HYDROKINETIC POWER

Overview:

Hydroelectric power is a clean, renewable energy source abundant in Alaska.

Objectives:

The student will:

- read about hydrokinetic energy and answer questions; and
- construct a simple model with a magnet and wire using kinetic energy to show the generation of electricity.

Targeted Alaska Performance Standards for the High School Graduation Qualifying Exam:

R4.4 Read and follow multi-step directions to complete complex tasks.

Targeted Alaska Grade Level Expectations

Science

[11] SA1.1 The student develops an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, analyzing data, developing models, inferring, and communicating.

[11] SB2.1 The student demonstrates an understanding of how energy can be transformed, transferred, and conserved by demonstrating energy (e.g., nuclear, electromagnetic, chemical, mechanical, thermal) transfers and transformations by comparing useful energy to total energy (entropy) (L)

Vocabulary:

BTU (British thermal unit) – the amount of heat that is needed to raise the temperature of one pound of water by one degree Fahrenheit; this unit is used mainly to measure heat

calorie – a small calorie is a unit of heat equal to the amount of heat needed to raise the temperature of one gram of water by one degree Celsius; a large calorie or kilocalorie is the amount of heat needed to raise the temperature of 1,000 grams, or one kilogram, of water by one degree Celsius

electricity – the collection of physical effects resulting from the existence of charged particles, especially electrons and protons, and their interactions; the electric current generated by the flow of electrons around a circuit and used as a source of power

energy – the capacity or power to do work; energy can exist in a variety of forms such as electrical, mechanical, chemical, thermal, or nuclear, and can be transformed from one form to another; it is measured by the amount of work done, usually in joules (J) or watts (J/s)

hydro – a prefix that means water, as in hydroelectric; or hydrogen, as in hydrocarbon

hydroelectric – generating electricity through the use of the energy of moving water

hydroelectric power plant – a power plant that produces electricity by the force of water falling through a hydro turbine that spins a generator

hydrokinetic – relating to the kinetic energy and motion of fluids; often refers to in-river power generation

hydrothermal – relating to thermal energy stored in water, especially water heated by Earth's internal heat; power that is generated using Earth's hot water is called hydrothermal energy

joule – a unit used to measure energy or work; one joule is equal to the work done when a force of one newton acts over a distance of one meter; named after British physicist James Prescott Joule who established the law of conservation of energy, stating that energy is never destroyed but may be converted from one form into another

kinetic – work done by an external force; energy an object possesses due to its motion

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renewable resource – energy sources that are continuously replenished by natural processes, such as wind, solar, biomass, hydroelectric, wave, tidal and geothermal

run-of-river hydroelectric – a type of hydroelectric facility that uses the river flow with very little alteration and little or no impoundment of the water

thermal – related to heat energy storage or movement

turbine – a device for converting the flow of a fluid (air, steam, water or hot gases) into mechanical motion

watts – a unit used to measure power, equal to one joule of work per second; in electricity, a watt is equal to the amount of current (amperes) multiplied by the amount of potential (in volts); named after James Watt, a British engineer, inventor and scientist

Whole Picture:

For Athabascan people, rivers are a source of life. Their waters provide subsistence food gathered in the summer and used year round. In the summer the open water provides transportation for boats. In the winter waterways are a frozen highway for dog sled and snow machine. Many communities rely on nearby rivers for their water supply. Now, many communities are also looking to the life-giving river for an alternative energy source.

Unlike fossil fuel, hydropower is a renewable energy resource that provides local, clean energy. High fuel costs, coupled with concerns about climate change, have inspired Alaskans to explore renewable energy such as hydroelectric power. Not only is it inexhaustible, it has a lower carbon footprint than burning fossil fuel to produce electricity.

Hydroelectric power uses the force of moving water to turn turbines. The turbines drive generators that convert the kinetic energy of moving water to electrical energy. The process is called electromagnetic induction. When a spool of wire moves through a magnetic field, it produces an electrical current. Electricity is then changed by a transformer to the appropriate voltage and sent along transmission lines to consumers.

