Wind Turbine Blade Labs

Working in groups do the following labs,

1. Exploring Blade Pitch
2. Exploring Number of Blades
3. Exploring Surface Area
4. Exploring Mass
5. Designing Optimum Blades

Read the directions for each lab. Each student in the group needs to fill out their own individual lab packet. All writing and graphing **must be legible**.

Make your Hypothesis before you do the lab. *(.25pts)*

Write down the Independent, Dependent and Controlled Variables when asked. *(.25pts)*

Fill out the Data Table for each lab. *(.5pts)*

For the Graph Data, draw the graph on the back on each lab sheet. *(.5pts)*

For the Conclusion, write your explanation on the back of each lab sheet. *(.5pts)*

1. Exploring Blade Pitch

Question

How does the blade's pitch (angle) affect the turbine's electrical output?

Hypothesis

Make a hypothesis to address the question using the following format: If (manipulated variable) then (responding variable) because ...

_____

_____

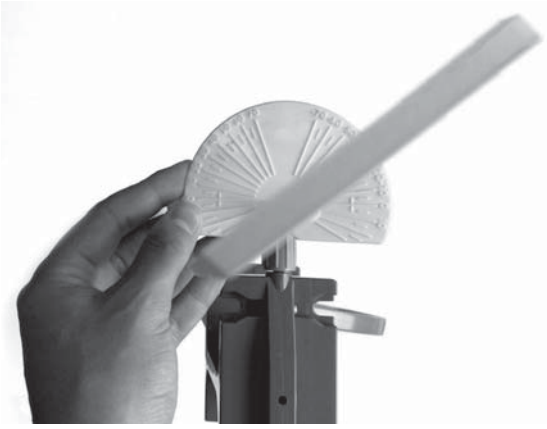
Independent Variable: Blade Pitch

Dependent Variable: Electrical Output

Controlled Variables: _____

Materials

- Poster board
- Dowels
- Scissors
- Masking tape
- Hub
- Protractor
- Turbine testing station (turbine tower, multimeter, fan)
- *Benchmark Blade Template*



✔ Procedure

1. Using the benchmark blade template, make three blades out of poster board. Space them evenly around the hub.
2. Slip the protractor around the dowel. Set the blades to a pitch of 90 degrees.
3. Put your hub on the turbine tower and observe the results. Record the data.
4. Set your blades to a new pitch and test again. This is your second trial. Record your data.
5. Repeat Step 4 at least once more to try to find the optimum pitch for the greatest electrical output.

Data Table

	PITCH	ELECTRICAL OUTPUT (VOLTAGE)
TRIAL 1	90 DEGREES	
TRIAL 2		
TRIAL 3		

Graph Data

The manipulated variable is written on the X axis (horizontal) and the responding variable is written on the Y axis (vertical).

Conclusion

Do you accept or reject your hypothesis? Use results from your data table to support your reasoning and explain which blade pitch you will proceed with for your next investigations and why.

Note: The pitch you decided was optimal for the greatest electrical output today will now be a controlled variable. You will continue to use this pitch in the next investigations.

2. Exploring Number of Blades

Question

How do the number of blades on a turbine affect electrical output?

Hypothesis

Make a hypothesis to address the question using the following format: If (manipulated variable) then (responding variable) because ...

_____

_____

Independent Variable: Number of Blades

Dependent Variable: Electrical Output

Controlled Variables: _____

_____

Materials

- Benchmark blades
- Poster board
- Dowels
- Scissors
- Masking tape
- Hub
- Turbine testing station
- Protractor

Procedure

1. Decide how many blades you will be testing and make enough blades for the maximum number you will be testing.
2. In the data table, put down the greatest electrical output from the blade pitch investigation of the three benchmark blades.
3. Put the number of blades you want to test into the hub. They should have the same pitch as in the previous investigation.
4. Put your hub onto the turbine tower and test the number of blades. Record the results as trial 1.
5. Repeat steps 3-4 at least two more times to try to find the optimum number of blades for the greatest electrical output.

Data Table

	NUMBER OF BLADES	ELECTRICAL OUTPUT (VOLTAGE)
BENCHMARK	3 BLADES	
TRIAL 1		
TRIAL 2		
TRIAL 3		

Graph Data

The manipulated variable is written on the X axis (horizontal) and the responding variable is written on the Y axis (vertical).

Conclusion

Do you accept or reject your hypothesis? Use results from your data table to support your reasoning and explain how many blades are ideal for a turbine.

Note: The number of blades with the greatest electrical output should become the benchmark blades for your next investigation.

3. Exploring Surface Area

Question

How does the surface area of a turbine blade affect electrical output?

Hypothesis

Make a hypothesis to address the question using the following format: If (manipulated variable) then (responding variable) because ...

