taking place in the radiometer?
4. How does the movement of the radiometer demonstrate what you observed with the thermometers in Part One? Explain your answer.

Station Three Guide

Part Three: Solar Panel

Question

- How does the angle of light affect the amount of electricity produced by a solar panel?

Hypothesis

Write a hypothesis in your science notebook stating how you think the angle of light affects the amount of electricity produced by a solar panel.

Materials

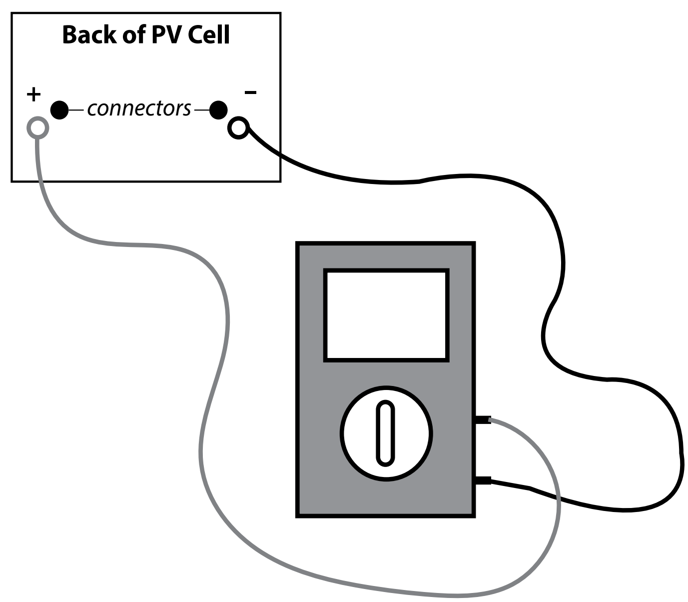
- Light source
- Protractor
- Safety glasses
- Solar panel with motor and fan blade
- Digital multimeter
- Alligator clips

Vocabulary

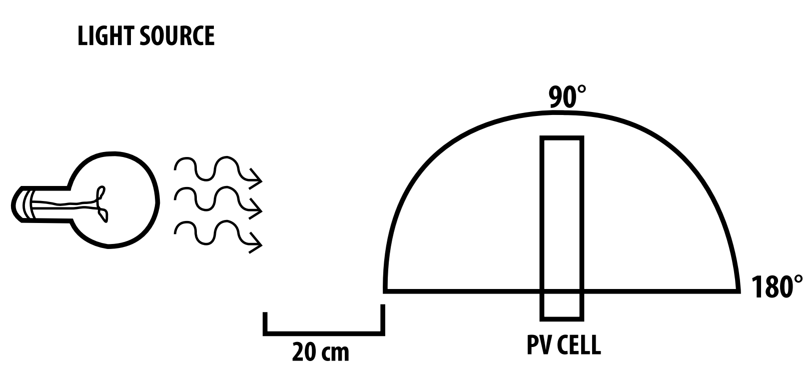
- absorb
- convert
- electrical energy
- kinetic energy
- photovoltaic cell
- radiant energy
- reflect
- renewable
- silicon
- transform

✔ Procedure

1. Connect two alligator clips to the posts on the back of the solar panel.
2. Connect the red lead of the multimeter to the alligator clip on the positive terminal. Connect the black lead to the alligator clip on the negative terminal.
3. Place the solar panel 20 cm away from the light source so it is directly facing the light.
4. Turn the light on.
5. Turn the multimeter on to 2000 mV DC and record the voltage.
6. Move the switch on the multimeter to 200 mA and record the current.
7. Using the protractor as your guide, tilt the solar panel back away from the light 15°. Record the voltage and current at this angle using the same settings on the multimeter as before.
8. Repeat step 7, each time tilting the solar panel an additional 15°, until the solar panel is lying flat on the lab table.
9. Turn off the multimeter.
10. Calculate the power produced (µW) at each angle and graph your data. Reference the *Units and Formulas* page for the correct formula, if needed.



**NOTE:* You may need to hold the solar panel closer than 20 cm away if working with certain bulbs such as halogen incandescents. If this is the case, be sure to monitor the panel to make sure it is not getting too hot or the plastic may begin to melt.



Station Three Guide

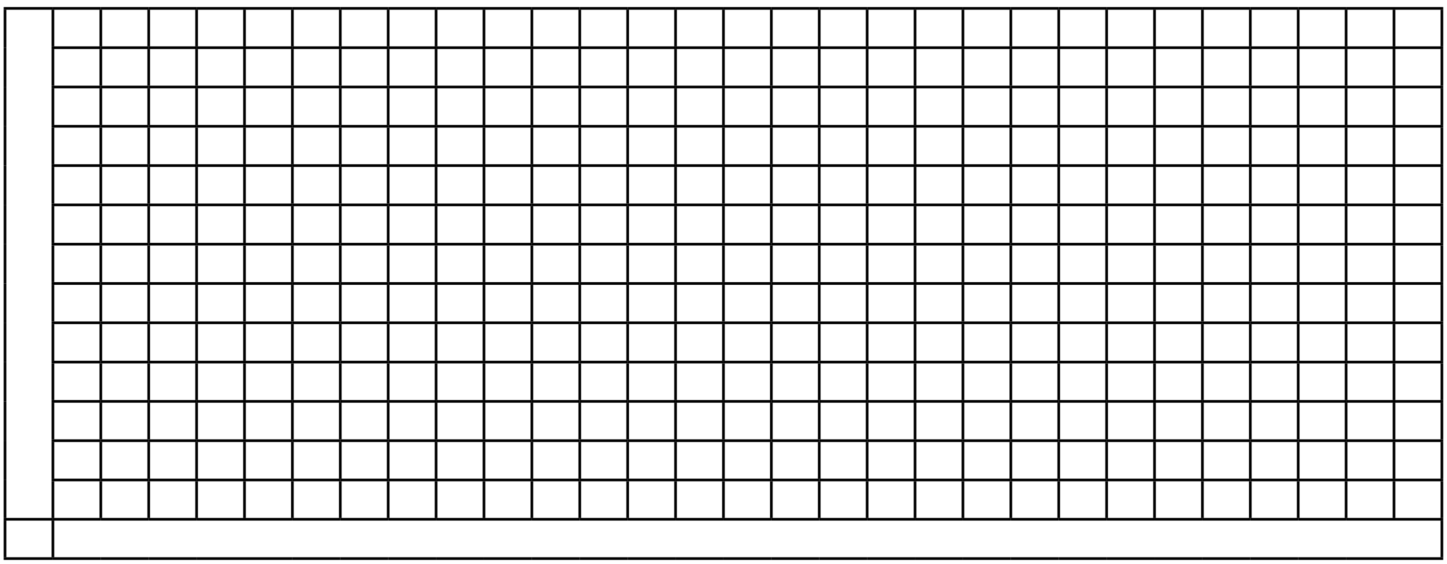
Data

Make this table in your science notebook:

Angle of Tilt	Voltage (mV)	Current (mA)	Power (µW)
0°			
15°			
30°			
45°			
60°			
75°			
90°			

Part Three Conclusion

Copy the graph section below and plot your data in your science notebook or create a digital graph of your data.



1. Describe how the angle from the light affects the power output of the solar panel.
2. Did the power generated by the solar panel change by the same amount for every 15° change in angle? Explain your answer.
3. Will you accept or reject your hypothesis? Upon what experimental evidence are you basing your conclusion?
4. In your graph, lightly sketch a curve that comes close to all points of your graph. Compare this graph to your radiometer graph.
5. Using this data and the radiometer data, write a general statement about the amount of energy available from a light source such as the sun with respect to distance and angle of incidence.

Station Three: Read

Read the *Station Three: What Was Happening?* article. Do not erase your original conclusions, but compare what you read to what you thought was going on. Summarize the article in your science notebook.

Station Three: What Was Happening?

Sunlight and Shade: Radiant Energy into Thermal Energy

You may have heard the expression, "It was 100 times cooler in the shade." Why do people say that? Even when the air temperature is the same, it feels hotter when you are in the sun than when you are in the shade. When you are in the sun, the sun's radiant energy is absorbed by your body and turned into thermal energy, making you feel hotter. In the shade, you only feel the thermal energy from the air molecules striking your body. The thermometers facing the light have higher temperatures because the sun's radiant energy is adding to the energy in the air around them.

On the sunny side of the cardboard, which thermometer had the higher temperature? It should have been the one on the black paper. Why is this? The sun produces light in all wavelengths – all colors of the rainbow. Objects that appear white to our eyes are actually reflecting all wavelengths of light, and are not absorbing much, if any, of the light striking them. Black objects, on the other hand, are absorbing nearly all of the light reaching them. Objects that appear black to our eyes are reflecting very little light. Because black objects are absorbing more energy, they get hotter than white objects left in the sun. This causes them to transfer more energy to their surroundings. If your car has a light-colored interior, it will feel cooler to sit on the seats on a sunny day than if your car has a very dark-colored interior.

Sitting in the shade protects you from directly absorbing the sun's radiant energy, keeping you cooler.

