Teachers at a Kidwind Workshop at the National Wind Technology Center Learning about wind turbine blade design and testing.

Wind Turbine Blade Design

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2/06 Version 1.3

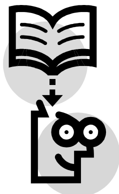
The production of the kits and other materials related to wind energy have been generously supported by these agencies.

We would like to thank the *Wright Center for Science Education* at Tufts University for giving us the time and space to develop a nugget of an idea into something that has proven to be useful to hundreds of teachers.

We would also like to thank Trudy Forsyth at *National Wind Technology Center* and Richard Michaud at the *Boston Office of the Department of Energy* for having the vision and foresight to help to keep the Kidwind Project going! Lastly we would like to thank all the teachers for their keen insights and feedback on making these wind turbine kits and materials first rate!

The production of this document was supported in part by the National Renewable Energy Laboratory through subcontract LEE-5-55877-01.

Lesson Zap! - Wind Turbine Blade Design



Background

Blade design and engineering is one of the most complicated and important aspects of current wind turbine technology. Today engineers strive to design blades that extract as much energy from the wind as possible throughout a range of wind speeds and gust yet be durable, quiet and cheap.

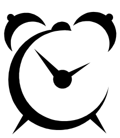
Objectives:

Students will be introduced to:

- The Design Process
- Scientific Method
- Science of Blade Design
- How to collect, evaluate and present data

Suggested Level

Middle & High School



Time Required

At least 5 class periods

Materials Required

- Some type of model turbine that can quickly interchange blades
- Multimeters or Voltage/Current Data Loggers or Multimeter Box
- Box fans
- Rulers
- Pictures of Wind Turbine Blades
- Scale Model Turbines (optional)
- PowerPoint of Wind Turbines Blades (optional)
- Wind Speed Meter (optional)
- Tachometer (optional)

<u>Blade Construction Materials:</u>

Cardboard, Balsa Wood, Tissue Paper, Plastic, Paper Cups, Index Cards, Exacto Knifes, Scissors, Glue, Tape, String, Knex, Lego, Tinker Toys, Popsicle Sticks, Toothpicks, Hot Glue Guns

Lesson Plan in a Nutshell

This lesson has students go through the design process and the scientific method to test important blade variables. Students then use this data create an optimal set of wind turbine blades. You can do the basic lesson in 3-4 days or extend with a larger challenge that takes 5-7 days.

Part I (Days 1-2)

During the first day try to link wind energy to other topics you have covered (energy, generators, weather & wind, etc.) and help students understand blade basics and set up primary experiments.

- What are wind turbines?
- How do wind turbines transform the energy found in the wind?
- What are the major variables that impact energy production?
- How can we develop an experimental protocol to test these variables?

Part II (Days 2-3)

During the next two days students will build and test blades according to their experimental protocol. Once this is completed they will share their results with their peers in a formal setting.

- What variables have the most impact on power output?
- Do some variables matter more than others?
- What is the best way to share the results?

If pressed for time you can stop at this point.

Part III (Days 3-4-5)

Once students have heard from their peers about the most important variables we can now ask them to create an optimal set of blades incorporating these results.

- What did my peers say about blades?
- How can I incorporate this research into my final design?

Part IV (Day 5)

This is a testing and evaluation day. Today you will test the student made blades on a standard set up for how much power they generate. You can also have a competition to evaluate the creativity and engineering prowess of your students. It is fun to make this a day celebration!

Doing the Activity - A Wee Bit of Preparation

When to explore wind energy

You can explore blade design at a variety of points in a the Middle and HS curriculum. I have seen teachers use these materials in energy, weather and environmental science units. Physics teachers have used it to teach aerodynamics. Personally I use it to teach students how to properly set up and use the scientific method while exploring something new and different. Technology teachers have used this lesson to teach about the design process. Some teachers have used this lesson as a small segment in a month long exploration of wind energy. As you can see it is all over the place!

Classroom Wind Turbines

To run these experiments you will need some classroom wind turbines. ***Kidwind*** has developed a number of easy to construct PVC wind turbines. Plans and materials can be found at http://www.kidwind.org/. ***Kelvin, Pitsco, Boreal Labs*** and ***Pico Turbine*** also have wind turbine kits that will work with this lesson plan. There are some nice plans for building wind turbines from *Windpower.org* and from *Renewable Energy Canada*. Addresses to these plans can be found at the Kidwind website.

