Lesson 4: Mapping Energy Increases and Decreases

Overview

In this lesson, students begin to consider how the amount of energy available changes as it is transferred from an energy source to the intended energy receiver. Students discover that not all of the energy available from a source is transferred to the receiver in useful forms.

Teacher Background

People have long put their knowledge of energy transfers and transformations to use in their everyday lives. Evidence of purposefully engineered energy use dates back as far as one million years ago when humans first began using fire to cook food, keep warm, and protect themselves from wild animals. Using fire for these purposes stands as one of the greatest energy breakthroughs of all time. Imagine what the world was like for early humans as they began using energy sources such as wood, water, and sunlight in progressively more sophisticated ways to accomplish various tasks. What would early humans think of the ways energy is used today?

While students continue to create and evaluate energy maps as they investigate everyday energy interactions, they also begin to consider how the amount of energy changes as it moves from an energy source to an energy receiver. Energy changes are discussed as decreases and increases as opposed to discrete quantities. It is intuitive that there would be a decrease in some form of energy in the source and an increase in some form of energy in the receiver as energy is transferred from one object to another. Before students are introduced to such ideas as "energy cannot be created or destroyed" (known as the First Law of Thermodynamics), energy efficiency and conservation, it is important for them to consciously consider what is happening to the amount of energy available as it is transferred. As students continue to map energy transfers and transformations, they begin to consider these in terms of how useful they are in achieving the intended effects for the intended receiver.

Key Ideas

- When an interaction occurs, there is a decrease in some forms of energy in the source and an increase in some forms of energy in the receiver as energy is transferred from one object to another.
- Not all the energy that goes into a device or process gets used in the way that people intend. As energy is transferred from one object to another, some transferred energy is likely to be transformed into heat.

Lesson Goals

Students will:

- identify the energy increases and energy decreases for an interaction in general terms.
- describe "intended" energy transfers and transformations and "unintended" energy transfers and transformations.

Vocabulary

energy efficiency: using less energy to perform the same function.

energy transfer: the movement of energy from one object, substance, or system to another.

energy transformation: energy changing forms.

Preparation

- Build and practice using a spool racer.
- Assemble the materials students will need to build spool racers. Determine how to effectively distribute and manage building materials.
- (Optional) Have a lamp with an incandescent light bulb on hand as a prop as students revisit the energy maps for this interaction.
- Make certain that there are enough colored markers for student pairs. Pairs will need a green and red marker to identify increases and decreases in energy.
- Copy Teacher Resource 4.1: Everyday Energy Interactions and cut the examples into individual strips. Each pair of students will need one example (one strip).
- Review Teacher Resource 4.2: Possible Responses for Everyday Energy Interactions to get a sense of the transfers and transformations students are likely to map. Please note that the resource is not exhaustive. Students may describe additional transfers and transformations.

- (Optional) Copy and precut Student Handout 4.2: Energy Map Words. Put word sets into resealable bags or envelopes for easy distribution.
- Prepare 20 beans in a paper cup for each pair of students.

Materials

Item	Quantity
Student Handout 4.1: Building a Rubber Band Powered Spool Racers	1 per pair
For spool racers: • rubber band • empty thread spool • paper clip • tape • metal washer • cotton swab	1 set per pair
Scientist's Notebook	1 per student
Teacher Resource 4.1: Everyday Energy Interactions	1 per class cut into strips
(Optional) Index cards (3" x 5") or Self-stick notes	10-15 per pair
Teacher Resource 4.2: Possible Responses for Everyday Energy Interactions	1 for teacher
Chart paper	1 piece per pair
Markers (make certain there are green and red markers for each pair in the set)	1 set per pair
(Optional) Student Handout 4.2: Energy Map Words (precut and put into resealable bags or envelopes)	1 set per pair
Dry beans, 20 per student pair in small paper cups (optional – to model units of energy)	1 bag per class
(Optional, as a props): Lamp with incandescent light bulb, bicycle or picture of bicycle	**1 per class**

Time Required: 2-3 sessions

Session 1: Construct spool racer, discuss and map energy increase and decreases for spool racer

Session 2: Introduce "intended" and "unintended" energy transfers, identify energy transfers and transformations in every day situations, debrief

Session 3: Model energy efficiency

Connection to *Maine Learning Results (MLR)*, *Benchmarks for Science Literacy (BSL)* and *Science for All Americans (SFAA):*

- People have invented ingenious ways of deliberately bringing about energy transformations that are useful to them. BSL (SFAA) 8C/M8** (6-8)
- Energy is required for technological processes such as taking apart, putting together, moving around, and communicating. BSL (SFAA) 8C/M7** (6-8)
- Use examples of energy transformations from one form to another to explain that energy cannot be created or destroyed. MLR D3 (6-8) i

Teaching The Lesson

Engage

1 Construct a spool racer and develop its energy map.

Provide each pair of students with a copy of Student Handout 4.1: Building a Rubber Band-Powered Spool Racer and the materials to construct a spool racer. Assist students as needed in the construction of their racers.

Alternatively, use the following video clip from the PBS program ZOOM to show students how to construct the racers but keep in mind some of the materials used in this lesson differ slightly than those shown in the clip:

http://www.teachersdomain.org/asset/phy03_vid_zsplcar/

Have students practice making their spool racers go. Students may need to spend some time adjusting the parts of their racer to get them to move.

Ask students to create an energy map in their scientists' notebooks that identifies the energy source(s), energy receiver(s), and energy forms. 107

Using students' input, construct an energy map similar to the one below for the spool racer on the board:

Energy Source		**Energy Receiver/Source**		**Energy Receiver/Source**		**Energy Receiver/Source**		**Energy Receiver/ Source**
hand	→	rubber band (twisted)	→	spool	→	floor	→	air

Note: *Students may also include the sun and/or the food the person ate as an energy source/receiver. At this point, some may not include the interaction between the spool and its parts or the spool and the floor. Friction is discussed later in the lesson.*

2 Explore how the amount of energy available at the source and intended receiver changes as transfers and transformations occur.

Call the class together. Pose the following:

- *How does the amount of energy available at the source compare to the energy available at the intended receiver?*

Students begin to consider how the amount of energy available at the beginning of an interaction at the source compares to that available to make things happen at the end and that not all energy input results in energy output. Students will likely respond that not all of the energy available in the beginning of the interaction is available to keep making things happen for the intended purpose. Ask students how we know – what evidence do we have? (Students may say that the spool racer slows down and doesn't keep going on forever but may not offer up any explanations as to why.)

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3 Demonstrate adding energy increases and decreases to maps.

Discuss how energy increases and decreases could be added to an energy map by asking students how the amount of energy available would change as energy is transferred and transformed in the spool racer.