Radiometer: Radiant Energy into Kinetic Energy

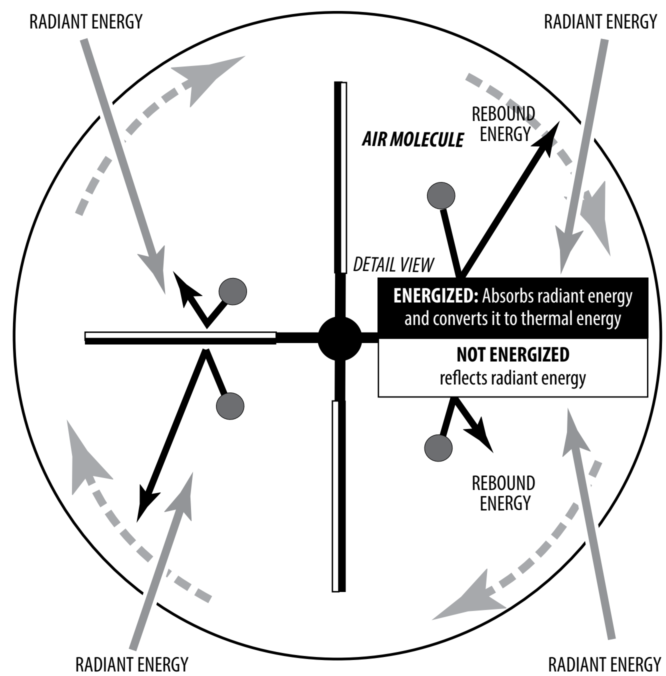
Have you figured out how the radiometer works? It is a glass bulb that is sealed with the parts inside. The space inside the bulb has very little air and is nearly a vacuum. The vanes inside the radiometer are balanced on a needle point. There are no moving parts or motors that make them spin, only the absorbance and reflectance of the light entering the radiometer.

But how can light make an object move if energy has no mass? After careful observation, you should have seen that the vanes of the radiometer are black on one side and white on the other. As you observed with the thermometers, the white sides of the radiometer vanes reflected more energy than the black sides. In fact, the black sides absorbed enough energy to heat the air molecules near them more than the air molecules near the white sides were heated.

When air molecules are heated, their movement increases. Air molecules may be too tiny to see without magnification, but you can see the effect their movement has. When the molecules next to the black vanes got hotter and moved faster, they bumped into the black sides more than they bumped into the white sides. The bumping of the air molecules was an unbalanced force and pushed the black vanes. You should have observed that the black sides of the vanes were moving away from the light source.

What happened when you moved the radiometer farther away from the light source? Did it move faster or slower? As you move farther from a light source, the intensity of the light is reduced. In fact, it is reduced according to the inverse square law. If the distance from the light source is doubled, the intensity of the light will be reduced to one-quarter its original intensity. Moving farther from the light source should have dramatically reduced the speed of the vanes inside the radiometer because the intensity of the light, and therefore the amount of radiant energy that could be transformed to thermal energy, also decreased dramatically.

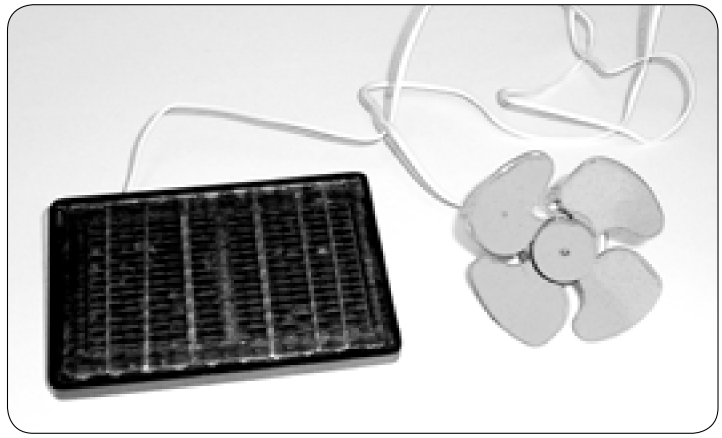
Top View of Radiometer



Solar Panel: Radiant Energy into Electricity

You know that electricity is moving electrons, and when you used the solar panel, you should have measured small amounts of electricity. Now that you understand how light can make air molecules move, understanding that light can make electrons inside of atoms move should also make sense. In fact, this is called the photoelectric effect, and describing this effect is what earned Albert Einstein his Nobel Prize. Light of specific wavelengths can energize electrons in different substances. Using the photoelectric effect, plants are able to manufacture sugar from a combination of sunlight, water, and carbon dioxide. This is called photosynthesis.

When we use the photoelectric effect, we are causing electrons in one substance to become energized, move through a circuit, and do work. This is done in a photovoltaic cell, and many photovoltaic cells are connected together into a solar panel. This is how radiant energy can be turned into electrical energy.



A solar panel transforms light into electricity, which powers the motor.

The variable in the solar panel exploration was not moved closer to or farther away from the light source, but was instead tilted farther and farther away from it. What happened as the panel was tilted? The amount of power being produced by the solar panel decreased.

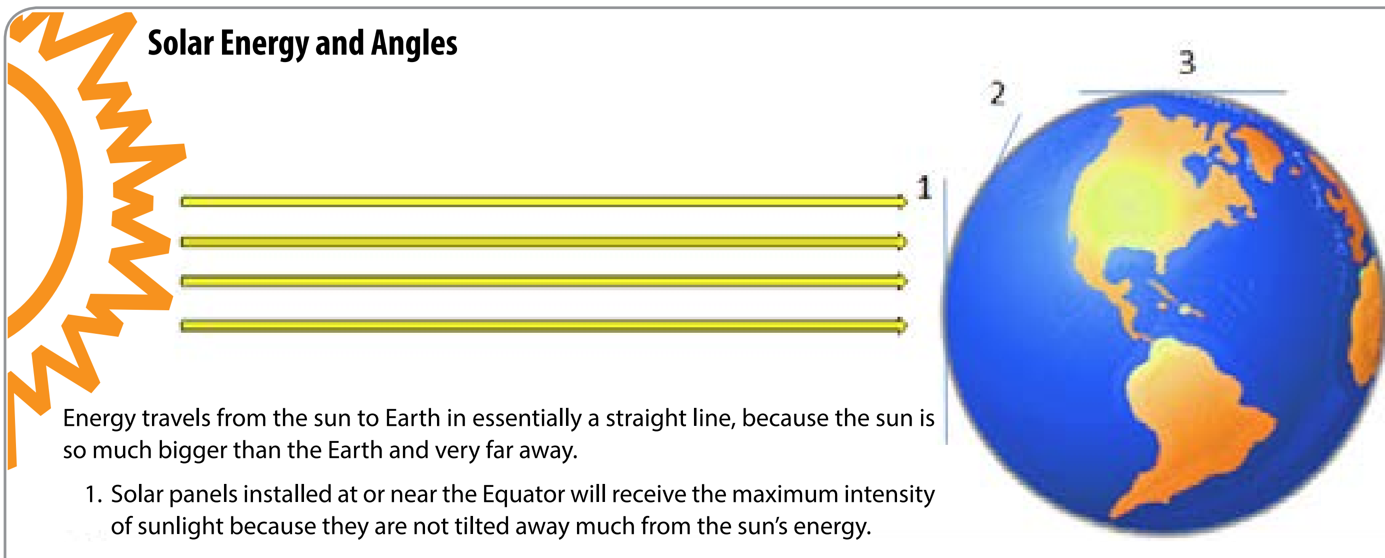
When we use solar energy to generate electric power, the distance from the sun is not an important factor. Being 92 million miles from the sun at ground-level, or 92 million miles less ten feet up off the ground, is such a small percentage change in distance from the sun. It does not make any measureable difference in the amount of electricity being produced. That is why installing solar panels at ground level produce about as much electricity as panels installed on the tops of buildings.

However, our location on the Earth, a round surface, makes a dramatic difference in the power generated. As you know, the Earth is tilted about 23° from vertical on its axis. This tilt is what causes the difference in seasons. In areas north and south of the Equator, there can be a great difference in the position of the sun in the middle of the day during the hottest part of the summer compared to the middle of the day during the coldest part of the winter. The farther away from the Equator you go, the greater the difference will be.

As you tilted the solar panel farther and farther from the light source, you should have seen a dramatic decrease in the amount of power produced by the solar panel. The same is true for solar panels installed outdoors to produce power from sunlight. That is why solar panels are mounted at an angle rather than lying flat; they are installed to face directly toward the sun as often as possible.

Solar energy is a clean, renewable natural resource, but PV cells are not very efficient. They convert only about 20 percent of the radiant energy that strikes them into electricity. The rest is changed into thermal energy or reflected off of the surface. Scientists are continually working on ways to make PV cells more efficient.

Solar Energy and Angles



Energy travels from the sun to Earth in essentially a straight line, because the sun is so much bigger than the Earth and very far away.

1. Solar panels installed at or near the Equator will receive the maximum intensity of sunlight because they are not tilted away much from the sun's energy.
2. Solar panels installed between the poles and the Equator will receive less sunlight because they are tilted away from the sun's energy.
3. Solar panels installed at the poles will receive almost no energy during winter because they are completely shielded, or tilted away from the sun's energy.

Station Four Guide

Part One: The Bi-Metal Bar

Question

- How does thermal energy affect the bi-metal bar?

Hypothesis

In your science notebook, write a hypothesis to address how you think thermal energy will change the bi-metal bar.

Materials

- Bi-metal bar
- Candle
- Matches
- Safety glasses
- Cup of ice water

Vocabulary

- absorb
- kinetic energy
- potential energy
- molecular
- reaction
- thermal energy

✔ Procedure

1. Look at the bi-metal bar. Record and illustrate your observations in your science notebook.
2. Light the candle.
3. Holding it by the wooden handle, carefully place the bi-metal bar sideways in the candle flame. Record your observations. Make a diagram of what happens to the bar.
4. Remove the bar from the flame, but do not touch the bar. Place the bar into the cup of ice water for 30 seconds and observe what happens.
5. Repeat steps 3 and 4 to verify your results.
6. Record and illustrate your observations.

