Grade 8

Can It Be Converted?

Major Topic and SOL Energy Conversion
Science SOL 6.2a, e, LS.1c, h, I PS.1a, b, d, j, l, n PS.6a, b

Length of Activity 3-4 class periods (50 minutes each)

Major Understanding
Students will:
- describe the nature of energy.

Essential Questions
- How can you describe the relationship between work and energy?
- How can you show the difference between potential and kinetic and potential energy,
- What are different forms of energy?
- What is energy conversion?
- What is the law of conservation of energy?
- How can you compare/relate between power and energy?

Student Objectives
- Student will describe various energy conversions.

Bloom's Taxonomy Skills	21st Century Learning Skills
• Understanding • Remembering • Applying	• Critical Thinking • Problem Solving • Communication • Collaboration

Assessment Evidence
Performance Tasks
- Follow lab safety guidelines
- Follow step by step instructions to complete each activity
- Work cooperatively & use critical thinking
- Complete activity assessment questions (with/without) assistance from teacher/aide
- Participate (voluntarily/prompted) in whole group discussion

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Other Evidence

- Organize and interpret data from stations
- Critical thinking teacher observation checklist/rubric
- Apply what is learned in previous activities to complete task
- Lab journals

Technology Computer, Internet connection, projector

Internet Resources

- **Energy Skate Park simulation**

Supplies/Materials

- www.need.org resource, Secondary Science of Energy stations (specifically pages 24-51 – You can choose to skip and not give the "What is Happening?" pages/explanations after each station handout)
- Lab Journal (optional)
- Critical thinking checklist/rubric

Lesson: Can It Be Converted?

Engage:

- Review the two types of energy (potential and kinetic) using the Energy Skate Park simulation as a whole class
- Verbally review the various forms of energy: mechanical, chemical, thermal, nuclear, electromagnetic (radiant), electrical

Explore:

- Ask students to get into groups of 2 or 3.
- Give groups 20-25 minutes to rotate through each of the 6 stations while teacher observes them (note: The stations should be set up previously).
- The teacher will use the essential questions to listen to answers and reshape necessary concepts.
- Encourage increased peer involvement and decreased teacher involvement.

E**xplain:**

- Have a discussion with the class about the stations they explored and what they found.
- Make sure to touch on that:
  - All stations are set up to explore energy conversions
  - Some stations may be easier than others

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    - All conversions involve the law of conservation of energy.
- Higher order thinking skills require explanation. (In science, the answer justification is just as important as the "right " answer)

Elaborate:

- Brainstorm and discuss other examples of kinetic and potential energy that we observe in everyday life
- Brainstorm and discuss other examples forms of mechanical, chemical, thermal, nuclear, electromagnetic (radiant), and electrical energy

Evaluate:

- Observe student interactions and discussions, as well as, completed activities including data collection and analysis on lab sheet and journal.
- Use the critical thinking checklist/rubric to evaluate and comment on student learning.

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Lesson: Can it Be Converted?
Instructions: Use this checklist/rubric to record students' critical-thinking skills while they work on lab activities.
Type of Assessment: Critical Thinking

Student Name:

	Consistently (10-7pts)	**Sometimes (6-3pts)**	**Rarely/ Never (2-0pts)**	**Comments**
Student determines which concepts are important in abstract and concrete systems.				
Student uses subject-area knowledge and personal experiences to make inferences and draw conclusions.				
Student uses multiple strategies for evaluating the reliability of different kinds of sources.				
Student explains opinions clearly and thoroughly.				
Student makes a concerted effort to learn about new ideas and concepts.				
	Total Points:		**(*2) =**	

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Station One Guide

POTENTIAL AND KINETIC ENERGY

Part One: Happy and Sad Spheres

Question

What will happen when you drop the spheres?

Hypothesis *In your science notebook, write a hypothesis to address the question.*

Materials

- Meter tape/stick
- 1 Set of happy/sad spheres
- Hard surface (to drop spheres on)
- Superball
- Tongs
- Cup of hot water
- Science notebooks
- Safety glasses

Vocabulary

- absorb
- collision
- gravitational energy
- kinetic energy
- potential energy
- rebound
- thermal energy

Procedure

1. Drop the Superball onto a hard surface from a height of one meter.
2. Record how high the Superball rebounds and any other observations in your science notebook.
3. Repeat steps 1-2 two more times for a total of three trials.
4. Drop one black sphere onto a hard surface from a height of one meter.
5. Record how high the sphere rebounds and any other observations in your science notebook.
6. Repeat steps 4-5 two more times for a total of three trials.
7. Place the first black sphere into the cup of hot water and let it sit in the hot water for two minutes.
8. Drop the second black sphere onto the hard surface from a height of one meter.
9. Record how high the sphere rebounds and any other observations in your science notebook.
10. Repeat steps 8-9 two more times for a total of three trials.
11. Using tongs, take out the first sphere and place the second sphere into the cup of hot water.
12. Drop the first black sphere onto a hard surface from a height of one meter for a total of three trials and record the results.
13. Set the first sphere aside and take the second sphere out of the water using tongs.
14. Drop the second black sphere onto the hard surface from a height of one meter for a total of three trials and record the results.

Data

Make these tables in your science notebook:

Table 1

ROOM TEMPERATURE	TRIAL 1	TRIAL 2	TRIAL 3	AVERAGE
SUPERBALL				
BLACK SPHERE 1				
BLACK SPHERE 2				

Table 2

HOT WATER TEMPERATURE	TRIAL 1	TRIAL 2	TRIAL 3	WHAT DO YOU NOTICE?
BLACK SPHERE 1				
BLACK SPHERE 2				

Part One Conclusion

Do you accept or reject your hypothesis?

What happened when you dropped the spheres initially? How was energy transformed? Was there a change in the results after they had sat in hot water? How was energy transferred when hot water entered the system? Explain what happened and why you think it happened. Use data to support your reasoning.

Apply what you learned here to the real world. What real world applications can you think of where energy transfers occur in the same manner?

Part Two: Toys

Question

In the case of each toy, how is energy being transformed?

Hypothesis *In your science notebook, write a hypothesis to address the question.*

Materials

- Toy car
- Balloon (see caution below)
- Yo-yo
- Science notebooks
- Safety glasses

Vocabulary

- compress
- contract
- conversion
- friction
- kinetic energy
- motion energy
- potential energy
- stored mechanical energy

Procedure

1. Make each toy move and observe them closely.
2. Record your observations and label the energy transformation in each of the three objects. Pay attention to what causes the object to start moving, the motion of the object, and what causes the object to stop moving.
3. Draw a picture of each object before motion begins and in motion. Label the energy transformations you observed.

Caution

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

Part Two Conclusion

Do you accept or reject your hypothesis?

Explain the energy transformations in each object. What made each object begin moving and what made each object stop?

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?

POTENTIAL AND KINETIC ENERGY

Happy and Sad Spheres

Kinetic energy comes in many forms: radiant, thermal, motion, sound, and electrical. When an object is moving, it has kinetic energy. Potential energy comes in many forms: chemical, nuclear, stored mechanical, and gravitational. When an object is still, but is in a position so that gravity can move it, the object has gravitational energy. For example, a rock at the top of a hill has gravitational energy. As it rolls down the hill, the gravitational energy transforms into sound, heat, and motion energy.

