Hydropower

Objective

Students will:

- Read and discuss information about hydroelectric power
- Work in groups to make waterwheels
- Conduct a series of experiments with the waterwheels

Background

People have used moving water to help them in their work throughout history. More than 2,000 years ago, farmers used waterwheels to grind wheat into flour. A waterwheel spins as a stream of water, which is being pulled down by gravity, hits its blades. The gears of the wheel drive heavy, flat, rotating stones that grind the wheat into flour.

Hydropower plants use the same action of falling water to generate electricity. A turbine and a generator convert the energy from the falling water to mechanical and then electrical energy.

The most common type of hydroelectric power plant uses a dam on a river to store water in a reservoir. Water released from the reservoir flows through a turbine, spinning it, which in turn activates a generator to produce electricity. The water in the reservoir is considered stored energy. When the water is released, the water flowing through the penstock has kinetic energy because it is in motion.

Another type of hydroelectric power plant—called a pumped storage plant—can store power. The power is sent from a power grid into the electric generators. The generators then spin the turbines backward, which causes the turbines to pump water from a river or lower reservoir to an upper reservoir, where the power is stored. To use the power, the water is released from the upper reservoir back down into the river or lower reservoir. This spins the turbines forward, activating the generators to produce electricity.

The basic components of a hydropower plant are a dam, intake, turbine, generator, transformer, power lines and outflow. Most hydropower plants rely on a dam that holds back water, creating a large reservoir. Large dams are vital for large-scale hydropower, but dams of all sizes are also used for flood control, water storage and irrigation throughout the world. Gates on the dam open, and gravity pulls the intake water through the penstock, a pipeline that leads to the turbine. Water builds up pressure as it flows through this pipe. The water strikes and turns the large blades of a turbine, which is attached to a generator above it by way of a shaft. As the turbine blades turn, so do a series of magnets inside a generator. Giant magnets rotate past copper coils, producing alternating current (AC). A transformer inside the powerhouse takes the AC and converts it to higher-

Oklahoma Academic Standards

GRADE 3
Physical Science: 2-1,2

GRADE 4
Physical Science: 3-1,2,3,4.
Earth and Human Activity: 3-1,2

Vocabulary

dam—a barrier constructed across a waterway to control the flow or raise the level of water
design—to plan out in systematic, often graphic form.
energy—the ability to do work
engineering design—the process of devising a system, component or process to meet desired needs
hydroelectric power plant—a power plant that uses water turbines to generate electricity
hydroelectricity—electricity produced by the energy of moving water
hydropower—generating power from the movement of water. Also called hydroelectric power.
kinetic energy—the energy of motion. For example, a spinning top, a falling object and a rolling ball all have kinetic energy.
mechanical energy—energy used to create motion. It is the sum of an object's kinetic and potential energy.
model—a small object, usually built to scale, that represents another, often larger object.
potential energy—the energy stored by an object as a result of its position. For example, a roller coaster at the top of a hill, or water being held behind a dam.
power plant—a complex of structures, machinery, and associated equipment for generating electric energy.
reservoir— natural or artificial pond or lake used for the storage and regulation of water.
rotational rate—how fast something turns. A measure of speed indicated by the number of turns that take place during a period of time. For example, 100 revolutions per minute.
turbine—a machine in which the kinetic energy of a moving fluid is converted into mechanical energy by causing a series of buckets, paddles or blades on a rotor to rotate.
waterwheel—a wheel that rotates by direct action of water; used to generate power or do work

voltage current that is carried on high-tension power lines. The used water is carried through pipelines, called tailraces, and this outflow re-enters the river downstream.

Materials (for each group)

- 1 empty, clean 2-liter plastic soda bottle with holes drilled in the cap and the bottom of the bottle so that a wooden dowel fits through length of the bottle like an axle
- 1 pair of scissors
- duct tape
- wooden dowel (¼ inch diameter and longer than the soda bottle length)
- string
- fin material, such as cardboard, index cards, straws, toothpicks, popsicle sticks, walls of plastic bottles, etc., that students can use to make turbine fins
- water-proofing materials (such as aluminum foil, plastic wrap, etc.) to wrap over any paper fins to keep them from disintegrating in the water
- water
- sink tap and drain access (Or take the demonstration outside with buckets of water.)
- stopwatch

