Vertical Axis Wind Turbines

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

Approx. 1 hour-long class period

Assembly Requirements

- None

Materials (for each lab group):

- Horizon Vertical Axis Wind Turbine STEM Kit
- Electric fan
- Metric ruler
- Horizon Renewable Energy Monitor or multimeter (optional)

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Lab Setup

- You should attach the magnets to the bottom blade plate (as described in Step 1 of the Assembly Guide) before students start their experiments. Be sure the magnets with the red dots are on opposite sides of the plate.
- 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 work best with more blades, while faster speeds will require fewer blades.
- 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.
- Be sure to install the turbine properly so that it will not move or topple over while running. Placing a rubber mat, foam padding, or a thin book under the base helps stabilize the turbine if the underlying surface is too smooth. Placing adhesive tape on the Base Extender also helps secure the turbine to a solid surface.
- If the turbine falls over while running, do not try to catch it. Extending the Base Extenders will increase the footprint of the base and reduce the chance of it toppling over. Please note that one of the Base Extenders must be aligned in the prevailing wind direction to effectively prevent it from toppling over.

Notes on 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.

Common Problems

- Placing a rubber mat, foam padding, or a thin book under the base helps stabilize the turbine if the underlying surface is too smooth. Placing adhesive tape on the Base Extender also helps secure the turbine to a solid surface.

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Goals

- Assemble a vertical-axis wind turbine
- Modify it to change its 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. You've probably seen wind farms made up of the tall, three-bladed turbines that spin along a horizontal axis. But there's an entirely different type of wind turbine that spins on a vertical axis.

Vertical-axis wind turbines (VAWTs) have a number of advantages over their horizontal-axis cousins. They can use wind from any direction and so don't need to be turned to face the wind. They are typically much smaller than horizontal turbines and so are much more practical for smaller communities or personal use, while also posing less of a danger to birds and taking up far less space.

VAWTs are separated into two types, named after the engineers who designed them: Sigurd Johannes Savonius and Georges Jean Marie Darrieus. A Darrieus turbine has vertical blades that spin around a center pole by using lift like the wings of an airplane. The slender profile of the blades often makes these turbines resemble egg beaters (see Figure 1).

Savonius turbines, in contrast, are built to use the drag force to power their blades. Instead of being shaped like an airplane wing to allow wind to flow over them, their blades are curved like scoops to catch the wind. Like a series of sails, these blades are pushed by the wind and spin the turbine.


Fig. 1: A Darrieus VAWT

During this activity, we will use a VAWT to generate electricity. We will experiment with different blade configurations to try and maximize the power produced by our wind turbine.

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Procedure

1. Your Savonius VAWT has different slots so that you can assemble your wind turbine with two, three, or four blades. Which configuration do you think will be most effective at producing an electric current?
2. Look at the base for the turbine. It has two coils of wire inside it. Why do you think the coils of wire are necessary?
3. The stator is the part of the turbine that doesn't move. It's the thin rod that fits in the small hole in between the coils of wire. Why does your turbine require a part that remains stationary?
4. Once your stator is in place, you can begin constructing your rotor. First you'll have to decide how many blades you want. You can tell where the blades should go by following the color-coded markings on the top and bottom plates of the rotor.
5. You can tell the top blade plate from the bottom because the bottom of the rotor has four magnets attached to it. Why are magnets necessary?
6. Insert the aluminum rotor pole into the hole in the middle of the bottom blade plate. What purpose does the rotor pole serve?
7. Attach the desired number of blades to the appropriate color-coded slots on the bottom of the rotor.
8. Fit the top blade plate onto the blades and rotor pole, again lining up the appropriate color-coded slots with the turbine blades.
9. Use the blade plate lock to secure the top of the blade plate.
10. Lower the assembled rotor onto the stator on the base.
11. Attach the LEDs to the base using the red and black wires. Why do you think we need two wires?
12. Turn on the fan and observe what happens. Record your observations below.

Observations

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Experimentation

1. Try changing the number of blades in your turbine. Does anything change about how the turbine rotates or the amount of electric current supplied to the LEDs? Record your observations below:

Number of Blades:	Observations:
2	
3	
4	

2. Move your fan farther away from your turbine. What's the farthest distance it can be before your LEDs no longer light up? Record your observations below:

Number of Blades:	Distance (cm)	Observations:
2		
3		
4		

What arrangement worked at the farthest distance?

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Measurement

For this section, you will need a multimeter or the Horizon Renewable Energy Monitor. For an introduction to using a multimeter, click here.

1. Move the fan closer to the turbine and record the current in Amps and highest voltage in Volts produced while the turbine is powering the LEDs. Record your answers below:

(Answers in this section will vary, but check that they are within reason, i.e. not >1A.)

Current: ______________ A

Voltage: ____________ V

2. Voltage is equal to the current in amps multiplied by the resistance in ohms (V = IR), so according to your data what is the resistance of the LEDs in ohms?

Resistance: _____________ Ω

3. Try to maximize the output of the current and voltage by changing the number of blades. Record your results below:

Number of Blades:	Current (A):	Voltage (V):
2		
3		
4		

4. Power is current times voltage (P =IV). Calculate the maximum power in watts of your turbine and compare it to the reading you get on the Energy Monitor. What might account for any differences you notice?

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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 four 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 lighting the LEDs was 57cm, when we had four blades 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 shape for the wind turbine's blades. 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 shape of the blades and measuring the effects of that change. There should be clear control and experimental groups in the description.

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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. What are other characteristics about your wind turbine that could be changed to increase the power output?

Students may come up with many creative answers for this, including but not limited to: size/shape of the blades, number of coils of wire, strength of the magnets, height of the rotor, etc.

3. Do you think vertical or horizontal axis wind turbines would be a better way to generate power for your school? Explain your reasoning.

Students can answer with either type as long as they can cite anecdotal evidence of wind directions, speeds, or other factors that might change which type of turbine would work best. More advanced students might attempt a rough estimate of the power needs of the school and the potential power output of wind turbines.