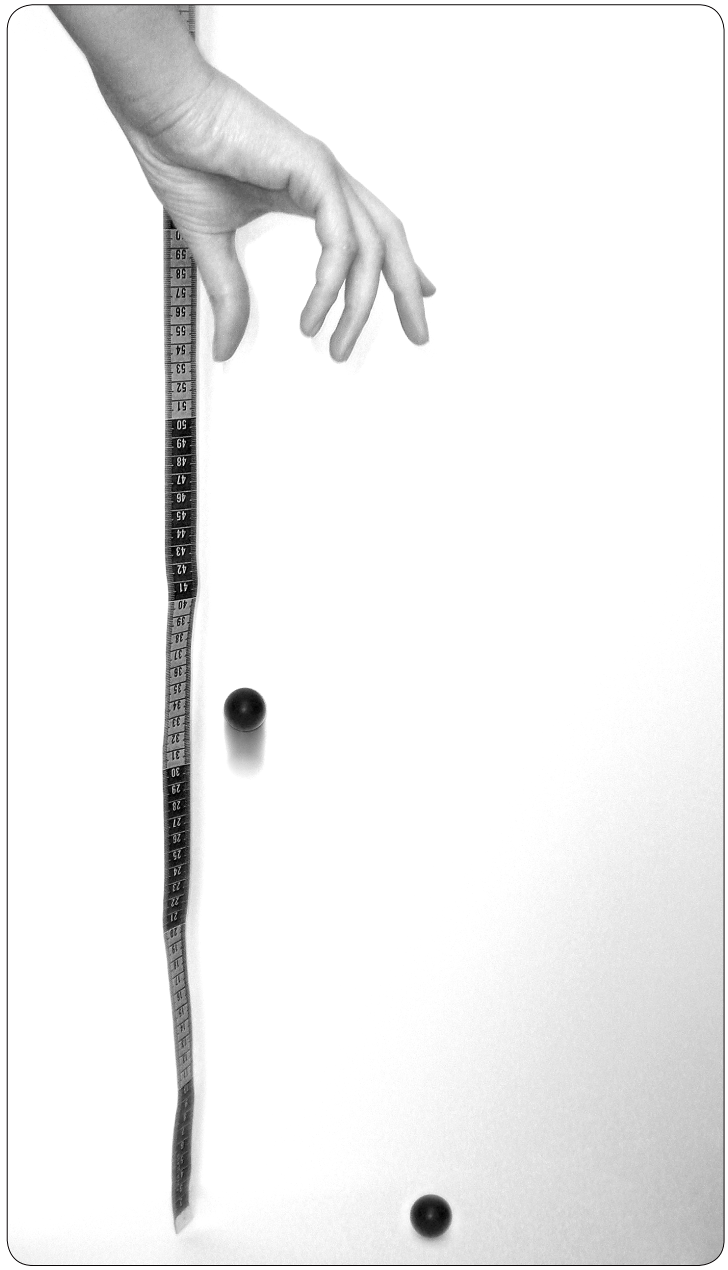
A collision occurs when a moving object hits another object. When you push a sphere, your hand gives it motion energy. The faster it goes, the more motion energy it has. When the sphere runs into your other hand, there is a collision. If it stops completely, it loses all its motion energy. The energy cannot just disappear. Where does it go?

The motion energy is converted into other kinds of energy—like sound and heat. Usually, when there is a collision, an object does not stop completely. It rebounds. This means it has not lost all of its motion energy. The sphere will continue bouncing until it no longer has any motion energy.

The happy sphere is made of *neoprene* rubber. When you held the neoprene rubber sphere above the table you gave it gravitational energy. If you drop the sphere, you know it will fall, because of the force of gravity. This sphere has gravitational energy because of its position. The sphere you dropped bounced back about 65 centimeters (cm). The collision converts 35 percent of the mechanical energy into sound and thermal energy. The sphere and the hard surface are both getting hotter every time you drop the sphere, even though you cannot really feel the difference. About 65 percent of the motion energy is conserved, rebounding the sphere towards its original position. When the sphere hit the hard surface, could you hear the collision?

The other sphere you tested also had the same amount of gravitational energy at the beginning, but it hardly bounced. What happened?

This sphere is not broken. It is made of a different kind of rubber called *polynorbornene* rubber. Almost all of the kinetic energy changes into other forms of energy. The motion energy changes into sound and heat. Feel both of the spheres. Do they feel different? Does the neoprene sphere seem harder than the polynorbornene sphere? The polynorbornene sphere is softer, so its shape can change more easily and it can absorb more energy in a collision than a neoprene sphere.



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.

When you put the polynorbornene sphere into hot water the sphere absorbed thermal energy from the hot water. The sphere bounced higher than in the prior experiment. Since the sphere has absorbed thermal energy from the water, it cannot absorb much more thermal energy from the collision. The motion energy is conserved, causing the polynorbornene sphere to bounce higher. As the sphere cools down, it loses its thermal energy and more of the motion energy can be changed into thermal energy when it hits the hard surface. The cooler it gets, the less the sphere bounces.

These experiments show us how potential energy is changed into motion and how motion is changed into sound and thermal energy.

Toys

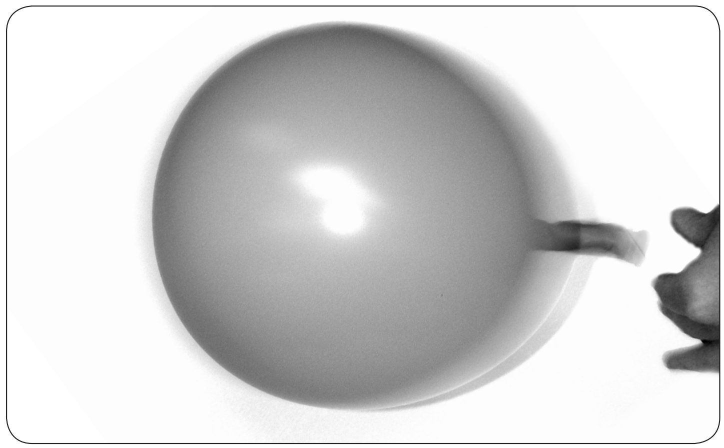
▪ Toy Car

As demonstrated with the spheres, holding an object in the air gives it potential gravitational energy. Another form of potential energy is stored mechanical energy. The car has a spring in it. When you compress the spring in the car, your mechanical energy is stored in the spring and we call this stored mechanical energy. When the car is released, the car starts to move. The stored mechanical energy in the spring changes to motion. Why does the car stop after a while? The car stops because of friction. Friction changes the motion into thermal energy and sound.

▪ Balloon

When you inflate a balloon, you are using mechanical energy to stretch the rubber, just like when you used energy to compress the spring in the car. The balloon now has stored mechanical energy.

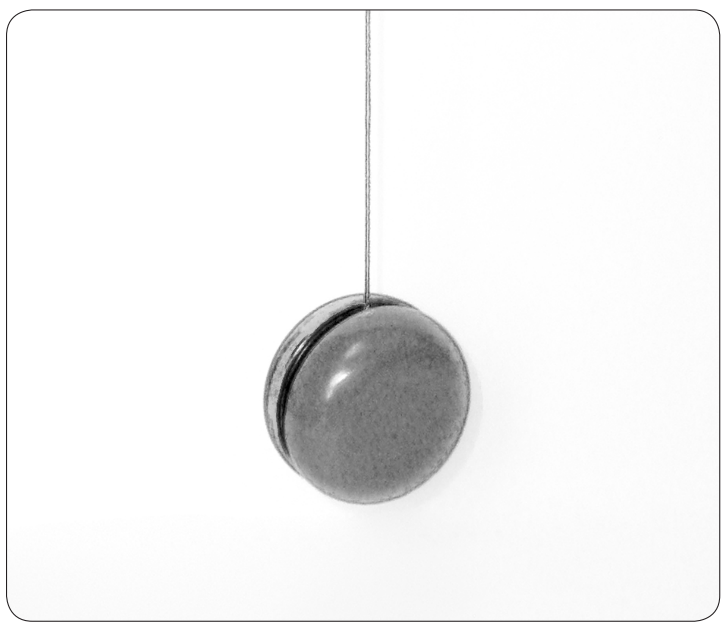
That energy is stored in stretched rubber and compressed air instead of a compressed spring. Where did the energy go when you let go of the balloon? The stored mechanical energy was converted into motion, thermal energy, and sound.



