Science Unit: ***Energy and Motion in Man and Machine***

Lesson # 3: ***Simple Machines II – Water Wheels and Gravitational Energy***

Summary: Students learn how water can be used to do work by building and designing their own water wheels from aluminum plates and doweling (instructions and diagrams included).

School Year:	2014/15
Developed for:	Beaconsfield Elementary School, Vancouver School District
Developed by:	Sheila Thornton (scientist); Susan Worthington and Angela Ward (teachers)
Grade level:	Presented to grade 5/6/7
Duration of lesson:	1 hour and 30 minutes
Notes:	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

1. Explore energy transfer from gravity (water wheel)
2. Discover how to build a simple machine – wheel and axle
3. Learn the principles of the concept of work

Background Information

Humans have been using hydropower for centuries, harnessing the change from potential energy to kinetic energy of water.

Potential energy is the energy stored in an object. For example, if you stretch a rubber band, it now has potential energy; it is ready to snap back to its original state.

Kinetic energy is the energy of motion. Once you let go of the rubber band and it is moving through the air, it has kinetic energy. The potential energy stored in the stretched rubber band changes to kinetic energy as soon as you let go of it.

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 science fair project, you will extract energy from water. You will convert the kinetic energy from falling water into mechanical energy. 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.
Gradient	The rate at which a physical quantity, such as temperature, pressure, angle, incline, increases or decreases
Hydroelectricity	Electricity generated by hydropower; the production of electrical power through the use of the gravitational force of falling or flowing water
Turbine	A machine in which the kinetic energy of moving fluid (or air) is converted to mechanical power.

Materials

- Aluminum pie plate – 9”
- dowels
- graduated cylinder or large measuring cups
- tape
- permanent marker
- washers or weights
- scissors
- cotton string
- stopwatch or clock
- Plastic bins or buckets with holes drilled in the sides to hold the dowel

In the Classroom

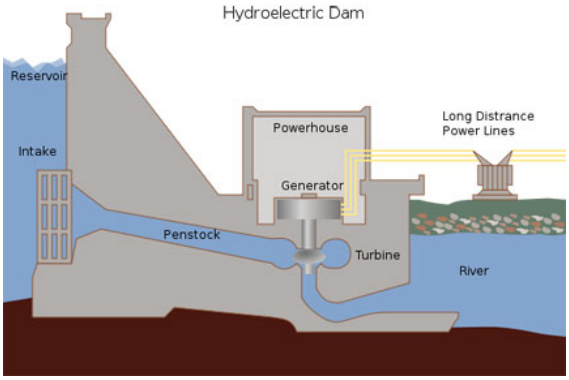
Introductory Discussion

1. 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 (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 heat or cooking).
- Explain how energy flow occurs from the sun (dying star), which is transferred to bonds within a plant during photosynthesis (e.g., a strawberry plant takes up carbon and hydrogen and oxygen, and using the energy of the sun, synthesizes glucose).
- The potential energy in the bonds of glucose within the strawberry can be transferred to us when we eat it (energy transfer to muscle movement; foot kicks a ball and that energy is transferred)

2. Where does most of our energy come from in Vancouver?

- Lead the students to 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)



3. The evolution of humans is intertwined with our ability to use machines.
    - 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

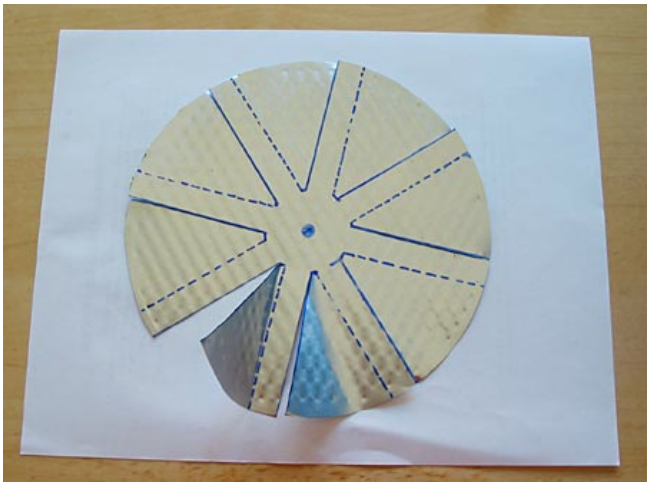
4. **Introduce simple water wheels**
    - In a water wheel, energy is transferred through the gravitational force of water turning the blades of the water wheel, resulting in the rotation of the axle. This motion can then be used to do work in the form of lifting a washer tied to a string.
    - Once you have explained the activity, have the students explore ideas as to how they can measure the efficiency of their machine, 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).