A sample of how this might be noted in a map is shown below:

Energy Source		Energy Receiver	
rubber band	elastic (stored mechanical) →	spool	mechanical/ motion →
decrease in elastic energy		*increase* in or mechanical/ motion energy	

Reiterate that when interactions occur, energy is being transferred from a source to a receiver. The source is decreasing in some forms of energy and the receiver is increasing in some forms of energy.

Select another example, such as the lamp/incandescent light bulb example below, to map for students by writing the top portion of the map on the board.

Energy Source		**Energy Receiver**	
electrical outlet (power plant)	**electrical** →	lamp (incandescent light bulb)	**light** → **and** **heat** →
decrease in electrical energy		*increase* in thermal and radiant energy	

Ask for student input how to note changes in energy in this example. Students should say that “decrease in electrical energy” should be added below “electrical outlet/power plant” and “increase in thermal and radiant energy” (heat/light) should be added below “lamp/bulb.”

4 Practice identifying energy increases and decreases (changes).

Have students work in groups of 4. Ask students to review the energy maps they made for the interaction stations. Explain that they are to select 3 station maps to discuss and identify the energy increases and energy decreases. Tell students they need to be prepared to share with the class a specific example of how energy was increasing and decreasing between any two parts of an interaction.

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(Remember that for these examples, students have already identified the energy sources, energy receivers, and forms of energy involved in the transfers.)

Have students take turns reporting out specific examples of energy increases and decreases.

> **Note:** *Recognizing that energy sources decrease in some forms of energy and that energy receivers increase in some forms of energy will most likely be intuitive to students. This exercise is intended to stimulate students' thinking about what happens to the amount of energy in sources and receivers in a semi-quantitative way. It is important as students begin to transition into considering why it appears that energy is “lost” as it is transferred from an energy source to an energy receiver.*

Explore

5 Develop the idea of using energy for intended effects.

Have the lamp with the incandescent light bulb available for this discussion. Consider having the energy maps for the incandescent light bulb available for students as a reference.

Ask students: *How do people want energy used when an incandescent light is turned on? In other words, what was the incandescent light bulb created to do? What energy transfers are desired?* Students should recognize that the light bulb was designed to emit light. The desired or engineered transfers involve electrical energy from the power plant being transferred to the light bulb. Electrical energy from the power plant is transformed into radiant (light) energy in the light bulb.

Ask students: *Are there any transfers and transformations that are undesirable or unwanted in the incandescent light bulb?* Students should notice that heat transfers also occur and these are unintended. Mention to students that often energy is transferred to objects or places or transformed into other forms that are unintended.

Energy transfers are often challenging to detect and/or control. In the case of the incandescent light bulb, the "unintended" effect is fairly obvious for us to observe; we can feel the incandescent light bulbs becoming noticeably warm. Consider demonstrating this effect. Other types of light bulbs, compact fluorescent light (CFL) bulbs, for example, have been engineered to reduce the amount of heat that is given off. Tell students that energy in the form of heat is almost always one of the transformations that occurs in an interaction and is one that is generally unintended for a variety of reasons. Ask students why heat would be an "unintended" transfer. Students may suggest that heat can cause mechanical devices to "overheat," damage parts, and cause a device to malfunction. Students may not recognize that heat is not "desired" or "useful" in most instances in the sense that it cannot easily be transformed to another form; heat tends to dissipate into the surrounding environment making it quite challenging if not virtually impossible to "repurpose."

6 Identify the energy transfers and transformations in everyday situations including those in common household devices.

Distribute to each pair of students one of the descriptions of an everyday energy interaction listed on the Teacher Resource 4.1, a piece of chart paper, and a marker. Ask students to affix the example to the top of the chart paper or write the example at the top of their chart paper with a marker. Instruct students to create energy maps that identify as completely as possible the:

- energy source(s)
- energy receiver(s)
- energy transfer(s)
- forms of energy
- increases and decreases of energy

(Optional) Students may prefer to use index cards or self-stick notes to organize these multi-step, more complex energy interactions. Students can write the names of the objects or devices specific to their situation on the index cards or self-stick notes. Each student pair would need approximately 10-15 index cards or self-stick notes. Students may also find using a set of precut energy words found on Student Resource 4.2: Energy Map Words helpful. Make sure students understand that the task is not to "match up" or necessarily use all the words but rather use them to construct draft maps without having to erase or cross out. Using them may make it easier to reorganize their thinking. When students are ready to construct the final version of their maps, they may choose to fasten the manipulatives to the chart paper instead of writing the words with a marker.

Make certain that students recognize that the interactions involve multiple transfers – some of which may be difficult to observe or detect. Students should identify as many as they can. Remind students that an energy receiver can become an energy source in a multi-step, complex interaction. Circulate among pairs of students as they are working, listen to their ideas, and address questions.

After pairs complete their energy maps, give each pair one red and one green marker. Instruct students to underline the "intended" effects in green and the "unintended" effects in red.

Reflect And Discuss

7 Debrief students' energy maps.

Have students post their maps. Discuss with students the patterns that they notice in the maps. Students should be able to identify heat as an undesired effect in virtually all of the examples. Mechanical/motion (observable by sound) and light are also sometimes a common "undesired" effect.

Tell students that they will continue to investigate "undesired" and "unintended" effects in future lessons as these are at the heart of thinking about efficient energy use. Instruct students to leave their maps up so that they can be referred to in future activities.

8 Engage students in a "quick write."

Ask students to refer to and consider the energy transfer maps they created in this lesson. Post the prompts below on the black/white board or on an overhead and ask students, individually and their scientists' notebooks, to do a quick write about the following:

- *Can energy "disappear?"*
- *Can energy be created?*

Provide reasoning and specific examples to support your answer.

Briefly discuss students' ideas.

> **Note:** *The idea here is not necessarily to have students come to an agreement or definitive answer to the prompts, but rather to surface students' ideas. The two prompts are phrased similarly to the First Law of Thermodynamics which states "energy cannot be created or destroyed." Many students have heard this idea and can recite it, but struggle when pushed to explain the scientific ideas behind the statement. Students may say that energy cannot be created or destroyed but do they really believe it? This idea is counterintuitive. As students look back at their energy maps and discuss everyday energy interactions, it appears that some energy gets "used up" or is "lost." For now, it is acceptable to leave students with some uncertainty, putting the focus on getting ideas out to stimulate thinking.*

9 Discuss the energy changes in a ball-floor interaction.

Show students a tennis ball. Hold it out as if it were going to be dropped. Ask students if the ball has energy. Students should recognize that the ball has potential energy. More specifically, students may recognize that the ball has gravitational potential energy due to its position and elastic energy (stored mechanical) due to its materials. Students may refer to their forms of energy cards if they are having difficulty deciding whether or not the ball has energy.