▪ Yo-yo

When you let go of the yo-yo, how far back up the string did it recoil? The yo-yo only came about 60 percent of the way. Why did it not come back to your hand? Friction between the string and the yo-yo changed some of the motion energy into heat energy.

Where is the energy that makes the yo-yo come back up after you let it go? The yo-yo has rotational kinetic energy, or energy because it is spinning at the bottom of its path. This energy is converted back into gravitational potential energy that makes the yo-yo come back up. Spinning objects have rotational kinetic energy and are sometimes called flywheels.



These demonstrations have explored forms of potential and kinetic energy, and how we can transform energy from one form into another.

Station Two Guide

CHEMICAL AND THERMAL ENERGY

Part One: Baking Soda and Vinegar

Question

How is the temperature of vinegar affected when combined with baking soda?

Hypothesis *In your science notebook, write a hypothesis to address the question.*

Materials

- Baking soda
- Safety glasses
- Measuring cups
- Plastic bags
- Thermometer
- Vinegar
- Science notebooks

Vocabulary

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

Procedure

Note: Milliliter (mL) is a liquid measurement and cubic centimeters (cm^3) is a dry measurement. 1 mL = 1 cm^3

1. Pour 10 mL of vinegar into an empty plastic bag.
2. Feel the bag. Observe and record how the temperature feels in your science notebook.
3. Place the thermometer in the bag. Make sure the bulb of the thermometer is in the solution. Record the temperature of the vinegar in your science notebook. Leave the thermometer in the bag.
4. Carefully pour 10 cm^3 of baking soda into the bag and gently mix. (Be careful—the chemical reaction will cause foam to fill the bag.)
5. Wait 30 seconds and record the temperature again. Calculate the difference in temperature and record in your science notebooks.
6. Remove the thermometer from the bag and carefully zip the bag.
7. Feel the bag again and note the temperature change in your notebook.
8. Record and illustrate your observations in your science notebook.

Data

Make this table in your science notebook:

	VINEGAR	VINEGAR + BAKING SODA	CHANGE IN TEMPERATURE
TEMPERATURE			

Part One Conclusion

Do you accept or reject your hypothesis?

How was the temperature of the vinegar affected when combined with baking soda? Explain what happened and why.

Part Two: Calcium Chloride

Question

How is the temperature of water affected when combined with calcium chloride?

Hypothesis *In your science notebook, write a hypothesis to address the question.*

Materials

- Calcium chloride
- Measuring cup
- Safety glasses
- Plastic bags
- Thermometer
- Water
- Science notebooks

Vocabulary

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

Procedure

1. Pour 10 mL of water into an empty plastic bag.
2. Feel the bag. Observe and record how the temperature feels in your science notebook.
3. Place the thermometer in the bag. Make sure the bulb of the thermometer is in the water. Record the temperature of the water in your science notebook. Leave the thermometer in the bag.
4. Carefully pour 4 cm^3 of calcium chloride into the water and gently mix.
5. Wait 30 seconds and record the temperature again. Calculate the difference in temperature and record in your science notebook.
6. Remove the thermometer from the bag and carefully zip the bag.
7. Feel the bag again and note the temperature change in your science notebook.
8. Record and illustrate your observations in your science notebook.

Data

Make this table in your science notebook:

	WATER	WATER + CALCIUM CHLORIDE	CHANGE IN TEMPERATURE
TEMPERATURE			

Part Two Conclusion

Do you accept or reject your hypothesis?

How was the temperature of the water affected when combined with calcium chloride? Explain what happened and why.

Could you think of ways that calcium chloride is used in real life? What other ways can this chemical be used?

Station Two Guide | *CHEMICAL AND THERMAL ENERGY*

Part Three: Hand Warmers

Question

How is iron affected when exposed to oxygen?

Hypothesis *In your science notebook, write a hypothesis to address the question.*

Materials

- Safety glasses
- Hand warmers
- Plastic bags
- Scissors
- Thermometer
- Water
- Sealed bag of iron oxide (old packet)
- Science notebooks

Vocabulary

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

Procedure

1. Remove the hand warmer from the plastic wrap. Cut open the cloth hand warmer 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.
3. Observe the old packet of iron filings. Touch the bag and observe how the temperature feels to the touch. Put a thermometer in the bag and record the temperature. Draw a picture and write a few observations about the old packet in your science notebook.
4. Feel the new packet and note how the temperature feels to the touch. Put a thermometer in the bag and record the temperature. Record your observations and the temperature in your science notebook.
5. Seal the new packet to prevent oxygen from entering the bag and set aside.
6. After three minutes, feel and measure the temperature of the new packet. Are there any changes to 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		
		IMMEDIATELY	AFTER 3 MINUTES	AFTER 6 MINUTES
TEMPERATURE				

Part Three Conclusion

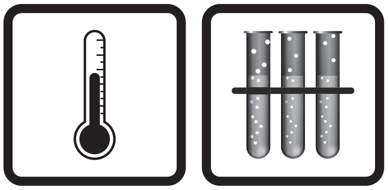
Do you accept or reject your hypothesis?

Explain what happens to iron when it is exposed to oxygen. Why do you think that is? What energy transformations took place? Use data and observations to support your thinking.

Can you think of real life examples where these applications are used?

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.



Station Two: What Was Happening?

CHEMICAL AND THERMAL ENERGY

Baking Soda and Vinegar

Chemical reactions occur when you mix two chemicals together to form another chemical. All chemical reactions involve heat or the transfer of energy. Some release or emit energy and some absorb or take in energy.

An exothermic reaction releases or emits energy. *Exo-* means out and *thermal* means heat. Exothermic—the heat goes out, or is released. An endothermic reaction absorbs heat. *Endo-* means in and *thermal* means heat. Endothermic—the heat goes in, or is absorbed. In Station Two you saw both types of reactions.

This first experiment was an endothermic reaction—it absorbed, or took in, heat. Combining vinegar and baking soda together made other chemicals: water, carbon dioxide, and sodium acetate.

When you added baking soda to the vinegar you were able to visually see a reaction taking place. The temperature of the substance also dropped, which you could tell by feeling the bag and from your thermometer reading.

The mixture felt colder because the reaction was absorbing thermal energy. It was an endothermic reaction. The energy the reaction absorbed from you and its surroundings was stored in the bonds of the new chemical that was formed. The reaction took thermal energy from the mixture and transformed it into stored chemical energy.

