

Blade Design: Pitch

(Vernier Energy Counter)

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 wind turbine blades move through the air, they also push against the atoms that make up air. These atoms cause resistance, just like the resistor in a circuit reduces the flow of electrons in a circuit. The resistance a blade feels when it moves through air is called *drag*.

Blade design engineers try to reduce the amount of drag experienced by blades while maximizing power output. 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 energy generated by a wind turbine with a Vernier Energy Counter.
- Investigate how blade pitch affects the total energy generated.
- Determine optimal blade pitch for maximum energy generation.

MATERIALS

Vernier Energy Counter
KidWind MINI Wind Turbine
KidWind Wind Turbine Hub
Blade Pitch Protractor
safety goggles
multi-speed box fan
centimeter ruler
2 premade blades **or** materials to make 2 blades:
 scissors
 hot glue
 wooden dowels
 blade material

VOCABULARY

Vocabulary term	Explanation
drag	Drag is the force caused by blades hitting air as the blades move. It is also called air resistance. Drag causes the blades to slow down.
hypothesis	an idea that can be tested through experimentation
pitch	the angle of a blade
variable	any factor that can be controlled, changed, or measured in an experiment

PRE-LAB ACTIVITY

In this experiment, you will test blades with the following blade pitches:

70° 55° 40° 25° 10°

1. Write a hypothesis about which blade pitch will generate the most energy.

Hypothesis

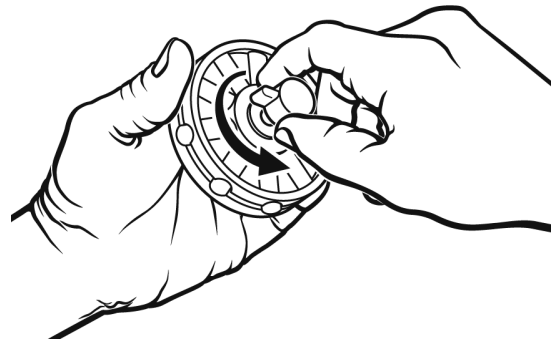
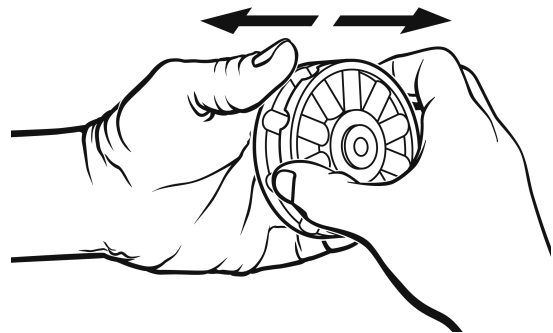
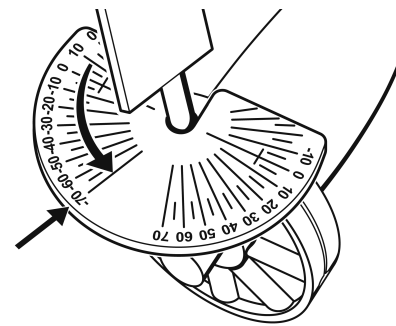
I think the blade with a pitch of _____ degrees will generate the most energy because

2. What variable will you change in this experiment?

3. List at least three variables that you will keep the same during the experiment.

PROCEDURE

1. Get two blades from your teacher or make two blades for your turbine.
 - a. If you are making blades, cut out two blades that are 12 cm long. They should be rectangular in shape.
 - b. Attach the blades to wooden dowels with hot glue.
2. Assemble the blades and Wind Turbine Hub.
 - a. Loosen the knob on the hub a little bit (see Figure 1). Do not loosen the knob too much or the hub will come apart.
 - b. Gently create a space between the front and back pieces of the hub that is just big enough for the dowel and insert one of the blades.
 - c. Insert the other blade in a hole on the opposite side of the hub.
 - d. Tighten the knob on the hub to hold the blades in place.
3. Connect the Wind Turbine Hub to the wind turbine.
 - a. If the Red Blade Set is connected to the turbine, ask your teacher to remove it.
 - b. Gently press the hub on to the turbine motor pin.
4. Adjust blade pitch using the Blade Pitch Protractor.
 - a. To adjust a blade, rotate the Wind Turbine Hub so that the blade is positioned vertically at the 12 o'clock position.
 - b. Slightly loosen the knob of the Wind Turbine Hub.
 - c. Slip the protractor around the dowel from the front side of the hub.
 - d. Turn the wooden dowel until the base of the blade is aligned with -70° .
 - e. Rotate the Wind Turbine Hub clockwise until the next blade reaches the 12 o'clock position.
 - f. Slip the protractor around the dowel and turn the blade until the pitch is -70° .
 - g. When you have adjusted the pitch on your blades, tighten the knob of the Wind Turbine Hub.
 - h. Give the blade set a gentle push with your finger to make sure it spins freely without hitting anything. If the blades hit the tower, adjust them until everything spins freely.