Materials:

- Compass (one per group)
- Coil of thin copper wire (one per group)
- Magnet (one per group)
- Fine-grit sandpaper (one small square per group)
- Multimeter (or volt meter) (one per group)
- VIDEO: "Ruby Turbine Fisheries Study"
- STUDENT INFORMATION SHEET: "Anchorage Daily News, In-river generator may give Bush power alternative"
- STUDENT WORKSHEET: "The Power of Water"
- STUDENT LAB: "It's Electric!"
- VISUAL AID: "It's Electric!"

Activity Preparation:

1. Find and bookmark the following locations for your information:
    a. REAP: Renewable Energy Alaska Project (http://alaskarenewableenergy.org/)
    b. AEA: Alaska Energy Authority (https://www.slideshare.net/ZX7/ef105) Review the document "Alaska Energy: A first step toward energy independence" (January 2009) either on the Alaska Energy Authority Website or at the link above.

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Activity Procedure:

1. Write the words "hydro," "electric" and "kinetic" on the board. Explain that the lesson is about producing electricity using the power of water. "Hydro" refers to water. When the word is put with "electric" it generally refers to the generation of power from the movement of water flowing from a higher to a lower elevation. "Kinetic" refers to work done by an external force, or specifically, the energy an object possesses due to its motion. Hydrokinetic power usually refers to a system that uses river currents to generate power. Hydrokinetic is the focus of the lesson because many Interior communities are considering using hydrokinetic power to supplement community power needs.
2. Access the document "Alaska Energy: A first step toward energy independence" (January 2009) either on the Alaska Energy Authority website. Read and discuss as much of the document as desired, including the Introduction (page 22), Energy in Alaska (page 24) and Current Energy Policy and Planning in Alaska (page 38). A description of hydrokinetic power in Alaska begins on page 190. Focus on the information presented on pages 191 through 195.
3. Hand out STUDENT INFORMATION SHEET: "Anchorage Daily News: In-river generator may give Bush power alternative." Choose an appropriate reading strategy for the class and read through the Anchorage Daily News article. This article discusses two communities working with hydrokinetic power: Ruby and Eagle. Hand out STUDENT WORKSHEET: "The Power of Water" and allow students time to complete.
4. Hold up a coil of copper wire and a magnet. Tell students that the two items you are holding are two of three ingredients needed to produce electricity. Ask if anyone knows the third thing needed. Take all the guesses but do not reveal the answer (motion/kinetic energy) until you are ready to move on to the lab.
5. Divide students into groups. Tell them they are now going to use the coil, the magnet and motion to produce electricity. Hand out STUDENT LAB: "It's Electric!" Allow students time to work through the lab and complete the questions. Display VISUAL AID: "It's Electric!" to help with set up for final questions, if needed.
6. Discuss the lab findings. Ask students to think about the source of energy in the lab (student) versus moving water in a river. Depending on time and interest, trace the energy backwards. In a person, for example, there is energy exerted by moving muscles that must be fueled by food energy. In a river the water source may be melting snow or glacier; energy from the sun melts the snow and gravity moves it downstream. What makes hydropower a renewable energy source?
7. Visit the State of Alaska – Alaska Energy Authority website (https://www.akenergyauthority.org/) and investigate whether there is an energy plan in place for your community. Click on Community Database. Find your community or one close by. Discuss the long-term plans for the community. For example, Bethel currently relies solely on diesel for electricity production, but in the next three years hopes to supplement 20 percent of the electrical needs with a combination of a wind/diesel generator. In the next ten years Bethel hopes to introduce hydropower to provide 70 percent of the electricity needs, reducing the need for diesel to just 10 percent. Bethel also plans to supplement home heating needs with hydro-thermal power.

Extension Ideas:

1. Visit the Teachers' Domain website (https://kuac.pbslearningmedia.org/search/?q=hydropower) to pick and watch a short video about hydropower. Discuss the video with your students and ask questions.
2. Lesson plans on how to build a hydroturbine are available on the Internet. Such a project is time intensive, taking several class periods to do, but will give students a working knowledge of how a turbine produces electricity.