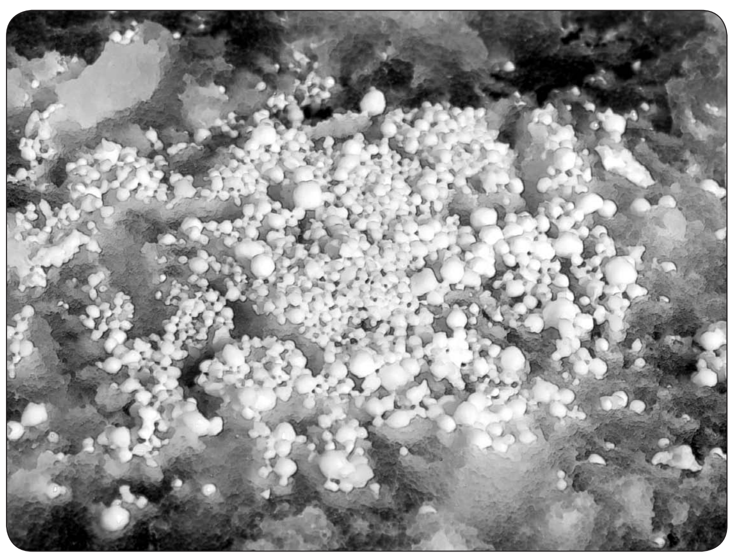
Most chemical reactions do not take in thermal energy like the vinegar and baking soda. Most chemical reactions give off thermal energy—they are exothermic. The second part of Station Two was an example of an exothermic reaction.

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

Calcium Chloride

When calcium chloride comes into contact with ice or water, it dissolves and the calcium chloride molecules dissociate into calcium and chloride ions. The attraction between the ions and water molecules leads to an overall exothermic process. Since exothermic reactions release heat, the temperature of the solution should have 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 during the winter.



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.

Hand Warmers

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

The new packet you opened felt warm. When oxygen came into contact with iron, the chemical reaction produced rust and released thermal energy. You can see that most of the iron filings are still black. They will slowly turn to rust as long as we let oxygen reach them. When you sealed the bag, oxygen was not allowed to reach the iron filings. The reaction should have slowed down and stopped.

Why do you think the hand warmer has a lot of iron filings instead of one large piece of iron? Using iron filings in hand warmers allows more oxygen to come in contact with the iron, which gives off more thermal energy.

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

Endothermic Reactions

Vinegar: CH_3COOH

Acetate: CH_3OO^-

Hydrogen: H^+

Baking Soda: $NaHCO_3$

Sodium: Na^+

Bicarbonate: HCO_3^-

Ionic Reaction

$$CH_3COOH + NaHCO_3 + \text{Heat} \longrightarrow H_2O + CO_2 + CH_3COONa$$

CH_3COOH	+	$NaHCO_3$	+	Heat	→	H_2O	+	CO_2	+	CH_3COONa
Acetic Acid		Sodium Bicarbonate		Heat		Water		Carbon Dioxide		Sodium Acetate

Exothermic Reactions

Iron Filings and Oxygen

Iron + Oxygen → Iron Oxide (rust) + Heat

$2\,Fe + O_2 \rightarrow 2\,FeO + \text{Heat}$

Calcium Choride and Water

$CaCl_2 \xrightarrow{H_2O} Ca^{+2}(aq) + 2Cl^{-}(aq) + \text{Heat}$

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. Heat is produced due to heat exchange from the ionization of the calcium chloride.

Station Three Guide

RADIANT ENERGY TRANSFORMATIONS

Part One: Sunlight and Shade

Question

How much does direct sunlight affect the temperature of an object?

Hypothesis *In your science notebook, write a hypothesis to address the question.*

Materials

- 2 Thermometers
- Tape
- Cardboard
- Light source (bright sunlight, clamp light, etc.)
- Science notebooks
- Safety glasses

Vocabulary

- absorb
- radiant energy
- thermal energy
- transform

Procedure

1. Tape one thermometer to each side of the cardboard. Label one side "sunny" and the other side "shade." Record the starting temperatures of both sides.
2. Place the cardboard so that the sunny side is facing the sunlight (or alternate light source) and the shade side is facing away.
3. Record the temperature of each thermometer every five minutes. Continue with the other parts of Station Three while passing the time.

Data

Make this table in your science notebook:

	STARTING TEMPERATURE	5 MINUTES	10 MINUTES	15 MINUTES	20 MINUTES
THERMOMETER IN SUN					
THERMOMETER IN SHADE					

Part One Conclusion

Do you accept or reject your hypothesis?

Explain how direct sunlight affects the temperature of an object. How can you apply this learning to real life?

Part Two: Radiometer

Question

How does radiant energy affect a radiometer?

Hypothesis *In your science notebook, write a hypothesis to address the question.*

Materials

- Radiometer
- Light source (bright sunlight, clamp light, etc.)
- Science notebooks

Vocabulary

- absorb
- expand
- molecule
- motion energy
- radiant energy
- thermal energy
- transform
- vacuum

Procedure

1. Observe the radiometer from all angles. In your science notebook, draw a diagram of the radiometer labeling all of the parts.
2. Place the radiometer in a bright light. Record your observations.
3. Move the radiometer closer to and farther from the light source. If you are using an artificial light source, find ways to partially and completely shield the radiometer from the light source. Record your observations.

Part Two Conclusion

Do you accept or reject your hypothesis?

Explain how sunlight affects a radiometer. Explain how you think a radiometer works. Would a radiometer work if the vanes were all one color? Why or why not?

Part Three: Solar Panel

Question

How do the angle of light and the amount of light affect the amount of electricity produced by a solar panel?

Hypothesis *In your science notebook, write a hypothesis to address the question.*

Materials

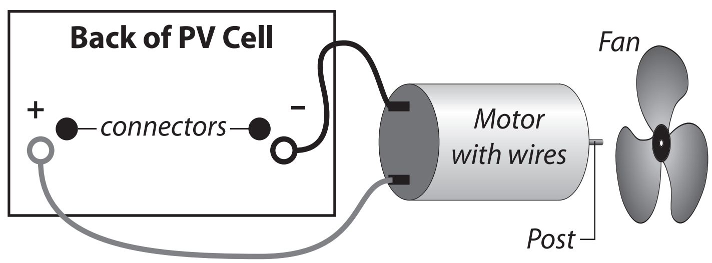
- Solar panel with motor and fan blade
- Light source (bright sunlight, clamp light, etc.)
- Protractor
- Science notebooks
- C battery (if needed)
- Safety glasses

Vocabulary

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

Solar Panel Assembly and Connection Instructions

1. Attach the wires from the motor to the connectors on the back of the PV cell by removing the nuts from the connectors, sliding the motor wires onto the posts, and replacing the nuts.
2. Attach the fan to the post on the opposite end of the motor.



Procedure

1. Place the solar panel in a strong light source. In your science notebook, record your observations.

   Note: If nothing happens, remove the motor leads from the solar panel and touch them to the ends of a C battery to "jumpstart" the motor, then try again.
2. Use a protractor to determine the best angle for the solar panel that will generate the maximum amount of power. Record your findings in your notebook.
3. Investigate how changing the amount of light and/or angle of the solar panel affect the amount of power generated. Record what you do and what happens in your science notebook.

Part Three Conclusion

Do you accept or reject your hypothesis?

How did changing the angle of the solar panel affect electricity production? What happened when the solar panel was partially obstructed? How would this information help you site a solar panel on your home?

Part Four: Glow Toys

Question

What affect does direct light have on glow toys?

