

# WATER POWER

*Students create a turbine and experiment with water current.*

## TEACHER NOTES FOR DISCUSSION

In this activity, students create a model to demonstrate and experiment with water current. The model will take at least two classes to construct and test. Allow one class for each trial, including a test trial and one class period for presentations and discussion. Extend time according to the quality and intensity of the discussion.

Before beginning this activity, ask students to collect the wattage of their own small household appliances. At the start of class, talk about what wattage is and what it means. Students will use the wattage later in their conclusions.

Discuss how a waterwheel works: the direct pressure of water moves against a wheel, which makes the wheel rotate. Discuss water current and turbines. Talk about the effects height, diameter, force, and momentum have upon a turbine and the produced energy.



### Height

The higher the bucket, the longer the column of water is inside the tubing. The greater the distance in height between the water in the bucket and the end of the tubing, the greater the pressure will be. If you have several columns of water, each at different heights, the longest column would have the greatest amount of force at the bottom of it. The greater the force at the bottom of the tubing, the faster the water will come out.

### Diameter

Squeezing the end of the tubing will also increase the momentum of the water if the force of the water remains constant. This momentum is a combination of the weight (gravity) and the speed of the water that keeps the water moving. The water at the end of the tubing is pushed out of the tube by the force of the other water behind it. This is what happens when you put your thumb over the end of a water hose and force the water out of a smaller hole.

## Objectives

By the end of this activity, students should be able to:

- explain how a water turbine operates.
- observe the principles of the water turbine.
- determine speed and amount of work done.

## Time Considerations

Instructor preparation:  
90 minutes

Student activity:  
five classes

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## Force and Momentum

Water cannot be compressed the way air can. Squeezing the end of the tube does not squeeze the water. It just forces the water to move faster. This is similar to a large crowd pushing to get out of a building with two different size doors. If the people in the back are always pushing with the same force, the people exiting from a narrow door will have to move faster than those leaving through a wider door do. Water leaving the tubing with a narrowed opening will have a higher speed and, therefore; greater momentum. The more momentum created by water hitting the wheel, the faster the wheel moves; however, if the opening becomes too small, not enough water will get through to run the wheel regardless of the speed. This water may be going at high speeds, but because the quantity of water is much smaller, there is a decrease of overall momentum. Less momentum results in a slower wheel.

## RELATED STANDARDS AND BENCHMARKS

### Science

**Standard 11. Understands energy types, sources, and conversions, and their relationship to heat and temperature**

- knows that energy is the property of many substances

**Standard 12. Understands motion and principles that explain it**

- knows that an object's motion can be described and represented graphically according to its position, direction of motion, and speed

**Standard 15. Understands the nature of scientific inquiry**

- understands the nature of scientific explanations

### Mathematics

**Standard 4. Understands and applies basic and advanced properties of the concepts of measurement**

- understands the basic concept of rate as a measure
- understands formulas for finding measures

### Language Arts

**Standard 8. Demonstrates competence in speaking and listening as tools for learning**

- organizes ideas for oral presentations
- makes formal presentations to the class

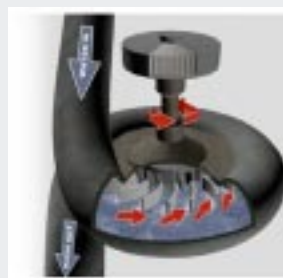
# WATER POWER

## UNDERSTAND YOUR MISSION

In this activity, you will create a working model of a water turbine.

### LEARN THE LINGO

energy	capacity to do work
force	amount of energy exerted on an object
hydroelectricity	electricity generated by turbines that are powered by water
hypothesis	an educated guess based on scientific evidence and tested for accuracy using scientific methods
joule	a unit of work or energy equal to the work done by a force of one newton acting through a distance of one meter
newton	the unit of force in the meter-kilogram-second system equal to the force required to cause an acceleration of one meter per second per second to a mass of one kilogram
turbine	a machine in which the kinetic energy of water or gas is converted to mechanical energy as the fluid reacts to a series of paddles, vanes, etc. arranged in a wheel
variable	a part of a process that changes depending on the situation
vertical	perpendicular to the horizon
waterwheel	a wheel driven by falling or moving water and used to power machinery
watt	work done at the rate of one joule per second



