Physics Lab

Wind to Hydrogen HS Physics

HORIZON ENERGY CURRICULUM

Teachers' Guide

Physics	High School	8 hours

Unit Plan - Description

For this activity, students will learn about wind power, hydrogen fuel cells, and renewable energy. They will build a wind turbine, test its efficiency, and use it to generate hydrogen. The primary content includes forces and kinetic energy, transfer and conservation of energy, and designing and constructing engineering solutions.

Focus

Students will engage with multiple resources to understand how energy is transformed during chemical reactions and the relationship between chemical and electrical energy.

Behaviors

SWBAT construct a functioning electrolytic cell and explain its chemical reaction.

SWBAT explain how a wind turbine works.

SWBAT understand the difference between renewable and nonrenewable sources of energy.

NGSS Science and Engineering Practices

- Asking Questions and Defining Problems
- 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 Crosscutting Concepts

- Patterns
- Cause and Effect
- Scale, Proportion, and Quantity
- Energy and Matter
- Structure and Function
- Stability and Change

NGSS DCIs

HS-PS1.B, HS-PS2.A, HS-PS3.A, HS-PS3.B

Energy Literacy Framework

1.1, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 4.1, 4.2, 4.6, 4.7, 6.1, 6.4, 6.5, 6.8

Common Core ELA and Math

RST.6-8.1, RST.6-8.3, WHST.6-8.7, MP.2, 6.RP.A.2, 6.RP.A.3, 6.SP.B.5

Classroom and Homework Activities

1. Lab Activity sheet
2. History of Wind Power
3. Aerodynamics of Wind Turbines
4. Parts of a Wind Turbine
5. Using a Multimeter
6. Stating a Scientific Claim

Electronic and Online Activities

1. What's Inside a Wind Turbine? Video
2. Wind Energy Virtual Lab
3. National Geographic Interactive Wind Activities
4. Wind Farm Virtual Tour
5. Global Wind Patterns
6. Convection and Worldwide Wind Cells

Procedure

Over the course of multiple lessons, students will engage with a variety of resources dealing with fuel cells, wind power, and renewable energy resources. Electronic and online resources will be available to supplement in-class resources as well as instructor-led small- and whole-group discussions. Formative assessment will be conducted with oral questions during activities and students will complete a final written assessment at the close of the activity.

Lab Setup

- Be sure to assemble the base and attach the red and black wires to their contacts before the lab begins to avoid having students use screwdrivers and potentially lose screws. This should take no more than 2-3 minutes per turbine.
- Assemble the fuel cell before the lab as described in steps 2-3 of the Assembly Manual so that students don't need to cut the tubing.
- 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.
- Do not allow the fuel cells to dry out or they will be irreparably damaged. Seal in a plastic bag for storage.
- Students should wear safety goggles at all times.

Notes on Using This 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 using the fuel cell to generate hydrogen, be sure to connect red to red and black to black! Connecting the fuel cell incorrectly could permanently damage it.

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.
- If the hydrogen fuel cell seems to stop working before using all its hydrogen, uncap one of the small tubes to purge impure gases, recap, and wait 3 minutes before connecting the motor again.

Using the Comprehension Questions Formative Assessment Tool

- As your students are working on their activities and you circulate from group to group, use the grid system to keep track of how well individual students are understanding the material.
- You can use a code to quickly assess each individual's level of mastery after talking with them, for example: (B)elow Grade Level, (A)t Grade Level, (E)xceeds Grade Level.
- Feel free to adopt your own code, and be sure to write them in pencil so you can adjust them as your

students improve over time. Use this tool to take stock of your students' progress at a glance and provide resources to those who need it.
- You can even add your own questions to gauge your students' knowledge of other areas of your curriculum.

Resource Availability

- The electronic and print resources included in this mini-unit are designed to be accessible by students at all levels of achievement. We suggest that you make as many resources as possible available to your students as they engage with the new content so they have multiple opportunities to familiarize themselves with the information.
- If you have additional resources or feel that some of our resources cover material outside the scope of your class, feel free to customize as needed.

Creating New Materials

- We include all our instructional files as modifiable files so that you can customize them to your own class. We've aligned our activities with the Next Generation Science Standards and the US Department of Energy's Energy Literacy Framework. If you need to add content to comply with a specific state standard or the scope and sequence of your course, feel free to do so.
- In fact, if you develop a great new experiment or additional student resource, let us know! We regularly select the best teacher-submitted lessons, labs, and activities and share them with other educators all over the world. Winners are all listed on our website and receive free Horizon Educational Kits for their classrooms.

Analysis

Make a scientific claim about the turbine blades: What characteristic was most important in getting them to turn faster? (Read Stating a Scientific Claim if you need help)

Level 1 example answer: "The type of blades was most important."
Level 2 example answer: "Higher angles made the blades turn faster."
Level 3 example answer: "Changing the number of blades had the biggest effect on the turbine speed."

What is the *evidence* you can use to back up your claim?

Level 1 example answer: "We counted 78 rpm."
Level 2 example answer: "Four blades turned faster than five blades."
Level 3 example answer: "The fan could still turn the blades from 36 cm away when we used type A blades."