Part One Conclusion

1. Explain the energy transformation that took place in the bi-metal bar.
2. Each metal expands at a different rate. The coefficient or rate of expansion for nickel is 13.0 x 10^{-6}/°C for each degree Celsius. The coefficient of expansion for stainless steel is 17.3 x 10^{-6}/°C. Use your observations to reason and identify which metals are on each side of the bar. Draw the bar and label the metals. Describe each metal's behavior and justify your identification of the metals citing experimental evidence.
3. When a train moves along its track, the wheels make a clickety-clacking sound as they cross small gaps in the rails. Using the concepts illustrated by the bi-metal bar, explain why there would be gaps in the rails.
4. How could the bi-metal bar be used to solve a real-world problem? Use your experimental observations to explain your answer.
5. Will you accept or reject your hypothesis? Upon what experimental evidence are you basing your conclusion?

Part Two: The Hanger

Question

- How does bending a piece of a hanger back and forth transform energy?

Hypothesis

In your science notebook, write a hypothesis stating how bending a hanger transforms energy.

Materials

- Metal hanger piece

Station Four Guide

✔ Procedure

1. Hold the metal hanger piece and note whether it feels warmer, cooler, or about the same as the air around it. Record all observations in your science notebook.
2. Bend the metal back and forth rapidly five times at the center.
3. Feel the metal at the stress point (where it was bent) with your finger. What do you notice? Draw a picture in your science notebook to demonstrate your observations.

Part Two Conclusion

1. What energy transformations did you observe? Label the diagram in your science notebook with the energy transformations.
2. Is there a connection between bending the hanger piece and the bi-metal bar bending? Explain your answer.
3. Will you accept or reject your hypothesis? Upon what experimental evidence are you basing your conclusion?

Part Three: The Rubber Band

Caution

Safety glasses should be worn for this exploration.
Rubber bands can be made from latex. If you have a latex allergy, do not handle the rubber bands.

Questions

- How does stretching a rubber band transform energy?
- How does relaxing a stretched rubber band transform energy?

Hypothesis

In your science notebook, write a hypothesis stating how you think energy is transformed by stretching and relaxing a rubber band.

Materials

- 1 Large rubber band
- Safety glasses

Vocabulary

- absorb
- contract
- convert
- expand
- thermal energy

✔ Procedure

1. Hold the rubber band firmly with your index fingers inside the ends of the rubber band and your thumbs on the outside.
2. Place the rubber band against your forehead. Allow the rubber band to remain in contact with your forehead for a few seconds so it can adjust to body temperature. While keeping it against your forehead, quickly stretch the rubber band to twice its original length and hold for three seconds. Let the rubber band contract. Repeat this step three times.
3. Record your observations in your science notebook.
4. Holding the rubber band away from your forehead, stretch the rubber band to twice its original length and touch the stretched rubber band to your forehead. Allow the stretched rubber band to remain in contact with your forehead for a few seconds so it can adjust to body temperature. While keeping it against your forehead, allow the rubber band to contract. Repeat this step three times.
5. Record your observations in your science notebook.

Part Three Conclusion

1. What energy transformation did you observe when the rubber band was stretched? What about when it was relaxed?
2. Is there a connection between stretching the rubber band and the bending of the bi-metal bar? Explain your answer.
3. Will you accept or reject your hypothesis? Upon what experimental evidence are you basing your conclusion?

Station Four Guide

Part Four: The Live Wire

Caution

Safety glasses should be worn during this activity.

NEVER place the live wire directly in a flame. You will ruin the tempering of the alloy and the wire will no longer be "live."

Question

- How does adding thermal energy affect the live wire?

Hypothesis

In your science notebook, write a hypothesis stating how you think adding thermal energy to a live wire affects it.

Materials

- Live wire
- Cup of very hot water
- Tongs
- Safety glasses

Vocabulary

- absorb
- kinetic energy
- molecular
- potential energy
- reaction
- thermal energy

✔Procedure

1. Get a cup of warm or hot water. Handle the hot water very carefully to avoid burning yourself. Always use the tongs when placing the live wire into, or removing it from, the water.
2. In your science notebook, draw a picture of what the live wire looks like in its original shape.
3. Twist the wire into different shapes, but do not tie it in a knot. Draw the new shape of the live wire in your science notebook.
4. Using the tongs, CAREFULLY dip the live wire into the hot water, and then remove it.
5. Record and illustrate your observations.

Part Four Conclusion

1. What happened to the wire when it came in contact with hot water?
2. What energy transformations took place in the live wire? Use your observations to support your thinking.
3. How could this technology be applied to solve a real-world problem? Explain why you think it will work.
4. Will you accept or reject your hypothesis? Upon what experimental evidence are you basing your conclusion?

Station Four: Read

Read the *Station Four: What Was Happening?* article. Do not erase your original conclusions, but compare what you read to what you thought was going on. Summarize the article in your science notebook.

Station Four: What Was Happening?

The Bi-Metal Bar

When substances and objects are heated, they expand. You may have noticed the spaces between sections of sidewalk. They are designed that way so that the concrete can expand on hot, sunny days without cracking. Bridges are built with expansion joints that allow the metal and the concrete in the bridge to expand and contract according to temperature, without breaking.

All objects expand when they are heated, but they do not expand at the same rate. Gases and liquids expand very quickly when they are heated. Their molecules can move about freely. A thermometer works because the liquid inside expands and contracts according to temperature.

Solids do not expand as much as gases and liquids because their molecules cannot move freely. It is sometimes hard to see them expand. The bi-metal bar is a good example of how metals expand when heated. This bar is made of two metals – one side is nickel, the other side is stainless steel. These metals expand at different rates.

What happened when you placed the bar in the flame? Did you notice which way it bent? The stainless steel in the bar expands more quickly than the nickel, so when it is heated, the bar bends. The stainless steel side is the outside of the curve. What happened when you took the bar away from the heat?

When placed in the cup of ice water the bar bent back the other way to its original shape. If you left the bar in the ice water long enough the bar would bend in the other direction. The stainless steel side also contracts faster when the temperature is lowered, so it is now on the inside of the curve.

Bi-metal strips like this are very useful. They are used in thermostats on furnaces and air conditioners to control the temperature. When the temperature in a room reaches a certain temperature, the bi-metal strip will bend enough to close a circuit and turn on the furnace or air conditioner. Bi-metal strips are also used in holiday lights that twinkle. When the metal gets hot it causes the strip to bend and stops the flow of electricity (breaks the circuit), which turns the light off. As the strip cools it bends back, allowing electricity to flow again, completing the circuit and turning the light on.

COEFFICIENT OF EXPANSION

$$\Delta L = \alpha \times L \times \Delta T$$

where:

Δ = change

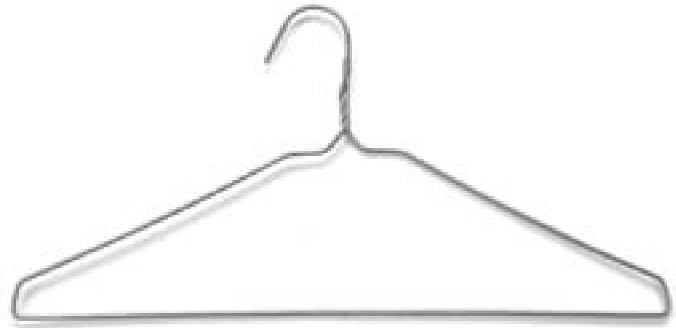
L = initial length

α = coefficient of linear expansion

T = temperature

The coefficient of expansion of a material is the change in length (or area) of the material per unit length (or unit area) that accompanies a change in temperature of one degree Celsius. The coefficient of linear expansion of nickel is 13×10^{-6}/°C and the coefficient of linear expansion of stainless steel is 17.3×10^{-6}/°C.

The Hanger

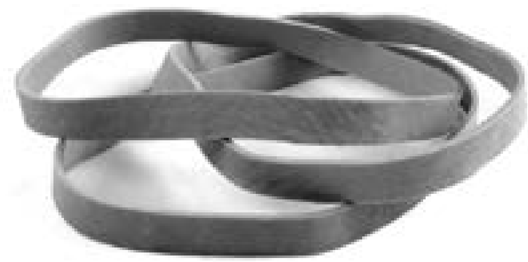


You used your own kinetic energy to bend a piece of the metal hanger a few times. What happened when you did this? When you bent the hanger, the atoms of the metal at the bend moved faster. The motion caused friction between the atoms, which increased the thermal energy of the atoms. When you touched the bent portion of the hanger, it should have felt warmer than when you started.

Let's trace the energy transformation from the thermal energy in this metal back to the sun. You put kinetic energy from the muscles in your hands and arms into the hanger. Your muscles got their energy from the stored chemical energy in the food you ate. The plants you ate transformed radiant energy from the sun into the stored chemical energy. The sun gets its energy from nuclear fusion. So the energy flow from the sun to the hanger is: nuclear energy, to radiant energy, to chemical energy, to kinetic energy, to thermal energy.

You have probably converted kinetic energy into thermal energy frequently on cold days. Put your hands on your face to note the warmth of your hands. Next, rub your hands together for about ten seconds and put them back on your face. They should feel warmer. You have just converted kinetic energy into thermal energy.