### Gather Your Supplies

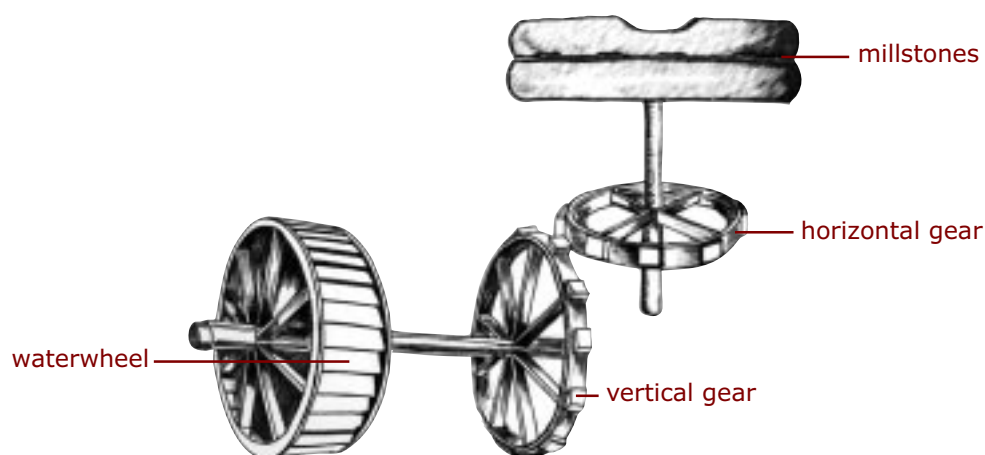
Each lab group will need:

- ballpoint pen tube
- cat litter tray or washtub
- duct tape (2" wide)
- hose
- hammer
- nail
- newton scale
- non-toxic water proof glue
- notebook
- pennies, washers, or nails
- plastic cups (12-3 oz.)
- plastic plates (4-6" diameter)
- plastic soup bowl (6" diameter)
- scissors
- stop watch or clock with a second hand
- string (50')
- wire coat hanger straightened or 16" of stiff wire (cut in half)
- wire cutters
- wood block (3 x 6 x 1" with a hole drilled through it)

# WATER POWER

## BACKGROUND

Originally, waterwheels were used to turn very heavy millstones that ground grain into flour. Whole grains were poured into a hole in the middle of a top stone. The grain was crushed between two flat round stones as they rotated. Flour pushed out the edges.



Gears were used to change the vertical motion of the waterwheel into the horizontal motion of the grinding stones.

Today, water turbines create hydroelectricity that is used to power several boat locks on the Mississippi River. St. Anthony Falls in the Twin Cities is a good example of the Mississippi River's energy being used to power locks and other parts of a working city. Cities and towns along the Mississippi and other major rivers in the United States are exploring the possibilities of hydroelectric plants.

# WATER POWER

## CHART A COURSE FOR EXPLORATION

After you build a turbine model, you will be able to determine the speed of your turbine; hypothesize what effect momentum and speed have on the turbine if the bucket of water is raised higher or the flow of water increased (the faucet turned up); determine the amount of work done by your turbine; and determine the watts your turbine can generate.

### Part A: Assembling Your Turbine

1. Find the center of the plates and the soup bowl.  
Punch a hole with a nail. Make the hole big enough for the ballpoint pen tube to fit tightly.
2. Glue or tape two plastic plates together in order to create one plate of double thickness.
3. Glue or tape the bottom of the soup bowl to the middle of the bottom of the double thick plate. Set aside to dry.



4. With the other two plates, glue or tape the facing bottoms together to form a spool. Set aside to dry.



5. Push one of the 8" wires through the hole in the wood block. Bend the end of the wire and tape the end under the wood.
6. After the glue on the plate-soup bowl is dry, glue and/or tape 6-8 plastic cups evenly around the wheel between the plate and bowl with the open end of the cups pointing out. This is your power-wheel.



wrap string collector with duck tape



power-wheel

7. Take the other glued paper plates and wrap a piece duct tape around the inside of these plates. This is your string collector.
8. Next, take the power-wheel and turn it so it faces one of the plates of the string collector, glue and/or tape the faces together. This your water turbine wheel.



