Next Generation Science Standards

NGSS Science and Engineering Practices:

- ☐ Asking questions and defining problems
- ☐ Developing and using models
- ☑ Planning and carrying out investigations
- ☑ Analyzing and interpreting data
- ☑ Using mathematics and computational thinking
- ☐ Constructing explanations and designing solutions
- ☐ Engaging in argument from evidence
- ☑ Obtaining, evaluating, and communicating information

NGSS Cross-cutting Concepts:

- ☐ Patterns
- ☐ Cause and effect
- ☑ Scale, proportion, and quantity
- ☐ Systems and system models
- ☐ Energy and matter
- ☑ Structure and function
- ☐ Stability and change

NGSS Disciplinary Core Ideas:

- ☑ PS2.A: Forces and Motion
- ☑ PS3.B: Conservation of Energy and Energy Transfer

Initial Prep Time

Approx. 5 min. per apparatus

Lesson Time

1 – 2 class periods, depending on experiments completed

Assembly Requirements

- Small Phillips-head screwdriver
- Small hex wrench

Materials (for each lab group):

- Horizon Wind Energy Education Kit
- Electric fan
- Metric ruler
- Stopwatch

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Lab Setup

- You should complete the Post and Support Base Assembly (described in section IV of the Assembly Guide) before students start their experiments.
- You may find it useful to test out different blade configurations before your students arrive to see which ones work best with the speed of your particular fans. In general, lower wind speeds will require more blades at a lower angle of attack, while faster speeds will require fewer blades at a higher angle of attack.
- Lab includes small parts that can go missing easily. Set up a resource area for each lab table or for the entire class to minimize lost pieces.

Safety

- With a powerful fan in front of them, the turbine blades can move very quickly. Students should keep their hands and faces at a safe distance and wear safety goggles at all times.

Notes on the Wind Energy Kit:

- A small, handheld fan won't be powerful enough to turn the turbine blades. Be sure to use a large, desktop fan.
- A fan with multiple settings is ideal and will allow your students to conduct more experiments about how the turbines operate at different wind speeds. If you don't have a fan with multiple speeds, you can simulate different wind speeds by adjusting the distance between the fan and the turbine, but turbulence will cause some variation in your data.
- When attaching the blade assembly to the nacelle, students should be sure to push it in until it clicks, otherwise it may fall off when spinning. There will be a gap between the blade assembly and nacelle, but it should be less than ¼ inch.

Common Problems

- The turbine spins best when the center of the turbine is lined up with the center of the fan.
- Students might choose configurations of turbine blades that don't spin very well. If their fan is lined up correctly and they can't get their turbine to turn, have them try other blade configurations.

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Goals

- Assemble a wind turbine
- Modify it to increase efficiency
- Make calculations based on data

Background

Wind turbines are quickly becoming a major source of electricity in countries around the world looking to decrease their dependence on harmful fossil fuels. In consistently windy areas, they can provide cheap, clean power nearly constantly. But is the common three-blade design that you may have seen before in wind farms really the best choice for maximizing the power that we can get out of these electricity generators?

Humans have used wind as a power source for millennia. From sailing ships to grinding grains in mills, wind power has had many uses. But it's really only in the last 30 years that major use of wind turbines to generate electricity has become commonplace. Nations like Denmark, with wind to spare, have been generating so much electricity that they actually sell the surplus to their neighbors.

With a miniature, working wind turbine, you can simulate conditions that wind turbines have to face as they generate electricity: different wind speeds and wind from different directions.

Your turbine is adjustable to try and compensate for these situations. There are three different shapes of turbine blades available for you to use. They can each be tilted to three different angles and you can have up to six blades on your rotor.

During this activity, we will experiment with different types of blades, different numbers of blades, and different angles of blades to try and maximize the power produced by our wind turbine.

Procedure

1. Look at the three different types of blades available (labeled A, B, and C). How are they similar? How are they different? Discuss with your group which type of blade you think would work best with your turbine and record your observations below.

2. Select the type and number of blades you want to test. Why do you want to test this type of blade first? Do you think it will be better or worse than the other types?

3. Check that the blades are in the same position using the three notches near the white bases of the blades. Rotate the individual blades if needed to get all the blades into the same position. Would your turbine still work if the blades were in different positions?