Experiment 6

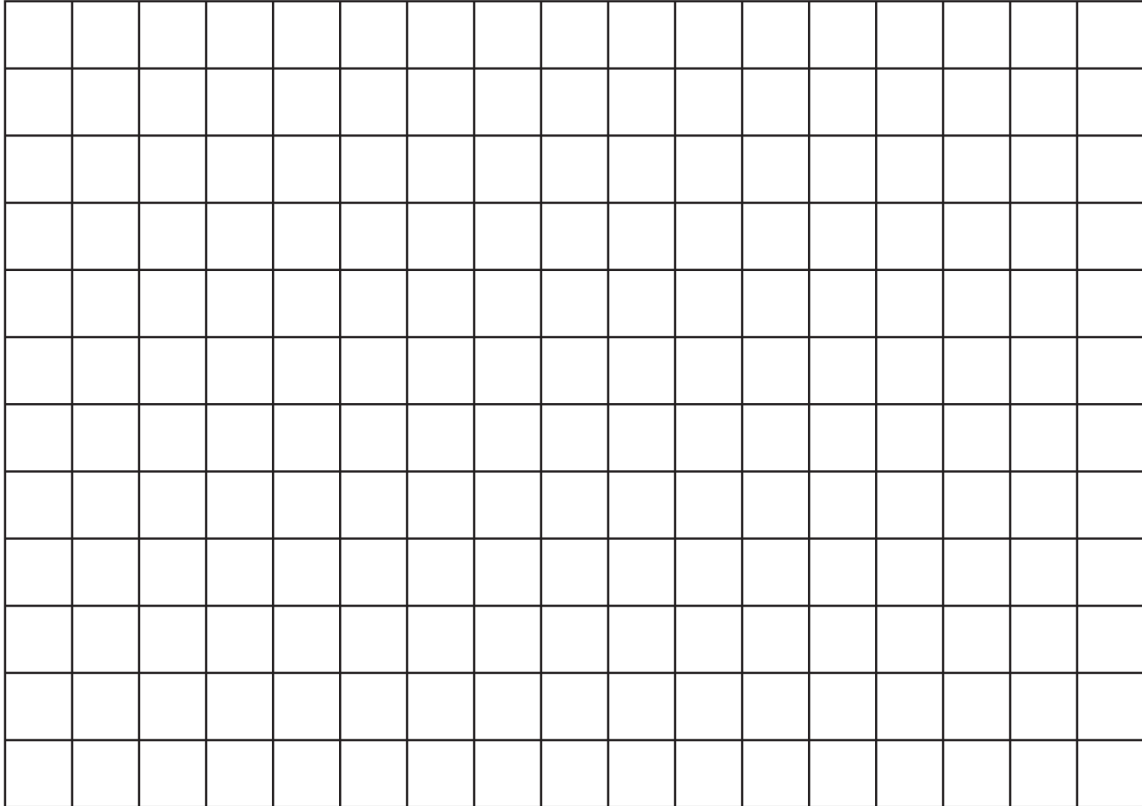
5. Connect the wind turbine to the Vernier Energy Counter.
 - a. Connect the red wire from the turbine to the red alligator clip.
 - b. Connect the black wire from the turbine to the black alligator clip.
 - c. Turn on the Vernier Energy Counter by pressing the Start/Reset button once.
6. Position the fan so the center of the fan is in line with the center of the hub of the turbine. The fan should be 15 cm from the turbine. The distance needs to be the same each time you collect data.
7. Observe the Live View of the wind turbine output on the Vernier Energy Counter.
8. Put on safety goggles and turn on the fan to the highest speed setting. **CAUTION:** Do not stand in the plane of rotation of the wind turbine rotor.
9. Collect data.
 - a. After the fan has been on for at least 30 seconds, you are ready to collect data. Waiting 30 seconds ensures that the wind turbine is spinning at a constant speed. Press the Start/Reset button to begin data collection. Data collection will stop after 30 seconds.
 - b. When data collection finishes, turn off the fan.
10. Record the total energy generated in the data table.
11. Use the Step 4 procedure to set the blades to a pitch of -55° .
12. Collect data.
 - a. Reposition the fan and turbine so that they are in the same positions as before. Measure to make sure they are 15 cm apart.
 - b. Turn on the fan to the highest speed setting.
 - c. After the fan has been on for at least 30 seconds, press the Start/Reset button to start data collection.
 - d. Data collection will stop after 30 seconds. When data collection finishes, turn off the fan.
13. Record the total energy produced in the data table.
14. Repeat Steps 12–13 to determine and record the total energy generated with blades set to pitches of -40° , -25° , and -10° .

DATA TABLE

Pitch ($^\circ$)	Total energy produced (J)
-70	
-55	
-40	
-25	
-10	

DATA ANALYSIS

1. Use the data in the data table to create a bar graph of energy vs. pitch.
 - Graph the blade pitch data on the x-axis (horizontal).
 - Graph the energy data on the y-axis (vertical).
 - Label the x-axis and the y-axis of your graph.
 - Add a title to your graph.



2. Which pitch produced the greatest energy? _____

3. Why do you think this pitch produced the greatest energy?

4. Which pitch produced the least energy? _____

Experiment 6

5. Why do you think this pitch produced the least energy?

6. In your own words, explain what drag means.

7. Describe the relationship between blade pitch and energy.
