Wind Power

Practical activities to investigate
the power of the wind and the
design and operation of wind turbines.

Acknowledgements

Wind Power is one of a series of five publications collated by the Queensland Sustainable Energy Industry Development Group, a non-government alliance of organizations whose aim is to enhance the sustainability of Queensland's energy supply. Each of the topics in the series contain a range of practical activity-based workshops for use in Queensland schools and aims to allow students and teachers to explore and discover the fundamental principles that underpin sustainable energy.

Other activity sets in this series include

- Global Warming and Climate Change
- Passive Solar Building Design
- Photovoltaics (Solar Electricity)
- Solar Cooking

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Special thanks to Peter Williams for assistance in collating these materials.

Wind Power provides a range of activities, suitable for mid-primary through to senior secondary school, allowing teachers to choose the level of activity most appropriate to their students' needs. A little background information for teachers is also provided, as well as a list of additional resources that will provide teachers with more in depth background information, ideas for assignments and/or more practical activities. Teachers and students are encouraged to utilize these additional resources (predominantly from the Internet) to enhance their understanding of the topic and to keep up with the rapid developments in the area of sustainable energy.

These **Wind Power** workshop activities have been provided from the organisations acknowledged below, and we gratefully acknowledge their valuable contribution and their willingness to allow these materials to be more widely disseminated:

Workshops 4a&b — Research Institute for Sustainable Energy,
Murdoch University, South Street, Murdoch WA
www.rise.org.au

Workshop 1 — Energy Action Australia,
c/ ecco2sol Global Energy Solutions,
36 Deniven Street, Corinda QLD 4075
www.esded.com.au

Workshops 2,3,5b — ATA (Alternative Technology Association),
PO Box 2919, Fitzroy VIC 3065
www.ata.org.au

Learning about Energy

Renewable energy should not be studied as an isolated topic, without consideration of the context in which it operates. Whilst renewable energy technologies play a very important role in reducing the greenhouse emissions in our society, a holistic approach to energy demand and supply, one that first addresses energy services and energy efficiency, is needed if our society is to become sustainable.

The following information about energy resources and energy services is taken from Chapters 1 and 2 of the book *Introduction to Renewable Energy Technologies,* published by the Renewable Energy Centre, Brisbane North Institute of TAFE, ISBN 1 876880384.

Energy sources

The society we live in uses energy - lots of it - to run the systems and services that we depend on. Where does all this energy come from? All our energy sources come from the natural world, so where can energy be found, and in what form?

Often the source of energy is not considered by the end user because the source is so remote and the energy is delivered by the relevant utility without us needing to know where it came from. It is important to be aware of the technology supplying our energy needs and to be aware of the impact that technology has on the environment.

Energy can be generalised into two categories: ***renewable*** and ***non-renewable***.

Renewable sources of energy are those which are continuously replenished by natural processes on the earth within relatively short periods e.g. 24 hours, a week, or a year. Examples include solar, wind and hydro energy. ***Geothermal energy*** is the only one for which the energy available may decline locally over time because of human use.

The sun rises daily offering a fresh supply of energy every 24 hours regardless of how much it gave us the day before. The wind can blow day or night regardless of the season, and even if we empty our dams, the rain will come again to renew our hydro resources. We know that the sun will continue to rise daily and that wind and rain will continue to happen. Since these sources of energy are renewed within the course of a human life, they are classed as renewable.

Non-renewable energy sources are those with finite reserves, and are not renewed within our lifetimes. They may take millions or billions of years to form, so in practical terms, once they are used they are gone forever. These are the fossil fuels such as oil, gas and coal; and nuclear fuel - i.e. uranium.

The major advantage of these fuels, and the reason why we have been able to use them so extensively, is that they are highly concentrated energy sources, and they can be easily stored.

Energy use

Prior to the Industrial Revolution, human societies were largely dependent on renewable energy sources such as solar energy. Solar energy was used to heat, cool and light homes and to dry crops. Wind and water power ground wheat and pumped water. Wood was used for cooking, crop drying and space heating. Now in most countries, we use a combination of fossil fuels, nuclear fuels and renewable energy.

In Australia, it is estimated that 94% of our energy demand is met from fossil fuels and only about 6% from renewable energy. However, the contribution of renewable energy to our total energy demand has been largely underestimated. For example, the contribution renewable energy makes to crop drying and production, or to space heating, cooling and lighting of buildings is not currently included in government estimates of energy consumption. The solar energy used to dry clothes on an outdoor clothes-line is never accounted for, yet when the same clothes are dried in an electric clothes dryer, the energy required is part of the official economy and is therefore counted.