Ask students to suggest some ways the potential energy of the ball could be transformed to kinetic energy. (Students may say that the ball could be thrown, dropped, hit with another object, etc.)

Say to students: *Let's say that right now the ball has 100 units of energy that can be used to make something happen (in this case, bounce the ball). If energy cannot be created or destroyed, how many units of energy are available to make something happen ("bounce")?* (Students should recognize that 100 units are available.) *If all of 100 units were transferred to the ball as it is bounced, how high do you think the ball would bounce?* (Help students recognize that if all of the energy is transferred to the ball, the ball would bounce as high as its release height.) Ask students to predict how high the ball will bounce when it is released and then drop the ball as students observe what happens.

Discuss with students why the ball does not bounce back to the same height at which it was dropped by focusing on the energy transfers and transformations that occur. Students should recognize that part of the 100 available units of energy was transferred to the floor as heat and part of the 100 units of energy available was transferred to the ball for the bounce and sound. Some of the energy also goes into temporarily changing the shape of the ball. As the ball hits the floor, the floor "pushes" back, squashing the ball into a new shape. The molecules of the ball are stretched apart in some places and squeezed together in others. The molecules in the ball collide and rub across each other. How much stretching and squeezing of the molecules in a ball depends its material.

> **Note:** *Students may be interested in learning more about how ball's bounce using the Exploratorium's Sport! Science: Why Do Balls Bounce? which features photographs by MIT professor Dr. Harold Edgerton. Dr. Edgerton used stroboscopic photography to find out more about how things work.* http://www.exploratorium.edu/sports/ball_bounces/ballbounces2.html

Make certain that students recognize that the ball demonstration is an oversimplified model but one that can help in understanding what happens to available energy as it is transferred.

10 Revisit the idea: *Can energy disappear? Can energy be created?*

Explain to students that these two questions are challenging to answer just by doing investigations in the classroom. Energy is difficult to measure quantitatively with tools available in classrooms. Tell students that scientists have considered these questions and through very careful experimentation using precise tools and methodologies have concluded that energy can neither be created nor destroyed. It can only be converted among various forms. This idea is known as the First Law of Thermodynamics. This law is also known as the Law of Conservation of Energy and essentially means that energy in = energy out. The energy "score" is always equal.

Have students revisit the energy maps of everyday energy interactions. Point to some of the maps and ask students: *How can we have increases and decreases of energy going on at the same time? Do these energy maps support or contradict the First Law of Thermodynamics?* Have students discuss their ideas in small groups before debriefing their ideas as a full group. (Students should recognize these energy maps do not contradict or confirm the Law of Conservation of Energy but rather show the way energy was moving from object to object. What is challenging is for people to observe, measure, and account for where energy is coming from and where all of it is going.)

11 Model energy transfers using dry beans.

Reinforce the conservation idea by doing some "bean counting" to depict energy transfer and transformations using the spool racers students constructed. Distribute a paper cup with 20 beans to each pair of students. Begin by reviewing the Law of Conservation of Energy — no energy is created or destroyed in the interactions of the spool racer. This means that the exact amount of energy decrease in the rubber band shows up as an energy increase somewhere else.

Model this increase and decrease by asking students to imagine that the twisted rubber band has 20 units of elastic (stored mechanical/motion) energy. After the spool racer is released, the rubber band has 0 units of elastic (stored mechanical) energy. How much energy would you expect to be transferred to the spool racer, moving it forward? Let's say 2 units of energy goes toward moving the spool racer forward (mechanical/motion energy) and 18 of units are transferred to the racer's parts, floor, and surrounding air as heat. Ask students to show how energy is transferred/transformed by moving the representative number of beans into smaller piles. Remind students that what is important to remember is that the Law of Conservation of Energy tells that all of the units of energy are accounted for – what goes in is equivalent to what goes out.

12 Introduce the idea of energy efficiency.

Ask students for suggestions on how to change their spool racers to make them go a greater distance using the same number of rubber band twists. Students may suggest a number of things that they could do such as adding tape to the edges of the spool, warming up the rubber band, adding additional washers to the band, etc. Ask students to imagine that their modifications made the spool racer go further on the same number of twists. Ask students what they might say about the way the improved racer uses its available (potential/elastic/stored mechanical) energy. Help students develop the idea that the improved racer is more "energy efficient" than the first because it "does more" with the same amount of energy.

The twisted rubber band in the second version could transfer its 20 units of energy differently, perhaps transferring 3 units of energy toward moving the spool racer forward (as motion or mechanical energy) and 17 units to the spool racers, floor, and surrounding air as heat and sound.

(Optional) Tell students that energy efficiency is often expressed as the following ratio:

$$\text{efficiency} = \frac{\text{energy output}}{\text{Energy input}} \times 100\%$$

For the car examples:

$$10\% \text{ efficient} = \frac{\text{2 energy units (“intended” energy output)}}{\text{20 energy units (energy input)}} \times 100\%$$

$$15\% \text{ efficient} = \frac{\text{3 energy units (“intended” energy output)}}{\text{20 energy units (energy input)}} \times 100\%$$

(Optional) Use a bicycle or other familiar device to provide students with additional practice in accounting for changes in energy using their beans. Use a bicycle as a prop, if available. Have students use 20 beans to represent the bicyclists' breakfast. (Note: One could use this as an opportunity to connect with nutrition.) Ask students where the energy could go besides moving the bicycle and its rider forward? Have students examine the bicycle, paying particular attention to the flow of energy through the bicycle's parts. Ask students what could slow the bicycle/person down? As students make suggestions, have students set aside a representative number of beans. For example, students could set aside 3 beans for a low amount of air in the tires, 4 beans for riding on a rough road, 5 beans for the rider sitting upright on the bike instead of tucking the body in, etc. Calculate the efficiency of the bicycle based on how many beans students have left at the end.

Discuss ways to improve the efficiency of the bicycle. As students make suggestions (pumping up the tires, lubricating the chain, etc.) have them move a representative number of beans into the "available" pile. Recalculate the efficiency.

13 Bring the lesson to a close.

Explain that in the next few lessons they will be examining energy efficiency in different contexts including those on a much larger scale (looking at the energy transfers and efficiency on large-scale situations). Students will also relate efficiency to energy conservation practices.