Independent Variable: _____

Dependent Variable: _____

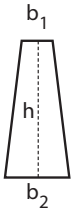
Controlled Variables: _____

Materials

- Benchmark blades
- Poster board
- Dowels
- Scissors
- Masking tape
- Hub
- Turbine testing station
- Protractor
- Ruler

Formula

Area of a trapezoid = ½(b_1 + b_2) h



Procedure

1. Calculate the surface area of the benchmark blade. In the data table, record the surface area and the greatest electrical output from your previous investigation of the benchmark blades. The formula for finding the area of a trapezoid is one half the sum of both bases, multiplied by the height or, $a=1/2\ (b_1 + b_2)\ h$.
2. Keep the same shape as the benchmark blade, but change the length and/or width. This will change the surface area of the blade.
3. Make your new blades. You should have the same number of blades that you found had the best results in your previous investigation.
4. Find the surface area for each of your new blades.
5. Put your blades into the hub and onto the turbine tower. Test for electrical output and record data.
6. Repeat steps 2-5 at least two more times to try to find the optimum surface area for the greatest electrical output.

Data Table

	SURFACE AREA	ELECTRICAL OUTPUT (VOLTAGE)
BENCHMARK		
TRIAL 1		
TRIAL 2		
TRIAL 3		

Graph Data

The manipulated variable is written on the X axis (horizontal) and the responding variable is written on the Y axis (vertical).

Conclusion

Do you accept or reject your hypothesis? Use results from your data table to support your reasoning and explain how surface area affects the electrical output. Why do you think this is?

Note: The blades with the surface area that achieved the greatest electrical output should become the optimum blades for your next investigation.

4. Exploring Mass

Question

How does adding mass to the blades affect the turbine's electrical output?

Hypothesis

Make a hypothesis to address the question using the following format: If (manipulated variable) then (responding variable) because ...

_____

_____

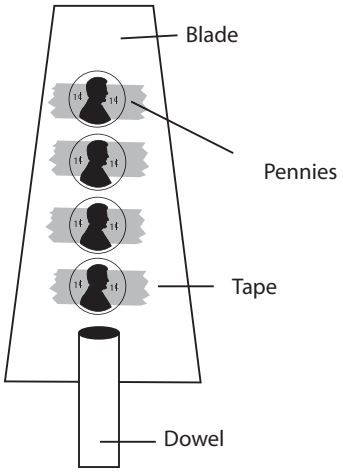
Independent Variable: _____

Dependent Variable: _____

Controlled Variables: _____

Materials

- Optimum blades from previous investigation
- Pennies (or other mass)
- Masking tape
- Turbine testing station
- Protractor



✔ Procedure

1. In the data table, record your results from your previous investigation on the row with zero grams.
2. Tape one penny near the base of each blade, an equal distance from the center of the hub.
3. Test and record the electrical output. Repeat, adding another penny. If adding mass increases the output, add more pennies one at a time until you determine the ideal mass for the greatest electrical output.
4. Distribute the pennies on the blades at different distances from the hub until you determine the optimal distribution of mass for the greatest electrical output.

Data Table

	ADDITIONAL MASS	ELECTRICAL OUTPUT (VOLTAGE)
OPTIMUM	0 GRAMS	
TRIAL 1		
TRIAL 2		
TRIAL 3		

Graph Data

The manipulated variable is written on the X axis (horizontal) and the responding variable is written on the Y axis (vertical).

Conclusion

Do you accept or reject your hypothesis? Use results from your data table to support your reasoning and explain how mass and mass distribution affect the electrical output. Why do you think this is?

Note: The blades with the mass that achieved the greatest electrical output should become the optimum blades for your next investigation.

Blade Aerodynamics Graphic Organizer

Objective

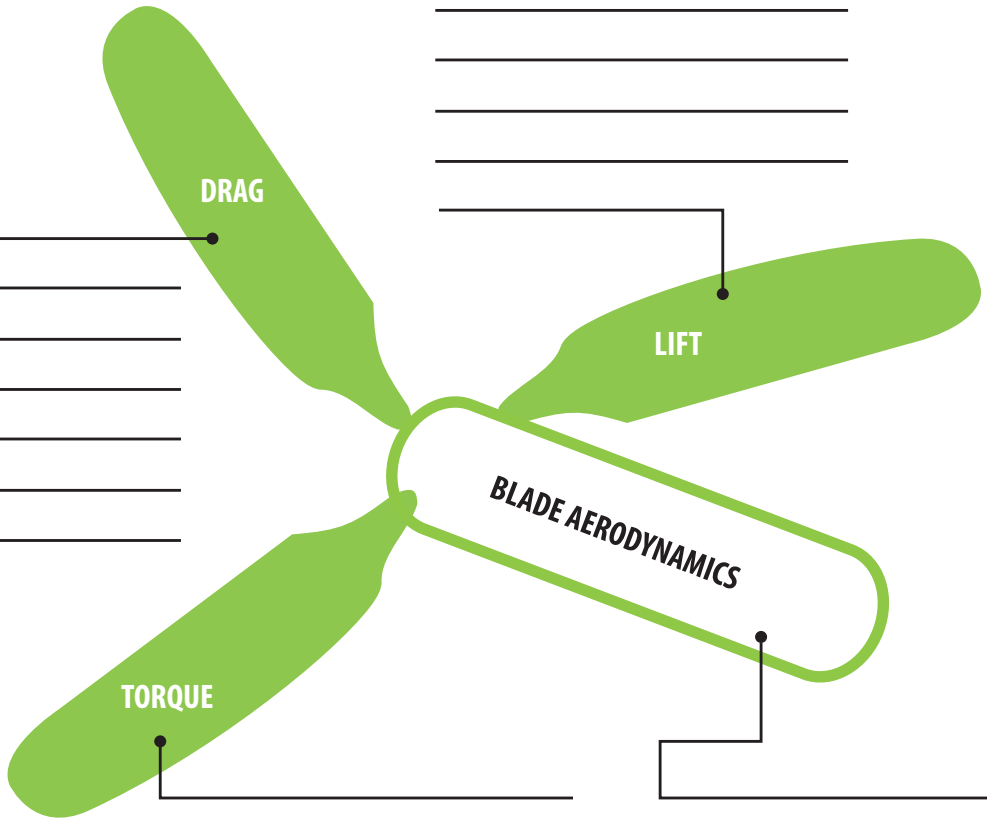
To identify important factors and principles that might influence the efficiency of a wind turbine.