Some of the wind turbines above are designed to make electricity others are designed to lift weights. You can use either one in these experiments as this lesson is exploring blade design. For this lesson we assume you are using electrical generating turbines.

For a class of 25 students it is recommended you have 3-4 wind turbine testing stations around the room. You can get away with two but things will slow down at the turbines. You can also have each student use their own turbine but that can get expensive.

Fans

You will need 2-3 box fans to produce wind. The bigger the better. You can change wind speed by moving the turbine away from the fan or turning the fan lower. Please note that wind coming off of a fan is ugly, turbulent stuff that is not really like the wind your turbine would find outside. Modern wind tunnels pull air through to get a more realistic affect. You can build one of these but it will add significantly to the prep time.

Blade Construction Materials

Place all of the construction materials in one central location on a table or desk. Put all the working tools in a location where you can monitor their use and make sure that students are using them safely. It is useful to have some blades, turbines and hubs ready so you can demonstrate how to safely use the tools and turbines.

Pictures, Slides and Websites

You'll want to have some large pictures, a PowerPoint slide show with some images of large turbines and some close ups of their blades. Many great resources can also be found on the web check the resources section for these.

A Small Prize

At the end of the blade design challenge it is fun to give small prizes to the top sets of blades and the kids really get into it. We have given away T-shirts with funny wind logos, but treats and other things work as well.

Part I

Setting up the Experiments

Your first job will be to link the topic you are currently covering to the wind turbine model that is sitting on your desk. Students will be curious about the model turbine as they enter class. Let them examine it until you want to start. Once they are settled you can start asking questions to gauge their knowledge of wind energy and wind turbines.

Some possible questions…I am sure that you can think of many more.

- What do they think these devices are and what do they do?
- Have they ever seen a wind turbine in real life? How big was it?
- Where do we get our electricity from that powers our homes?
- Why would we want to build wind turbines?
- Where are the major wind projects occurring in the US?
- How much energy do we get from wind?
- How much could we get?
- How much do they get in other countries?

You can let this go for 5-10 minutes. There will be lots of questions. Answer the ones you can, challenge them to "look up the answers" to ones that you are not sure about. **(If you are looking for an intro lesson to electricity use in the US look at KidWind Lesson - Energy Notions.)**

Now we want to narrow down our discussion to the blades.

Show them the wind turbine. Spin the hub and show them how it makes electricity or moves a weight. This is a good time to show them a picture of a real wind turbine and how the one you are using is similar and different.

Ask the students' what they think will affect the power output from the wind turbine. You will get many answers; wind speed, generators, designs, size etc. Hopefully someone will say blades. Push them on this idea. What if we had the same generator at the same wind speed what would **PRIMARILY** determine the power we can get from this turbine? **THE BLADES.** That is what we are going to explore for the next couple of days.

Blade Variables

We now want to explore some of the variables that affect how much energy the blades can "capture". Ask the students what some of these variables might be. The list below is a start.

Length	Number	Weight	Pitch/Angle
Shape	Material	Curvature	Twist
Wind Speed			

As you can see there are quite a few variables which makes it interesting and challenging. Students may have others that are not on this list. If the variable sounds testable and the students can present a solid argument and plan for testing I'd let them do it.

Test Plan

Break students into groups of 2-3 and give them a ***Blade Experiment Sheet.*** Make sure they fill out and understand this sheet completely before starting experiments. **This will make your life much easier**. In many cases I pick a group to torture and they must come up to the front of the class and explain what they are going to do in detail. While they are doing this I pepper them with *why* and *how* questions about their research.

> While students are demonstrating how they will perform their experiments it is a good time to talk about safety.
>
> Things to look out for:
> - Students using tools improperly.
> - Standing in the plane of rotation while testing blades.
> - Goggles off while testing blades.
> - These are all BAD!!!

For the next two class periods the students will perform these regulated experiments on one blade variable (length, shape, etc). Once they have collected their data they will need to produce a graph and make a short (3-5 min) presentation to the class about what they discovered.

Using the data discovered from all of the groups students will then have an additional 1-2 class periods to make and test an optimal set of blades for a design competition.