The Rubber Band



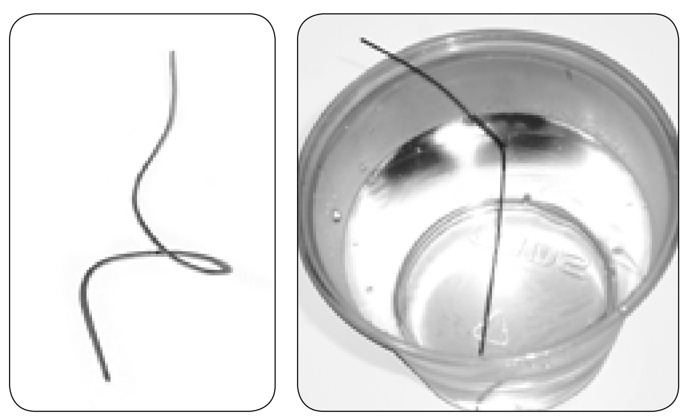
This activity demonstrated an energy transformation that both released and absorbed energy.

When you quickly stretched the rubber band to twice its length and placed it against your forehead, or when you let it contract, did you feel a change in temperature? The rubber band should have felt warm when it was stretched and cool when it contracted. When you stretch the rubber band, the weak intermolecular bonds (an attraction force between the molecules) are disrupted and the reduction of this attraction force releases thermal energy, making the rubber band feel warm. Contracting the rubber band causes the intermolecular bonds to re-form, absorbing thermal energy, causing it to feel cooler.

The Live Wire

The "live wire" is a nitinol (nī-tĭn-ŏl) wire, made of nickel and titanium that has been treated in a heat process so that it has a "memory." Most metals stay in whatever shape you put them in, but nitinol is different. Nitinol "remembers" its original shape when it is heated. Nitinol is used in space to move robot arms. It is also used to control the temperature of greenhouses. If the temperature gets too hot, a nitinol spring opens a door to let in air. Dentists and orthodontists use it in braces to straighten teeth. As the wires in your mouth warm, they attempt to return to their original shape, slowly moving your teeth with them. You were able to bend and twist the original shape of the wire any way you wanted. The thermal energy in the water made the wire return to its original shape. The thermal energy was transformed into motion.

You have just seen how thermal energy can be changed into motion.



Left: The nitinol wire is bent and twisted before being placed in hot water.

Right: Thermal energy is transformed into motion as the nitinol wire is placed in hot water, causing it to return to its original shape.

Station Five Guide

Part One: The Apple Electrolytic Cell

Question

- How do variables such as surface area and types of metals affect the ability of an apple electrolytic cell to produce electricity?

Hypothesis

Write a hypothesis in your science notebook describing how you think surface area and the type of metal affect the ability of an apple electrolytic cell to produce electricity.

Materials

- Apple
- Large nail
- Small nail
- Tin wire
- Thick copper wire
- Thin copper wire
- Two alligator clips
- Microammeter
- Permanent marker
- Metric ruler

Vocabulary

- chemical energy
- conduct
- conversion
- current
- direct current
- electricity
- electrode
- electrolyte
- energy flow
- transform

✔ Procedure

Part One

1. Using the marker, make marks on each piece of wire and both nails one centimeter from the end.
2. Insert each piece of metal into the apple 1 cm deep. Make sure none of the metal pieces are touching. Space them at least 1 cm apart.
3. Attach the end of one alligator clip to the positive terminal of the microammeter, and the other end of the clip to one piece of metal.
4. Attach one end of the other alligator clip to the negative terminal of the microammeter, and the other end of the same to a different piece of metal in the apple.
5. Record the reading on the microammeter in the data table. If the needle goes below the zero line, reverse the connection and record the new measurement.
6. Repeat steps 2-5 for each combination of metals listed in the data table.

Part Two

1. Choose the combination of metal pieces that produced the greatest amount of electric current from Part One.
2. Use the metric ruler and permanent marker to make marks at 2 cm, 3 cm, and 4 cm on each piece of metal.
3. Insert each piece of metal back into the apple 1 cm deep, making sure they do not touch.
4. Reattach the alligator clips as before, to the positive and negative terminals of the microammeter.
5. Record the current in the cell.
6. Repeat steps 3-5 for the additional depths, taking care each time to not allow the metal pieces to touch inside the apple.
7. Push the two pieces of metal into the apple so that they are touching inside the apple. Watch the microammeter as you push them in, and record what happens to the current when they touch.
8. Make a diagram of the electrolytic cell, labeling the two pieces of metal you used.
9. If you have not done so already, diagram the way the electricity flows through the apple in your science notebook.

Station Five Guide

Data

Part One

Make this table in your science notebook

Combination	Reading on meter (µA)
Large nail with small nail	
Large nail with tin wire	
Large nail with thin copper wire	
Large nail with thick copper wire	
Small nail with tin wire	
Small nail with thin copper wire	
Small nail with thick copper wire	
Tin wire with thin copper wire	
Tin wire with thick copper wire	
Small copper wire with thick copper wire	

Part Two

Make this table in your science notebook

Metal pieces used____

Depth (cm)	Reading on meter (µA)
1 cm	
2 cm	
3 cm	
4 cm	
Touching inside apple	

Part One Conclusion

1. What energy transformations took place in the apple electrolytic cell?
2. What was the best combination of metals for this activity? Justify your answer.
3. What was the optimal depth for the pieces of metal in the apple? Use experimental data to support your answer.
4. Will you accept or reject your hypothesis? Upon what experimental evidence are you basing your conclusion?

Station Five Guide

Part Two: Glow Sticks

Question

- How does thermal energy affect a glow stick?

Hypothesis

In your science notebook, write a hypothesis stating how you think thermal energy affects a glow stick.

Materials

- 1 Unbroken glow stick (remains uncracked)
- 2 Glow sticks of the same color (these will get cracked)
- 1 Cup of very warm water (NOT BOILING)
- Safety glasses
- 1 Cup of ice water

Vocabulary

- ampule
- chemical reaction
- convert
- molecular
- radiant energy
- reaction
- thermal energy

Procedure

1. Look at the unbroken glow stick carefully. Record and illustrate observations in your science notebook.
2. Bend the other two glow sticks until the ampules inside break or crack. Record and illustrate what happens.

NOTE: When presenting this station you do not need to break new glow sticks each time. Break new glow sticks each day and use the same ones with each group that rotates through.

3. Place one broken glow stick in the ice water, then place the second broken one in the hot water. Record and illustrate your observations.
4. Drop the unbroken glow stick into the warm water and wait a few minutes. Take it out of the warm water and place it in the ice water. Record your observations in your science notebook.

Part Two Conclusion

1. What energy transformations are taking place in the glow stick?
2. Explain how a glow stick works.
3. How does thermal energy affect the rate of reaction in the glow stick?
4. Did increasing or decreasing the temperature of the unbroken glow stick change it at all? Why or why not?
5. Explain why some people store their batteries in the refrigerator to make them last longer. Use the observations from this activity to support your answer.
6. Will you accept or reject your hypothesis? Upon what experimental evidence are you basing your conclusion?

Station Five: Read

Read the *Station Five: What Was Happening?* article. Do not erase your original conclusions, but compare what you read to what you thought was going on. Summarize the article in your science notebook.

Station Five: What Was Happening?

The Apple Electrolytic Cell

In the apple electrolytic cell investigation you used the chemical energy in the apple to make electricity. Everything we encounter in our daily lives, such as water, oxygen, sugar, and plastic, could be called a chemical. An apple contains a chemical called malic acid. The malic acid in the apple made an electrolytic cell when combined with two different metals. Most nails are made of steel but are coated in zinc to prevent corrosion. When you pushed the zinc nail and a piece of copper wire into the apple and attached them to the microammeter you saw the needle move. This shows that there is an electric current moving through the circuit.

As you observed the microammeter, you saw that the needle moved to the right to indicate an electric current. When you put the zinc on the nail and copper from the wire into the apple, they both reacted with the acid, but they did not react the same way. The different reactions created an imbalance in electrical charge. When the zinc and copper were connected to the meter, the electrons flowed from the zinc on the nail through the meter to the copper wire in the apple. This flow of electrons registered on the microammeter. Chemical energy is converted to electrical energy. Because the microammeter moved to the right, it showed that the charge was flowing. This is the way all electrical circuits with batteries work. A battery contains two metals and an electrolyte. The electrolyte ions migrate within the battery to balance out the imbalance of charge when the circuit is closed.

