HANDS-ON ACTIVITY

Wind Power!
Designing a Wind Turbine

Quick Look

Grade Level: 4 (3-5)
Time Required: 1 hours 45 minutes
(can be split into two 50-minute sessions)
Expendable Cost/Group: US $4.00
Group Size: 2
Activity Dependency: None
Associated Sprinkle: Wind Power (for Informal Learning)
Subject Areas: Measurement, Physical Science, Science and Technology
NGSS Performance Expectations:

4-PS3-4

Summary

Students learn how engineers transform wind energy into electrical energy by building their own miniature wind turbines and measuring the electrical current they produce. They explore how design and position affect the electrical energy production.
This engineering curriculum aligns to Next Generation Science Standards (NGSS).

How do wind turbines work?

Engineering Connection

Engineers design wind turbines to capitalize on wind as a clean, renewable and reliable source of power generation. Wind energy offers a viable, economical alternative to conventional power plants in many areas of the country. The concept of wind can also produce power in other applications, such as a turbocharger, for example, which is a compressor used in auto or jet internal-combustion engines to increase power output. A compressor increases the amount of air and fuel entering the engine because the more air a car is able intake and burn, the more power it can put out. This increased airflow (wind) can be equivocated to wind turbine generators. In fact, a turbocharger includes a turbine that powers the compressor using waste energy from the exhaust gases.

Learning Objectives

After this activity, students should be able to:

- Describe the transformations of energy that occur in a wind turbine.
- Describe how engineers construct a wind turbine.
- Explain how the design and position of a wind turbine affects the electrical energy produced by it.

Educational Standards

- NGSS: Next Generation Science Standards - Science
- Common Core State Standards - Math
- International Technology and Engineering Educators Association - Technology
- State Standards

Materials List

Each group needs:

- small DC toy motor; available online
- 2 pieces of thin electrical wire with alligator clips, each about 50 cm or 20 inches long
- rubber band
- stiff ruler
- cylindrical-shaped cork, at least 2 cm or ¾ inch in diameter; alternative to cork: Styrofoam ball
- 4 paperclips
- scotch tape
- scissors
- 4 pieces of cardboard, each 3 x 5 cm
- (optional) safety goggles or glasses
- Wind Turbine Worksheet, one per team

For the entire class to share:

- 1 or 2 small electric fans or hair dryers
- DC voltmeter; available online

Worksheets and Attachments

Wind Turbine Worksheet (pdf)
Scaling Activity: Wind Power! Math Worksheet (pdf)
Scaling Activity: Wind Power! Math Worksheet Answers (pdf)

Visit [www.teachengineering.org/activities/view/cub_energy2_lesson07_activity2] to print or download.

Introduction/Motivation

Have you ever felt a really strong wind? How does it feel? Have you ever felt blown around by the wind? Wind can do work for us by moving things around. Sometimes we do not want the wind to move things, like when it blows our papers around and we have to pick them up. But sometimes we want the wind to move things around for us. For example, when the wind moves the blades of a *wind turbine* (a machine that converts the moving energy of wind into *mechanical energy* and *electrical energy*), the turbine produces some useful *energy* (in the form of electricity).

Let's talk about what happens to get electricity from the wind. First of all, to change the wind energy to electricity, *rotor* blades spin the *hub* (center) of the *turbine*. Inside the turbine is an electric *generator*, which is a rotating machine that supplies an electrical output with voltage and current. The rotating action of the hub turns a magnet inside a coil of wire in the generator, producing electricity.

A turbine is basically a motor connected backwards. Rather than connecting a battery to the motor to make something move, a wind turbine is connected to the motor, and its movement generates electricity. You can measure how much electricity (voltage) is produced with a *voltmeter*.

Engineers design wind turbines that turn the *kinetic energy* of the wind (the movement of the wind) into mechanical or electrical power.

So, when does a wind turbine work best? The power produced by a wind turbine depends on elevation, wind speed and air temperature. Wind turbines need wind speeds of at least 15 kilometers (9 miles) per hour, for small wind turbines, and 21 kilometers (14 miles) per hour, for utility-scale turbines. Wind turbines are best located in areas in which wind speeds are 26-32 kph (16-20 mph) with the windmill at 50 meters (55 yards) high. That's pretty high up. The greater the wind speed, the more power generated. Think about it: when the wind blows harder, those papers move around even faster. If the wind speed doubles, the power available to a wind turbine increases by a factor of eight. That means the power doubles and doubles and doubles again!

