Science Unit: The Force, Energy Transfer and Machines
Lesson #2: *Water Wheel – Energy Transfer, Work and Machines*

Lesson Summary

Students build a simple wheel and axle machine (water wheel) from aluminum pie plates and doweling (template provided). They then test how the number of blades on the water wheel (3, 6 or more) impacts its ability to do work (lift a small weight).

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Grade level:	Presented to grades 4-5, suitable for grades 4-7 with modifications.
Duration of lesson:	1 hour and 20 minutes
School Year:	2016/2017
Developed for:	Cunningham Elementary School, Vancouver School District
Notes:	This lesson links with two other lessons on force and energy transfer. You will need access to a sink (and a mop/paper towels for clean-up). Safety note: **The cut edges of the aluminum plates can be very sharp.**

Objectives

a) Learn about how a turbine (water wheel) machine converts potential energy of a dam (gravitation energy of falling water) to kinetic energy (moving water) to undertake work.
b) Students will build a simple wheel and axle machine and learn about the concept of a machine doing work and observe, record and test water wheel blade design and highlight its importance in transferring energy efficiently within the water wheel
c) Experiment can be used to discuss how humans use machines, including recent development of tidal turbines, the need for renewable energy in our future, as well as some of the energy sources used today to do work (oil and gas, solar, nuclear).

Background Information

Energy makes things happen – it's in sunlight, waves, wind, cars, humans, everything. Energy helps us do things – it runs machines, it makes things move, energy is light and heat, energy can male things grow. Our tides are caused by the gravity of the sun and moon and we are starting to make renewable (replaceable) energy from the tides – using tidal turbines.

In lesson one, we learnt that energy can be transferred (change from one form to another) but it can NOT be created or destroyed. This is called the Universal Law of the Conservation of Energy. Work or an applied force cannot be done without energy. When work is done - energy is used and transformed into another (often multiple) forms of energy, including heat and sound energy. Different forms of energy include chemical (from food), movement energy called kinetic energy and a special energy you can't see – called potential energy. This is the energy stored by an object – either through its position relative to the earth's gravitational force field or by tightening an elastic band or a spring release.

Humans have been using hydropower for centuries, harnessing the change from potential energy to kinetic energy of falling water. The Greeks attached waterwheels to grinding wheels and used the kinetic energy in falling water to grind grain into flour. Waterwheels have also been used to saw logs in sawmills and to provide irrigation for farms along rivers.

In this class lesson, you will extract energy from water. You will convert the kinetic energy from falling water into mechanical energy (turning a wheel and axle). See how falling water can lift a small weight. If just a little flow of water can lift a weight, imagine the amazing energy of the Niagara Falls!

Vocabulary

Gravity: Gravity is the natural force that causes things to fall toward the earth. Gravity is partly responsible for an object's potential energy.

Renewable energy: the energy collected from resource that is naturally replenished or replaced, like sunlight, wind, tides, rain and waves.

Hydroelectricity: Electricity generated by hydropower; the production of electrical power through the use of the gravitational force of falling or flowing water

Machine: Mechanical devices that allow us to make our energy transfer more efficient. Work is performed by applying a force over a distance. Simple machines create a greater output force than the input force (called mechanical advantage). There are six simple machines: the lever, wheel and axle, inclined plane, wedge, screw and pulley. All six have been used for thousands of years. These machines can be used together to create even greater mechanical advantage, as in the case of a bicycle.

Turbine: A machine in which the kinetic energy of moving fluid (or air) is converted to mechanical power.

Materials

- Aluminum pie plate – 9"
- Wooden dowels 1cm by 50 cm
- Cotton or string
- Waterproof tape
- Bucket with holes drilled in side to hold dowel
- Watering can with rosette
- Scissors and marker pen
- Graduated 2l cyclinder
- Washer or small weight

<u>In the Classroom</u>

Introductory Discussion

1. Short description of 'hook' to capture student's attention.

   Today we are going to learn about how humans build machines and use the transfer of energy to undertake work**.** Remember from last week that energy is conserved or maintained. It can be transferred from one form to another but not be created or destroyed.