Extension

Students may:

- review the How Stuff Works "Elements of Physics: Energy Exchanges" online video clip http://videos.howstuffworks.com/hsw/10794-elements-of-physics-energy-exchanges-video.htm focusing on the last minute of the 3 minute clip. Consider *Why is it important that cars have cooling systems?*
- learn about infrared images. View an image that has been heated by friction from the road: http://coolcosmos.ipac.caltech.edu/cosmic_games/what/img10.html or view an image of someone rubbing their hands together: http://www.youtube.com/profile?user=nutscode&view=videos (worldofwarmth.com)
- consider the energy transfers in this 2003 Rube Goldberg Honda advertisement. What are the desired and undesired effects? http://autorepair.about.com/od/glossary/a/honda_rube.htm
- learn how artist Vollis Simpson creates kinetic sculptures and whirligigs using bearings in all of his spinning pieces so that they move smoothly. Try the investigation featured on the Science Museum of Minnesota's website: http://www.thinkingfountain.org/f/friction/friction.html
- find out how energy is measured: http://www.uwsp.edu/cnr/wcee/keep/Mod1/Whatis/energymeasures.htm
- find out more about how a particular device works. Websites such as How Stuff Works (www.howstuffworks.com) or print resources like David Macaulay's *The Way Things Work* can be useful. Be aware that depending on the device and the resource, this information may overwhelm or confuse students as they consider energy transfers.
- play energy conversion dominoes described on describe on pages 5-7 of School's Power Naturally Lesson #4: www.powernaturally.org/Programs/pdfs_docs/4_PV-games.doc Some of the dominoes would need to be modified to reflect the forms of energy introduced to students in *Energy for Maine*. Substitute devices that would be unfamiliar to students with more familiar ones, but make sure examples include a variety of energy forms.

- take the Design Squad Challenge. Build a car that goes really far, really fast. The challenge: use a rubber band as the power source and the car can only have two wheels. http://pbskids.org/designsquad/projects/rubber_band_car.html

Connection to Maine Agencies

A Maine Energy Education Program (MEEP) is a no cost resource for schools and teachers in Maine. MEEP representatives will come to interested schools, free of charge, to guide and support the concepts in lesson and have several programs that supplement concepts in this lesson:

- Electricity and the Environment including Icebreaker with comparison of CFL and incandescent light bulbs. Students become aware of electricity in our awareness session. They make electricity from an apple in the Apple Battery experiment and then learn how electricity is made in the real world. Next, with MEEP's PV Fan and Mini-Wind Turbine activities, they make electricity from renewable resources. These activities can be combined with the Great Energy Debate and Energy Jeopardy in a full-day workshop.

More information can be found on the MEEP website:
www.meepnews.org/classroomactivities

For schools in Aroostook County, a Maine Public Service (MPS) representative will come to interested schools, free of charge, to guide and support concepts developed in this lesson. A description of programs is available at www.mainepublicservice.com. Click on the education section of the site. To schedule a presentation contact Nancy Chandler at 207.760.2556 or nchandler@mainepublicservice.com.

Online References and Resources

KEEP's Website:
http://www.uwsp.edu/cnr/wcee/keep/Mod1/Rules/EnConversion.htm

Spool Racers:
http://www.pbs.org/saf/1103/teaching/teaching3.htm
http://www.teachersdomain.org/asset/phy03_vid_zsplcar/

Teach Engineering Activity: Energy Conversions
http://teachengineering.org/view_activity.php?url=http://teachengineering.org/collection/cla_/activities/cla_activity2_energy_conversion/cla_activity2_energy_conversion.xml

Urban Heat Islands: An Introduction to Energy Transfer and Transformation by Kate Porter, Cornell Science Inquiry Partnerships, Cornell University (NSF) http://csip.cornell.edu

Rubber Band-Powered Spool Racer

What you will need:

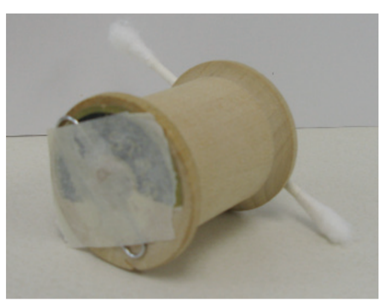
- rubber band
- empty thread spool
- paper clip
- tape
- metal washer
- cotton swab

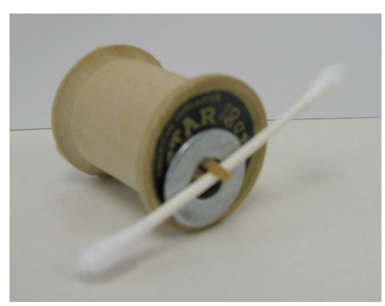
Directions:

1. Attach a rubber band to the paper clip by sliding the rubber band onto the paper clip as you would add a key to a key chain.
2. Insert the rubber band through the hold in the middle of the spool. Make sure that the ends of the rubber band stick out from both ends of the spool. (One end already has a paper clip looped onto it.)
3. Securely tape the paper clip attached to the rubber band to the one side of the spool.
4. Slide a washer onto the rubber band loop sticking out of the other end of the spool racer. Pull the rubber band up through the washer so that the washer lies flat against the spool.
5. Stick a cotton swab through the loop.
6. Turn the swab to wind the rubber band. Put the spool racer on the floor and let it go.

Record:

In your notebook create an energy map that identifies the energy source(s), energy receiver(s), and energy forms for the spool racer.





Energy Map Words

energy source	energy receiver	decrease
energy source	energy receiver	decrease
energy source	energy receiver	decrease
energy source	energy receiver	decrease
energy source	energy receiver	decrease
energy source	energy receiver	decrease
energy source	energy receiver	decrease
energy source	energy receiver	decrease
thermal energy	thermal energy	decrease
thermal energy	thermal energy	decrease
thermal energy	thermal energy	decrease
thermal energy	thermal energy	decrease

Energy Map Words

elastic energy	elastic energy	increase
radiant energy	radiant energy	increase
chemical energy	chemical energy	increase
chemical energy	chemical energy	increase
electrical energy	electrical energy	increase
electrical energy	electrical energy	increase
electrical energy	electrical energy	increase
mechanical/ motion energy	mechanical/ motion energy	increase
mechanical/ motion energy	mechanical/ motion energy	increase
mechanical/ motion energy	mechanical/ motion energy	increase
mechanical/ motion energy	mechanical/ motion energy	increase
gravitational potential energy	gravitational potential energy	increase

Everyday Energy Interactions

Directions:

Distribute one of the descriptions below to each pair of students. Students are to create energy maps that identify as completely as possible the:

- interaction(s)
- energy source(s)
- energy receiver(s)
- energy transfer(s)
- forms of energy
- increases and decreases of energy

Clarify that the interaction could involve multiple transfers; some of which may be difficult to observe or detect. Students should discuss what they know about these everyday interactions with their partner before making their maps.

Once pairs complete their energy maps, provide one red and one green marker. Instruct students to underline in green "intended" or "desired" effects and underline in red "unintended" or "undesired" effects.