Explain the *reasoning* behind your claim.

Level 1 example answer: "The turbine spun faster."
Level 2 example answer: "Since we counted more rpm, the turbine must have been spinning faster."
Level 3 example answer: "The farther away the fan was, the lower the wind speed, so the blades that could keep spinning at a larger distance were most efficient."

Did other people come to a different conclusion about their turbine blades? Use your observations to *develop an argument* that supports your position and defend your findings.

Conclusion

You were able to change the angle, shape, and number of your turbine blades. *Design an experiment* that would change a feature of your turbine that you weren't able to test.

Level 1 example answer: "We could test what material is best."
Level 2 example answer: "We could test what weight is best by measuring lighter and heavier blades."
Level 3 example answer: "We could compare different sizes of turbines in different wind speeds to see if different sizes are better in different wind speeds by measuring how fast they spin."

Based on your data, what angle, shape, and number of blades for your wind turbine would produce the most energy?

Level 1 example answer: "Type A, with 3 blades, at 6º"
Level 2 example answer: "Type C, with 2 blades, at 50º because that's when we recorded the highest rpm."
Level 3 example answer: "2 Type B blades and 2 Type A blades, at 28º, because it produces power in both high and low wind speeds."

Which characteristic (angle, shape, or number of blades) had the greatest effect on the electricity production from your wind turbine? Use the data from your experiments to *develop an argument* that defends your position.

Level 1 example answer: "The blade angle had the greatest effect on the production of electricity."
Level 2 example answer: "The number of blades was most important because the amount of electricity generated increased as we changed the number of blades."
Level 3 example answer: "The shape of the blades was most important because our data showed that the difference in the electricity generated by the worst was very small compared to the amount generated by the best."

If changing characteristics of your turbine didn't transfer energy from the wind to your turbine, where did the energy go? *Construct an explanation* of what happened to the wind's energy based on your data and your knowledge of kinetic energy.

Level 1 example answer: "The energy was destroyed."
Level 2 example answer: "Not all the energy of the wind hit the turbine since some wind went right through it without hitting the blades."
Level 3 example answer: "Not all the wind hit the blades, and even when it did some energy was used up in friction and heat from the turning blades."

Using the experimental data you gathered, *design an experiment* that could determine the minimum number of revolutions per minute a turbine would have to spin to power the LEDs.

Level 1 example answer: "Run the turbine and see when the lights go off."
Level 2 example answer: "Count the revolutions per minute when the lights start to come on."
Level 3 example answer: "Move the fan farther and farther away until the LEDs are just barely on, then count the revolutions per minute."

Run the experiment you described above. What is the minimum RPM for power generation according to your findings?

Answers will vary.

If you had 60 revolutions per minute (60 RPM) that would be 1 Hertz (cycle per second). Using the data from the previous question, calculate the cycle rate of your turbine at its minimum power generation in Hertz.

Answers will vary.

You can also describe how fast your turbine was turning using its tangential speed. Use a ruler to measure the radius of your turbine and use 2πr to find the circumference. You can find the tangential speed in m/s by using your rotations per minute from above.

Radius: __________cm Circumference ________ m RPM (from above) _____________

Rotations per second (RPM/60) ___________

Tangential velocity (Circumference × RPS)____________ m/s

Measurement

This section requires a multimeter or the Horizon Renewable Energy Monitor. For help setting up a multimeter, see "Using a Multimeter."

If the turbine is spinning faster or slower, we should be able to figure out how much faster or slower it's moving based on how much electricity it's producing. Using a multimeter like the Horizon Renewable Energy Monitor we can measure the voltage and amperage of the electric current. See "Measuring Current in a Circuit" if you need to know the difference between volts and amps.

With your multimeter attached to the turbine and LEDs, you should be able to see differences in the current produced by the turbine. Change the number, type, or angle of the turbine blades and see what changes you can observe when the turbine is placed in front of the fan. Record your observations on the table below:

Blade Type (A,B,C)	***Number of Blades***	***Blade Angle (6º, 28º, 50º)***	***Volts***	***Amps***

Your energy monitor can also measure the revolutions per minute (RPM) of the wind turbine blades if you push the “Select” button until RPM appears. Knowing the RPM, you can calculate the angular velocity, or how long it takes for one blade to complete one rotation. For example, if your blades are spinning at 60 RPM, then one blade completes one rotation in one second.

How fast are your blades spinning? Start by recording the fastest RPM you can record, using the most effective blade angle, number, and type.

RPM: ____________

Dividing your RPM by 60 will tell you revolutions per second: ______________ RPS

Angular acceleration is a measure of how fast a spinning object changes its speed. You can calculate the angular acceleration of your turbine by knowing its fastest speed in RPS and measuring how long it takes to reach that speed.

You already recorded your peak RPS above. Using the Horizon Energy Monitor and a stopwatch, can you determine how long does it take for your turbine to go from completely stopped to its peak RPM?

RPS divided by time will tell you your angular acceleration: ______________ rev/sec^2