Hypothesis *In your science notebook, write a hypothesis to address the question.*

Materials

- Glow toys in pouch with label
- Glow toys in plain pouch
- Light source (bright sunlight or clamp light, etc.)
- Safety glasses
- Science notebooks

Vocabulary

- absorb
- conversion
- convert
- electrical energy
- phosphor
- radiant energy
- transform

Procedure

1. Do not remove the glow toys in the pouch with the label or sticker.
2. Remove the glow toys from the plain pouch and expose them to a light source for 2-3 minutes.
3. Draw and label a picture of the glow toys under the light. What do you think is happening?
4. Peek into the pouch with the label. What do you see? Record your observations in your science notebook.
5. Place the glow toys exposed to light back in the plain pouch. Peek in the pouch. Record your observations.

Part Four Conclusion

Do you accept or reject your hypothesis?

What affect did light have on the glow toys? Explain what happened in the investigation and why.

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?

RADIANT ENERGY TRANSFORMATIONS

Sunlight and Shade: Radiant Energy into Heat

You may have heard the expression, "It was 100 degrees 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 thermometer facing the light has a higher temperature because the sun's radiant energy is being transformed into thermal energy.

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

Radiometer: Radiant Energy into Motion

Did you realize that light can make things move? In the radiometer investigation, you saw light change into thermal energy, then into motion—radiant energy into thermal energy into motion energy.

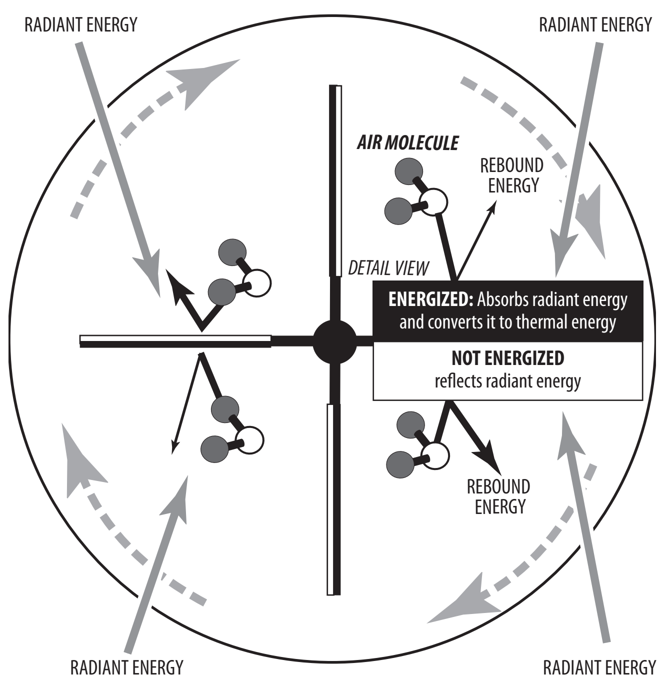
The radiometer has very little air inside the bulb; it is almost a vacuum. The black and white vanes are balancing on a needle. There is nothing else inside the bulb.

When you put the radiometer in the light, the vanes begin to turn. How is the light making the vanes turn? Black objects get hotter than white objects in the sun. That is why people wear light colored clothes in the summer. A black object absorbs most of the radiant energy that strikes it and reflects only a little. A white object reflects most of the radiant energy that strikes it and absorbs only a little.

When you put the radiometer in the light, the vanes absorb sunlight. The radiant energy is changed into thermal energy. The black side of the vane is absorbing more energy than the white side. When the air molecules hit the black side, they bounce back with more energy than when they hit the white side. The brighter the light, the faster the vanes turn. If both sides of the vanes were the same color, the vanes would never move because the air molecules would be bouncing off the vanes with the same amount of force.

To the right is a picture of the radiometer from the top. When the air molecules hit the white sides of the vanes, they push a little. When the air molecules hit the black sides of the vanes, they push a lot. Since there is more of a push on one side than the other, the vanes begin to turn. The more radiant energy that reaches the radiometer, the more thermal energy is transformed into motion energy, and the faster the vanes spin.

Top View of Radiometer



Solar Panel: Radiant Energy into Electricity

You have probably seen solar calculators or solar toys that use light to produce electricity. In this investigation you saw radiant energy converted into electrical energy, then into motion energy. Most of the electricity we use today comes from the sunlight stored in fossil fuels such as coal. Changing light directly into electricity with a solar panel is clean, though the current technology is very expensive. Solar power costs about four times as much as coal or nuclear power.

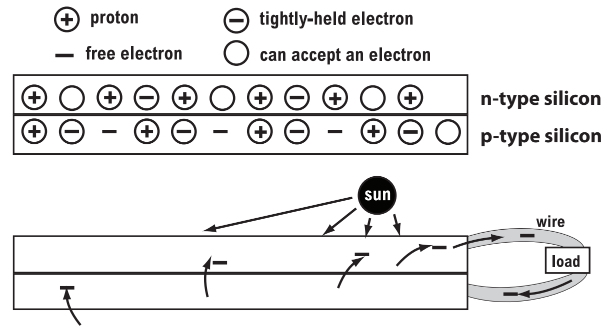
A solar panel is made of lots of photovoltaic cells, or PV cells, connected together. *Photo* means light and *volt* is a measure of electricity. PV cells are made of silicon, the same substance that is in sand. When light strikes PV cells, the electrons in the cells move, producing an electric current. It happens instantly and silently. There are no moving parts to wear out.

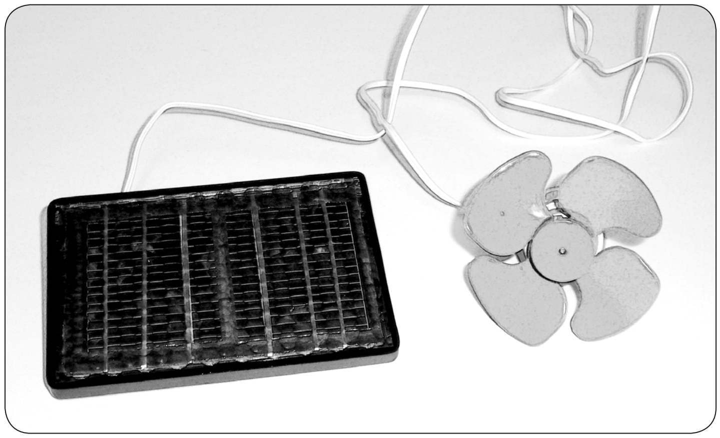
The motor converts electrical energy into kinetic energy, causing the spinning motion, which you saw with the fan. The amount of electrical energy depends on the number of cells in the panel. What happened when you covered half of the panel? When half of the cells were covered, the amount of electrical energy dropped, and the fan slowed down.

When you changed the angle of the panel toward the light, you also changed how much electricity was produced. More electricity is produced if the light is shining directly on the PV cells, because more radiant energy is striking the cells.

Solar energy is a clean, renewable natural resource, but PV cells are not very efficient. They convert only about 10-20 percent of the radiant energy that strikes them into electricity. The rest is changed into thermal energy or reflected off the surface. Scientists are working on ways to make PV cells more efficient.

Photovoltaic Cell





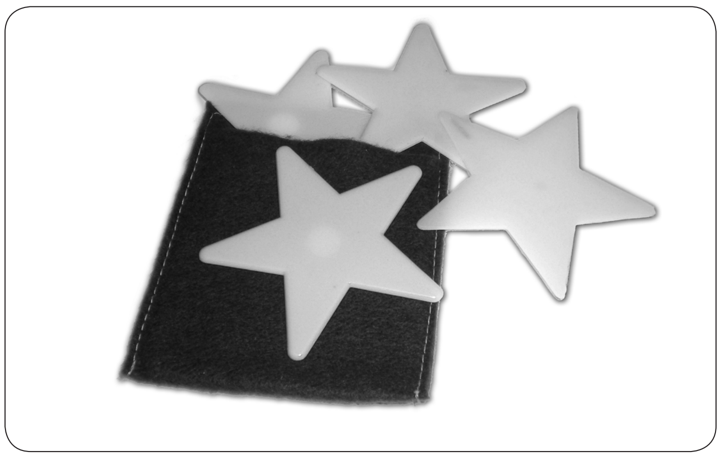
A solar panel transforms light into electricity, which powers the motor.

