**Experiment #1: Testing the influence of sail area on boat speed.**

 Selecting the correct size and shape of a sail for a boat or a blade for a wind turbine is complex stuff. There are all sorts of considerations regarding the three-dimensional shape of the sail. However, we can perform a simple experiment to see how sail size influences the speed of a boat and by inference the amount of lift generated by the sail. Keep in mind that while bigger sails create more lift, they also create more drag. A sailboat with a displacement hull can only go up to its “hull speed” before it trips over its own wave and falls sideways. So a bigger sail is not always better!

 We will use three different-sized head sails on a 30-foot sailboat to measure the effect of sail area on speed. We will sail the boat on a beam reach (apparent wind coming from 90 deg.) for 5-minute trial runs.

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| --- | --- | --- | --- |
| Sail Number | Sail Area (m2) | Avg. True Wind Speed (Kts) | Avg. Boat Speed (Kts) |
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Determining the area of each sail:

1. Lay the sail on the ground and measure each side with a meter tape.

2. Use the formula below to calculate area in m2.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Sail # | a | b |  c | p =(a+b+c)/2 | herons formula in m2 |
| 1 |  |  |  |  |  |
| 2 |  |  |  |  |  |
| 3 |  |  |  |  |  |

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| --- |
| *A method for calculating the area of a triangle when you know the lengths of all three sides.Let a,b,c be the lengths of the sides of a triangle. The area is given by:*  |

|  |
| --- |
| *herons formula* |
| *where p is half the perimeter, or herons formula* |

**Questions**

1. Make a graph of Average Boat Speed (Y-axis) versus sail area (X-axis). Choose runs where the true wind speed was about the same for each sail size.

2. What can you conclude about the effect of sail area on boat speed?

3. How is this information important for designers of wind turbines?

4. Are sails only for recreational boats in the modern era, or can they be part of commercial shipping once again? What keeps modern commercial vessels from making use of wind power today?

**Experiment #2. Designing a windmill**

The classic Dutch windmill had four cloth blades. The one typically found on farms in the late 19th and early 20th centuries had numerous galvanized steel blades. Today's modern wind turbines use either 2 or 3 long, thin blades. In this experiment we will test effect of increasing the surface area by varying the number of blades on the rotor.

You will be provided with a windmill kit that has an LED. The kits come with rotors containing 6 blades. In this experiment you will change rotors to test the effect of number of blades (surface area) in producing electricity. You will compare 6-, 3- and 2- blade configurations.

1. Use the electric fan on the high setting to create artificial wind. Place the 6-blade rotor on the turbine and put it in front of the fan. Move the turbine away from the fan and measure the maximum distance from the fan that the LED light can be seen. Record that distance. Do the same for the 3- and 2-blade configurations. You may have to move the turbine back and forth several times to find maximum distance for LED illumination.

|  |  |  |  |
| --- | --- | --- | --- |
|  | 6-blade | 3-blade | 2-blade |
| Maximum Distance (cm) at which the LED produces light. |  |  |  |

What can you conclude about the role of surface area (number of blades) and the electricity produced by wind turbines? Is this consistent with modern wind turbine design? What is the difference?

1. Use 6-blade configuration to determine the effect of orientation toward the wind. Place the turbine close enough to the fan to produce a strong light. Next orient the turbine away from the wind 45 degrees. Then turn it 90 degrees to the wind. What effect does orientation have on speed of the windmill? Use sound as a clue to how fast the turbine is spinning.

**Web Investigation – Find the latest facts online! Be sure to include the URLs in your answers.**

1. What is the most recent estimate of the % of electricity in the United States that is produced by wind power?
2. Which nation produces the most electricity by wind?
3. Which nation produces the largest % of its electricity use by wind?