# Wind to Hydrogen Physics Lab

Physics Lab

HORIZON ENERGY CURRICULUM

| Name: ____________________ | Class: _____________ | Date: ______________ |
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Physics | High School | 8 hours

## Objective

To explore wind and hydrogen fuel cell power sources and try to improve the power output of both.

## Materials

- Horizon's Wind to Hydrogen Science Kit
- Electric Fan
- Distilled Water
- Stopwatch
- Horizon Renewable Energy Monitor (optional)

## Background

Humans have been using the wind to power machines since ancient times. Even today, you can see windmills powering water pumps on farms and the huge wind turbines that are becoming an important part of our electricity production. Read more about how humans have used wind energy in History of Wind Power.

Wind turbines can be classified as Horizontal axis or vertical axis, depending on how they turn. Horizontal axis wind turbines (HAWTs), like the ones pictured in Figure 1, consist of a rotor and a horizontal main rotor at the top of a tower. They also typically have a gearbox, which turns a slower rotation into a faster one, and a generator which produces electricity. You can find out more about how wind turbines work by reading Parts of a Wind Turbine.

HAWT pumping water on a

farm

The optimal number of rotating blades varies on horizontal wind turbines. The multi-bladed, water-pumping windmills often seen on farms are designed differently than those designed for generating electricity. Water-pumping windmills tend to have a large number of blades while electricity-generating turbines usually have no more than three blades on their rotors.

The blades of a turbine rely on the same principles as a plane's wing, with lift and drag affecting how they move. The forces involved in spinning turbine blades are discussed in detail in Aerodynamics of Wind Turbines.

HAWT for electricity generation

Our wind turbine will also be used to produce hydrogen from water with an electrolyzer, which is also a fuel cell. You can find out how our electrolyzer works by reading Introduction to Electrolyzers and Fuel Cells.

Wind turbines today are one of the ways we are harnessing clean energy to generate electricity. They create no pollution, but they are limited by where they can be used and when the wind is blowing. With these restrictions, a wind turbine must be built to generate the most electricity possible.

How can we make the wind turbine more effective at generating power? How does the power output of a wind turbine compare to a hydrogen fuel cell? How could they work together to produce power? We'll be looking at these questions and more as we learn about wind and hydrogen fuel cell power.

## Method

You will be using your miniature turbine and a fan to simulate a full-sized wind turbine in a consistently windy location. You will change the characteristics of your turbine to make it more effective at generating electricity and compare its power output to a hydrogen fuel cell.

## Procedure

Use these guiding questions as you assemble and test your turbine. Record anything interesting you observe while building and experimenting in the **Observations** section below.

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.
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?
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 on the next page: 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 ($6^o$, $28^o$, $50^o$)*** | ***Observations:*** |
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**Experimentation:** Hydrogen Fuel Cell

You've used the turbine to generate electricity and provide power to lights, but you can also use it to generate hydrogen gas using the hydrogen fuel cell. Disconnect the lights from the base of the turbine and connect the turbine to the fuel cell.

The more electricity the turbine generates, the faster the cylinders will fill with hydrogen and oxygen gas. Use a stopwatch to measure the amount of time it takes to fill the hydrogen cylinder (it will fill up first). Stop the timer when you see bubbles start to escape from inside the cylinder and disconnect the fuel cell. Try different blade characteristics to see which generates electricity fastest. Record your observations on the next page.

Once you've generated hydrogen, you can use the fuel cell to create electricity. Attach the motor or the lights to the fuel cell and watch as it puts hydrogen and oxygen back together to make water and create electric current.

 

| ***Blade Type (A,B,C)*** | ***Number of Blades*** | ***Blade Angle (6º, 28º, 50º)*** | ***Time to fill $H_2$ cylinder (sec)*** |
|---|---|---|---|
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Which blade characteristics were most effective at producing electricity? Why do you think it was?

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**Experimentation:** Revolutions per Minute

Put a piece of masking tape around one of your blades. This will allow you to count the number of times that blade rotates in a given amount of time. Have one group member operate the stopwatch and another stand next to the turbine to count the revolutions. (It’s easier to count if you stand beside the turbine and count the times the taped blade comes over the top.)

Look at your data from the previous experiment. Note which trials had the brightest lights and which had the dimmest or none at all. Use these extreme cases to find a range for your turbine’s revolutions per minute (RPM).

Have the time keeper say “Go!” once the fan has got the turbine turning and count the number of times the taped blade completes a revolution. Stop counting at exactly 15 seconds. You can then multiply your count by 4 to get the total revolutions per minute. Record your data on the next page.

| ***Blade Type (A,B,C)*** | ***Number of Blades*** | ***Blade Angle (6º, 28º, 50º)*** | ***Count (15 seconds)*** | ***Revolutions per minute (count × 4)*** |
|---|---|---|---|---|
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What was your greatest number of revolutions per minute? How did that compare with other groups in your class?

**Experimentation:** Fan Distance

Increasing the distance between the fan and the turbine will decrease the energy of the wind that reaches it. What is the maximum distance the fan can be moved and still light up the LEDs?

Look at your data from your previous experiments. What are the trials that lit up the LEDs the brightest? Pick the three or four brightest to use in this experiment.

Start with the fan very close to the turbine and gradually move it backwards until the lights no longer light up. Measure the distance on your desk from the turbine blades to the fan in cm and record your data on the next page.

 

| ***Blade Type (A,B,C)*** | ***Number of Blades*** | ***Blade Angle (6º, 28º, 50º)*** | ***Maximum Distance (cm)*** |
|---|---|---|---|
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Which type, number, and angle of blades could keep the lights on for the farthest distance? What do you think that means?

## Analysis

Make a *scientific claim* about the turbine blades: What characteristic was most important in getting them to turn faster? To help you write a claim statement, see Stating a Scientific Claim.

### Claim

 

What *evidence* can you use from your **observations** and your **experimentation** to back up your claim?

## Evidence

State the *reasoning* you used to make your claim.

## Reasoning

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.

Based on your data, what is the best angle, shape, and number of blades for your wind turbine?

How could you use a hydrogen fuel cell with a wind turbine to generate power even when there isn't any wind?

 

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.

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.

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

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.

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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 on the next page:

 

| ***Blade Type (A,B,C)*** | ***Number of Blades*** | ***Blade Angle (6º, 28º, 50º)*** | ***Volts*** | ***Amps*** |
|---|---|---|---|---|
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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$^2$