One of the metals in a battery is often called an anode. In your cell, the zinc coating the nail is the anode because it is made of a positively charged electrode that attracts electrons or negative charge:

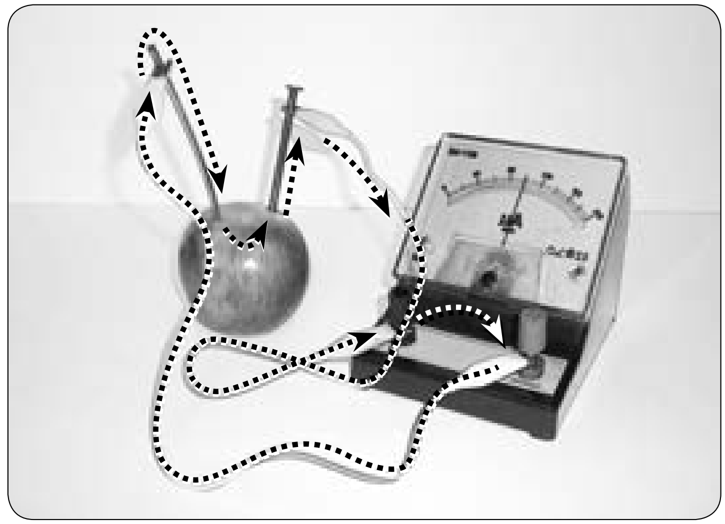
$$Zn \rightarrow Zn^{+2} + 2e^{-}$$

The other metal in a battery is called a cathode. In your cell, the copper acts as a cathode because it is made of a negatively charged electrode that donates electrons or accepts positive charge.

$$Cu^{+2} \rightarrow 2e^{-} \rightarrow Cu^{\circ}$$

There were five pieces of three different types of metals that you combined in Part One. You should have seen no movement of the meter when two pieces of the same metal – the thin and thick copper wires, for example – were connected. This is because both pieces of copper were reacting similarly with the malic acid in the apple, and there was no imbalance of charge to compel electrons to move. A battery must have two different metals to work correctly, and some metals are better than others in forming a battery.

You should have discovered in Part One that the large (zinc) nail and thick copper wire produced the greatest amount of current through the meter. The thicker pieces of metal produced more current because they each have more surface area to come in contact with the acid.



Zinc and copper react with the acid in the apple to produce an electric current. The arrows show the path of the electrons.

In Part Two, the deeper you pushed the nail and copper wire into the apple, the greater the movement of the meter needle, indicating the greater the flow of electrons. There was more electric current because there was more metal to react with the acid, and more electrons were free to move. Direct current (DC) electricity is movement of electrons in only one direction. This type of electrolytic cell generates DC electricity.

The next step was to push both metals into the apple so they were touching each other. No current was flowing through the meter. This does not mean there was not any electric current. It just means the electrons were flowing straight from one metal to the other. Electrons always take the easiest path. This is called a short circuit because the electrons are taking the shortest path.

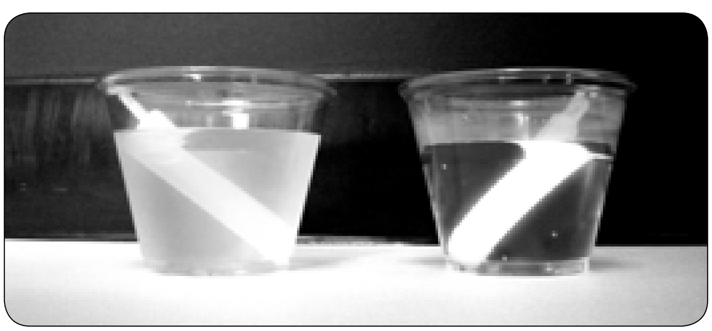
Glow Sticks

The glow stick is filled with a solution of ester and dye. Inside the glow stick you can see a little glass container, or ampule. The ampule holds hydrogen peroxide, a liquid used as an antiseptic in first aid. Before you bent or cracked the glow stick, the two chemicals could not touch each other. When you bent the glow stick and broke the ampule, the chemicals could mix together and a chemical reaction resulted in new chemicals.

The glow stick is producing light—radiant energy. When you broke the glass, the hydrogen peroxide and ester reacted to form different chemical compounds. The new compounds do not need as much energy to hold their molecules together, so they release the extra energy. The fluorescent dye in the glow stick then becomes energized. When the dye gives up the extra energy and returns to its normal state, it emits the energy it absorbed as the light we see. You have probably seen glow sticks of different colors. They have different fluorescent dyes in them. The reaction between the hydrogen peroxide and the ester is the same regardless of the color of the light stick. The difference in color is because different dyes are used.

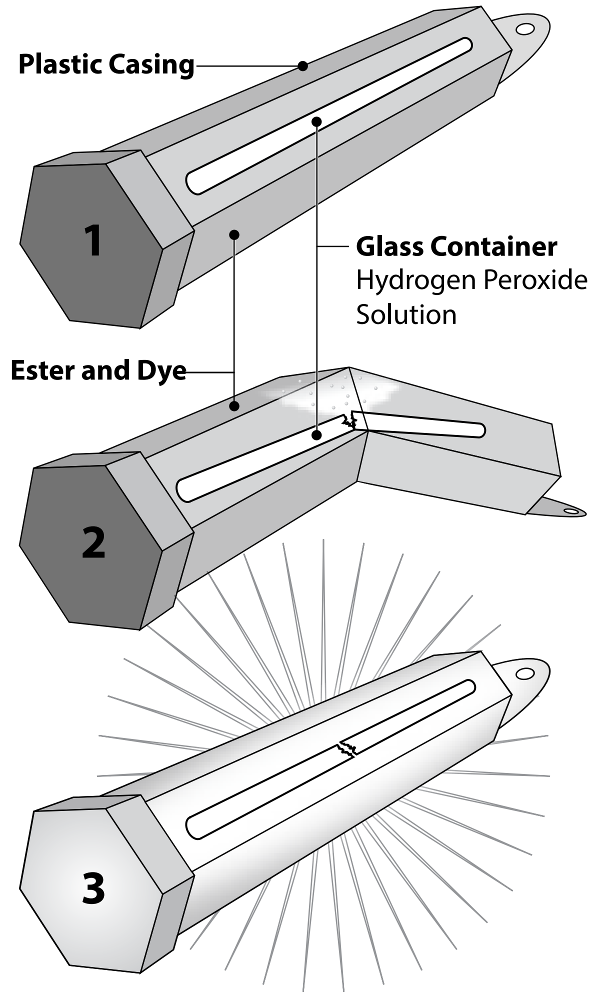
When you put the glow stick in cold water what happened? The glow stick was not as bright, was it? The cold water absorbed some of the thermal energy from the glow stick, so the reaction slowed down.

How did increasing the temperature of the glow stick change its brightness? Some of the thermal energy from the hot water was transferred to the chemicals in the glow stick. The added energy made the chemicals react more quickly and produce more light. At room temperature, the glow stick will glow for about two hours, but only for about 30 minutes in the hot water. It might glow for six hours in the cold water. Whether heated or cooled, the same total amount of light will be produced. The glow stick is a good example of transforming chemical energy into radiant energy.



The glow stick in the hot water (right) glows brighter than the glow stick in the cold water (left) because the higher temperature increases the speed of the chemical reaction.

How a Glow Stick Works



1. The glow stick is filled with a chemical compound called an ester and dye. Inside, a small glass container is filled with hydrogen peroxide.
2. When the glow stick is bent and the container is broken, the chemicals from the ampule and the glow stick mix, causing a chemical reaction.
3. During the chemical reaction, energy is released as light.

Station Six Guide

Part One: Electromagnet and Compass

Question

- How will electric current passing through a wire affect a compass?

Hypothesis

In your science notebook, write a hypothesis stating how you think electric current passing through a wire will affect a compass.

Materials

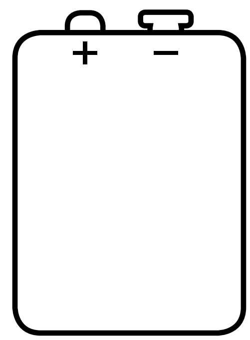
- 9-volt Battery
- Compass
- Alligator clip
- Nail

Vocabulary

- conduct
- direct current
- electricity
- electromagnet
- energy flow
- magnetic field
- repel

✔ Procedure

1. Take the nail and hold it next to the compass. Move the nail around over the compass and observe the interaction. Record your observations in your science notebook.
2. Connect one end of the alligator clip to the negative terminal of the 9 V battery.
3. Wrap the wire of the alligator clip around the nail, starting at the flat end or head of the nail, and moving towards the pointed end. Leave enough wire to reconnect the battery.
4. Connect the other alligator clip to the positive terminal of the 9 V battery.
5. Hold the pointed end of the nail near the compass. Observe the interaction. Record your observations in your science notebook.
6. Hold the flat end or head of the nail near the compass. Observe and record the interaction.



Part One Conclusion

1. What did the electric current create when it passed through the wire around the nail?
2. What are the two poles of a magnet called?
3. Which pole was the flat end of the nail? Which pole was the pointed end of the nail? Support your answer with your observations.
4. How do the parts of an electromagnet work together to create magnetism?
5. Will you accept or reject your hypothesis? Upon what experimental evidence are you basing your conclusion?

Station Six Guide

Part Two: Motors and Generators

Question

- How are electricity, magnetism, and motion related?

Hypothesis

Write a hypothesis stating what you think about the relationship between electricity, magnetism, and motion.

Materials

- Two motors
- Two alligator clips
- 9-volt Battery
- Disassembled motor
- Hand generated flashlight
- Masking tape

VOCABULARY

- chemical energy
- conduct
- direct current
- electricity
- electrode
- electromagnet
- energy flow
- kinetic energy
- potential energy
- transform

✔Procedure

1. Fold a piece of tape like a flag onto the shaft of the assembled motor and put an X on one side.
2. Connect the terminals of one of the assembled motors to the 9-volt battery with the alligator clips. What happens? Make observations in your science notebook.
3. Connect the alligator clips to opposite terminals of the battery. Observe and illustrate your observations. (Hint: pay attention to the direction of the spinning motor shaft.)
4. Look at the disassembled motor. Remove the rotor (coil of wire and magnets). Record and illustrate the disassembled motor and label the parts in your science notebook.
5. Connect the terminals of the two assembled motors to each other using alligator clips (no battery is involved here). Grasp the shaft of the motor without tape and give it a hard, swift spin, observing the tape on the shaft of the other motor. Record your observations.
6. Using the assembly from step #5, turn the shaft in the opposite direction and observe the tape. Record your observations. Make a diagram in your science notebook, indicating the direction the taped shaft spins according to the direction of the motor without tape.
7. Observe the hand generated flashlight but do not shake it or attempt to generate light yet. Pay attention to the coil of wire and the magnets.
8. Draw the hand generated flashlight in your science notebook and label the parts. Try to explain how the flashlight works.
9. Shake the hand generated flashlight several times and observe what happens. Record your observations in your science notebook.