Procedures

1. Read and discuss background and vocabulary.
2. Prepare and test a model waterwheel (directions provided with this lesson) before demonstrating it to the class.
   —Pour a fixed amount of water over the waterwheel and count the number of turns it makes. Have a student time this test by using a stopwatch to record the elapsed time.
   —Ask students how might the rate of rotation be found. Then with the class, determine the rate of rotation (divide the number of turns by the elapsed time).
3. Divide the class into groups. Provide materials listed and the directions for making a waterwheel for each group. Students will follow the directions provided to make their own waterwheels. (Video demonstration: https://www.youtube.com/watch?v=nHGRcXD5SMM)
4. Students will create a procedure to count the turns of the waterwheel during a given period of time. For example, during the pouring, as the waterwheel spins, students could count the number of turns by noting how many times the marked catcher passes the top of the wheel.
   —(Conduct this step over a sink or outside.) One team member will keep track of the elapsed time using a stopwatch

or the second hand on a clock or watch. As soon as the wheel is spinning, start taking the time while other team members count the number of turns the waterwheel makes. Stop counting turns and keeping track of the time when the waterwheel slows down.
—Change roles and repeat until every member has counted or there is a consistent measurement for the rate at which the waterwheel spins. Students will record their data on the worksheet provided.

4. Students will determine how the size of the index cards affect the efficiency of the waterwheel.
—Students will measure the length and width of the index card, and find its area.
—After the sides of the index card have been bent to create the box-shaped "catchers," students will calculate the volume of water that the catcher can hold. What folding method allows for the largest amount of water to be held in the catcher? Is it better to have a waterwheel catcher that can hold a lot of water or a little bit of water?
—Compare results as a class to find out what shapes and sizes work best.
5. If a sink is available, each team will run tap water over their waterwheels at a constant flow rate for each.
—Students will compare their waterwheels to other groups based on the number of turns per minute at the same flow rate of water. Ask each group why their waterwheel performs differently than the others'. Which type works best? Why?
6. Students will fasten string to the necks of their waterwheels and tie objects to the other end of the string so the spinning waterwheel pulls the object up as the string rolls up around the neck of the bottle.
—Students will try lifting objects of different weights to determine how much weight the waterwheel can lift.
7. Provide bottles with different shapes and volume/capacities.
—Students will make waterwheels from the different kinds of bottles. How do the different of bottles affect the amount of work the waterwheel does?
8. Students will work individually or in groups to brainstorm how they could make a waterwheel work more efficiently if they had additional resources (different materials, time).
—Students will sketch their proposed designs and present them to the class.

Activity adapted from "Waterwheel Work," TEACHENGINEERING: https://www.teachengineering.org/activities/view/cub_energy2_lesson08_activity2

Waterwheel Directions

Materials (for each group)

- 1 empty, clean 2-liter plastic soda bottle with holes drilled in the cap and the bottom of the bottle so that a wooden dowel fits through length of the bottle like an axle
- 1 pair of scissors
- duct tape
- wooden dowel (¼ inch diameter and longer than the soda bottle length)
- string
- fin material, such as cardboard, index cards, straws, toothpicks, popsicle sticks, walls of plastic bottles, etc., that students can use to make turbine fins
- water-proofing materials (such as aluminum foil, plastic wrap, etc.) to wrap over any paper fins to keep them from disintegrating in the water
- water
- sink tap and drain access (Or take the demonstration outside with buckets of water.)
- stopwatch

Directions

1. With a pen or marker, draw 6 to 8 lengthwise equidistant lines along the length of the large plastic bottle. These mark the locations where index card “water catchers” will be taped.
2. Cut on the solid lines, being careful not to cut the center circle. Poke holes in the circles with a sharp pencil or hole punch. Follow the instructions below to make your pinwheel. With a pen or marker, draw 6 to 8 lengthwise equidistant lines along the length of the plastic soda bottle. These mark the locations where index card “water catchers” will be taped.
3. Fold the index cards to make small boxes (“catchers”) with open sides. These will serve as waterwheel paddles (or buckets or blades) to catch the water. Exactly how the index cards are folded and attached provides an engineering design opportunity for 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 marked catcher reaches the top of the waterwheel while turning.)
5. Tape the index card “catchers” to the soda bottle at each line. Your waterwheel will spin in one specific direction (choose either clockwise or counterclockwise), so make sure each catcher 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. If the hole is too tight, then the bottle will have trouble spinning on the dowel.

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Name____________________________________

Waterwheel Worksheet

What happened to the waterwheel as you poured water on it?

In the table below, record your waterwheel data

Start Time	End Time	Elapsed Time (End Time — Start Time)	Number of Turns	Rate of Rotation (Number of Turns + Elapsed Time)

What is the average rate of rotation?

In the table below, record your waterwheel with weight data

Start Time	End Time	Elapsed Time (End Time — Start Time)	Number of Turns	Rate of Rotation (Number of Turns + Elapsed Time)

What is the average rate of rotation?

What happened to the rate of rotation when weight was added?

What would you expect to happen to the rate of rotation if more weight was used?

What changes could you make to your waterwheel to improve how well it works?