Today, we are going to act as if we are engineers and create small-scale wind turbines that convert wind energy connected to a motor into electrical energy (voltage). Then, we will measure how the wind speed affects our little wind turbines. This will help us understand what engineers need to know when designing and placing wind turbines in the best locations.

Procedure

Before the Activity

- It is helpful to build and test a wind turbine in advance, to use as an example.
- Gather materials and make copies of the Wind Turbine Worksheet.
- Attach wires to the DC motors.
- Set up a test station with a voltmeter and a wind source (fan or hair dryer) where teams can take turns measuring the output of their wind turbine generators.
- Test to make sure the motors and voltmeters are working correctly.

With the Students

1. Divide the class into teams of two students each. Provide each team with materials and a work space.
2. Emphasize safety precautions. Students should never touch any bare or exposed metal in a circuit that is generating electricity.
3. Have students use a rubber band to attach the electric motor to the ruler with the motor shaft positioned at the end of the ruler (see Figure 1). The ruler serves as a platform for the wind turbine.
4. Straighten out the lower part of each of four paperclips.
5. Cut out four 3 x 5 cm pieces of cardboard. Use tape to firmly attach a piece of cardboard to each paperclip.
6. Stick the straightened part of each paperclip into the curved sides of a cork to create four turbine blades. Be sure to space the blades equally around the cork.
7. Push the cork into the motor shaft. Make sure the shaft goes into the exact center of the cork.

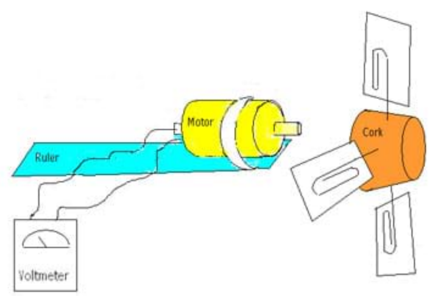
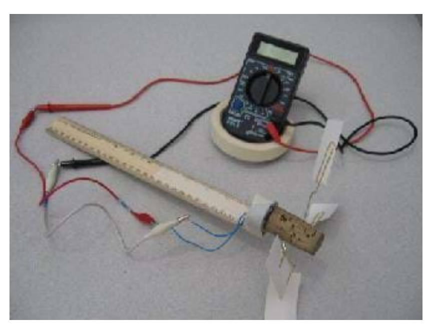


Figure 1. The activity setup: A wind turbine prototype hooked to a voltmeter.

8. Rotate the blade in the cork so that it is at a 45° angle to the flat plane of the edge of the ruler. You have completed your wind turbine!
9. In teams, have students bring their wind turbines to the testing station.



10. For one team at a time, use alligator clips to attach the free ends of the wires to a DC voltmeter. While waiting, have other teams work on the worksheet.
11. Start by placing the wind turbine about 30 cm (12 inches) away from the wind source (fan or hair dryer). Adjust the

distance, depending on the strength of the wind source.

Figure 2. The activity setup.

12. Turn on the wind source and measure the voltage produced. Record on the worksheet.
13. Repeat with the wind turbine at different distances from the wind source.
14. Have team members work together to complete the worksheet.
15. After all teams have had a turn at the test station and have completed their worksheets, conclude with a class discussion. Describe the movement of energy in your generator, starting with the wind and ending at the voltmeter. Review each team's results and observations. Did the turbine design of any team produce more voltage at the same distance, compared to the rest? Did anyone adjust the angle of the blades? What did that do? What happened as you moved your wind turbine closer or farther away from the wind source? How might you alter your turbine design or position to better capture the wind and produce more voltage? What factors might engineers consider when deciding where to put a wind turbine generator or a wind farm?

Vocabulary/Definitions

electrical energy: Electrical energy exists when charged particles attract or repel each other. Television sets, computers and refrigerators use electrical energy.

energy: The ability to do work.

generator: A device that transforms mechanical energy into electrical energy.

hub: The center part of a wheel, fan or propeller.

kinetic energy: The energy of motion. For example, a spinning top, a falling object and a rolling ball all have kinetic energy. The motion, if resisted by a force, does work. Wind and water both have kinetic energy.

mechanical energy: Mechanical energy is energy that can be used to do work. It is the sum of an object's kinetic and potential energy.

potential energy: Potential energy is the energy stored by an object as a result of its position. A roller coaster at the top of a hill has potential energy.

renewable energy: Energy that is made from sources that can be regenerated. Sources include solar, wind, geothermal, biomass, ocean and hydro (water).

rotor: The rotating part of an electrical or mechanical device.