⁂ Part Two Conclusion

1. What energy transformation occurs in this activity?
2. What happened to the motion of the motor when the clips on the battery were swapped? Explain what is occurring in the battery to cause this.
3. Think back to when the two motors were hooked together. What happened to the direction of the shaft on the second motor when you reversed the turn on the first? Explain why this occurred.
4. Will you accept or reject your hypothesis? Upon what experimental evidence are you basing your conclusion?

⁂Station Six: Read

Read the *Station Six: What Was Happening?* article. Do not erase your original conclusions, but compare what you read to what you thought was going on. Summarize the article in your science notebook.

As a final conclusion, summarize how electricity and magnetism are related. Explain how both electricity and magnetism can be created. In your explanation, also describe how motors and generators are similar and different in function. Record your answer in your science notebook, citing evidence and reasoning from your experimental observations and reading.

Station Six: What Was Happening?

Part One: Electromagnet and Compass

This activity took a non-magnetic object, a nail, and made it magnetic. Ordinarily, iron is not in and of itself a magnet, but it will respond to a magnetic field. Only three metals are noticeably magnetic: iron, nickel, and cobalt. This is related to the movement of electrons within the atoms.

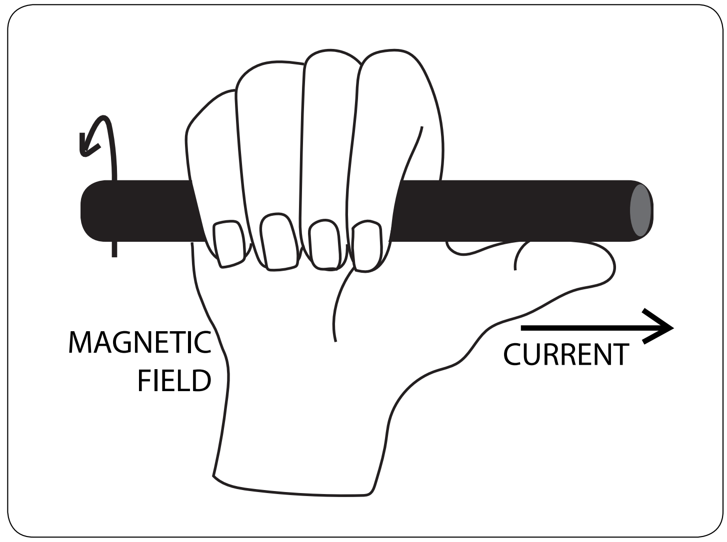
Electrons don't just move around the nucleus of an atom; they also spin. Michael Faraday was the first to demonstrate that a moving electrical field creates a magnetic field, and because electrons have an electrical charge, their movement creates tiny magnetic fields. Ordinarily electrons exist in pairs. Each electron in the pair spins in an opposing direction from the other. The magnetic field generated by one electron is canceled by the magnetic field generated by the other electron in the pair. However, in nickel, cobalt, and iron, there are unpaired electrons with magnetic fields that are not canceled. This creates tiny sections in the metal where magnetic fields align, called magnetic domains.

When the wire was wrapped around the nail, and electric current moved through it, a magnetic field was created that moved through the center of the coil of wire, out from one end of the nail, and around, back to the other end of the nail. The way electric and magnetic fields are related is demonstrated with the "right-hand rule." If you outstretch your right hand, and your thumb indicates the direction of one field, the fingers of your right hand will curl around in the direction of the other field. If the electric current was straight, the magnetic field would curl around the wire. If the electric current was moving in a coil, however, the magnetic field would be straight.

When the wire was connected to the battery and electric current moved through it, the magnetic field induced by the moving electric field in the wire caused the magnetic domains in the nail to align, and the nail became a magnet itself. Even after the wire was disconnected from the battery, the nail may have remained magnetic until dropped on the floor or tapped on the table, which would have caused the magnetic domains to move back into their original configuration.

Electromagnetism allows us to transform electrical energy into kinetic energy and make things move. The chemicals in the battery interact to generate electric current, and like the apple electrolytic cell in Station Five, transform chemical energy into electrical energy.

Right Hand Rule



Inside the motor are magnets and three copper coils. The electric current causes the coils of wire to become electromagnets. The interaction between the induced magnetic fields of the coils and the permanent magnetic fields inside the motor housing causes the spinning of the shaft. Electrical energy has been transformed into kinetic energy.

Part Two: Motors and Generators

In this station we had two tiny electric motors. Lots of little toys have motors like these. They make the toys move; they convert electrical energy into motion energy. Inside the disassembled motor, you can see a coil of wire on the shaft with small magnets around the coil.

Remember that in the compass demonstration we learned that when electricity flows through a coil of wire, it produces a magnetic field around the wire. When electricity passes through the coils of wire in the motor, magnetic fields are created in each of the three coils. These generated magnetic fields interact with the magnetic fields of the permanent magnets on the casing of the motor. The attractive and repulsive forces created from the interaction of these magnetic fields causes motion – the spinning of the motor. Electrical energy is converted to magnetism and then to motion. Toy motors get their electrical energy from batteries that make electrical energy from the chemical energy stored in them. The tape was attached so you could see the shaft turning.

Electromagnetism is one of the four fundamental forces of nature, along with gravity, strong nuclear force, and weak nuclear force. While we cannot explain why it works, we know that moving an electric charge will induce a magnetic field, and moving a magnetic field will induce an electric current. Electromagnetism allows us to transform movement into electricity with a generator, and electricity into movement with a motor.

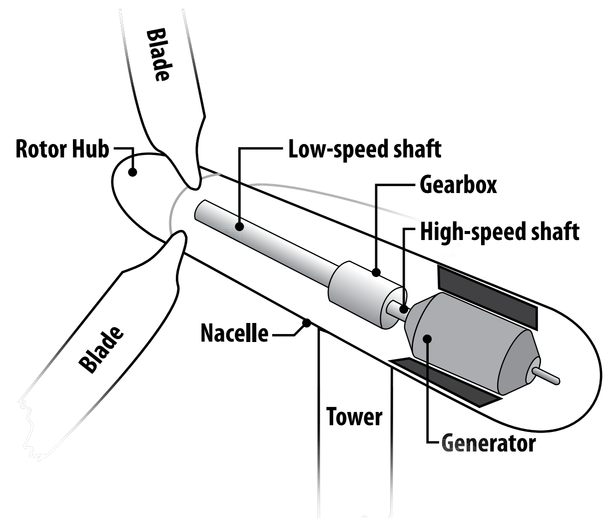
You ended Part Two of this station by looking at a hand generated flashlight. It uses a person's kinetic energy to produce electricity to light the bulb. Inside there is a coil of wire and a magnet. When you used your energy to shake the flashlight, the magnet passed through the coil of wire. Moving the magnet through the coil of wire generated electricity, which was stored in the capacitor or battery. When you turned the flashlight on, electricity flowed from the capacitor or battery to the bulb.

Power plants use the same concept to produce electricity. Many energy sources are used to spin turbines that rotate coils of copper wire inside magnets to generate electricity. The picture below shows a diagram of a coal power plant. Coal is burned to superheat water to very high temperatures and high pressure steam spins the turbine. Natural gas power plants work the same way as coal power plants, and nuclear power plants use the thermal energy from the fission of uranium atoms to generate steam. Wind turbines use the force of the wind and hydropower plants use the force of falling water to turn turbine blades.

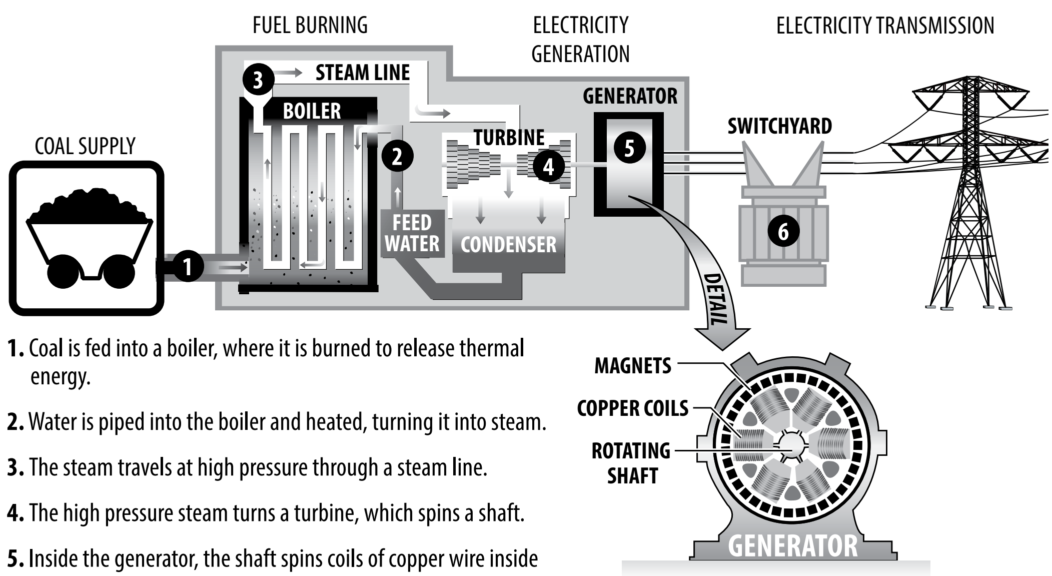
The turbine in a power plant turns the shaft with the copper wire coil inside the magnets. Electric current is induced as electrons move through the wires. The type of current produced by a power plant generator is alternating current, or AC, which moves in alternating directions. Because the generator has a rotating coil, the electrons flow in one direction and then alternate directions as the coil turns. AC power is more desirable in a power plant because it can provide more power and can be transported a long distance without losing strength. Also, the strength, or voltage, of AC power can be made stronger or weaker using transformers. Transformers reduce the voltage along a power line before it comes into a home. When we charge our laptops or other electronic devices that require DC power, we use an adaptor that converts the AC power from the electrical outlet to DC power going into the device.