Problems & Issues:

- Make sure they understand how to analyze one variable — VERY IMPORTANT that you approve and they follow their work plan. Take your time with this!
- Groups of two or three are best.
- Blade pitch is very important make sure this group understands what this is and how they will measure it.   Inadvertently changing blade pitch can also can mess up other experiments. Make sure that students keep pitch constant while testing other variables or the results can be problematic.

Blade Construction & Testing

Once students have an approved plan they can start to construct and test blades. As they are doing this make sure they sticking to their plan, are being safe and are collecting meaningful data. Remind them that they must be prepared to make a presentation to the class at the end of experimentation and that you will grade this presentation (they love that one).

Problems & Issues

- Students sometimes take too much time making blades. For this part of the lesson they do not need to be perfect. They need to work efficiently as they need to collect data from 3-4 different tests.
- Students need to know how to record voltage and amperage with a simple multimeter. Make sure you have done this yourself and can explain to the students. **Having the units correct is important**! You do not want to multiply volts times milliamps….you will get a very large incorrect number. It is OK to just record voltage which can make things easier.
- The hubs on many homemade wind turbines are not industrial scale. At high RPMs the blades may come off. If this continues to happen students need to find a solution (glue or tape). **SAFETY!! SAFETY!**
- Often there can be a wait at the testing stations. Student only need a few minutes to test and then change their blades. **More stations = less waiting.**
- Having the same fans at each station would be ideal but sometimes not possible. Make sure that students use the same fan and at the same speed. This is important during testing!

Presentations

Once you feel that your students have collected enough data they should answer the questions on the ***Blade Experiment Sheet*** and make a larger graph of their data to present to the class. Students can draw on the chalk board, but it is nice if it is on a large piece of paper so you can post it and the students can refer to it later. The data collection handout is a guide to giving their presentations . Tell them to discuss what they wrote down on their paper.

Remind students that it is a good idea to pay attention as the team that harnesses all of these variables most efficiently will probably win the competition step.

The questions below will help you examine the data more generally.

- What variable has the greatest impact on power output?
- What type of blades worked best at low speeds? High speeds? Were they the same types blades?
- What numbers of blades worked best?
- What shapes worked the best?
- What length worked the best?
- What problems did you encounter?
- What is the impact of quality of construction?
- Did the materials got really bendy when they got longer - was this a problem?
- What happened when the wind turbine blades were bigger than the fan?

Once the discussion is finished post the graphs and student "reports" where all students can read them. This data will be useful as they create their optimal blades.

Optional Discussion Idea

Write a simplified wind energy equation on the board. This equation was developed over years during experimentation.

Power in the Wind

$$P = 1/2\ \rho\ A\ V^3$$

Power = ½ x AIR DENSITY x BLADE AREA x WIND VELOCITY^3

There are a variety of questions that can be asked once they see this equation?

Ask them if they think the data the class collected reflects the basics of this equation. Based on this formula what is the most important variable? What is the next most important? What variable in this equation did we not test? What variables did we test that are not expressed in the formula? Why might their findings conflict with this equation. **HINT** - *It is common to find in a classroom that bigger blades do not make much power….this is typically due to the fact that large student made blades also have lots of drag! Something to look out for!*

Class Period 3 & 4

Setting Up the Challenge

Based on the data and the presentations give the students 1-2 class periods to create an optimal set of blades. Hopefully they learned something from their peers. Their final set of blades will be evaluated in three ways (you may pick one use all three)

- **Power output at low and high wind speeds**
- **Quality of Construction**
- **Level of Innovation**

Power output in this lesson will be measured by voltage and amperage or just voltage. If you are using other types of wind turbines you will compare weight lifted, or if you have a geared wind turbine that has more power output you can calculate the amount of water pumped etc. Quality of construction and innovation can be evaluated by the whole class using the voting sheets in the resources section. We recommend evaluating all three things as you give students with a variety of skills a chance to show mastery.

It is nice to have models of well constructed and innovative blades. That is tough the first time around, but as the years go by you will accumulate quite a few, I know that I have.

Working on the Optimal Blades

Same rules apply as students work on their second set of blades. One thing to watch out for is students taking lots of time to prep and not testing their blades. They need to get these things attached and tested so they can modify them. It can be a little depressing if a student spends two periods on a beautifully crafted blades and then they are total flop when they test them.

One way to make this more challenging is to limit supplies or attach costs to supplies. This cuts down on waste and makes students think a little more before junking materials.