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.

voltmeter: An instrument that measures electromotor force in units called volts.

wind turbine: A machine that converts the moving energy of wind into mechanical and/or electrical energy.

Assessment

Pre-Activity Assessment

Brainstorming: Have students engage in open discussion to think of how wind could be used as an energy source. Remind them that no idea or suggestion is "silly." All ideas should be respectfully heard. Write their ideas on the classroom board.

Activity Embedded Assessment

Worksheet: Have student teams record their measurements and observations on the Wind Turbine Worksheet. Review their answers to gauge their mastery of the subject.

Post-Activity Assessment

Question/Answer: Ask the students and discuss as a class:

- When can wind power be used? (Answer: The wind must have a high enough speed.)
- Why might engineers be interested in developing wind power? (Answer: Wind is a renewable energy resource. Wind power does not produce greenhouse gases or pollution. Using wind power reduces the consumption of non-renewable fossil fuels.)
- Why are large wind turbines often located on hills? (Answer: Wind speed is greater up high above the ground.)
- If we remove the motor from the rotor of the wind turbine, we will not be able to produce electricity, but we will still be able to do work with our windmill. What kind of work could we do? (Answer: We could do mechanical work by making the blades of the windmill move.)

Engineer Challenge Question: Ask students to think about the following engineering design problem. Have them discuss their answers in teams and share their thoughts with the class.

- A homeowner wants to use a wind turbine to supply electricity for their home, but no hills are near the house. Where could an engineer place the wind turbine? (Answer: As high up as possible, such as on a pole above the roof, or on a separate structure that puts it up very high in the air.)

Safety Issues

- Emphasize safety precautions. Students should never touch any bare or exposed metal in a circuit that is generating electricity.
- Remind students not to put anything, including their hands, near the wind turbine or fan while it is rotating.

Troubleshooting Tips

In advance of the activity, test the motors and voltmeters to make sure they are working correctly.

If the activity does not work well, try the following alternative: Attach a DC motor to a wheel. Duct tape 2 Popsicle sticks to the wheel to form a straight line. Duct tape a rectangular piece of cardboard to each Popsicle stick at such an angle as to create spin when wind blows past it. Tape the motor to a ruler to serve as a handle.

If time is limited, speed up the activity by bringing in two fans to provide two test stations.

Activity Extensions

Have students design their own sets of blades, varying the size, shape, material and number. Have students attach these new blades to the motor and adjust them at various angles to produce the greatest voltage. Have them record their variables and results in a data chart they create during the activity. Have students share and compare their designs by giving brief engineering reports to the class.

Explore how wind velocity affects the amount of electricity produced by changing fan speeds.

Explore the Renewable Energy Living Lab for real wind measurement, energy collections systems and real-world data. See: http://www.teachengineering.org/livinglabs/

Activity Scaling

- For lower grades, have the motor setup already prepared. Just have the students create the blades on the paperclips and press them into the cork. Help students measure the voltage generated by their wind turbines.
- For upper grades, have students graph the voltage produced as a function of fan distance. Have students solve the power problems in the Wind Power! Math Worksheet.

References

- *Buy into Wind and Fight Global Warming! Clean Air-Cool Planet*. Accessed October 20, 2005. (Good photographs of the first large utility-scale wind turbine installed on the Rosebud Sioux Indian Reservation) http://www.cleanair-coolplanet.org/action/windbuilders.php
- *Renewable Energy Lesson Plans*. Infinite Power, Texas State Energy Conservation Office. Accessed October 19, 2005. http://www.infinitepower.org/lessonplans.htm
- *How Wind Turbines Work*. Updated October 3, 2005. Wind & Hydropower Technologies Program, Energy Efficiency and Renewable Energy, U.S. Department of Energy. Accessed October 19, 20015. (Great animation of a wind turbine generating electricity) http://www1.eere.energy.gov/wind/wind_animation.html

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Supporting Program

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Acknowledgements

The contents of this digital library curriculum were developed under grants from the Fund for the Improvement of Postsecondary Education (FIPSE), U.S. Department of Education and the National Science Foundation (GK-12 grant no. 0338326). However, these contents do not necessarily represent the policies of the Department of Education or National Science Foundation, and you should not assume endorsement by the federal government.

Last modified: July 20, 2021