   Discuss:

   a. What is renewable energy?

      - Explore the concept of *non-renewable* versus *renewable* energy:
      - Fossil fuels (non-renewable)
        - Wood (possibly renewable, depending on the source)
        - Hydroelectric, solar, wind, tide and wave (renewable)

- Encourage the students to provide examples of *combustion energy* (fossil fuels, gases, burning of wood, diesel, natural gas, etc.) that we use to do work (cars, stoves and heaters).

- Explain how energy flow occurs from the sun (dying star), which is transferred to bonds within a plant during photosynthesis and the potential energy in those bonds of glucose within the plant can be transferred to us when we eat it (energy then transfer to muscle movement i.e., foot kicks a ball.

b. **Where our energy in Vancouver comes from**.

Lead the students in a discussion of hydroelectric energy and the concept of a dam and reservoir (potential energy), and the gravitational flow of water through a turbine (kinetic energy). See notes above.

c. **The machines that humans have used in the past and are now using.** (e.g., ploughs, looms, might machines, cars, bicycles, wheel barrows, water wheels, catapults!).

Talk about how machines have helped humans evolve – e.g., from the wheel to the industrial revolution. Machines are mechanical devices that allow us to make our energy transfer more efficient. Provide examples for the students of simple machines and encourage them to identify other machines in their life that increase efficiency:

- Wheel barrow to transfer a pile of dirt vs. a shovel
- Riding a bicycle vs. walking
- Sliding down a hill on a toboggan vs. walking down the hill
- Hammering a tent peg into the ground vs. pushing it in

d. Lastly, introduce simple water wheels.

The Greeks attached water wheels to grinding wheels and used the kinetic energy in falling water to grind grain into flour. Water wheels have also been used to saw logs in sawmills and to provide irrigation for farms along rivers.

We will be extracting energy from water. We will convert the kinetic energy from falling water into mechanical energy and see how falling water can lift a small weight. If just a little flow of water can lift a weight, imagine the amazing energy of the Niagara Falls in a water wheel!

Once you have explained the activity, have the students explore ideas as to how they can measure the efficiency of their machine (time to raise a weight, amount of water needed), and what measures they can take to optimize it. Demonstrate this with a completed water wheel in the front of the classroom, and turn the blades to show how to optimize the design (blades turned perpendicular to the flow will result in the washer being lifted higher than blades turned parallel to the flow, number of blades).

2. Remind students that our populations and use of planets resources have grown very quickly in the last century and so urgent need for conservation required. Get the students to brainstorm solutions – REDUCE, RECYCLE, RESUSE, RENEWABLE ENERGY, and SUSTAINABLE USE.

3. **Briefly describe science experiment/activity**. Groups of 4-5 students will team up to build their own water wheel using an aluminum pie plate and doweling. They will observe the potential energy of falling (moving) water being converted into kinetic energy via the spinning water wheel, which in turn will lift a weight (transfer energy to do work). They will make predictions on how many blades and how the angle of blades will affect the amount of energy that is transferred and the amount of work the water wheel 'machine' will produce. They will test their predictions through observation and measurements.

4. **Describe the processes of science in this lesson**:
   This lesson includes making predictions, planning and conducting an experiment and observing and making measurements, collecting data and making conclusions.

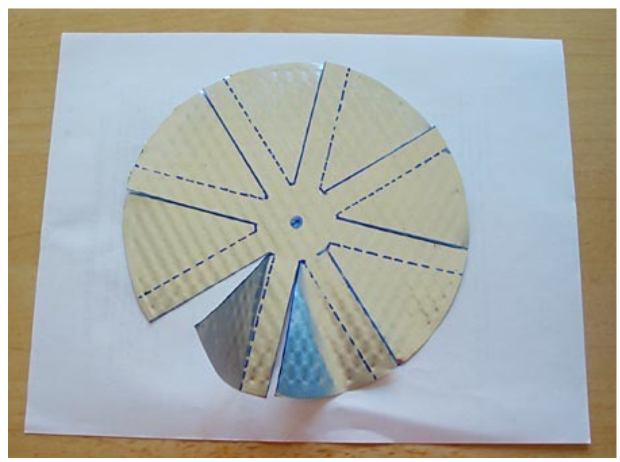
5. **Briefly describe safety guidelines**.
   - Remind students to be cautious with the pie plate blades, as the tin can be sharp.
   - Provide them with guidelines regarding water transfer and wiping up any spills as they occur in order to prevent slips and falls.

