STEM in the lab

Inspiring Idaho's future STEM workforce

WATERWHEEL WORK

MISSION

Create a waterwheel out of a plastic bottle.

VOCABULARY

KINETIC ENERGY: Energy of movement.

POTENTIAL ENERGY: Stored energy.

ELEVATION: Height above a given level.

DAM: A barrier to obstruct the flow of water, especially one made of earth, rock, masonry and/or concrete, built across a stream or river.

HYDROELECTRIC POWER: Renewable energy generated by water flowing through turbines.

RESERVOIR: An artificial lake where water is collected and stored behind a dam.

TURBINE: A machine that converts the kinetic energy of falling water (or any moving fluid, including steam, gases or air) into electrical energy by connecting a generator to a rotating shaft that is spun by water pressure pushing blades, buckets or paddles.

WATERWHEEL: Spins as a stream of water (which is being pulled down by gravity) hits its paddles or blades.

MATERIALS

» 1 empty, clean water bottle. The bottle needs to have smooth sides. A two liter soda bottle will also work.

» Scissors

» Tape

» 6-8 large index cards (4 x 6)

» Waterproofing materials to wrap around the index cards (aluminum foil, plastic wrap, etc.)

» Pen or marker

» Wooden dowel
The dowel needs to fit in the bottle opening with a little room to turn and needs to be longer than the length of the water bottle. If the dowel is big enough to fill the opening then the water bottle lid is not needed. If the opening is too loose, put the water bottle lid on bottle and drill a hole in the lid.

» Clock or watch

» String

» Flat washer or other objects (weights) that can be tied to string

» Water source

» Pouring container to hold water

» Sink or outside area that can get wet

ABOUT THIS ACTIVITY

With energy consumption increasing, alternate energy sources are in greater demand. The U.S. Department of Energy's (DOE) Water Power Technologies Office (WPTO) is leading research to modernize hydropower to meet current and future electrical grid needs. Idaho National Laboratory (INL) is part of this research. Instead of building dams with huge reservoirs of water, researchers are trying to harness the water power of rivers. This is called "run of the river" (ROR). The researchers at INL are collaborating with Idaho Falls Power. There are currently four "run of the river" power plants on the Snake River. Instead of using a reservoir, a portion of a river is channeled into a hydropower plant. Because the amount of water in a river can vary, it makes it hard to rely on how much water can be used to generate electricity. INL is leading the WPTO's Integrated project. This is a research effort to provide grid balancing through integration with energy storage systems so that a ROR hydropower plant can control the amount of power it puts on the grid, filling the same balancing role as conventional hydropower.

In this activity, students will create an experimental waterwheel (precursor to the turbines used today in hydroelectric power plants) from a plastic water bottle. Using the waterwheel created, students will watch both kinetic and potential energy at work and see how weight affects the rotational rate of the waterwheel.

INSTRUCTIONS

Optional: Teachers can complete step 6 before students start experiment

1. Make 4 x 6 index cards waterproof. Wrap either aluminum foil or plastic wrap around each card.
2. Measure the circumference of the water bottle. With a pen or maker, divide the total circumference into evenly spaced lengths. These mark the locations where index card "water paddles" will be taped.
3. Fold the "waterproof" index cards to make small boxes or envelopes ("catchers") with open sides. These will serve as waterwheel paddles (or buckets) to catch the water. Exactly how the index cards are folded and attached to the bottle is up to each team.
4. Mark one index card with an "X" so counting the number of turns is easier. The students will count each time the "X" paddle reaches the top of the waterwheel while turning.
5. Tape the index card "paddles" to the water bottle at each line. Your waterwheel will spin in one specific direction (choose either clockwise or counterclockwise), so make sure each paddle faces the same direction to help the bottle to spin in that direction.
6. Make a hole in the bottom of the bottle so that the dowel can be inserted through the center of the bottle like an axle (from the opening at the top through the hole in the bottom. The hole in the bottom of the bottle should be slightly larger than the dowel, so that the whole bottle can freely spin on the dowel.
7. <u>Conduct this step over a sink or outside.</u> Pour water over "paddles". Have one team member keep track of the elapsed time. As soon as the wheel is spinning, start taking the time while other team members count the number of turns the waterwheel makes (watch for the "X"). Stop counting turns and keeping track of the time when the waterwheel slows down.
8. Change roles and repeat until every member has counted or there is a consistent measurement for the rate at which the waterwheel spins. Make a table and record your data (elapsed time and number of rotations).
9. Have teams fasten a string to the neck of their water turbines. Tie objects (nut) to the string.
10. Repeat Step 7 with the extra weight, so the spinning waterwheel pulls the weight up as the string rolls up around the neck of the bottle.