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Answers to STUDENT WORKSHEET: The Power of Water

1. Two of the following answers: silty water could damage the turbine, logs and/or other debris such as ice could hit the turbine, the turbine could disrupt river navigation, and the turbine could harm the fish population.
2. After it was assembled in Fairbanks, it was put on a barge and sent down the river.
3. 5 kilowatts of power
4. 2 homes
5. 10 homes
6. No, rivers freeze so there is little or no flow and ice would jam the turbine.
7. Answers will vary.

Answers to STUDENT WORKSHEET: It's Electric

Student answers will vary.

Anchorage Daily News
adn.com

In-river generator may give Bush power alternative

RUBY: Device shows promise for remote riverfront villages.

By George Bryson
02/04/09

A technology almost as simple as a Yukon River fishwheel could one day power the laptop computers and microwave ovens of Alaska's river people. In Ruby it's beginning to do just that.

Last summer, the Western Alaska village on the banks of the Yukon became the first community in America to tap into the power of an in-stream hydrokinetic generator, a submersible turbine that looks a bit like a tipped-over fish wheel.

In-stream power also gets called "low-impact hydro" and "hydro without the dam." By any name, it may be an idea whose time has finally come.

A 100-kilowatt turbine about 20 times larger than Ruby's is scheduled to be installed later this year in the Upper Yukon River village of Eagle, where it's expected to power all the homes in town from breakup to freezeup.

That could eventually provide a fuel-free alternative to Eagle's present practice of burning about 80,000 gallons of increasingly costly diesel fuel each year to generate electricity.

In-stream hydro is no longer just a quirky, renewable energy concept, Ruby project director Brian Hirsch said Tuesday, displaying a slide-show image of four generators now in production during a workshop on the subject at the 2009 Alaska Forum on the Environment under way in Anchorage.

"Every one of these devices that you see up there are not just an artist's rendering anymore but actually a device that is made of steel and now producing electricity," Hirsch said.

Admittedly not a whole lot so far. Unlike increasingly popular wind farms and geothermal power plants, in-stream hydro is still a costly technology in its infancy, with lots of unanswered questions. Especially in Alaska.

Can the turbines floating on the surface of the Yukon withstand bombardment by the huge logs that regularly drift downstream? Will the Yukon's notoriously silty water damage their intricate mechanism? Or might the turbines cause problems of their own, disrupting river navigation or posing a threat to migrating fish?

The Ruby generator, a mere 5-kilowatt turbine capable of powering only two households, was an experiment. After one month of operation last summer, Hirsch can report that it works.

"But there's a lot to improve," he said.

On the plus side, in-stream hydro is a simple, highly portable technology that can be up and running in a matter of weeks and might be ideal for remote riverbank communities.

The Ruby project, sponsored by the Yukon River Inter-Tribal Watershed Council (Hirsch serves as the council's energy program manager), was partly assembled in Fairbanks, then barged downstream from Nenana. Its price tag was $65,000.

That included the cost of the turbine itself, manufactured by a Canadian firm, as well as the cost of a pontoon boat to float it, gear to anchor it, a debris boom to protect it and underwater transmission cables to connect the generator to Ruby's power grid.

Ruby was selected as a test case partly because diesel-generated power there is so expensive, and partly because its residents enthusiastically supported the project, Hirsch said. Ruby also satisfied some technical requirements.

In-stream turbines ideally get placed in the part of a river where the current is strongest. That's usually on the surface near the middle, where the river is deepest. But placing it in the middle of a river increases the length of the transmission lines required and possibly creates navigational hazards. Ruby proved ideal because the fastest, deepest current was close to shore.

To protect the turbine from floating driftwood, the construction team fashioned a simple A-frame prow out of two logs. That was only halfway successful, Hirsch said. It diverted everything that floated on the surface. But some debris on the Yukon floats beneath the surface, and it accumulated on the vessel's anchor chain. Eventually all the snagged flotsam began to shield the turbine from the current and lowered its electrical output.

"It's a challenge, and it's something we're working on," Hirsch said.