Science Activity/Experiment

Water Wheel – Energy Transfer, Work and Machines

Purpose of Experiment:
Students will learn how water can be used to do work (lift a weight) by building and designing their own water wheel machine from aluminum pie plates and doweling.

Methods:



1. Use scissors to cut out the flat bottom part of the aluminum pie plate. Use a pen to punch a hole through the middle of the pie plate. This can be done before the class to save time.

2. With the permanent marker, copy the design below to make a six bladed water wheel template onto the circle of the plate.

3. Make sure to draw the lines from the edge of the circle to about 2 centimeters (cm) from the middle of the circle. Cut along the lines but bend every other one to make a 3 bladed waterwheel. Bend them so they will catch the maximum amount of falling water.

4. Slide the dowel through the centre. Once the dowel is in position and the wheel is set up, have the students tape the pie plate to the dowel. This will ensure that the wheel will not spin on the dowel.

5. Push the dowel through the holes in the bucket (one side at a time), leaving one end of the dowel extending further out to one side. Check it spins ok.

6. Tape a string to the longer end of the dowel that protrudes out of the bucket. Tie a washer to the end of the string (predetermine the length of the string so that the students can quantify the efficiency of energy transfer – so that the weight is just held above the table top). The bucket can be placed on a chair for smaller students, as the experiment works best if the watering can be held above the water wheel.

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7. Have the students (as consistently as possible) pour a volume of water (using a rosette watering can) over their wheel and measure the volume of water required in order to completely wind the string around the dowel, lifting the weight off the desk to a set height, i.e., How much water poured evenly and from the same height on the blades does it take to raise the washer to the level of the axle? ***Repeat three times.***

8. If time, the amount of water can be measured accurately using measuring cylinders.

   For shorter length lessons, one can use a marker pen to mark (on the outside of the bucket) the level of the water after each pouring session. Use a code to know which is which (i.e., 3.1, 3.2, 3.3, 6.1, 6.2, 6.3, Lots.1, Lots.2, Lots.3). One can then use a ruler to measure to each line marked or rank simply on the level of the marks on the bucket.

9. Next, bend the three extra blades out - to make a 6 bladed water wheel. Measure water needed to raise the weight to the same height as previously and repeat three times. Remind them about recording data for each water wheel design on the worksheet.

10. Lastly, allow students to do anything to optimize their water wheel, bending blades in any way, cutting new blades. Test this final design three times.

11. Use a calculator to estimate average amount of water used or marked height for each design and assess which is the best water wheel blade design.

12. Fill out worksheet and draw conclusions on which water wheel design is best based on amount of water used to raise washer data. Rank the water wheel designs from best (least water used, lowest mark). Ask students try to explain why their top water wheel design worked the best.

Closure Discussion

- Which design used the least amount of water to raise your washer up to the top of the container? Go through each team and discuss their results and highlight what special features they added to their last design.
- What other factors influenced the efficiency of energy transfer – i.e., size and angle of fins, speed of pour or height of water make any difference? In a water wheel, the speed of the water and the height drop of the water are key factors in the energy created. These are the kinetic and potential energy of the system.
- What are some of the aspects of the experiment that would benefit from greater control?
- Examples include consistent flow, rate and accuracy of pouring, size of water stream, height of water when poured.
- Discuss how wind turbines all now use three blades, but lots of different tidal turbine designs still being tested.

Extension of Lesson Plan

1. Test different weights to lift.
2. Add a second water wheel.

Water Wheel Data Sheet

Name(s):

Date:

What water wheel design works best?
(fill out the section in grey).

Number of water wheel Blades	How much water did it take to raise the washer	Rating of water wheel (Best to worst)
3 Blades		
6 Blades		
Lots of Blades		

Conclusion: What **number of water wheel blades** worked the **best** and why**?**