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Exploring Renewable Energy: Wind Turbine Design for All Levels

Experiments

Blade Variable: Pitch

Go Direct® Energy Sensor

Blade Variable: Quantity

Go Direct Energy Sensor

Project: Maximum Energy Output

Workshop Presenter

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Blade Variable: Pitch

Do you know that the air you breathe is actually made up of atoms? When you are running down the street or moving fast on a bike, have you felt wind blowing on your face? What you are feeling is the force of many atoms against your skin.

When blades move through the air, they also push against the atoms that make up air. The atoms push back, creating a force that resists or opposes the motion of the turbine blades. The resistance experienced by blades moving through air is called *drag*.

Blade design engineers try to reduce the amount of drag experienced by blades while maximizing the power output of the turbine. One of the ways they do this is by changing the pitch or angle of a blade. In this experiment, you will explore the relationship between blade pitch and wind turbine output.

OBJECTIVES

- Measure power output of a wind turbine with an Energy Sensor.
- Investigate how blade pitch affects power output.
- Determine optimal blade pitch for maximum power output.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis app
Go Direct Energy Sensor
assembled wind turbine setup and fan
Wind Turbine Hub
Blade Pitch Protractor
3 blades
safety goggles

PROCEDURE

Answer the Pre-Lab Questions.

1. Insert three blades, spaced evenly apart, into the Wind Turbine Hub.
2. Using the Blade Pitch Protractor, adjust the blades so they are set to a pitch of -60° . Tighten the knob of the Wind Turbine Hub so the blades do not move.
3. Attach the hub to the wind turbine setup by firmly pressing the hub onto the drivetrain. Give the blade set a gentle spin to make sure it rotates freely without hitting anything.
4. If necessary, set up the sensor and data-collection app.
 - a. Launch Graphical Analysis.
 - b. Connect the Energy Sensor to a Chromebook, computer, or mobile device.
 - c. Click or tap View Options, , and choose 1 Graph.
 - d. Click or tap the y-axis label. Select Power and deselect the other option(s) to display a graph of power vs. time.
5. Check the equipment.
 - Make sure the switch on the Energy Sensor is set to Internal $30\ \Omega$ Load.
 - Connect the wind turbine to the Energy Sensor Source wires.
 - Position the fan so the center of the fan is in line with the center of the hub of the turbine. The fan should be about 15 cm from the turbine.
 - Make sure that when the fan and the turbine are moving, nothing will be in the way.
6. Put on safety goggles. Turn on the fan to the highest speed setting. **Caution:** Do not stand in the plane of rotation of the wind turbine rotor.
7. Wait 30 seconds or until the fan and turbine blades reach a constant speed.
8. Click or tap Collect to start data collection. Data will be collected for 30 seconds.
9. When data collection is complete, turn off the fan and remove the hub from wind turbine setup.
10. Determine the mean power output.
 - a. Click or tap Graph Options, , and choose View Statistics.
 - b. Record the mean power in the data table.
11. Collect data for four other pitches:
 - a. Plan as a group and decide which four pitches to test.
 - b. Record the pitches in the data table.
 - c. Repeat Steps 2–10 to determine and record the mean power values for the other pitches.

Name _____

Date _____

Data Sheet for Experiment 5

Blade Variable: Pitch

PRE-LAB QUESTIONS

1. What variable will you change in this experiment?
2. List at least three variables that you will keep the same during the experiment.

DATA

Pitch (°)	Trial	Mean power for trial (mW)	Average power (mW)
-60	1		
	2		
	3		
	1		
	2		
	3		
	1		
	2		
	3		
	1		
	2		
	3		
	1		
	2		
	3		

Blade Variable: Pitch

DATA ANALYSIS

1. Calculate the average power for each pitch and record the values in the data table.
2. Use the data in the data table to create a graph of average power vs. pitch.
3. Which pitch produced the greatest power output?
4. Why do you think this pitch produced the greatest power output?
5. Which pitch produced the least power output?
6. Why do you think this pitch produced the least power output?
7. In your own words, explain what drag means.
8. Describe the relationship between blade pitch and power output.

Blade Variable: Quantity

Do all wind turbines have the same number of blades? There are other devices that have blades, too, such as box fans and ceiling fans. How many blades do these fans have? Is it always the same?

Engineers face many challenges when designing devices that are blade driven, and the number of blades can vary for several reasons. In this experiment, you will vary the number of blades on the wind turbine and measure the power output for each trial. You will discover the optimal number of blades that you need for your particular blade design in order to generate the greatest power output.

OBJECTIVES

- Measure wind turbine power output with an Energy Sensor.
- Investigate how the number of blades affects the power output of a wind turbine.
- Determine the optimal number of blades for maximum power output.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis app
Go Direct Energy Sensor
assembled wind turbine setup and fan
Wind Turbine Hub
Blade Pitch Protractor
6 blades (minimum)
safety goggles

PROCEDURE

Answer the Pre-Lab Questions.