Electricity is a secondary source of energy; it does not exist in a form that we can readily tap into to do useful work. Electricity generation begins with some other form of energy.

Energy Transformations in a Wind Turbine: Motion to Electrical Energy



Energy Transformations Inside a Coal Power Plant: Chemical to Thermal to Motion to Electrical Energy



1. Coal is fed into a boiler, where it is burned to release thermal energy.
2. Water is piped into the boiler and heated, turning it into steam.
3. The steam travels at high pressure through a steam line.
4. The high pressure steam turns a turbine, which spins a shaft.
5. Inside the generator, the shaft spins coils of copper wire inside a ring of magnets. This creates an electric field, producing electricity.
6. Electricity is sent to a switchyard, where a transformer increases the voltage, allowing it to travel through the electric grid.

Design Your Own Investigations

What new questions do you have? Brainstorm new investigation questions for each station.

Station 1: I wonder what would happen if …

Station 2: I wonder what would happen if …

Station 3: I wonder what would happen if …

Station 4: I wonder what would happen if …

Station 5: I wonder what would happen if …

Station 6: I wonder what would happen if …

Secondary Science of Energy Brochure

New students have moved to your school. They have not learned about energy transformations. Your assignment is to help them by developing an energy transformation brochure. At least five energy transformations must be addressed. Three of these may be examples from the *Secondary Science of Energy* unit. At least two must be transformations not experimented with in class.

The majority of the grade will be on content; however, it is expected that you will use correct grammar, spelling, and punctuation. Graphics (i.e., pictures, drawings, diagrams, etc.) are to be incorporated. All aspects of the brochure must follow copyright guidelines.

BROCHURE	3	2	1	0
Content	At least five energy transformations are correctly identified and explained. At least two are examples that are not included in the *Secondary Science of Energy* unit.	Three to four energy transformations are correctly identified and explained.	One or two transformations are correctly identified and explained.	No energy transformations are correctly described.
Graphics		Graphics are incorporated that enhance understanding of transformations.	Graphics are incorporated, but do not help with the understanding of energy transformations.	No graphics are incorporated.
Mechanics		There are no errors in grammar, spelling, or punctuation.	There are fewer than five errors in grammar, spelling, or punctuation.	There are five or more errors in grammar, spelling, or punctuation.
Copyright		No copyright violations are present. Sources are cited properly.	No copyright violations are present; however, not all sources are cited properly.	Copyright violations are present.
Total	**/9 Points**			

Secondary Science of Energy Assessment

Name: ______________________________ Date: ______________

1. When you drop a basketball from eye level, will the ball return to its original height? Why or why not?

2. Give an example of potential energy transforming into kinetic energy. Identify the form(s) of energy present in the transformation.

3. When iron rusts, is it an endothermic or an exothermic process? Explain your reasoning behind your answer.

4. How does changing the amount of reactants affect the change in temperature of a chemical reaction? Explain your answer.

5. Explain how a radiometer works, including the energy transformation taking place.

6. When installing a PV array, what factors need to be taken into consideration to produce the most electricity?

7. If a bi-metal bar was made with two metals that have nearly the same coefficients of linear expansion, would it behave the same way in the candle as the bi-metal bar used in your experiment? Explain your answer.

8. Compare and contrast a bi-metal bar and nitinol wire.

9. How does temperature affect the rate at which the chemical reaction occurs in a glow stick? Explain your answer.

10. What variables affect the ability of an apple electrolyte cell to produce electricity?

11. How does a hand generated flashlight transform kinetic energy into radiant energy?

12. Compare and contrast a motor with a generator.

13. Starting with the sun, trace the energy flow needed to ride a bike. Identify what is transformed as well as the energy forms being changed.

SCIENCE OF ENERGY BINGO

A. Knows what type of reaction releases thermal energy

B. Knows the form of energy that comes from the sun

C. Knows one way to store energy

D. Knows the form in which our bodies store energy

E. Knows the force responsible for the attraction between the Earth and nearby masses

F. Knows why rubbing your hands together makes them warm

G. Can name a form of kinetic energy

H. Has visited a thermal power plant

I. Knows where most energy on Earth originates

J. Knows what type of reaction absorbs thermal energy

K. Has used a radiant clothes dryer

L. Knows what form of energy is stored in most energy sources

M. Knows how an electric generator works

N. Knows what device turns energy from the sun directly into electricity

O. Can name a form of potential energy

P. Knows what energy can be transformed into

A NAME	**B** NAME	**C** NAME	**D** NAME
E NAME	**F** NAME	**G** NAME	**H** NAME
I NAME	**J** NAME	**K** NAME	**L** NAME
M NAME	**N** NAME	**O** NAME	**P** NAME

Forms of Energy in the Round Cards

I have chemical energy. Who has the process where very small nuclei are combined into large nuclei?	**I have the Law of Conservation of Energy.** Who has the movement of objects or substances from one place to another?
I have nuclear fusion. Who has stored energy?	**I have motion.** Who has the process by which plants convert radiant energy into chemical energy?
I have potential energy. Who has a material that moves thermal or electrical energy well?	**I have photosynthesis.** Who has a chemical process that releases thermal (heat) energy?
I have conductor. Who has the form of energy that includes visible light?	**I have exothermic process.** Who has the form of energy that is the movement of electrons?
I have radiant energy. Who has the concept that energy is neither created nor destroyed?	**I have electrical energy.** Who has the change where one or more substances become one or more new substances?

I have chemical change. Who has the form of energy commonly referred to as heat?	**I have inertia.** Who has energy that is stored in objects when stretched or compressed?
I have thermal energy. Who has the ability to cause change or do work?	**I have elastic energy.** Who has the force of attraction between any two objects?
I have energy. Who has a device that converts radiant energy into electrical energy?	**I have gravity.** Who has the process of splitting large nuclei to release energy?
I have photovoltaic cell. Who has the energy of moving things?	**I have nuclear fission.** Who has the form of energy that is stored in the nucleus of an atom?
I have kinetic energy. Who has what must be overcome to change the speed or direction of an object?	**I have nuclear energy.** Who has a material that does not transfer thermal or electrical energy well?

I have insulator. Who has the process by which thermal energy is transferred by moving through a gas or liquid?	**I have friction.** Who has a change where no new substance is formed?
I have convection. Who has a device that converts motion into electrical energy?	**I have physical change.** Who has a chemical process that absorbs thermal (heat) energy?
I have generator. Who has the movement of energy through substances in longitudinal waves?	**I have endothermic process.** Who has the portion of radiant energy that lets us see?
I have sound. Who has radiant energy bouncing off an object?	**I have visible light.** Who has the process by which thermal energy is transferred between objects that are touching?
I have reflection. Who has a force that opposes motion?	**I have conduction.** Who has the form of energy stored in the bonds between atoms and molecules?