Evaluating the Blades

If you plan on evaluating quality of construction and innovation I recommend having the students help out! Make all the students display their blades on a desk or table. They should label them with a card to identify them. Spend 10-15 min having the students walk around and evaluate the blades. In the appendix we have included voting sheets that you can use. It is also an opportune time for you as the teacher to do your own grading as well. You can even have students predict what blades will be the best and why.

Once the voting and evaluation is finished collect their sheets and get onto power output testing. Use students as recorders, timers and multimeter experts. Let each student mount and set their own blades.

Place the turbine at about one meter away and let it run for 30 seconds. Record data (voltage, amperage or both). We recommend picking the highest number you see in 30 seconds. Make sure that a student is recording this data. Do the same in low speed conditions, to simulate low speed you can turn the fan down or move the wind turbine back 2 meters. If after a few seconds students want to adjust let them do it once but that is it!

After all of the blades are tested, collect them in one place. Copy the data collected on the board so the students can transcribe the data to their **homework sheets**. Depending on their experience you may need to help them calculate power output in watts. (These numbers will be small and we will compare these values to other things they may be familiar with like light bulbs and refrigerators. Most of these model wind turbine make much less than 1 watt...small when compared to a light bulb at 60w!)

Conclusion/Discussion

It may take a day to tabulate all the data, but once you select the blades that make the most energy, are most innovative and well constructed (these can be the same or different). You can give small prizes to these student engineers. We often give t-shirts to denote champions.

Further Study (Optional)

Ask the students if they looked at "real" wind turbine blades while making their blades? How are they different or similar to your blades that you have created?

If you can find some model airplane propeller blades develop a way to attach them to the hub and test. Make sure to turn these propellers around as on a plane they are designed to push air not "catch" it. Record the data from the low and high speed tests on the board. These blades may be much more effective than the ones they built. They may not if you have really smart students!

Ask them why are these blades are so much more effective? The easy answer to this is that these blades produce and harness lift much like a plane wing does. Except in this case the "wing" is attached to a hub to produce rotational motion. This is where things can get interesting. Discussion about blade design can get as complicated as you would like about and you can use the supporting materials to go as deep as you would like

Wind Energy is Here & Now

If you have the time and money take your students to see a wind turbine or wind farm. The American Wind Energy Association has listing of wind farms on their website. Head to **http://www.awea.org** to see if there is a wind farm near your school. They often love to give tours to students.

One important thing to leave with students is that wind energy is a technology that is here and now. The large scale production of energy from the wind is not futuristic or far fetched, it is happening NOW.

Recent research from ***Smart Power*** shows that one of the major failures of the renewable energy movement is that people do not realize renewable energy technologies are viable and available right now. This is especially true of wind energy and needs to be emphasized.

It is also important to have some discussion about the limits of wind energy and some of the benefits/challenges it will pose to communities where it is sited. As we must go where the wind resources exist these challenges will occur in many locations. These challenges include view shed impacts, proper siting to avoid migration pathways, noise, and the intermittent nature of the resource. To examine these issue we recommend checking out **Kidwind Lessons on Wind Farm Siting or Scale Models.**

Additional Resources

Additional resources for this lesson can be found on the KidWind website.
http://www.kidwind.org/materials/Lessons/bladedesign/bladedesign.html

http://www.windpower.org/en/tour/manu/bladtest.htm
A great page from Windpower.org on how they do blades tests on commercial wind turbines. Windpower.org is a fantastic site for all sorts of wind energy information. This page http://www.windpower.org/en/tour/wtrb/lift.htm also has nice information about blade design.

http://www.awea.org/projects/
The American Wind Energy Association has a great deal of interesting information on wind energy. But this page will tell you if there are any wind turbine projects in your state.

http://www.nrel.gov/data/pix/
At this website you can get tons of really neat wind energy pictures. Do a text search for wind turbines, blades, whatever and you will get lots of images to look at and download.

http://www.kidwind.org/materials/buildingwindmills.html
We have compiled a long list of ideas for building your own wind turbine. We have complete kits and even instructions on how to do it yourself and where to find other types of kits for sale.

http://www.lmglasfiber.com/
This is one of the largest wind turbine blade manufactures in the world. They have a great picture archive and neat info on the testing and development of the latest blade technology. Neat site to poke around on.

