

Designing a Wind Turbine

In this lab, you will construct a wind turbine from some basic motors and plumbing parts (yes, you read correctly, plumbing parts). KidWind Project, a company that develops educational content for wind technology, created the materials and directions for this turbine assembly. See www.kidwind.org for more information.

The goal of this lab is to design a high-performance wind turbine through the intelligent design (aghast!) of blades. Everyone will be able to assemble their own wind turbine using the exact same number of components. You will be able to adapt your wind turbine with the number of blades used and the pitch of the blades. As you design the blade system for your turbine, focus on the concepts presented in the Wind lecture.

Materials

PVC turbine for turbine assembly	Tape
DC motor	Scissors
Coroplast (plastic) sheets	Turbine assembly instructions (KidWind)
Crimping hub	Vernier system with Voltage and Current probes
Wooden dowels	Decade resistance box

Procedure

Unpack your the materials above from your kit. Lay out your materials before beginning assembly being sure you have all the PVC pieces necessary to assemble the turbine base.

- Using the attached instructions published by KidWind, assemble the base of the wind turbine up to adding the crimping hub.
- Sketch out a design for your windmill blades. Think about what makes a good fan blade, but be creative as well. The only real suggestion is to make all of the blades identical in size and shape. You can use up to four (4) blades for your turbine.

Blade design sketch area

Use this space to begin sketching your blade design, including approximate dimensions.

Design aspects

Things to think about:

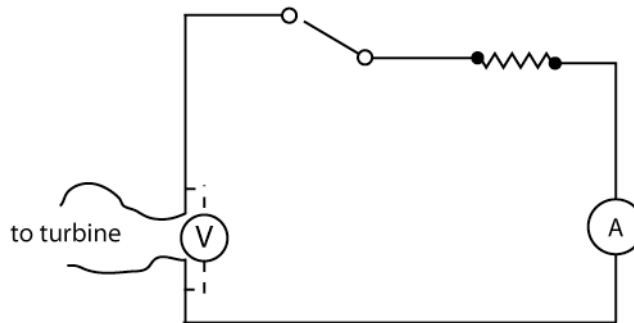
Drag: Are the blades catching the wind? Are they also letting the wind *flow* past them? Think about a big rectangular 18-wheeler on the highway. It catches the wind, but would it make a good windmill? Are the blades small enough to catch all the wind (from the fan)?

Methods for adjusting drag

- Number and weight of blades
- Angle of blades
- Length of blades
- Shape of blades
- Motor resistance

Procedure *cont'd*

- Cut out your blades, attach the wooden dowels to the crimp-on hub, and tape your fan blades to the dowels.
- Once your turbine is assembled, test out your performance with the fan (or outside) and Vernier voltage and current probes. You can use a Kestrel anemometer to get a windspeed. Record windspeed vs. voltage and current for your design and make modifications as you see fit. To construct this circuit, place the current probe in series with a resistance decade box set at 100 Ω. Collect data, averaging over 10 seconds at a time. Try adjusting the speed of the fan and/or moving the turbine. How does this effect windspeed, voltage, and current?



Fan speed	Average Voltage	Average Current (@ 100Ω)	Maximum power (W)	Measured windspeed (mph)
High				
Medium				
Low				

Can you calculate power on the LabQuest using calculated columns?

The voltage produced by the turbine is governed by the speed of the blade (and turbine) rotation. Measuring operating current of your turbine is essentially a direct measure of the electrons traveling through the circuit, translating to torque. (Why not electrons *produced* in a turbine?).

- Calculate a windspeed power curve, P vs. speed, for your wind turbine. What is the maximum power of your turbine? (Check with Dr. Beal about this definition)
- What is the efficiency of your turbine? This is little tricky to calculate because you must know the power *IN* as well as the power out. Recall that the power of the wind is given by the following equation:

$$\text{Power of the wind (watts)} = \frac{1}{2} \rho \cdot A \cdot V^3$$

ρ = air density, A = sweep area, V = air velocity

$\rho_{\text{air}} = 1.2 \text{ kg/m}^3$ at ambient temperature and pressure; Sweep area = πr^2 (*r in meters*)

$$\text{Watts} = \frac{1}{2} \left(\frac{\text{kg}}{\text{m}^3} \right) \times (\text{m}^2) \times \left(\frac{\text{m}}{\text{s}} \right)^3$$

$$\% \text{ efficiency, } \eta = \left(\frac{\text{power out}}{\text{power in}} \right) \times 100$$

Note: Power In should be multiplied by 0.597, the Betz limit to get a best case scenario.

$$\text{Power (Watts)} = \text{Voltage (V)} \times \text{Current (A)}$$

Watch your units!

Fan speed	Turbine power (W_{out})	Wind power (W_{in})	% Efficiency ($P_{\text{out}}/P_{\text{in}}$)
High			
Medium			
Low			

How much power is going unused? How could you modify your design to improve this? What is the Betz limit for your turbine?

- Try using the wind turbine to charge a capacitor. What can you run/light/power with it?
- Once everyone has assembled and tested their turbines, we will have a “wind-off” and see whose turbine generates the highest power under testing conditions.

Thought and Discussion

Given what you learned from the “wind-off”, how would you modify your blade design: Shape of blades? Number of blades? Pitch of blades?

1. What happens to the power of the wind (air) when the air temperature is cooler than normal (such as NY in the winter)? What about when it is warmer? Think about the concept of density (mass *per unit* volume).
2. Given similar wind speeds, how would the power of the wind differ on Jupiter, where the atmosphere is composed mostly of hydrogen and helium (density = 0.16 g/cm^3)?