Energy services

The whole purpose of our use of energy is that it provides us with services. Whether it is light to read by, refrigeration for food or just getting from place to place, it is the service that we are after, not the joules. Joules or kilowatt hours or litres of petrol in themselves are of no use to us! Whenever we design an energy system then, we need to consider the system from the starting point of ***energy services***.

Your lifestyle determines what energy services you require and this is where the whole story starts.

In a domestic dwelling, these energy services are usually fairly clearly defined. They depend most of all on lifestyle. They also depend to some extent on location. A list of the major categories of energy services are as follows:

Heating	Space heating, water heating and cooking
Cooling	Space cooling, refrigeration
Lighting	Visual (task oriented) & mood
Entertainment	TVs, DVDs, music systems, computers, electronic games etc.
Communication	Phones, computers, office equipment
Work	Cleaning and maintenance appliances and tools (e.g. washing machines, dishwashers, vacuum cleaners, power tools, lawn mowers etc), office equipment
Other	Water pumping, waste disposal

Energy could be supplied for these services from different energy sources and in different combinations. Where energy is supplied by a utility, this will usually be electricity or gas. Where a dwelling is remotely situated, a generator and portable gas cylinders are often used to provide the same services.

Our aim should be to select the source that is most appropriate for each service. This means taking into account the first and second laws of thermodynamics (i.e. efficiency and energy quality), other factors such as environmental impacts, as well as the usual economic constraints. This often means replacing fossil fuel energy sources with renewable energy sources, and it always means maximising the efficiency of energy use.

The following table shows the proportions of energy use in the home in Queensland. Water heating is usually the largest consumer of energy, often accounting for more than one third of the energy use in the household. The energy required for space heating, cooling and refrigeration depend very much on climate. It is interesting to note the dramatic increase in air-conditioning in many parts of Australia in recent years. Is it because the climate is much hotter or because our lifestyle expectations have changed?

Energy Service	Australian average* Proportion of Household Energy Use (End- Use)	Brisbane average** Proportion of Household Energy Use (End- Use)
Water heating	27%	38%
Refrigeration	9%	16%
Cooking	4%	10%
Lighting	5%	11%
Space heating & cooling	39%	11%
Standby / ghost power	4%	6%
Other / appliances	12%	8%

*Data from AGO 1999

** Data RMIT – Green Plumbers (data for 1998)

NOTE 1: For Brisbane between 1994 and 2001 there has been an increase in the daily average energy use per person of 20.4% (Courier Mail. Oct 2001)

NOTE 2: the typical standby power is now said to be around 11% of the daily energy use.

Composition of household energy use in Australia and a sample for Brisbane.

Of course there is no such thing as an 'average' home, and your household energy use may vary from these figures considerable. Variations are largely dependent on climate and life style choices.

Wind Power

Background information

The energy in the wind has been used by humans for centuries to provide a variety of services for us, for example:

- Drying (e.g. clothes, food)
- Transport (e.g. sailing ships)
- Entertainment: sport (e.g. wind surfers), music (e.g. wind chimes), fun (e.g. kites)

A wind turbine is the general name for the technology that utilizes the energy of the wind to turn a wind machine (mechanical energy). The earliest wind turbines were used around 200 BC in Persia (modern day Iran). These turbines used sails mounted on a giant merry go round and were used for grinding grain. Vertical axis windmills, like the ones we use today, were developed around the 10th century in the Mediterranean Sea and the 13th Century in Europe.

The Dutch Windmills were invented around the 15th Century and were still in widespread use up until the early 1900s. Australian water pumping windmills, like those found on outback stations, have been manufactured in Australia since about 1903.

Key principles

Modern wind turbine generators convert the mechanical energy into electricity which can be either stored in batteries, or used directly. They produce electrical energy through a series of steps:

1. Wind causes the blades of the turbine to spin due to kinetic energy, or the energy of movement.
2. Spinning blades cause an axle and magnets to rotate inside a coil of conducting wire.
3. Electricity is generated in the wire when the magnets spin around inside the coil.

There are **three basic physical laws governing the amount of energy available from the wind**.

The **first law** states that the power generated by the turbine is proportional to the wind speed cubed. For example if the wind speed doubles, the power available increases by a factor of eight; if the wind speed triples then twenty seven times more power is available! Conversely, there is very little power in the wind at low speed. This law means that accurate and detailed local wind speed data is necessary to determine the likely energy yield from a given site, and generators should be designed for that particular site. Average wind speed information alone is often of limited value.

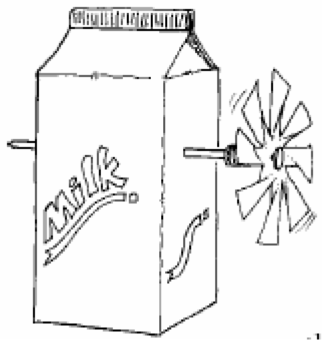
The **second law** states that the power available is directly proportional to the swept area of the blades, i.e. the power is proportional to the square of the blade length. For example, doubling the blade length will increase the power by four times, and tripling the blade length will increase the power by nine times.