The world's largest test bed for rotor blades is located at LM Glasfiber in Lunderskov, Denmark. It can test blades of up to 80 meters in length using state-of-the-art testing methods.
Source http://www.lmglasfiber.com

Student/Teacher Handouts

Name ___________________________ **Blade Experiment Sheet**

What variable will you test for your experiment? ___________________________

Describe how you will perform this experiment. BE SPECIFIC! What materials will you use, how many times will you test, how will you change your variable, how will you record output. **Use another sheet if necessary!**

Important!! What things do you have to keep the same (constant) as you perform this experiment?

Make a prediction! What do you think will happen as you change your variable?

Teacher Authorization to Begin Experimentation ______________________

Data Tally Sheet

Trial #	Variable (Length, Number, etc)	Voltage (mV or V)	Amperage (mA or A)	(*V x A*) =Power (mW or W)
1				
2				
3				
4				
5				
6				

Make a quick graph of your data

Power Output
Voltage?
Wattage?

Variable Tested (Length, Number, etc)

How did the voltage/amperage/wattage change as a result of manipulating your variable?

Do you think that your variable has a large or small effect on power production?

What was the optimal setting for the variable that you tested?

If you were a lead design engineer what would you recommend your company do to their turbine blades? Why?

What problems did you encounter as you performed your experiments? What other variable was it hard to hold constant?

Design Team _______________ Wind Turbine Blade Competition

Details: The ***WindNRG Corporation*** needs a team of wind engineers to design and build a set of blades for their new wind generator. These blades must be durable, quiet and effective at converting the energy of the wind into electrical energy.

Time: Unfortunately the ***WindNRG Corporation*** needs these blades fast. You have two periods to build and test an optimal set of blades.

Design Constraints:

- Can use any materials found in the resource area
- Cannot use any manufactured blades or propellers
- Blades cannot be more than 20” long
- Must have no “sharp” points
- Must keep track of the materials you use on your data sheet
- Must test blades at least once before presentation time

Competition
Each blade set will be tested at high and low wind speeds for 30 seconds. Power output will be calculated and averaged. The team with the highest average output will be the winner.

Design Questions

How many blades do you plan to place on your hub? ____________________

How long are you going to make these blades? ____________________

What materials are you going to use? Why are you going to use these materials?

After your first test what modifications did you make to the blades? Why did you make these modifications?

Final design

How many blades _________

Length of Blades _________ (cm)

Width of Blades _________ (cm)

What materials did you use to make your blades?

Individual Power Data

High Wind Speed	Voltage _______	Amperage _______	Power Output _________
Low Wind Speed	Voltage _______	Amperage _______	Power Output _________

Average Power Output (High & Low) ____________________________

Class Data

Group	Blade #	Materials	Length (cm)	High Power	Low Power	Average
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Which blades seemed to perform the best?

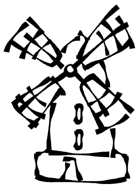
Why do you think that they did well?

How would you change your blades to perform better?

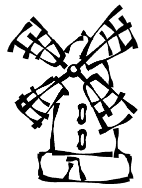
NICE JOB! You are done with your work!

Optional Voting Forms

You can use these forms to have students vote on each others creations. This allows you to compare power output to other characteristics that are important. Place all the blades on a table with labels and let the students vote. Tally votes (1st—3 points, 2nd—2 points, 3rd—1 point). Team with the most points wins that category.



Windmills
Voting Form



Quality of Construction

________ 1st Place

________ 2nd Place

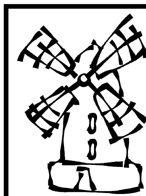
________ 3rd Place

Innovation

________ 1st Place

________ 2nd Place

________ 3rd Place



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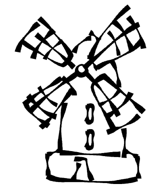
Voting Form



Quality of Construction

________ 1st Place

________ 2nd Place

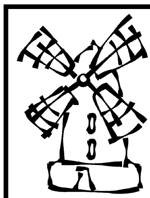
________ 3rd Place

Innovation

________ 1st Place

________ 2nd Place

________ 3rd Place



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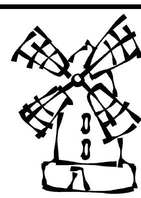