Vacuuming cleaning dog hair off a carpet.
A neighbor playing a hand-held video game.
A hockey player skating across the ice.
A softball striking a bat.
Water being cooled by drinking fountain.
Scissors cutting out a coupon from the newspaper.
A cordless drill used to assemble a picnic table.
A basketball player running down the court to shoot a lay up.
A campfire toasting a marshmallow on a skewer.
A hair dryer used to dry hair.
Bread baking in the oven.
A person washing up using the hot water from a solar shower.
Jeans hanging on the clothesline.
A ball from a slingshot knocking down cans at a carnival game.

Possible Responses for Everyday Energy Interactions

(Students may include additional details and/or show activities as a series of interactions – this is a guide; accept reasonable answers.)

Energy Source	Form(s) of Energy	Energy Receiver	Form(s) of Energy
power plant	→ decrease in electrical energy	vacuum	→ increase in mechanical/motion energy (sucking and sound) → increase in heat
power plant or battery	→ decrease in electrical or chemical energy	game	→ increase in motion/mechanical (sound) → increase in radiant energy (light) → increase in heat
hockey player	→ decrease in chemical energy	skate / ice / puck	→ increase in mechanical/motion energy (movement and sound) → increase in heat (ice melts)
battery	→ decrease in chemical energy	bat / ball	→ increase in mechanical/motion energy (movement and sound) → increase in heat
power plant	→ decrease in electrical energy	fountain/cooler/ water	→ increase in mechanical/motion energy (movement and sound) → increase in heat → increase in chemical
person or could start with scissors	→ decrease in chemical energy	scissors/ newspaper	→ increase in mechanical/motion energy (movement and sound) → increase in heat
cordless drill	→ decrease in chemical energy (battery)	screw / wood	→ increase in mechanical/motion energy (movement and sound) → increase in heat
basketball player	→ decrease in chemical energy	floor/ball	→ increase in mechanical/motion energy (movement and sound) → increase in heat
wood	→ decrease in chemical	environment/ skewer / marshmallow	→ increase in radiant → increase in thermal
power plant	→ decrease in electrical	hair / hair dryer	→ increase in mechanical/motion energy (air movement and sound) → increase in heat
oven	→ decrease in electrical	bread	→ increase in thermal → increase in chemical
sun	→ decrease in radiant, thermal, and gravitational potential	water warming up and falling from shower	→ increase in thermal → increase in mechanical/motion
sun	→ decrease in thermal and radiant	clothes	→ increase in thermal
slingshot	→ decrease in elastic (stored mechanical) energy	shot / cans	→ increase in mechanical/motion → increase in thermal

Lesson 5: Modeling Energy Efficiency

Overview

Students construct model water wheels using simple materials. Students test the water wheels and compare how efficiently each uses available energy.

Teacher Background

Water wheels are devices that use energy to accomplish a variety of tasks. The use of water as an energy source dates back to ancient Greece and Rome where water wheels were used to mill corn. Widespread use of water as an energy source developed around the 12th century as large wooden water wheels were engineered. Water as an energy source played a significant role in the development of early American towns. The grist and sawmills of colonial times gave way to textile, leather, and machine-shop industries in the 1800's.

Modern water turbines are the product of the Industrial Revolution as the demand for energy increased and factories developed. Engineers investigated blade design working to maximize energy output. Hydroelectric power stations contain water turbines that are direct descendants of water wheels. Almost all electrical power generated on Earth involves using a turbine of some type.

This lesson has two major goals: the first is to provide students with the opportunity to engage in the technological design process as they observe, design, and build a working model water wheel. The second is to provide a context for students to compare, in a relatively simple way, the efficiency of their models in terms of energy. When engineers design, build, and construct dams that generate electricity from the flow of water, they calculate the efficiency of the plant and use this to determine the amount of power that can be generated by the plant. In this context, the calculation is critical. Calculating the dam's potential power generation allows an estimate of how many homes and businesses can be supplied with electricity generated from the plant.

A conscious effort was made in this lesson to minimize the reliance of mathematical calculations of values such as work and power that are related to efficiency. *Benchmarks for Science Literacy* states: "Work, in the specialized sense used in physics, is often considered a useful, even necessary, concept for dealing with ideas of energy. These benchmarks propose to do without a technical definition of work for purposes of basic literacy, because it is so greatly confused with the common English-language meaning of the word. The calculation of work as force times distance is not essential to understanding many important ideas about energy…"

The approach taken to consider differences in efficiency relies on keeping several components of students' water wheel models constant. For example, models will utilize a plastic 2-liter bottle as the hub so that the wheel's diameters are equivalent; the same volume of water will be poured at the same rate onto the wheel as it is tested; the water will be poured from the same height above the water wheel; the mass the wheel lifts will be constant; and the distance the mass is lifted will be the same. Some thought should be given as to how the most efficient water wheel will be determined. Elicit students' ideas for determining efficiency and a method for measuring that efficiency. Some students might consider the most efficient water wheel to be one that lifts the mass in the shortest period of time. Some might consider that the most efficient wheel raises the weight using the least amount of water, calculating the water left and concluding the most efficient will be the one with the most amount of water left. Others might suggest measuring the length of string that the wheel wound up after using a specified amount of water.

For teachers interested in engaging students in extending the lesson to include calculating work and power for their models, they can refer to the Teach Engineering Lesson: Power, Work, and the Water wheel from which this lesson was adapted at: **http://www.teachengineering.org/view_activity.php?url=http://www.teachengineering.org/collection/cub_/activities/cub_energy/cub_energy_lesson02_activity1.xml** Students would need to be familiar with the scientific definitions of work and power and units of measure (Joules, Watts, Newtons).

Additional information about the technological design process can be found at the Boston Museum of Science's Engineering is Elementary (EiE) link: The Engineering Design Process: **www.mos.org/eie/engineering_design.php**

Key Ideas

- Water can be an energy source. Water's energy can make things happen.
- Humans have purposefully used (engineered) energy transfers and transformations to accomplish tasks that improve the quality of life.

- Technological design involves using scientific principles to solve problems.
- Predicting, observing, designing, building, testing, analyzing, and retesting are all steps in the technological design process.
- Things that are energy efficient use less energy to do the same task. Energy efficient devices minimize or redirect unintended energy transfers and/or transformations.

Lesson Goals

Students will:

- describe how water can be used as an energy source.
- describe examples of purposefully engineered energy transfers and transformations.
- describe a "intended" energy transformation and an "unintended" energy transformation using the context of a water wheel.
- recognize that energy efficient devices use less energy to do the same task.