The larger in-stream hydro turbine waiting to be installed in Eagle this summer may offer an answer to that problem. It'll come equipped with a heavy, metal sieve-like prow that will extend deep into the river, deflecting subsurface debris.

Underwritten by a $1.6 million grant from the Denali Commission, the Eagle project was proposed and advanced by the Alaska Power & Telephone Co., a Washington-state- based utility that provides Eagle residents with electricity. The company chipped in some seed money of its own.

But it's still "really expensive" per kilowatt to put a hydrokinetic generator in the water when you compare the new technology with more mass-produced renewables like wind power, said Benjamin Beste, an AP&T engineer who also addressed the forum.

Even so, Beste thinks in-stream hydro is a viable summer source of power for Eagle, as well as other small, isolated river communities in Alaska. He doesn't think the turbines could avoid damage in winter or spring, when break-up occurs. Like Ruby, the in-stream hydro operators in Eagle plan to remove their turbines from the river each fall.

And its effect on migrating salmon? "The fishery impact is not really well known yet," Beste said.

What is known is that adult salmon that migrate upstream favor the slowest current in the river, rather than the fastest, where in-stream turbines are typically placed, said Gwen Holdman, director of the Alaska Center for Energy and Power at the University of Alaska Fairbanks.

So adult salmon might be OK, as well as the fishing vessels that pursue them. But juvenile salmon migrating downstream to sea as smolts prefer the faster current to expedite their journey, and they represent a potential concern, Holdman said.

The university's energy center plans to study such issues if and when a 50-kilowatt in-stream generator is installed this summer as planned in the Tanana River at Nenana.

And Ruby might receive another turbine -- a 25-kilowatt generator large enough to satisfy about half the village's summer energy needs -- if a renewable energy appropriation previously approved by the Alaska Legislature survives the current session.

NAME: ______________________________

THE POWER OF WATER

Read STUDENT INFORMATION SHEET: "Anchorage Daily News: In-river generator may give Bush power alternative" then complete the following questions.

The nation's first in-river hydrokinetic turbine was placed in the Yukon River at Ruby in the summer of 2009 to test the viability of harnessing the power of the river in order to power the village.

1. Explain two potential problems with placing a hydroturbine in a river like the Yukon:

   Problem One: ______________________________

   ____

   Problem Two: ______________________________

   ____

2. How was the turbine transported to Ruby? ______________________________

   ____

3. How many kilowatts of power does the Ruby generator produce? ______________________________

4. How many homes will this power? ______________________________

5. Based on the information in questions 3 and 4, how many homes would a 25-watt generator power?

   ____

6. Can a turbine run year-round in an Alaska river? Why or why not? ______________________________

   ____

Critical Thinking

7. An in-river turbine system to generate electricity is costly to set up and may take many years to pay for itself. On the other hand, it is a renewable energy source that provides unlimited clean energy without adding greenhouse gases to the atmosphere. Pretend you are a member of your local tribal council and present an argument either for or against an in-river turbine for your community.

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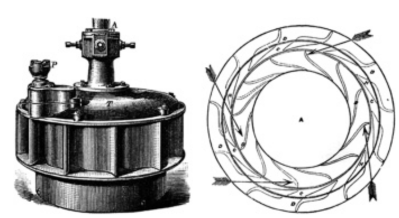


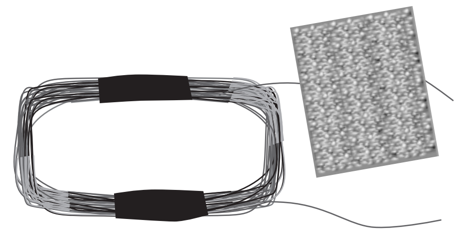
"The most efficient form of water-wheel is the turbine, one form of which is shown." – Avery, 1895

NAME: ____________________________
IT'S ELECTRIC!

Directions: Use the materials listed to generate electricity!