9. Push the ballpoint pen tube through the center of the newly assembled water turbine wheel. The tube should be longer on the side of the power wheel. Secure the pen tube to the water turbine wheel with glue or tape.
10. With the long end of the pen tube facing down, slide the assembled turbine wheel onto the wire until the tube rests on top of the piece of wood block.
11. Wrap the string around the string collector and leave the end loose
12. Place the assembled water turbine in the litter box or tub. This is the river in which you will conduct your experiments.



water turbine wheel



Mississippi  
science River

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## Part B: Setting up the Experiments: Create a Speed Measuring Device

1. Take half of coat hanger or wire and make a 1/2" loop at one end.  
This is your string guide.
2. Tape the unlooped end of the wire vertically to the side of your river.  
Position the loop so it can be a guide for the string collector.
3. Thread the loose end of the string from the string collector through the loop and tape it to the same side of the river as the guide.
4. Measure the amount of string from the string guide to the side of the box.  
Subtract this from the original 50' of string. This is the number you will use to calculate the approximate speed of your turbine.  
600 inches - \_\_\_\_\_ inches = \_\_\_\_\_ inches.
5. To operate your model you need a source of water—a faucet works well.  
Connect a plastic tube to the faucet. (If this source of water is not available, use a bucket of water as your water source. Place the bucket above the water turbine wheel. Use a funnel to channel the water from the bucket to the plastic tubing.)
6. To add more force to the water, place an eyedropper, or tapered pen tube in the end of the hose or tubing. This narrows the opening, constricting the water flow.

## Part C: Experiment and Document

1. Before starting the experiments, make a trial run. Play around with the tubing. Try different ways of squirting the water into the cups.
2. Squirt water into the cups until the string from the collector completely unravels.
3. Pour the water into the tube and record how long it takes to use up all the string.
4. Change your technique; time it again.
5. Determine the technique that most quickly unwinds the string.
6. Identify the different variables working on your turbine.
7. Write down your results in your notebook the way scientists do.

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## Problem 1: Turbine Speed

Determine the speed of your turbine. Speed is the distance an object travels per unit of time ( $D/t$ ). To calculate the approximate speed of your turbine, divide the length of the string by the time (in seconds) it takes to rewind the string onto the collector. Repeat the trial three times and average your results.

TRIAL #1
TRIAL #2
TRIAL #3
AVERAGE SPEED OF ALL 3 TRIALS:

## Problem 2: Water Pressure

Hypothesize how the speed of the turbine will be affected by raising the height of the bucket and by turning up the faucet.

Write out your hypothesis

Test your hypothesis and record the data. How high is the bucket? Does the water pressure increase? Be sure to repeat your trial with the same variables three times.

Variable Effect (What happened?)

TRIAL #1
TRIAL #2
TRIAL #3
AVERAGE SPEED OF ALL 3 TRIALS:

Was your hypothesis correct or incorrect? Explain.

## Problem 3: Newtons, Joules, and Watts

Determine the watts your turbine can generate. Use light bulb wattage as your model.

1. Unwind the string from the collector and lay it on the floor.
2. Attach a mass (nails, pennies or washers) to the end of the string. Make the mass reasonable; the turbine is going to move the mass.
3. Measure the length of the string. \_\_\_\_\_ inches
4. Operate the turbine so the collector takes up the string. How long does it take to rewind the string? \_\_\_\_\_ seconds

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5. Connect a newton scale to the mass and drag it across the floor taking note of how many newtons of force it takes to move the mass.  
newtons (N) = \_\_\_\_\_
6. Calculate the work done by the turbine. Multiply the force/newtons (N) by the distance/meters (M) to find the mass traveled. The answer is labeled newton-meters (N-M). One newton-meter equals one joule of work.  
\_\_\_\_\_ (joules) J
7. The definition of a watt is the amount of work (joules) divided by the time (seconds) it takes to do the work (J/sec). To calculate how many watts of power your turbine can generate, divide the amount of work (joules) (determined in #6) by the time (seconds) that it takes to rewind the string on the collector. watts = \_\_\_\_\_

## Conclusions

1. What affects the speed of the turbine?
2. What size light bulb could your turbine generate power for?  
How many light bulbs could your turbine generate power for?
3. What other appliances could run on the power from your turbine?
4. Describe how a water turbine works to generate power. Include a comparison of your model to an actual turbine. Also, include an explanation of the forces working on the turbine and how to calculate the amount of work done by the turbine.