Glow Toys: Stored Radiant Energy

Glow toys produce radiant energy because we can see them in a dark room. The radiant energy comes from the radiant energy that was absorbed by the toys earlier and stored. Zinc sulfide, a special chemical called a phosphor, has been added to the plastic. A phosphor absorbs radiant energy and stores the energy. The electrons in a phosphor become energized and jump to a higher energy level. When the electrons drop back to their usual energy level, they give up that energy and emit it as radiant energy.

You had two glow toys in this demonstration. One glow toy was left in the light and the other was kept in the pouch with the label away from the light. When you looked at the toy in the labeled pouch, it was not glowing. Since light could not strike the glow toy in this pouch, it could not store any radiant energy. When you looked at the toy that had been placed in the light, the toy was glowing. This toy absorbed and stored radiant energy when it was left in the light.

There are many naturally occurring phosphorescent materials; some organisms such as fireflies even contain them. The difference between luminescence and phosphorescence is that luminescent materials cease to glow as soon as the radiant energy is removed, whereas phosphorescent materials continue to glow, sometimes for a long time.



Glow toys store radiant energy.

Station Four Guide

THERMAL ENERGY AND MOTION

Part One: The Hanger

Question

What energy transformations take place when you bend a metal hanger back and forth?

Hypothesis *In your science notebook, write a hypothesis to address the question.*

Materials

- Piece of thin metal hanger
- Safety glasses
- Science notebooks

Vocabulary

- conversion
- exothermic
- friction
- molecule
- motion energy
- thermal energy

Procedure

1. Feel the metal hanger and note the temperature. Record observations in your science notebook.
2. Bend the metal back and forth five times at the center.
3. Feel the metal with your finger. What do you notice? Draw a picture in your science notebook to demonstrate your observations. Label the energy transformations that took place.

Part One Conclusion

Do you accept or reject your hypothesis?

What energy transformations did you observe? Record all of the energy transformations back to the sun. What real life applications can you think of?

Part Two: The Rubber Band

Question

What energy transformations take place when you stretch and release a rubber band multiple times?

Hypothesis *In your science notebook, write a hypothesis to address the question.*

Materials

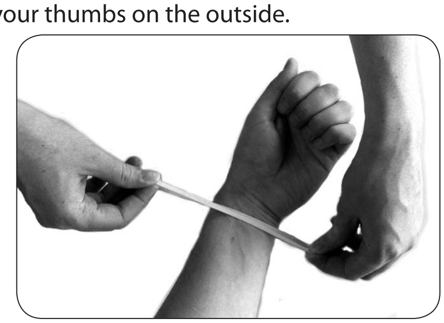
- 1 Large rubber band
- Partner
- Science notebooks
- Safety glasses

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 partner's wrist. While keeping it against their wrist, quickly stretch the rubber band to twice its original length and hold for three seconds. Remove the rubber band and let it contract. Repeat this step three times.
3. Holding the rubber band away from your partner's wrist, stretch the rubber band to twice its original length, then let it contract against your partner's wrist, and hold for three seconds. Repeat this step three times.
4. Switch roles and repeat.
5. What did you notice? Record observations in your science notebook.



Part Two Conclusion

Do you accept or reject your hypothesis?

What energy transformations did you observe? What real life applications can you think of?

Part Three: The Live Wire

Question

How does adding thermal energy affect the live wire?

Hypothesis *In your science notebook, write a hypothesis to address the question.*

Materials

- Live wire
- Cup of hot water
- Tongs
- Safety glasses
- Science notebooks

Vocabulary

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

Procedure

1. Get a cup of very hot water (but not boiling). Handle the hot water very carefully. It could burn you. 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. Label the energy transformations that took place.

Part Three Conclusion

Do you accept or reject your hypothesis?

What happened to the wire when it came in contact with heat? What energy transformations took place? Why do you think this is? Use your observations to support your thinking.

Part Four: The Bi-Metal Bar

Question

How does thermal energy affect the bi-metal bar?

Hypothesis *In your science notebook, write a hypothesis to address the question.*

Materials

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

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. Carefully hold the bi-metal bar sideways in the top of the candle flame so that both sides of the bar are in the flame. Record your observations.
3. 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.
4. Record and illustrate your observations. Label the energy transformations that took place.

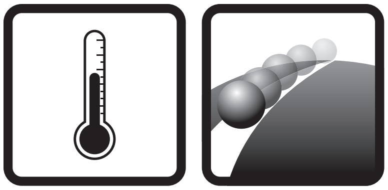
Part Four Conclusion

Do you accept or reject your hypothesis?

Explain the energy transformations that took place in the bi-metal bar. Can you think of real life applications for the bi-metal bar?

Station Four: Read

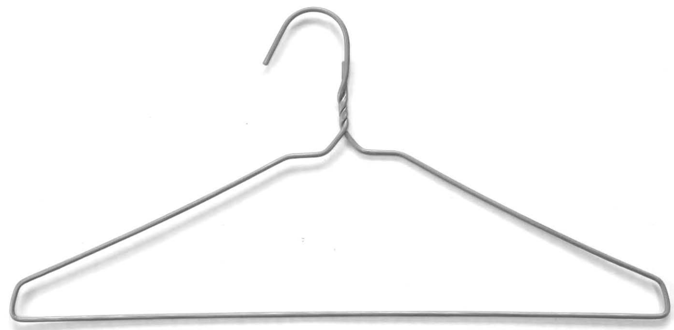
Read the *Station Four: What Was Happening?* article. Do not erase your original conclusions, but compare what you read to what you thought was going on. Summarize the article in your science notebook.



Station Four: What Was Happening?

THERMAL ENERGY AND MOTION

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 molecules of the metal at the bend moved faster. The motion created friction, which in turn transformed motion energy into thermal energy. When you felt the hanger, you should have felt it was warmer than when you started.

Let's trace the energy flow from the heat in this metal back to the sun. You put motion 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 stored chemical energy, to motion energy, to thermal energy.

You have probably converted motion into heat lots of times on cold days. Try this. 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 motion into thermal energy.

The Rubber Band

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

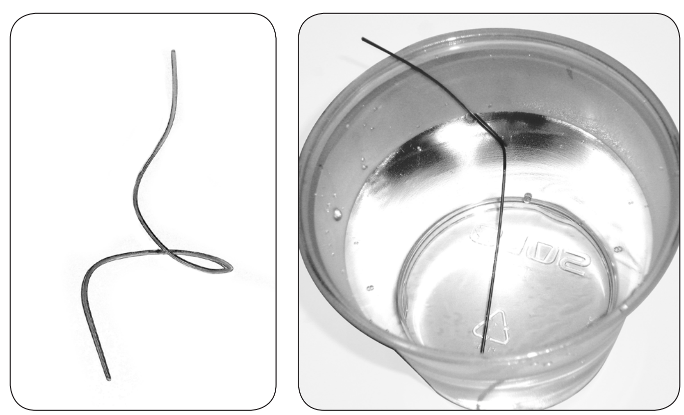
When you quickly stretched the rubber band to twice its length and placed it against your partner's wrist, or when you let it contract, did your partner feel a change in temperature? The rubber band should have felt warm when it was stretched and cool when it contracted.