Quality of Construction

________ 1st Place

________ 2nd Place

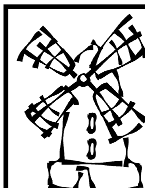
________ 3rd Place

Innovation

________ 1st Place

________ 2nd Place

________ 3rd Place



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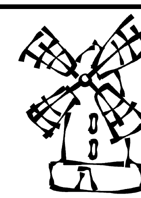


Quality of Construction

________ 1st Place

________ 2nd Place

________ 3rd Place

Innovation

________ 1st Place

________ 2nd Place

________ 3rd Place

Additional Information

Fans, Wind & Testing

We are stuck using fans to test our wind turbine blades and unfortunately they create really bad air flow. It is really turbulent, rotational and varies quite a bit throughout the column of moving air. Fans definitely have limits...and it is good to realize that! If you have time you can try to build a wind tunnel, but this can get complicated. One quick way to “clean” up the air is to build a honeycomb of circles or squares in front of the fan. You can use milk cartons, PVC pipe or other items to do this. It will slow the wind coming off the fan, but it will also straighten it out.

SAFETY & BLADE TESTING AREA

◊ It is important to wear safety goggles when constructing blades with hot glue or sharp knives.

◊ You should always stand **<u>in back of</u>** or **<u>in front of</u>** the wind turbine during testing. If you stand in the PLANE of ROTATION you could be hit if your blade flies off during testing.

◊ Never make blades using metal or any sharp edged material as these could cause injury while spinning fast during testing.

◊ The voltage and current produced by your turbine is not enough to cause injury, but it is always a good idea to treat electricity with care and caution.

SETUP FOR TESTING

Safely set up your testing area like the picture below. It is important to clear this area of debris and materials.

Make sure the center of the fan matches up with the center of the wind turbine. You may need to raise your fan with some books or a container

Stand In Front or Behind Turbine

NEVER STAND HERE!!!

Power in the Wind — A simple look

If a large truck or a 250lb linebacker was moving towards you at a high rate of speed you would move out of the way right?

Why do you move? You move because in your mind you know that this moving object has a great deal of ENERGY as a result of its **mass** and its **motion** and you do not want to be on the receiving end of that energy.

Just as those large moving objects have energy so does the wind. Wind is the movement of air from one place on earth to another. That's the motion part.

What is air though? Air is a mixture of gas molecules. It turns out that if you get lots of them (and I mean lots of them) together in a gang and they start moving pretty fast they can definitely give you, a sailboat or a windmill a serious push. Just think about hurricanes, tornadoes or a very windy day!

Why aren't we scared of light winds while we stay inside during a hurricane or wind storm? The velocity of those gangs of gas molecules have a dramatic impact on whether or not we will be able to stay standing on our feet. In fact, in just a 30 mph gust you can feel those gas molecules pushing you around.

Humans have been taking advantage of the energy in the wind for ages. Sailboats, ancient wind mills and their newer cousins the electrical wind turbines, have all captured the energy in the wind with varying degrees of effectiveness. What they all do is use a device such as a sail, blade or fabric to "catch" the wind. Sailboats use energy to propel them through the water. Wind mills use this energy to turn a rod or shaft.

A simple equation for the ***Power in the Wind*** is described below. This is instantaneous and does not take time generating power into consideration.

$$P = 1/2\ \rho\ \Pi\ r^2\ V^3$$

ρ = Density of the Air
r = Radius of your swept area
V = Wind Velocity

From this formula you can see that the size of your turbine and the velocity of the wind are very strong drivers when it comes to power production. If we increase the velocity of the wind or the area of our blades we increase power output. The density of the air has some impact as well. Cold air is more dense than warm air so you can produce more energy in colder climates (as long as the air is not too thin!).

You could calculate the peak power production of your wind turbine using this equation. It will be way off as it leaves out a number of variables that impact the actual power output of your turbine. This includes things like how well your blades transform the energy in the wind and the efficiency and type of generator that you are using. It might be fun to calculate the hypothetical and compare it to how much you are producing and generate some efficiency numbers. Be prepared to be shocked at how low your efficiency is.

We recommend you check out the Kidwind website for more links that explore this equation and its variants in more complexity.

How to use a Multimeter with your Wind Turbine

Small DC motors do not produce much power when we spin them slowly. Direct drive you will not get more that 1 volt. On a wind turbine with gears we can increased the power output (2-4 volts) using gears to spin the shaft of the generator faster than the hub.   Kidwind sells both geared and direct drive turbine systems at their website http://www.kidwind.org.