Vocabulary

energy efficiency: using less energy to perform the same function.

turbine: a device made up of a series of blades that is turned by a fluid (gas or liquid) and as it turns, transfers mechanical/motion energy to a generator.

Preparation

- Collect and drill holes in the bottom of the bottles and center of caps. Holes should be drilled slightly larger than 3/8" to accommodate the dowel. Make sure there are enough predrilled plastic 2-L bottles so that each pair of students has one to work with. Prepare extra bottles as spares and for the redesign process. (Note: Smaller plastic bottles may also be used instead but adjustments may be needed for the dowel size, string length and weight lifted.)
- Assemble a model water wheel and practice using the water to lift a mass.
- Determine how students will test their water wheels. Testing needs to be done over a sink or outside. Have enough dowels and weights on hand for students to do some intermediary testing of their designs. Suggestions for testing are included on the *PowerSleuth* companion website (**www.powersleuth.org**), *Energy for Maine*, Lesson 5.

- Become familiar with the technological design process and consider the level of guidance and support students will need in working through this project. A reference guide to this process can be found at Boston Museum of Science's Engineering is Elementary: The Technological Design Process (www.mos.org/eie/engineering_design.php)

Safety

- If testing water wheels inside, the floor can become slippery. Advise students to use caution.
- Make certain that students use the dowel rods appropriately.

Materials

Item	Quantity
Scientist's Notebook	1 per student
For water wheel/turbine construction: • 2-liter plastic bottles with caps (pre-drill hole in center of cap and bottom of bottle slightly larger than 3/8") • string, 1.2 meters • a variety of blade/paddle making materials: index cards, Styrofoam meat trays, plastic and paper cups, waxed cardboard from school milk cartons • scissors • tape (duct tape or other water resistant tape is preferable) • rubber bands (to place around neck of bottle – helps to keep string from slipping as wheel turns) • 50-80 gram weight (2 large washers attached to a paperclip work well. The paperclip can easily be attached to the string.)	1 per pair
For testing of water wheels/turbines: • 3/8" dowel rod (must be longer than the 2-liter bottle) (30" jumbo bamboo roasting skewers may be substituted) • funnel • water jug or pitcher	1 or more station per class
Device as required to measure efficiency of water wheels (graduated cylinder, meter stick, stopwatch, etc)	1 or more per class
Student Handout 5.1: Water Wheel Design Challenge	1 per student

Time Required: 4-5 sessions

Session 1:	Introduction of project, background research on water wheels and water turbines, initial design sketches
Session 2:	Development of clear prototype plan, building of first prototype and some testing
Session 3:	Prototype testing, modification of plans and reworking of prototype, additional testing
Session 4-5:	Final testing of models, debrief

Connection to *Maine Learning Results (MLR)*, *Benchmarks for Science Literacy (BSL)*, and *Science for All Americans (SFAA)*

- Whenever energy appears in one place, it must have disappeared from another. Whenever energy is lost from somewhere, it must have gone somewhere else. Sometimes when energy appears to be lost, it actually has been transferred to a system that is so large that the effect of the transferred energy is imperceptible. BSL 4E/M1* (6-8)
- Transformations and transfers of energy within a system usually result in some energy escaping into its surrounding environment. Some systems transfer less energy to their environment than others during these transformations and transfers. BSL 8C/M1* (6-6)
- Energy can be transferred from one system to another (or from a system to its environment) in different ways: 1) thermally, when a warmer object is in contact with a cooler one; 2) mechanically, when two objects push or pull on each other over a distance; 3) electrically, when an electrical source such as a battery or generator is connected in a complete circuit to an electrical device; or 4) by electromagnetic waves. BSL 4E/M2* (6-8)
- People have invented ingenious ways of deliberately bringing about energy transformations that are useful to them. BSL (SFAA) 8C/M8** (6-8)
- Use examples of energy transformations from one form to another to explain that energy cannot be created or destroyed. MLR D3 (6-8) i

Teaching The Lesson

Engage

1 Discuss water as an energy source.

Hold up a container of water. Ask students if the water has energy. Students should recognize that the water has (gravitational) potential energy. Ask students to brainstorm ways that the potential energy could be used to do something – to make something happen! Allow students 2-3 minutes to make a list of the different ways the potential energy in water could be used to cause a change something or make something happen. Make a list of students' ideas on the board. Students may suggest that water generates electricity in hydroelectric dams, causes erosion, makes boats move, powers hydroelectric cars, keeps time (water clocks), and so on.

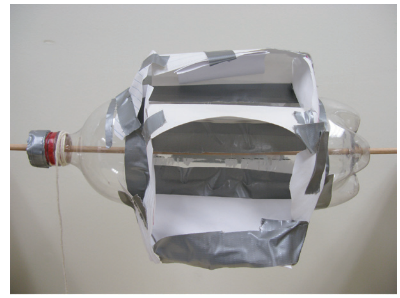
2 Discuss technological design.

Engage students in a conversation about technological design. Ask about things they have designed and/or built. Extend the conversation by asking if anyone has designed and built something to solve a problem. Accept all answers and encourage creativity in ideas. Reiterate that humans have engineered devices to use the potential energy in water in many creative ways to do many different tasks as they mentioned earlier. Water is readily available and plentiful in most areas of the world and is considered a "clean," renewable resource. Explain to students that in Maine and around the world, people have been and are continuing to design and build creative solutions using natural, renewable resources such as water to address our energy needs. Water is a major source of energy. People have used it successfully throughout history to generate mechanical energy for grinding grains (gristmills), pounding linen into paper, powering paddle boats, and most prominently today, generating electricity (hydropower). Tell students that they will join this challenge by designing and building an efficient water wheel.

> **Note:** *If students are not familiar with renewable resources consider taking the time to discuss them here. More about renewable and nonrenewable resources can be found in* Energy Lights Maine, *Lesson 7: Around and Around They Go- Turbines or in* Energy Heats Maine, *Lesson 8: Energy Warms Maine.*

3 Introduce students to the water wheel design challenge.

Explain to students that they will be using their knowledge of energy transfers and transformations to design the most efficient water wheel they can. Review with students what is meant by "efficient." Show students the basic design of the water wheel and the materials that they will be using to engineer their water wheels.



Provide students with Student Handout 5.1: Water Wheel Challenge Design. Divide students into pairs. Direct pairs to discuss ways the "efficiency" of the water wheels could be determined. Point out to students the components that will remain constant in students' designs and during the testing process. For example, each team will be using a 2-liter bottle as their water wheel's "hub," so the wheel's diameters will be equal; the same volume of water (specify volume: 1 gallon of water is recommended) will be poured at the same rate onto the wheel; the water will be poured from the same height (15 cm/6 inches) above the water wheel; the mass the wheel has to lift will be constant (50-80 gram weight/certain number of washers attached to paperclip), and the distance the mass is lifted will be the same (100 cm or 1 meter).