To describe the following terms: drag, lift, and torque.

Question

Why do turbine blades move in the wind?

Define apparent wind:



Blade Aerodynamics

Objective

To describe how aerodynamics of blades can affect the turbine's efficiency.

Observations

How does the shape of the blade in this demonstration differ from your original benchmark blades?

How many airfoil blades provide the optimal electrical output? Compare this to your findings from the previous explorations, and explain any similarity or difference.

How is blade pitch affected when using an airfoil blade? Compare to your findings from previous explorations, and explain any similarity or difference.

Describe how mass and surface area may be affected when using airfoil blades. Cite evidence from previous investigations in your answer.

Conclusion

1. Would you choose to use an airfoil shape if designing the optimum blade for efficiency? Why or why not?

2. Describe what your plan might look like if you were to design the optimum blades for an actual wind turbine to be placed at your school.

Designing Optimum Blades

Challenge

The engineers at Wind for Tomorrow Turbine Co. want help to optimize their turbine blades for higher energy output. They are accepting bids from companies to design blades that more effectively convert kinetic energy than their current blade design.

Explore

Using data from your previous investigations and data from other groups, explore ideas for the best blade design.

✔ Make a Plan

In your science notebook, sketch your design, list the materials you will need, and detail the steps you will take to make the blades. Construct blades that will give you the greatest electrical output.

Data

Test and record the electrical output from your new blades. Compare your data to the benchmark blades in Blade Investigation #1 and your blades in Blade Investigation #4.

Data Table

BLADES	ELECTRICAL OUTPUT (VOLTAGE)
INVESTIGATION #4 OPTIMUM BLADES	
AIRFOIL TEST BLADES	
1ST DESIGN	
2ND DESIGN	

Analysis

How did the output of your new blades compare to the output of the airfoil blades and the optimum blades from the #4 investigation? In your science notebook, explain why your blade design is more or less effective than the comparison blades.

✔ New Plan

Using your data from the data table above, draw and describe specific changes you will make to your blade design to increase its electrical output and why you will make these changes.

☑ Redesign

Using your changes, alter the design of your blades, test, and record your data.

Analysis

How did the outcome of your re-designed blades compare to the output of the airfoil blades, the optimum blades, and your first design? Explain your results.

Report

Write a report to the Wind for Tomorrow Turbine Co. detailing your best blade design. Use data to explain why the company should or should not go with your design.

Investigating Gear Ratios

Question

How do different gear ratios within the gear box affect the electrical output of a turbine?

Hypothesis

Make a hypothesis to address the question using the following format: If (manipulated variable) then (responding variable) because ...

_____

_____

Independent Variable: _____

Dependent Variable: _____

Controlled Variables: _____

Materials

- Multimeter
- Fan
- Turbine
- Gears
- Optimum blades (from the previous investigation or investigation #4)
- Watch with second hand
- Protractor

✔ Procedure

1. In the table below, record your results from the previous investigation where you used the turbine with the standard gear ratio of 64:8 (64=tooth gear and 8=tooth gear).
2. Configure a new gear ratio (for example 32:8) with the turbine, making sure that you minimize all other variables (keep everything else the same). You have the option of three gear ratios (64:8, 32:8 or 16:8 – additional adjustment is required for 16:8 gear ratio.)
3. Turn the fan on and record the voltage output every 20 seconds for one minute. Record your results below and find the average.
4. Test different gear ratios to compare their effect on voltage output.

Data Table

	20 SECONDS	40 SECONDS	60 SECONDS	AVERAGE
STANDARD GEAR, BEST RESULTS				
GEAR RATIO 1				
GEAR RATIO 2				
GEAR RATIO 3				

Conclusion

1. Were the different gear ratios giving you consistent results? Why or why not?
2. What did you notice about the different gear ratios?
3. What did you notice about rotations per minute?