Power = Voltage (V)   X Current (A)   <—- **Watch Your Units**

Make sure you are recording volts and amps (not milli or microvolts unless you want to!)

Voltage

1. Attach the wires from the generator to the multimeter.

2. To check the voltage select DC Volt (V) and choose a the whole number setting say up to at least 5 volts.

Set at 20 DC Volts

3. Place your turbine out in the wind or in front of a fan and let it run up to speed. It is normal for the readings to fluctuate. Power output is not steady because the wind is not steady.

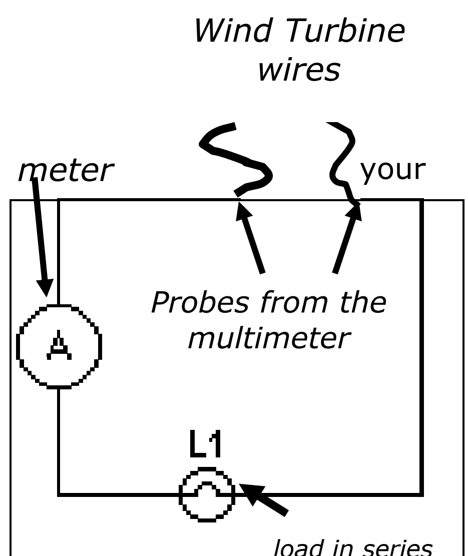
4. When you are measuring voltage you are measuring how fast the DC generator is spinning. The faster it spins the higher the voltage. As there is no load on the generator it has very little resistance so it can spin very fast. If you look closely when you add a load (like a light bulb) the RPM may drop as will your voltage.

Amperage

1. To get a more accurate picture of the power output of turbine you should measure amperage as well. To accurately measure the amperage you need to hook up your multimeter differently.

2. You need to place a load (or a resistive object - small bulb, resistor, pump etc.) in series with the meter so that the generator is "loaded" and has to do work.

When you are measuring amperage you are measuring how many electrons your turbine can push. This relates to how much torque your blades are generating.



To accurately record current you need to put a load in series. In this picture you can see the load (bulb, pump) between the connection with the meter and the turbine

DON'T FORGET!

TURN OFF THE METER OR THE BATTERY WILL DIE!!

More Power: How to Improve Your Blades

Kidwind model wind turbines are designed for use in science classes or as a hobby or science fair project.   They were created to allow students a cheap method to perform various blade design experiments quite quickly. They are not specifically designed to light bulbs, spin motors and charge batteries but they can if you have a good fan and manage to design some efficient blades.   **Having efficient blades is a key part of making power from a wind turbine. Sloppy, poor made blades will never make enough energy to do anything. It takes time and thought to make good blades so get to it!!!**

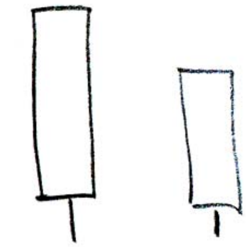
One thing you must always think about when making turbine blades is, **"Are my blades creating DRAG?"**. Sure your blades are probably catching the wind and helping to spin the hub and motor drive shaft, but are they slowing you down as well? Because if they are adding **DRAG** your who system will slow down and in most cases low RPM means less power output. The faster you go the more power you make!

Some tips on improving blades:

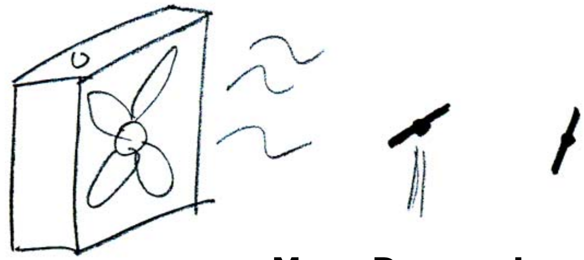
- **SHORTEN THE BLADES** - Many times students make very big, long blades thinking bigger is better. Well in the turbine business bigger is better, but students and teachers have a very hard time making long blades that add lots of drag and inefficiency. See what happens when you shorten them a few centimeters.
- **CHANGE THE PITCH** -   Often students will set the angle of the blades to around 45° the first time they try to use the turbine. Try making the blades flatter towards the fan and see what happens. Pitch dramatically affects power output, play with it a bit and see what happens.
- **USE LESS BLADES** - In an effort to reduce drag try using 2, 3 or 4 blades.
- **USE LIGHTER MATERIAL** - In effort to reduce the weight of the blades use less material or lighter material.
- **SMOOTH SURFACES** - The smoother your blade surface the less drag you will have. A blade with lots of tape and rough edges will have more drag.
- **GET MORE WIND** - Make sure you are using a decently sized box or room fan. Something with at least a diameter of 14"-18".
- **BLADES VS. FAN** - Are your blades bigger than your fan? That could be a problem as the tips of your blades are not catching any wind and are just adding drag.
- **BLADE SHAPE** -   Are the tips of your blade thin and narrow or wide and heavy? The tips travel much faster than the root. That means if you have lots of junk out there you will add more drag.