When you stretched the rubber band, you put stress on the molecules and released heat. When the rubber band contracted, the stress was removed and the molecules absorbed heat.

The Live Wire

The "live wire" is a nitinol (nī-tĭn-ōl) 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 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.



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.

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 energy is taken away, 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

$$\Delta L = A \times L \times \Delta T$$

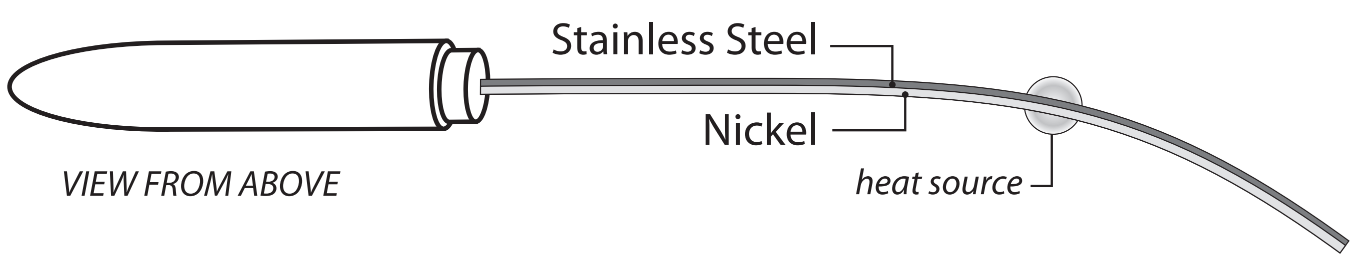
where:
Δ = change
L = length
A = coefficient of linear expansion
T = temperature

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.

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

Why the Bi-Metal Bar Bends

Metals expand at different rates when heated, causing the bi-metal bar to bend when placed over the flame.



Station Five Guide

CHEMICAL ENERGY

Part One: Lightsticks

Question

How is a lightstick affected by thermal energy?

Hypothesis *In your science notebook, write a hypothesis to address the question.*

Materials

- 1 Unbroken lightstick (remains uncracked)
- 2 Lightsticks of the same color (these will get cracked)
- 1 Cup of hot water
- Safety glasses
- 1 Cup of ice water
- Science notebooks

Vocabulary

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

Procedure

1. Look at the unbroken lightstick carefully. Record and illustrate observations in your science notebook.
2. Bend the other two lightsticks until the ampules inside break. Record and illustrate what happens.
   Note: When presenting this station you do not need to break new lightsticks each time. Break new lightsticks each day and use the same ones with each group that rotates through.
3. Place one broken lightstick in the ice water, then place the second broken lightstick in the hot water. Record and illustrate your observations. Label the energy transformations taking place.

Part One Conclusion

Do you accept or reject your hypothesis?

How is the amount of light produced by the chemical reaction affected by thermal energy?

Part Two: The Apple Battery

Question

How do variables affect the ability of an apple battery to produce electricity?

Hypothesis *In your science notebook, write a hypothesis to address the question.*

Materials

- 1 Small zinc nail
- 1 Large zinc nail
- 1 Tin wire
- 2 Thick copper wire
- 1 Thin copper wire
- 1 DC micrometer
- Metric ruler
- 1 Apple
- 2 Alligator clips
- Permanent marker
- Science notebooks
- Safety glasses

Vocabulary

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

Station Five Guide | *CHEMICAL ENERGY*

☑ Procedure

1. Use the metric ruler and permanent marker to make marks at 1 cm, 2 cm, 3 cm, and 4 cm on each nail and wire.
2. Insert the large zinc nail and the thick copper wire into the apple about one centimeter, making sure the ends do not touch each other in the apple.
3. Attach the end of one alligator clip to the positive (red) terminal of the micrometer, and the other end of the clip to the thick copper wire.
4. Attach one end of the second alligator clip to the negative (black) terminal of the micrometer, and the other end of the clip to the zinc nail.
5. What do you observe? In your science notebook, draw a diagram and record your observations in your notebook.
6. Push the nail and wire into the apple in one-centimeter increments, up to four centimeters. Draw the table into your notebook. Record the micrometer readings in the data table.
7. Reverse the arrangement of the alligator clips, observing the micrometer. Record your observations in your notebook.
8. Switch the alligator clips back to the original position. Push the nail and wire into the apple so that the ends are touching. Record your observations in your notebook.
9. Remove the thick copper wire and replace it with the thin copper wire inserting it into the apple. Reattach the alligator clips and repeat steps 5 and 6.
10. Remove the large zinc nail and replace it with the small zinc nail, inserting it into the apple. Reattach the alligator clips and repeat steps 5 and 6.
11. Attach the two copper wires to the micrometer. Record your observations in your science notebook.
12. Insert the tin wire into the apple, along with the copper and zinc, making sure none of the ends touch. Explore the different combinations of metals.
13. If you have not done so already, diagram the way the electricity flows through the apple in your science notebook.

Data

Make this table in your science notebook:

	LARGE ZINC NAIL AND THICK COPPER WIRE	LARGE ZINC NAIL AND THIN COPPER WIRE	SMALL ZINC NAIL AND THIN COPPER WIRE
1 cm			
2 cm			
3 cm			
4 cm			
METALS TOUCHING			

COMBINATION OF METALS	MICROMETER READING
2 COPPER WIRES	

⁂ Part Two Conclusion

Do you accept or reject your hypothesis?

What energy transformations took place in the apple battery? What variables affected the electrical output of the apple battery? Use observations and data from your investigation to support your reasoning.

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?

CHEMICAL ENERGY

Lightsticks

The lightstick is filled with a solution of ester and dye. Inside the lightstick 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 the lightstick, the two chemicals could not touch each other. When you bent the lightstick and broke the ampule, the chemicals could mix together and a chemical reaction resulted in new chemicals.

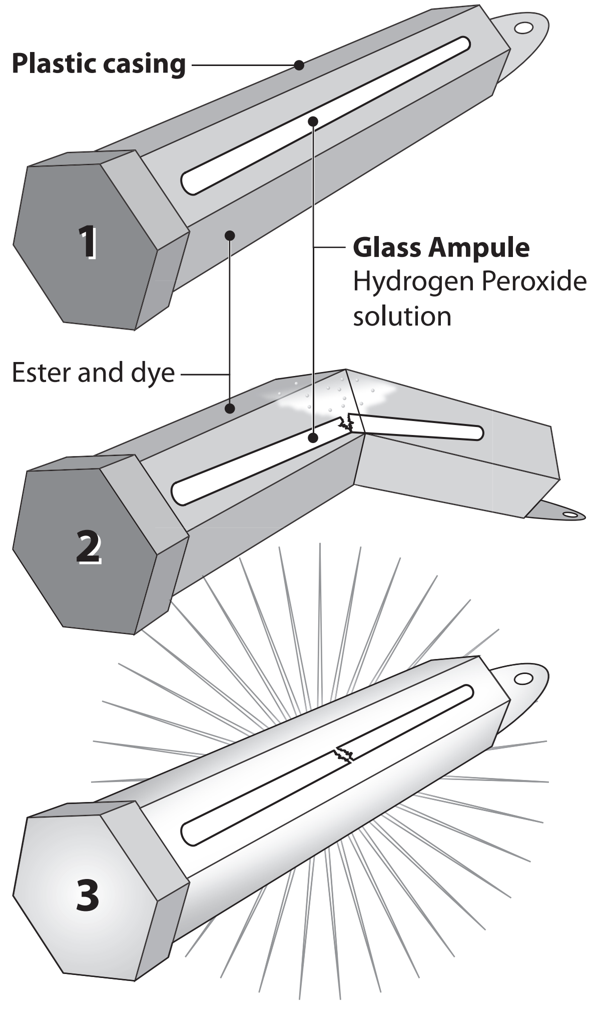
The lightstick is producing light—radiant energy. When you broke the glass, the hydrogen peroxide and ester reacted to form different chemical compounds. The new compounds do not need as much energy to hold their molecules together, so they release the extra energy as light. Only a few chemical reactions emit light—most emit heat. The fluorescent dye in the lightstick absorbs the light and becomes energized. When the dye gives up the extra energy and returns to its normal state, it emits the light it absorbed and that is the light we see. You have probably seen lightsticks of different colors. They have different fluorescent dyes in them. The reaction between the hydrogen peroxide and the ester is the same.