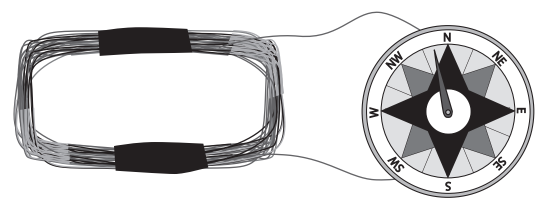
Materials:

- Compass
- Coil of thin copper wire
- Magnet
- Fine-grit sandpaper
- Multimeter



STEP 1

Uncoil about 2 inches of wire at each end of the coil. Use the sandpaper to remove the protective varnish that coats the wire.



STEP 2

Place the coil of copper wire on the table. Lay the two wire ends on the table outward away from the coil. Place the compass on the ends of the wires where the varnish has been removed.

STEP 3

Hold the magnet over the center of the coil, then move the magnet back and forth over the coil. Try moving the magnet across the center and over the wire at different angles to see what happens. Record your observations below:

1. What happens on the compass when you start in the center then move the magnet left and right?

   ____

   ____

2. Does the compass act differently if the magnet is moved in different directions? Explain. ____________

   ____

   ____

STEP 4

Again, move the magnet side to side centered over the coil, watching the compass. Now, flip the magnet upside down and repeat. Record your observations below:

3. What did you observe when you flipped the magnet upside down? ______________________

   ____

4. Can you make the compass needle move in a circle? How? ______________________________

   ____

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STEP 5

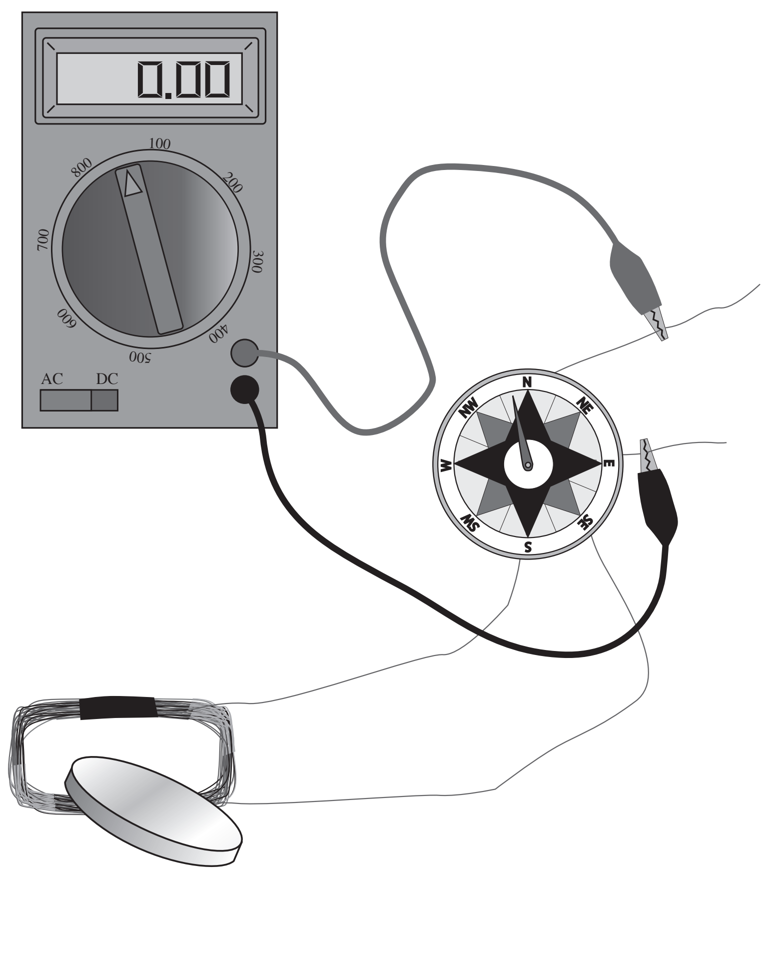
Connect each clip of the multimeter to one bare wire. Turn on the multimeter and select AC volts. Repeat STEPS 1 – 4 with the magnet and the coil. Record your observations below:

5. What is happening on the multimeter display? ____

____

6. What does the multimeter tell you about what is happening when you combine the wire, the magnet and kinetic energy? ____

____



IT'S ELECTRIC!