Bring the class together to debrief their ideas. Help students reach an agreement as to how the most efficient water wheel will be determined. Have students enter this under "Define Efficiency" on Student Handout 5.1: Water Wheel Design Challenge. Encourage students to consider the number of trials necessary for accurate data collection. (Three to five trials is sufficient.)

Explore

4 Design a water wheel.

To initiate the technological design process for their water wheels have students consider the following:

- *How do water wheels work? What parts do they have?*
- *What do the paddles or blades of a water wheel have to do?*
- *What features make efficient water wheels?* (Possible answers: "Efficient" water wheels have many blades or paddles to turn the wheel/bottle, each blade/paddle holds a large amount of water, symmetry, etc.)
- *How can we use the available materials in the best possible way?*

Give students time to discuss and record their thinking in their scientists' notebooks. Encourage students do some research reviewing a collection of photographs and/or diagrams showing a variety of styles of water wheels and water turbines. Direct students to pay particular attention to the design and placement of the paddles or blades on the wheels/turbines. Encourage students to make simple sketches of the ideas they are thinking about.

Students can view examples of water wheels at: http://www.waterwheelfactory.com/

David Macauly's *The Way Things Work* has simple cut-away diagrams showing the key components of water wheels and hydroelectric turbines.

Ask students to decide on one design and make a detailed drawing of the water wheel they would like to build. Students' design plans should include labeled drawings and a list of materials. As students are working, circulate among groups and offer assistance and guidance as needed. Listen to students' ideas.

Note: *Each student should record in his or her own notebook.*

5 Peer review.

When student pairs are done designing their water wheels they will share their design with another team. During this time, students work together explaining their designs. Peers write constructive comments and questions they have on sticky notes and then post the notes in the reviewed notebook. Consider requiring each student to offer one constructive comment or one question for the design that they review. Model for students the types of comments that are helpful in improving designs. For example, comments such as "I like ….." are not helpful in pushing students' thinking about their designs. A comment such as "Have you thought about the amount of water the spoon shaped blades will hold?" helps students think about their designs more critically.

Note: *Review students' notebooks to get a sense of students' ideas before students begin building. If some students are particularly protective of their designs, the peer review process may be eliminated or require modification.*

6 Build water wheels.

Provide time for teams to review their designs before building materials are distributed. Encourage students to follow their designs. As teams are working, circulate among students. Ask guiding questions and support students as needed in constructing their models.

> **Note:** *Guiding questions about students' designs are appropriate and helpful. However, it is often tempting to correct a flawed design. Part of the design and building process is the experience of making something that may not work and redesigning and rebuilding it until it does. Be careful not to take that learning experience away from the students.*
>
> *It is easy to place too much emphasis on having students follow their designs rigidly. While following a plan is important, it is equally important to balance students' need to experiment with the building process. Often students get quite excited with the building process that they don't exactly follow their design or remember to record the changes they make to their designs. Encourage students to keep good records without squelching their excitement, enthusiasm, and creativity that this type of activity brings out. Excitement, enthusiasm, and creativity are all scientific traits that should be encouraged. If students are struggling with following the design/build process then consider allowing a certain amount of time for less structured "free" exploration with the materials prior to the building. Keep in mind that "free" exploration may not be practical if materials are limited and/or if it involves cutting or activities that are challenging for teachers to safely monitor.)*

7 Test the students' water wheel designs.

Prior to testing students' water wheels, review the protocol for testing water wheels with students. Remind students to keep track of their data. Model for students how to set up a data table and/or provide the data table on Student Handout 5.1: Water Wheel Design Challenge.

Coordinate supervised opportunities for students to test their water wheels. Make certain that for each trial, the components outlined in step 3 are held constant so that wheels are tested fairly. Consider video taping students' tests. Analysis of performance is enhanced when students can review a tape of the trials.

> **Note:** *If the weight is too heavy, the water wheel may not work. If the weight is too light, you won't get a sense of the water wheel's efficiency. Adjust weights as necessary but keep in mind that each group should lift the same weight in order for fair testing to be upheld.*

Note: *It is rare for a first design to be entirely successful. Repeated attempts are part of the engineering process. When students' trials aren't as successful as they would like them to be, use the opportunity to ask guiding questions to aid in the redesigning of their model. Questions can focus on any areas of their models that appear to be problematic, such as the shape or position of the paddles or blades, attachment points of the blades, number of and size of blades, angle of blades, etc. This is also a good opportunity to remind students that many inventions begin with partially successful or unsuccessful attempts. This is part of the designing and building process and is to be expected. Encourage students to think of these attempts as learning opportunities!*

8 Redesign, rebuild, and retest.

Guide students to use both words and sketches to record their thoughts on what aspects of their first model worked and didn't work. Students can then begin to "tweak" their design on paper using labeled drawings. Once their new designs are entered into their notebooks, they may partner up with their peer reviewers to discuss any new design elements. As before, peers use sticky notes to add constructive comments and questions to their peer's notebooks. Once students have reviewed their new designs with peer reviewers, they may move on to rebuilding and retesting.

Note: *As tempting as it may be to eliminate this step due to time, the redesigning, rebuilding, and retesting process is an integral component of the design process. However, the peer review process may be omitted, as noted earlier.*

Reflect And Discuss

9 Reflect in notebooks.

Have students reflect and write about their experiences in their notebooks. Include the following:

- *Describe energy transfers and/or transformation that are "intended" in your model water wheel.*
- *Describe energy transfers and/or transformations that are "unintended" in your model water wheel.*
- *Use an example of an energy transfer or transformation in your water wheel to explain that energy cannot be created or destroyed.*
- *These parts of our model worked well ….*
- *If I could redesign the blades of our model again I would… because…*
- *How do you think that water could be used to generate electricity for a community?*

- *What else besides blade design would need to be considered before building water wheels or water turbines in a community?*
- *If you were asked to build a turbine that utilized the energy from wind, how would the turbine blades be similar to and different from the turbine blades you constructed for water?*

10 Debrief the experience as a class.

After students have finished writing in their notebooks, have them bring their notebooks to the group area for a class discussion. In addition to discussing the questions above, ask questions that focus students on their designing and building experiences. For example:

- *What were some challenges you and your partner experienced during this process?*
- *What parts of the designing and building process were most challenging or difficult?*
- *What was the purpose of having the chance to redesign your model?*
- *What are some design characteristics that made water wheels successful?*
- *How did the most efficient model differ from the other models?*

11 Bring lesson to a close.

Compare students' design process and their models to "real world" applications of energy issues and solutions. Explain that there are and always will be challenges in using energy in the most efficient ways. In addition to "efficiency challenges" there are usually positive aspects and negative aspects for every resource and design used. Problems include finding enough energy resources and using them in nonpolluting and safe ways as well as engineering new machines that use resources in new ways. The exciting part is that there are people who have jobs studying energy and designing devices to use energy in the most efficient ways. They work together creatively to solve our world's energy crisis.