4. Insert the blades into the Rotor Base and put the Blade Holder and the Blade Assembly Lock, then attach the Blade Unit to the metal shaft of the turbine. Can your blades be positioned backwards? How do you know if there's a "right way" for a blade to be positioned?

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5. Connect the base of the turbine to the LED lights using the black and red wires. Why do you think the lights need two wires to work?

6. Turn on the fan and position it in front of the turbine. It will work best if you keep the fan close to the turbine and line up the center of the fan with the center of the turbine. Why would changing the position of the fan affect the wind hitting the turbine?

7. Record your observations in the Data Table below: Did the lights turn on? Were they dim or bright?

8. Discuss what you observed with your group and discuss what you want to change: the number of blades, the angle of the blades, the type of blades, or some combination of those.

9. Repeat steps 1-8 with as many changes as you can think of.

Observations

Data Table:

Blade Type (A, B, C):	Number of Blades:	Blade Angle (6°, 28°, 56°):	Observations:

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Experimentation

1. Based on your data from the previous experiment, keep the angles of the blades the same and try different numbers of different types of blades to see which works best. Record your observations below:

Trial:	Turns:	Time (sec):	Observations:
1			
2			
3			
4			

According to your data, how many seconds of running time do you get per turn of the generator?

Number of Each Type of Blade:	Observations:

What combination worked best?

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Wind Turbine Efficiency

2. If you used a combination of different types of blades, try changing the arrangement of the blades (A, B, A, B or A, A, B, B, for example) to try and get the rotor to turn faster. If your rotor spun fastest with only one type of blade, you can skip this experiment.

Blade Order:	Observations:
1	
2	
3	
4	

What arrangement worked best?

3. Move your fan farther back, to reduce the speed of the wind hitting your turbine. Test different configurations of blades and record your observations below.

Blade Type (A, B, C):	Number of Blades:	Blade Angle (6°, 28°, 56°):	Observations:

Was the best arrangement the same as at the higher wind speed?

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Wind Turbine Efficiency

4. What's the farthest distance you can move your fan and still turn your turbine? Use your ruler to measure how far your fan is from your turbine blades. Try different arrangements to see if you can get the turbine to turn at even farther distances.

Blade Type (A, B, C):	Number of Blades:	Blade Angle (6°, 28°, 56°):	Observations:

5. Try to maximize the output of the current and voltage by changing the different characteristics of the blades. Record your results below:

Blade Type (A, B, C):	Number of Blades:	Current (A):	Voltage (V):

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Wind Turbine Efficiency

Analysis

1. Make a scientific claim about what you observed while running your wind turbine.

Claim should reference the turbine's capabilities.
Example: "The turbine works best with six blades at low wind speeds."

2. What evidence do you have to back up your scientific claim?

Evidence should cite data in Observations and/or Experimentation sections.
Example: "The farthest distance we could move the fan while still turning the turbine was 57cm, when we used a configuration of A, B, A, B, A, B blades at 6° on the turbine rotor."

3. What reasoning did you use to support your claim?

Reasoning can draw from Background section and/or other materials used in class.
Example: "The wind slows down farther from the fan, so the configuration that works with the farthest distance must work with the lowest wind speed."

4. Design an experiment that would determine the best height for a wind turbine's support pole. Explain the steps of your experiment below:

Students may have many different acceptable answers, as long as they can provide a method for changing the height of the support pole and measuring the effects of that change. There should be clear control and experimental groups in the description.

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Wind Turbine Efficiency

Conclusions

1. Did your turbine would work better at faster or slower wind speeds? Explain:

Answers should cite their experimental data and explain how they come to the conclusion that one configuration worked "better" than another, e.g. output of electrical energy.

2. How would you calculate the percentage of kinetic energy from the wind that was transformed into electrical energy by the wind turbine?

Students may come up with many creative ways to calculate this, as long as they clearly state how they would measure the energy of the wind and how they would measure the energy of the electricity.

3. Do you think wind turbines would be a good way to generate power for your school? Explain your reasoning.

Students can answer "Yes" or "No" as long as they can cite anecdotal evidence of frequency of wind in the local area, as well as note the presence or absence of tall buildings, trees, or other potential wind-blocks in the vicinity of the school. More advanced students might attempt a rough estimate of the power needs of the school and the potential power output of wind turbines.

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