5. Ask the students to design a way to quantify the efficiency of their machine:
    - How many cup fulls of water poured on the blades does it take to raise the washer to the level of the axle?
6. Task them with optimizing their wheel and testing it.

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



Activity Title: Building a Water Wheel

Purpose of Activity: To understand the transfer of energy from one source to another using a simple machine (axle and a wheel) and gravitational energy (water flow).

Experimental Observations: How would you measure efficiency of the water wheel? What are the factors that make the water wheel more efficient?

Methods and Instructions:

1. Take your scissors and cut out the flat bottom part of the aluminum pie plate.

2. With the permanent marker, copy the design from the waterwheel template onto the circle of aluminum.

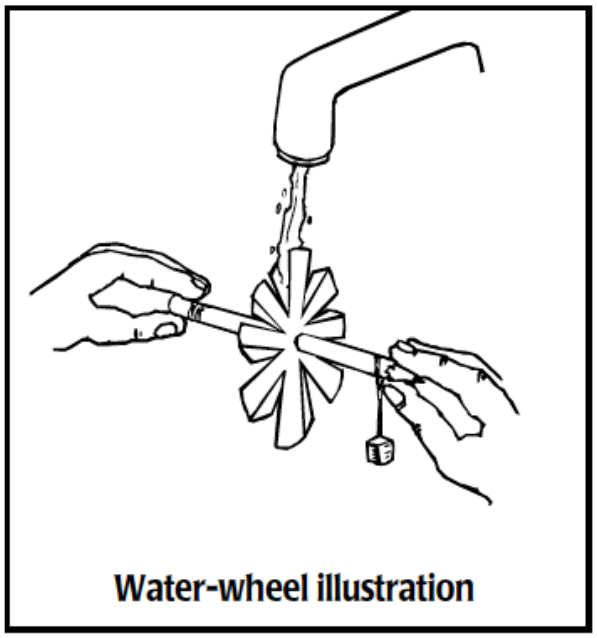
3. Draw the lines from the edge of the circle to about 2 centimeters (cm) from the middle of the circle.

4. Once the wheel is complete, cut a small flap in the middle of the wheel and slide the dowel through the centre. Once the dowel is in position and the wheel is set up, **have the students tape the flap 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, leaving one end of the dowel extending further out to one side.

6. Tape a string to the longer end of the dowel that protrudes out of the bucket. Tie a weight to the end of the string (predetermine the length of the string so that the students can quantify the efficiency of energy transfer).

7. Have the students pour a volume of water over their wheel and measure the volume of water required in order to completely wind the string around the dowel, lifting the weights off the desk.



Water-wheel illustration

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Closure Discussion

1. How many cups of water did it take to raise your washer up to the top of the container?
2. What are some of the factors that influenced the efficiency?
3. What are some of the aspects of the experiment that would benefit from greater control?
    - Consistent flow:
    - Rate and accuracy of pouring
    - Size of water stream
    - Height of water, etc).
8. What technique resulted in the greatest efficiency of energy transfer?
    - Small fins (8 vs 4)?
    - Slow pour?
    - Did the height of the water change the efficiency/speed of the water wheel turning?
4. What kind of work could a water wheel be used for? (mills, stored electric energy, turning the spit on a bbq, etc).