These are a few ideas to help you improve your turbine blades. For more information head to www.Kidwind.org and look for the Blade Design Lesson under the curricular materials. There are lots of helpful links and ideas there to help you make the best blades.

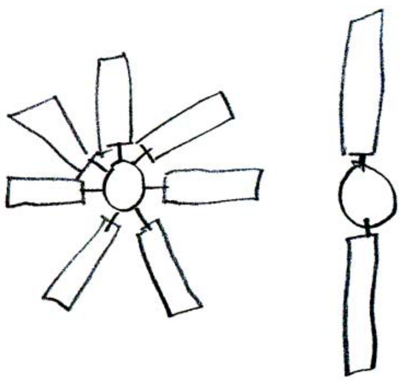
How to Reduce Blade Drag!!



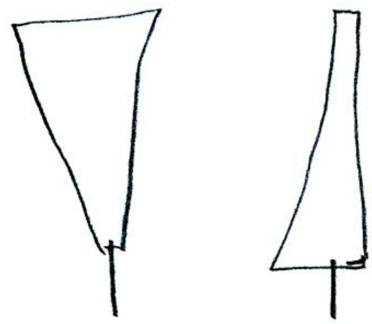
More Drag **Less Drag**



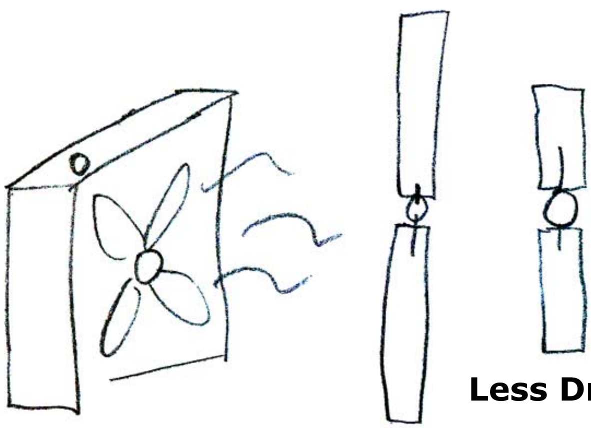
More Drag **Less Drag**



More Drag **Less Drag**



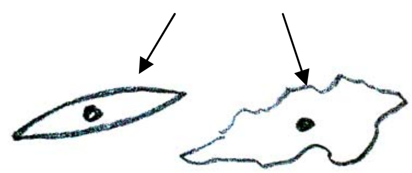
More Drag **Less Drag**



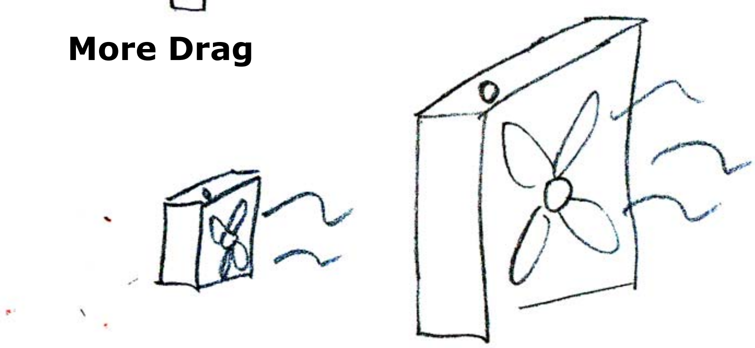
Less Drag

More Drag

Blade Cross-Section



Less Drag **More Drag**



Less Wind **More Wind**