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

How did heat change the brightness of the lightstick? Some of the thermal energy from the hot water was absorbed by the chemicals in the lightstick. The added energy made the chemicals react faster and produce more light. At room temperature, the lightstick 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.

If we add heat, the lightstick will glow brighter, but for a shorter time. If we take away heat, it will glow for a long time, but not as brightly. Either way, the same total amount of light will be produced. The lightstick is a good example of transforming chemical energy into radiant energy.

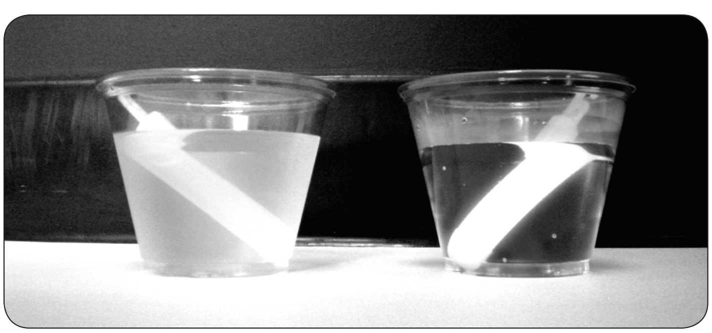
How a Lightstick Works



1. The lightstick is filled with a solution of ester and dye. Inside, a small glass ampule is filled with hydrogen peroxide.

2. When the lightstick is bent and the ampule is broken, the chemicals from the ampule and the lightstick mix, causing a chemical reaction.

3. During the chemical reaction, energy is released as light.



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

The Apple Battery

In the apple battery investigation you used the chemical energy in the apple to make electricity. Chemicals are everywhere. An apple contains a chemical called malic acid. You used the malic acid in the apple to make a battery. When you pushed the zinc nail and a piece of copper wire into the apple and attached them to the micrometer you saw the needle move. This shows that there is an electric current moving through the circuit.

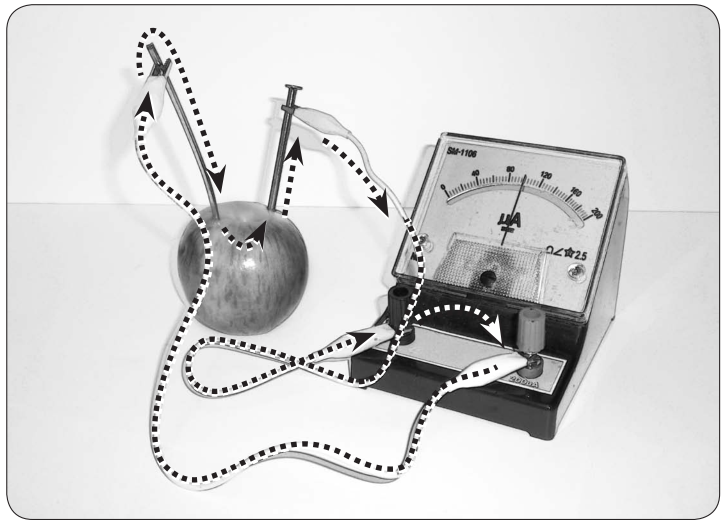
As you observed the micrometer, you saw that the needle moved to the right to indicate an electric current. When you put the zinc and copper into the apple, they both reacted with the acid, but they did not react the same way. The different reactions created an imbalance in electrical charge. The electrons flowed from the zinc nail through the meter to the copper wire and then back through the apple to the zinc nail. This flow of electrons registered on the micrometer. Chemical energy is converted to electrical energy. Because the micrometer moved to the right, it showed that the charge was flowing. This is the way all batteries work. There are two metals and an electrolyte, an electric conductor, in batteries, and the electric charge flows from one metal to the other, converting chemical energy into electrical energy.

The further you pushed the zinc nail and copper wire into the apple, 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.

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.

Next, you added a thin copper wire into the apple, so we could compare the current. The thick wire produced more current because it has more surface area to come in contact with the acid.

When you attached the two copper wires to the micrometer, there should not have been any current. Both copper wires are electron accepters. There is no electron donor. If you attached both zinc nails to the micrometer, there was no current produced in this case either. Both nails are electron donors. There is no electron acceptor. The combination of metals determines which metal will be the electron donor and which will be the electron acceptor.



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

Station Six Guide

ELECTRICAL ENERGY

Part One: Battery and Compass

Question

How does an electric current affect the needle of a compass?

Hypothesis *In your science notebook, write a hypothesis to address the question.*

Materials

- Heavy-gauge coated wire
- D Battery
- D Battery holder
- Compass
- Science notebooks
- Safety glasses

Vocabulary

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

Procedure

1. Place the battery in the battery holder.
2. Clip one end of the wire onto each end of the battery holder.
3. Move the battery and wire over the compass. Observe the movement of the needle. Record your observations in your science notebook.
4. Pick up the compass and move it over the battery and wire. Observe the movement of the needle. Record your observations in your science notebook.

Part One Conclusion

Do you accept or reject your hypothesis?

How does an electric current affect a compass? What is the relationship between magnetism and electricity? Use your observations to support your thinking.

Part Two: Motors and Batteries

Question

What is the relationship between batteries and motors?

Hypothesis *In your science notebook, write a hypothesis to address the question.*

Materials

- Hand generated flashlight
- 2 Motors (1 disassembled)
- 1 9-Volt battery
- 2 Alligator clips
- Masking tape
- Science notebooks
- Safety glasses

VOCABULARY

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

Procedure

1. Observe the hand generated flashlight. Pay attention to the coils of wire and the magnets.
2. Draw the hand generated flashlight in your science notebook and label the parts. Try to explain how the flashlight works.
3. Shake the handle of the hand generated flashlight several times and observe what happens. Record your observations in your science notebook.
4. Look at the disassembled motor and pull out the coil of wire and magnets. Record and illustrate the disassembled motor and label the parts in your science notebook.
5. Fold a piece of tape like a flag onto the shaft of the assembled motor and put an X on one side.
6. Connect the assembled motor to the 9-volt battery with the alligator clips. What happens? Make observations in your science notebook.
7. 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 by watching the X on the flag.)
   Note: Do not try this with other types of batteries without permission from your teacher.

Part Two Conclusion

Do you accept or reject your hypothesis?

What is the relationship between batteries and motors? How does a motor work? Why do you think these relationships are important? Use data and observations to explain your thinking.

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.