## Go Beyond

The locks and dams on the Mississippi River regulate water level for navigation. Most of the dams were also designed to house electrical power producing turbines and generators, but do not. Instead coal is transported by barge or train to generating sites on or near the river banks. Research hydroelectric energy and draw conclusions as to why the locks and dams are not producing electricity.

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## PROBLEMS

	EXPERT	PROFICIENT	NOVICE
<b>PROBLEM 1: 3 TRIALS</b>	<input type="checkbox"/> three trials are accurately measured	<input type="checkbox"/> two trials are accurately measured	<input type="checkbox"/> one trial is accurately measured
<b>PROBLEM 1: CORRECT AVERAGE</b>	<input type="checkbox"/> the average of three trials are correctly calculated and work is shown	<input type="checkbox"/> two trials are correctly calculated and work is shown	<input type="checkbox"/> one trial is calculated and work is shown
<b>PROBLEM 2: DATA CHART</b>	<input type="checkbox"/> the variable includes the measurement of increase and the effect includes the measurement of the speed on all three variables	<input type="checkbox"/> the variable includes the measurement of increase and the effect includes the measurement of the speed	<input type="checkbox"/> insufficient data collected
<b>PROBLEM 2: CORRECT AVERAGE</b>	<input type="checkbox"/> the average of three trials are correctly calculated and work is shown	<input type="checkbox"/> the averages of two trials are correctly calculated and work is shown	<input type="checkbox"/> one trial is correctly calculated and work is shown
<b>PROBLEM 2: EXPLANATION OF THE RESULTS OF TESTING THE HYPOTHESIS</b>	<input type="checkbox"/> the explanation describes the results and compares the results to the hypothesis and a possible change in the hypothesis is included if needed	<input type="checkbox"/> the explanation describes the results and compares the results to the hypothesis	<input type="checkbox"/> the explanation describes the results, but does not explain how the result of the trials proved or disproved the hypothesis
<b>PROBLEM 3</b>	<input type="checkbox"/> all five calculations are correct and work is shown	<input type="checkbox"/> all five calculations are correct	<input type="checkbox"/> fewer than five calculations are correct and work is not shown

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## CONCLUSIONS

	EXPERT	PROFICIENT	NOVICE
DRAWING CONCLUSIONS #1	<input type="checkbox"/> the explanation of effects on speed includes three variables	<input type="checkbox"/> the explanation of effects on speed includes more than one variable	<input type="checkbox"/> the explanation of effects on speed includes only one variable
DRAWING CONCLUSIONS #2	<input type="checkbox"/> the wattage of the individual light bulb is correct	<input type="checkbox"/> the number of light bulbs, as calculated at a lower wattage, is correct <input type="checkbox"/> wattage is calculated	<input type="checkbox"/> wattage not calculated
DRAWING CONCLUSIONS #3	<input type="checkbox"/> the wattage necessary for three or more appliances is included in the explanation	<input type="checkbox"/> the wattage necessary for at least two appliances is included in the explanation	<input type="checkbox"/> the wattage necessary for at least one appliance is included in the explanation
EXPLANATION OF HOW A TURBINE WORKS	<input type="checkbox"/> compares how the model works and compares it to a turbine at a hydroelectric power plant	<input type="checkbox"/> accurately describes how the model works	<input type="checkbox"/> inaccurately describes how the model works
FORCES WORKING ON THE TURBINE	<input type="checkbox"/> correctly identifies and explains all the forces working on the turbine	<input type="checkbox"/> correctly identifies all the forces working on the turbine	<input type="checkbox"/> correctly identifies at least one force working on the turbine
EXPLANATION OF THE CALCULATIONS	<input type="checkbox"/> the explanation correctly identifies the equation needed to calculate work done by the turbine	<input type="checkbox"/> correctly identifies some of the needed equations	<input type="checkbox"/> the explanation incorrectly identifies the equation needed to calculate work done by the turbine

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