1. Place two blades, spaced evenly apart, into the Wind Turbine Hub.
2. Using the Blade Pitch Protractor, adjust the blades so they are set to a pitch of -20° . Tighten the knob of the Wind Turbine Hub so the blades do not move.
3. Attach the hub to the wind turbine setup by firmly pressing the hub onto the drivetrain. Give the blade set a gentle spin to make sure it rotates freely without hitting anything.
4. If necessary, set up the sensor and data-collection app.
 - a. Launch Graphical Analysis.
 - b. Connect the Energy Sensor to a Chromebook, computer, or mobile device.

Blade Variable: Quantity

- c. Click or tap View Options, , and choose 1 Graph.
- d. Click or tap the y-axis label. Select Power and deselect the other option(s) to display a graph of power vs. time.
5. Check the equipment.
 - Make sure the switch on the Energy Sensor is set to Internal 30 Ω Load.
 - Connect the wind turbine to the Energy Sensor Source wires.
 - Position the fan so the center of the fan is in line with the center of the hub of the turbine. The fan should be about 15 cm from the turbine.
 - Make sure that when the fan and the turbine are moving, nothing will be in the way.
6. Put on safety goggles. Turn on the fan to the highest speed setting. **Caution:** Do not stand in the plane of rotation of the wind turbine rotor.
7. Wait 30 seconds or until the fan and the turbine blades reach a constant speed.
8. Click or tap Collect to start data collection. Data will be collected for 30 seconds.
9. When data collection is complete, turn off the fan and remove the hub.
10. Determine the mean power output.
 - a. Click or tap Graph Options, , and choose View Statistics.
 - b. Record the mean power value in Table 1.

PREDICTION: When you add another blade, will the power value increase, decrease, or stay the same? Record your prediction in Table 2.

11. Collect data for three blades.
 - a. Adjust the blades so that there are three blades spaced evenly around the hub.
 - b. Repeat Steps 2–10.
12. Collect data for other two other trials with different quantities of blades:
 - a. Make a plan as a group for how many blades you will test for the two trials.
 - b. Record the number of blades for each trial in the data table.
 - c. Adjust the number blades in the hub and make a prediction about how power will be affected by the quantity of blades you are testing.
 - d. Repeat Steps 2–10 to determine and record the mean power value.
 - e. For the last trial, adjust the blades, make a prediction, and repeat data collection to record the mean power value.

Name _____

Date _____

Data Sheet for Experiment 6

Blade Variable: Quantity

PRE-LAB QUESTIONS

1. What variable will you change in this experiment?
2. List at least three variables that you will keep the same during the experiment.

DATA

Table 1: Blade Quantity Test	
Blade quantity	Mean power (mW)
2	
3	

Table 2: Prediction	
Blade quantity	Predicted change: increase, decrease, or stays the same
<i>example</i>	<i>stays the same</i>
3	

Blade Variable: Quantity

DATA ANALYSIS

1. Use the data in the data table to create a graph of mean power vs. quantity.
2. How many blades did you use in the trial that produced the greatest power?
3. Why do you think this blade design produced the greatest power? If you have learned about drag, use the word drag in your answer.
4. How many blades did you use in the trial that produced the least power?
5. Why do you think this blade design produced the least power? If you have learned about drag, use the word drag in your answer.

Project: Maximum Energy Output

Generating electricity from fossil fuels (primarily coal and natural gas) produces carbon dioxide (CO₂) and an array of other pollutants that are injected into the atmosphere each year. The Intergovernmental Panel on Climate Change (IPCC) estimates that 20–25% of the CO₂ produced by humans comes from the generation of electricity around the world. Increasing CO₂ concentrations in the atmosphere is one of the key drivers of climate change.

While electricity generation produces a significant amount of the CO₂ released by humans, there are millions of people around the world who do not currently have access to electricity. When individuals or communities seek out reliable electricity, they have a variety of options, including generators that run on gasoline or diesel. Developing ways to efficiently produce electricity from renewable sources, such as wind or solar power, can greatly improve people's quality of life and ability to sustainably support themselves and their communities.

Wind turbines are a rapidly maturing technology that can help reduce the carbon footprint of electricity generation and bring electricity to even the most remote communities. In this project, you will construct a small wind turbine that maximizes energy output at low and high wind speeds. This turbine could be used to provide energy that would charge small electronics or provide lighting. During the project, you will work with your group to design, test, and then optimize your wind turbine design. At the end of the project, you will submit a set of deliverables.

DESIGN REQUIREMENTS AND CONSTRAINTS

- Turbine diameter: No larger than 50 cm
- Wind speed range: 2–6 m/s
- Output: Unregulated Direct Current
- Generator: Any available DC generator or you can build your own generator
- Turbine must be robust enough to withstand outdoor conditions over time
- Turbine should track the wind direction (yaw)
- Do not exceed the project budget

DELIVERABLES

- Prototype
- Detailed design specifications (so the unit can be replicated)
- Expected energy output over a 24 hour period at wind speeds of 2 m/s, 4 m/s, and 6 m/s
- Social and environmental impact statement on the benefit of your design