RESEARCH & DESIGN PROCESS

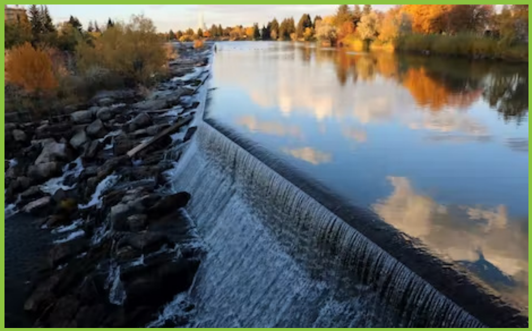
» When water was poured over them, what happened to the "paddles"?

» Where there patterns in the results? Have all teams average their rotation rate and write it on the board. Why are there different average rates of rotation?

» What happened to the rate of rotation when different weight was added? How would engineers use this understanding to design hydroelectric power plants? (Answer: Engineers would learn about the different paddle or blade designs to see how well they moved the weight. The better the blade design, the faster the waterwheel turned and moved the weight upwards. They would use this information to design a turbine that generated the most electricity from the turning wheel.)

» How might we have altered the experiment or our methods to make a better experiment?

THE SCIENCE BEHIND IT



Water at a higher elevation has stored potential energy compared to water at a lower elevation. The moving water has **kinetic energy**. As the water falls through the air, its kinetic energy grows as its potential energy decreases. So when it finally reaches the bottom, all of its potential energy has been converted into kinetic energy. This is because energy is never created or destroyed, it just changes form. This is why a waterfall has so much power. This is also why **hydroelectric power** works.

A hydropower plant located at a dam takes the potential energy of water located high up in a reservoir and captures its energy as it drops to the bottom of the dam. Hydropower plants are designed to take the power of falling water and use it to create electricity. Throughout human history, waterwheels performed many types of mechanical work: saw timber, run farm equipment, grind grains into flour, make iron products and power textile mills. Today, the modern equivalents of waterwheels are the huge turbines of hydroelectric power plants, which generate electricity that we use every day to perform all types of work: heating, cooling, refrigeration, and the powering of appliances, televisions and entertainment. Hydropower is away to produce electricity using a renewable energy source that does not use fossil fuels, pollute or produce greenhouse gases.

EXTENSIONS

Image credit: The renewable Energy Hub

» Research the history of hydropower. How has it changed over the years?

» Research the design of hydropower dam. How do hydropower plants use the water to create electricity?

» Think of all the benefits of building a dam (such as water storage, hydroelectricity, flood mitigation, etc.). Create a list of these benefits on the board. Next, think of some negative effects of dam construction (such as impeding fish migration, damaging flora and fauna, etc.). Next to the list of benefits, create a list of these negative effects. Write about "What should engineers do when their designs have both positive and negative impacts on society?"

» Hoover Dam on the Colorado River in Nevada is 221 meters high, 379 meters long and 14 meters wide at the top. That is pretty big! It has 17 electric generators and provides electricity for about 500,000 homes in Nevada, Arizona and California. The world's largest hydroelectric power plant — the Itaipú Power Plant on the Paraná River in Brazil — provides energy to two countries (25% of Brazil's electricity and 78% of Paraguay's electricity). Research other Dams and find the one that supplies your house with power.

» Change the size or folding of the index card. How does that effect the waterwheel?

RESOURCES

» Water Resources: Why Do We Build Dams?
https://www.teachengineering.org/lessons/view/cub_dams_lesson01

» Waterwheel Work: Energy Transformations and Rotational Rates
https://www.teachengineering.org/activities/view/cub_energy2_lesson08_activity2

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