Wind Turbine Generator Project
High School Physics Level

Dave Parker
National Board Certified Physics Teacher
Noble High School
North Berwick, ME 03906
dparker@sad60.k12.me.us

## Abstract

Students design wind turbine blades and explore the harnessing of wind to generate electricity. Through hands-on inquiry, students modify and improve their original design, then take data to map the electrical and mechanical performance of their wind turbine and evaluate the efficiencies of the individual steps and the system as a whole.

## Design of the Project

This unit is designed in accordance with Science Curriculum Topic Study, and the following is the Hierarchy of Content Knowledge for this Topic.

The Unifying Themes are Systems, Models, and Science, Technology and Society.

The Big Idea is Energy Transformation.

The major Concepts are Electricity, Mechanical Energy, Design and Modification

The Specific Ideas addressed are Data Acquisition and Evaluation, Work, Power, Energy, Efficiency, Ohm's Law, and Graphing.

Classroom setting: 18-22 students per class, heterogeneous grouping, required course for graduation, 80 minute block schedule, class meets every other day, rural public high school.

## Introduction

Wind power is becoming an increasingly important source of energy. Students hear about it in the news and see small and large scale applications in many places. This is a change that is happening within their short lifetime, and they are inherently interested in knowing more about it. The concept of Going Green is resonating with this age group, so now is the time to teach it!

The materials are not expensive. "Wind" is supplied by a square 20" window fan. Having one fan per group of students works best, but two groups can share one fan without being slowed down too much. The wind turbine base is a piece of 1/2" plywood 8" x 24". The shaft that the turbine blades rotate on is the hub from a bicycle wheel (I found a local shop that donated used hubs, and I gave them a receipt for tax credit on their donation). I made a wooden block that supported the hub and left the axel end extended beyond the end of the base to allow for blade clearance. To generate electricity, I used a small gearmotor from a hobby supply site. The motor is designed to produce 170 RPM on the output shaft when supplied with 6volts DC, but when you put rotation into the drive shaft, you get voltage and amperage out. These motors worked well and students typically generated 2-10 volts DC, up to 300 milliamps, and up to one watt of power. I built a wooden block to support the gearmotor with the shaft aligned with the bicycle hub. To connect the hub and gearmotor, I used a universal joint from a radio-controlled car. The gearmotor had a 1/8" shaft that the universal joint fit onto and locked in place with a setscrew. The outer diameter of the universal joint was 5/16" which was the same OD as the inboard end of the bicycle hub shaft. To connect the universal joint to the bicycle shaft, I used a piece of 5/16" ID clear plastic tubing. The friction fit was sufficient, and this solved any minor misalignment problems between the gearmotor and the bicycle shaft.

The wind turbine blades are designed by the students from whatever material they want to use, the cardboard from cereal boxes worked well. I supplied 3/8" dowels cut 10" long to mount the blades on. Masking tape was sufficient for attaching the cardboard to the dowel as long as students taped it carefully so that blade angle could be controlled.

Mounting the blades on the bicycle hub shaft was challenging. I originally used TinkerToy® hubs as they have the right bore size for the shaft and socket size for the blade dowels. The hubs relied on a friction fit that often allowed the dowel to move and alter blade angle. I had our Regional Vocational Center machine some two-piece aluminum hubs for the project, and they worked much better. These hubs have 12 radially spaced sockets for the blade dowels, giving students design options of 2, 3, 4, 6, or 12 blade turbines, and the two-piece design allows the students to clamp the dowels in place securely. If you have multiple classes, you will want enough hubs that each group in each class can have their own hub throughout the project. I found that when students had to remove their blades at the end of a block, and remount them next class, small variations in blade angle created large variations in test data, resulting in problems calculating efficiencies. When students could use one hub and therefore not alter their design once established, the results were very consistent.

Students test their blade design by seeing how fast it turns without a load, how much current it produces with a significant load. The gearmotors have a nearly linear relationship of speed and voltage, so an easy test for speed is measuring the no-load voltage; attach a voltmeter to the two motor leads and record DC voltage with the fan blowing on the blades. Current under load is tested with a multimeter set on DC milliamps and a 10Ω resistor connected in series to the two motor leads. Students will see and hear the turbine slow down when the resistor is attached and the motor starts generating current. Students can compare their results with other students' results to see how effective their design is. They can also determine which their design is better at; speed or torque, and look at other designs for ideas on how to improve their week area.

The wind turbine base also has a 1" diameter hole drilled directly beneath the clear tubing connection between the bicycle hub shaft and the universal joint. This is where the string from the cup comes up and ties around the clear tubing for the Direct Drive power evaluation. The power that the blades extract from the "wind" is determined by putting weights in the cup, measuring how high the cup is lifted, timing how long it takes to lift the weight and calculating a mechanical power. (watts = kg * g * m / sec). This is data for Part Three.

The second base is also 1/2" plywood, 8" x 24". This is the base for the Useful Power section of Part Three. I used a wooden block to support another gearmotor (identical gearmotor that the main turbine base uses) connected to another universal joint. The other end of the universal joint is connected to a 1/8" diameter 4" long section of brazing rod. The rod is supported on bearings (RC car supply site) that are mounted in wooden blocks. There is a 1" diameter hole drilled through the base below the shaft for a string that is tied to a cup. Students connect wires from the gearmotor on the wind turbine base to the motor on the second base and use the generated electricity to lift weights. The output power that the gearmotor delivers is determined by putting weights in the cup, measuring how high the cup is lifted, timing how long it takes to lift the weight and calculating a mechanical power. (watts = kg * g * m / sec).

Students graph power as a function of tip speed to see the "loss of energy" going from wind to electricity, and from electricity to mechanical power. This allows an exploration of where that "lost" energy goes, and how our current electricity generation, distribution and usage impact our society. Overall Efficiency is typically 10-15% for student wind turbines, and in our society, overall efficiencies are similar for fossil fuel generated electricity, the losses of the distribution grid, and the efficiency of the devices that run on electricity.

This unit takes about three weeks of class time. The reports that the students hand in break the assignment into four distinct parts that work together. In the first report, the focus in on the Engineering Design Process; design, testing, modification, re-testing and critical evaluation of strengths and limitations. The second report focuses on understanding and communicating the electrical generating capability of their wind turbine generator at various loads and speeds. The third report focuses on the input power to the turbine and the delivered power after transforming wind power to electricity, and using that electricity to do mechanical work. The final report focuses on the efficiencies of each step, the overall efficiency, and the impact of the overall efficiency on our society.

| | | |
|---|---|---|
| Supplies: | gear motors from Hobby Engineering | www.hobbyengineering.com |
| H02530-01H | miniature gear motor 170 RPM | $19.99 each |

Bicycle hubs were donated by a local bike shop (used) (offer a receipt for tax purposes!)
Universal joints were from a hobby supply website, Hobby Engineering should carry them soon.
Resistors, multimeters, jumper wires from Radio Shack

Bearings from www.teammaximus.com or any RC car supply store 1/8" bore x 3/8" OD
Shaft is 1/8" brazing rod from Ace Hardware
Photogate is from Vernier
Motion detector could also be used under the cup as the cup is being lifted.