Glossary

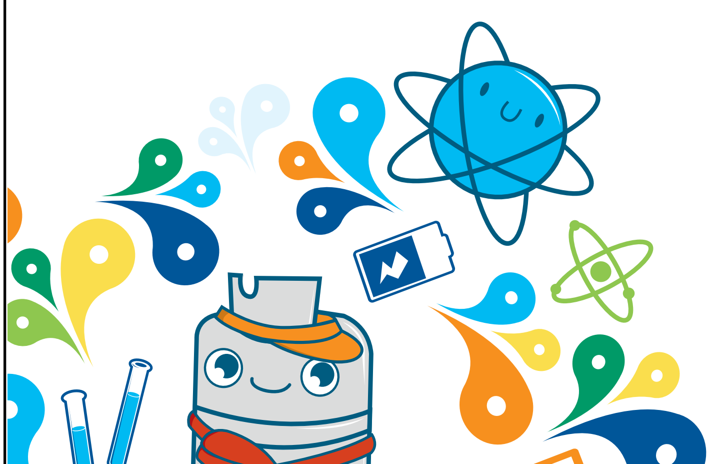
absorb	to be drawn into an object or substance
alternating current (AC)	electricity in which the electrons change direction at regular intervals; used to move energy from one place to another, usually through a wire; the electricity used in homes to operate lights, televisions, and other household devices
ampule	small glass vial with a substance, usually a liquid, sealed inside
atom	simplest form of matter, with a nucleus and one or more electrons moving around the nucleus
catalyst	object or substance that changes the rate of reaction, but is not itself directly consumed in the reaction
Celsius	temperature scale named after Anders Celsius, where the freezing point of pure water is set at zero degrees and the boiling point of pure water at sea level is set at 100 degrees
chemical energy	energy stored in the bonds between atoms or ions
chemical reaction	changing of one or more substances into one or more new substances
collision	two objects bumping into each other
compress	decreasing the volume of something
conduct	transfer of thermal or electrical energy via direct contact
contract	shrinking of a substance, usually after having been expanded
conversion	the act of change or transformation
convert	to change from one form or use to another
current	electrons moving through a conductor
direct current (DC)	electrons moving through a conductor in one direction only
dissipate	spread out
elastic energy	energy stored in an object that has been stretched or pulled out of its natural state
electrical energy	energy transferred by electrons moving
electricity	electrons moving to transfer energy
electrode	conductor in contact with a nonmetallic portion of an electrochemical cell through which electric current flows
electrolyte	nonmetallic conductor of electricity, ions in solution
electromagnet	magnet induced as the result of electric current
endothermic	chemical process where thermal energy is transferred to the system of reactants from its surroundings
energy	the ability to do work or cause a change
energy flow	a diagram or explanation depicting how energy is transformed through a system, such as when an apple is eaten
exothermic	chemical process where thermal energy is transferred from the system of reactants to its surroundings
expand	to grow in size or volume
extrapolate	to estimate, extend, or conclude by inferring from data trends
Fahrenheit	temperature scale named after Daniel Gabriel Fahrenheit, where pure water freezes at 32 degrees and pure water boils at sea level at 212 degrees
fission	process where the nucleus of an atom breaks into two or more smaller pieces
friction	resistance force from two objects or substances rubbing against each other
fusion	process where the nuclei of two very small atoms combine to make one larger nucleus
generator	device that transforms kinetic energy into electrical energy
gravitational potential energy	energy stored in an object held up against gravity, such as water behind a dam or a child at the top of a slide

heat	verb meaning to transfer thermal energy from high temperature to low temperature
hypothesis	an educated statement of what may happen based on observation
iron oxide (iron II oxide)	compound made by combining iron and oxygen, also known as rust
kilowatt-hour	unit used to measure how much electricity is used; one thousand watts used in one hour is one kilowatt-hour of electricity used
kinetic energy	the energy of motion
Law of Conservation of Energy	scientific principle stating that energy is neither created nor destroyed, but transformed from one form to another
magnetic field	area surrounding a magnetized object that will act upon other magnets
mass	a measure of the amount of matter contained in an object
molecular	a description of the smallest parts of matter
molecule	tiny piece of matter consisting of two or more atoms bonded together with covalent bonds
neutralization	type of chemical reaction where an acid reacts with a base, forming a salt and water
nonrenewable natural resource	resources that cannot be replenished quickly
nuclear energy	the energy contained in the nucleus of an atom
oxidation	chemical reaction that removes electrons from an atom
phosphor	a substance that glows or is luminescent; usually transition metal or rare-Earth element compounds
photovoltaic cell	a device composed of silicon and other substances used to generate electricity from sunlight
potential energy	stored energy
prediction	a statement of what the observer believes will happen
product	substance formed in a chemical reaction that was not present in the system before the reaction started
radiant energy	energy that is transmitted via electromagnetic waves
reactant	substance used in a chemical reaction to form a product
reaction	process whereby one or more substances is changed into one or more new substances by rearranging the chemical bonds between atoms
rebound	to bounce back after a collision
reduction	gain of electrons
reflect	to redirect electromagnetic waves from their original direction
renewable natural resource	resources that can be replenished in a short amount of time
repel	to push apart
retention	keeping
silicon	an element from the metalloids in the Periodic Table that is a black, brittle, shiny semiconductor
surroundings	objects or substances associated with a study, such as a collision or chemical reaction, that are not directly involved in the study
system	substances directly involved in a study, such as a collision or chemical reaction
temperature	measure of the average kinetic energy of a substance
thermal energy	internal energy of substances that causes the atoms or molecules to move
titanium	a transition metal on the Periodic Table that is a lightweight, strong metal with a high melting point
transform	change from one form of energy into another form
transformation	a change from one form of energy into another form of energy
turbine	a device that generates electricity by transforming linear motion into rotational motion of conducting coils of wire inside a magnetic field
vacuum	the absence of any matter at all; no air pressure

YOUTH ENERGY CONFERENCE AND AWARDS

The NEED Youth Energy Conference and Awards gives students more opportunities to learn about energy and to explore energy in STEM (science, technology, engineering, and math). The annual June conference has students from across the country working in groups on an Energy Challenge designed to stretch their minds and energy knowledge. The conference culminates with the Youth Awards Ceremony recognizing student work throughout the year and during the conference.

For More Info: www.youthenergyconference.org



YOUTH AWARDS PROGRAM FOR ENERGY ACHIEVEMENT

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

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

What's involved?

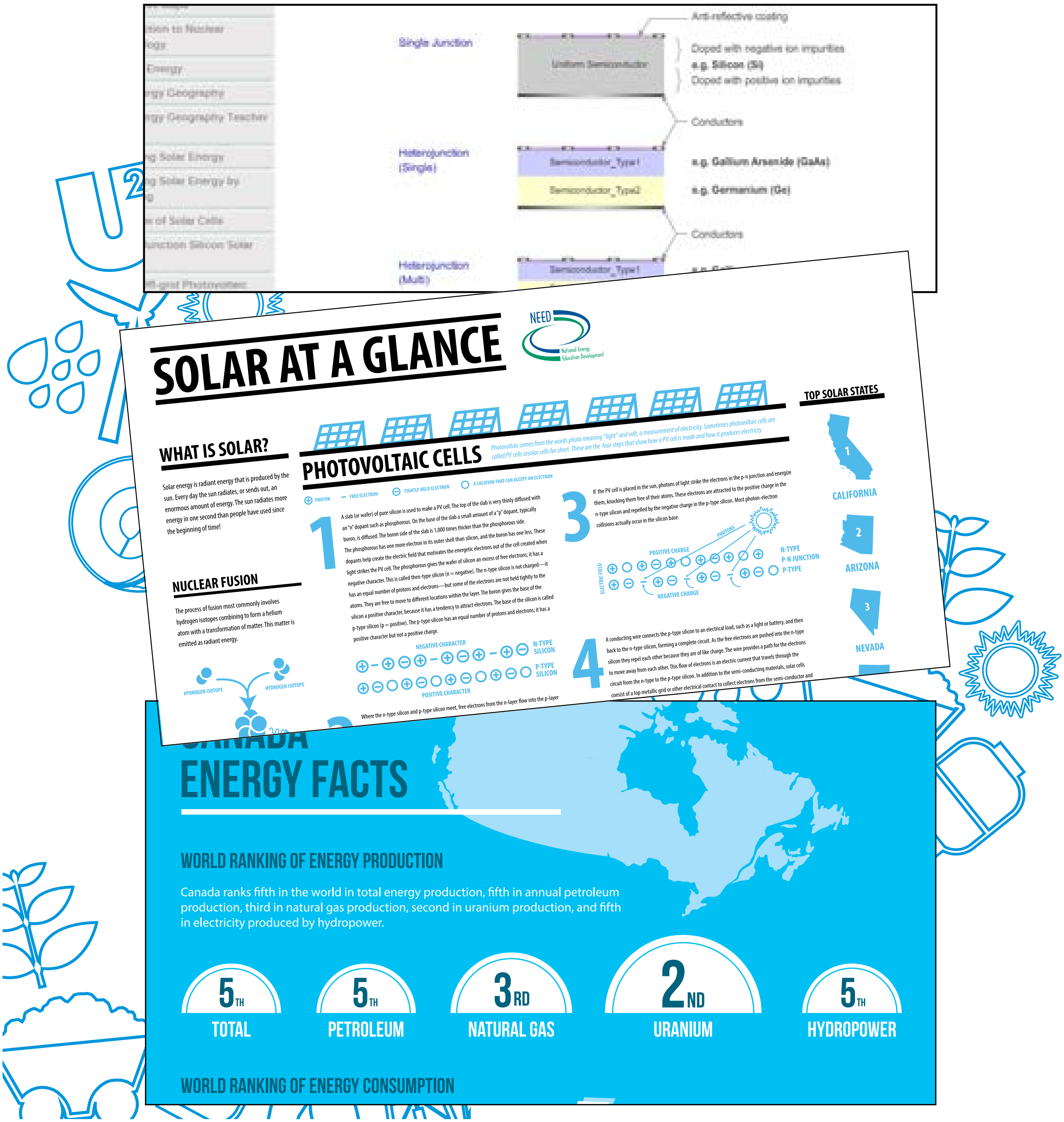
Students and teachers set goals and objectives and keep a record of their activities. Students create a digital project to submit for judging. In April, digital projects are uploaded to the online submission site.

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

Awesome Extras!

Our Awesome Extras page contains PowerPoints, animations, and other great resources to compliment what you are teaching!

This page is available at www.NEED.org/awesomeextras.



Secondary Science of Energy 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**
8408 Kao Circle
Manassas, VA 20110
FAX: 1-800-847-1820

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National Grid
National Hydropower Association
National Ocean Industries Association
National Renewable Energy Laboratory
NC Green Power
Nebraskans for Solar
New Mexico Oil Corporation
New Mexico Landman's Association
NextEra Energy Resources
NEXTracker
Nicor Gas
Nisource Charitable Foundation
Noble Energy
North Carolina Department of Environmental Quality
North Shore Gas
Offshore Technology Conference
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Opterra Energy
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