> **Note:** *This is a nice time to make the connection to careers. Use the careers section of the* PowerSleuth *website to look for ideas to include in this discussion/exploration.*

Extensions

Students may:

- build and design mousetrap racers as an alternative or in addition to building and designing the water wheels. As in this investigation, students could discuss the ways the "efficiency" of a mousetrap racer could be determined. Guidelines and patterns for constructing mousetrap racers can be found on London's Science Museum's website at: www.sciencemuseum.org.uk/educators/classroom_and_homework_resources/resources/mousetrap_drag_racer.aspx
- build a solar car and compare its efficiency when its battery pack is used versus its solar panel. Students could also compare the efficiency of a solar car to that of the mousetrap drag racer. MEEP's Junior Solar Sprint model car competition is a springtime activity involving middle school students across the state. http://www.meepnews.org/ontheracetrack.htm.
- learn more about how water is used in hydroelectric power plants to generate electricity. http://www.teachersdomain.org/asset/phy03_vid_hooverelec/
- build their own hydroelectric generator using plans and guidelines from the Pembroke Institute. Extensive background information and step-by-step plans to build a working hydroelectric generator is available at: http://www.re-energy.ca/t-i_water-build-1.shtml
- watch this Discovery News clip to learn more about how two businesses in New York City are getting their power from underwater turbines. Clip is approximately 2 ½ minutes. http://dsc.discovery.com/videos/tech-underwater-turbines-pump-out-energy.html (movie)
- read how scientists from Georgia Tech have harnessed hamster power. http://dsc.discovery.com/news/2009/03/09/hamster-energy-power.html
- explore how to determine the best location on a dam to generate electricity by investigating how the height of water above a hole in the dam wall affects the length of the stream flow from that hole in this lesson from Science Buddies called Leaky Clues to Dam Design: http://www.sciencebuddies.org/science-fair-projects/project_ideas/Energy_p029.shtml
- visit a local hydroelectric plant.

Connection to Maine Agencies

A Maine Energy Education Program (MEEP) is a no cost resource for schools and teachers in Maine. MEEP representatives will come to interested schools, free of charge, to guide and support the concepts in this lesson and have several programs that supplement concepts in this lesson:

- Electricity & the Environment including Icebreaker with comparison of CFL and incandescent light bulbs. Students become aware of electricity in our awareness session. They make electricity from an apple in the Apple Battery experiment and then learn how electricity is made in the real world. Next, with MEEP's PV Fan and Mini-Wind Turbine activities, they make electricity from renewable resources. These activities can be combined with the Great Energy Debate and Energy Jeopardy in a full-day workshop.
- KidWind: Students design and build their own mini wind turbine blades. They then compete to see whose design makes the most electricity.
- Junior Solar Sprint

More information can be found on the MEEP website: www.meepnews.org/classroomactivities.

For schools in Aroostook County, a Maine Public Service (MPS) representative will come to interested schools, free of charge, to guide and support concepts developed in this lesson. A description of programs is available at www.mainepublicservice.com. Click on the education section of the site. To schedule a presentation contact Nancy Chandler at 207.760.2556 or nchandler@mainepublicservice.com.

References:

Teach Engineering http://www.teachengineering.org/view_activity.php?url=http://www.teachengineering.org/collection/cub_/activities/cub_energy/cub_energy_lesson02_activity1.xml

http://www.pplweb.com/NR/rdonlyres/FDC67F7C-94C9-4EB9-9E7D-8D8147D6A164/0/HydroUnit4.pdf (extended water wheel lesson)

www.historychannel.com

Explore More: The Future of Energy (Iowa Public Television) http://www.iptv.org/exploremore/energy/issues/efficiency.cfm

http://www.re-energy.ca/t-i_waterbuild-1.shtml

Water Wheel Design Challenge

The Challenge

In this design challenge, you will use your knowledge of energy transfers and transformations to design the most efficient water wheel as you can! Your team will have the following materials:

- one 2-L plastic bottle
- tape
- scissors
- 1.2 meters of string
- paperclip
- 50-80 gram weight (2 large washers)
- rubber band
- a variety of blade/paddle making materials: index cards, Styrofoam meat trays, plastic and paper cups, waxed cardboard from milk or juice cartons

The following will remain constant:

- the diameter of the water wheels (2-L plastic bottle)
- the volume of water poured over the water wheels (1 gallon)
- the rate of water being poured (use of a funnel and the same person pouring)
- the height from which the water will be poured (15 cm / 6 inches above the water wheel's hub)
- the mass of the weights that the water wheel will lift

Define Efficiency

Describe how your class will determine the most efficient water wheel. Include in the description tools needed to gather efficiency data:

The most efficient water wheel is one that…..

Research and Planning

Use the available web and print resources to consider:

- *How do water wheels work? What parts do they have?*
- *What do the paddles or blades of water wheels have to do?*
- *What features make efficient water wheels?*
- *How can my team use the available materials in the best possible way?*

Designing and Building of Water Wheel

Use your scientists' notebook to keep research, ideas, plans, and update progress. Keep entries dated and include labeled diagrams.

Testing the Water Wheel

Develop a data table to record team and class data. A sample data table is provided below:

[sample]

Student Team	Trial 1 time	Trial 2 time	Trial 3 time	Observations

Redesign, rebuild, and retest.

Use your scientists' notebook to keep research, ideas, plans, and update progress. Keep entries dated and include labeled diagrams.

Designing and Building of Water Wheel

Analyze the efficiency of water wheel. Use both words and sketches to describe what aspects of their first model worked well and which aspects could be improved.

In your notebook, include the revisions to your design.

Reflection Questions

Reflect and write about your water wheel experiences in your notebooks. Include the following:

- *Describe energy transfers and/or transformation that are "intended" in your model water wheel.*
- *Describe energy transfers and/or transformations that are "unintended" in your model water wheel.*
- *Use an example of an energy transfer or transformation in your water wheel to explain that energy cannot be created or destroyed.*
- *These parts of our model worked well ….*
- *If I could redesign the blades of our model again I would… because…*
- *How do you think that water could be used to generate electricity for a community?*
- *What else besides blade design would need to be considered before building water wheels or water turbines in a community?*
- *If you were asked to build a turbine that utilized the energy from wind, how would the turbine blades be similar to and different from the turbine blades you constructed for water?*