The **third law** states that there is a maximum theoretical efficiency of wind generators of 59%. In practice, most wind turbines are much less efficient than this, and different types are designed to have maximum efficiency at different wind speeds. The best wind generators have efficiencies of about 35 - 40%. Practical wind turbines are designed to work between certain wind speeds. The lower speed, called the 'cut in speed' is generally 4 - 5 ms^{-1}, as there is too little energy below this speed to overcome system losses. The 'cut out speed' is determined by the ability of the particular machine to withstand high wind. The 'rated speed' is the wind speed at which the particular machine achieves its maximum rated output. Above this speed, it may have mechanisms that maintain the output at a constant value with increasing wind speed.

Additional resources

1. www.greenhouse.gov.au: website of the Australian Greenhouse Office: lots of information about renewable energy in Australia, government programs, policy issues etc.
2. www.epa.qld.gov.au/environmental_management/sustainability/energy: Qld government website with specific information about Queensland programs and resources.
3. www.rise.org.au: Research Institute for Sustainable Energy, Murdoch University: RE Files: a series of fact sheets on renewable energy technologies
4. www.ata.org.au: Alternative Technology Association: a not-for-profit environmental organization; provides information, advice and publications about renewable energy and other sustainability issues to the community.
5. www.anzses.org.au: Australian and New Zealand Solar Energy Society: news, events, extensive links to a range of other sites
6. www.bcse.org.au: Business Council for Sustainable Energy: contains information about renewable energy projects and issues in Australia
7. www.auswea.com.au: website of the Australian Wind Energy Association: the best site to visit to get the latest information about wind farm developments in Australia.
8. http://www.windpower.org/en/kids: excellent interactive and educational website with lots of information and activities for students of all ages (as well as teachers!)
9. http://www.nrm.qld.gov.au/energy: Qld government site regarding energy policy and regulations as well as energy resources.
10. www.bom.gov.au: the Australian Bureau of Meteorology.

Workshop 1: Propeller Design



Context

The blades of the rotor are designed to spin in the wind, driving the turbine generator. The design of wind propeller blades affects the efficiency of wind turbines. the blades need 'capture' as much of the wind as possible, transferring the movement of the wind into mechanical energy.

Curriculum Links

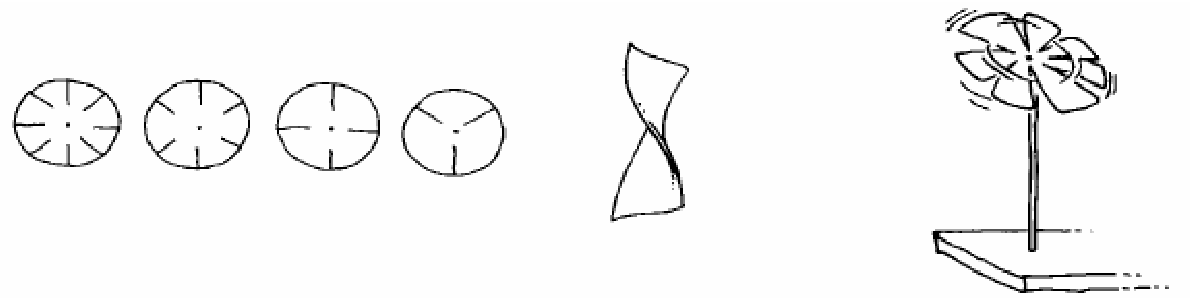
Science, Energy and Change: level 2+

Equipment needed

- Material from which to cut *blades*: e.g. card, aluminium pie plates, plastic containers
- Cotton reels and spools to act as *hubs*
- Nails or coat hanger wire for *spindles or axles*
- Drinking straws or washers for *spacers*
- Milk cartons or plastic bottles for *stands*, and sand to weigh them down
- Iceblock sticks for hand holders
- Blu-tack or plasticine, glue, scissors, and paints or crayons.

What to do

Using the designs presented as a start, allow the students to freely experiment with different blade shapes to construct their own 'windmill' then test it under a number of wind speeds (e.g. the wind outside, their own breath, a fan). The pictures below show some patterns for propellers.

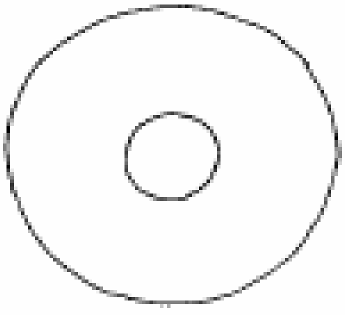
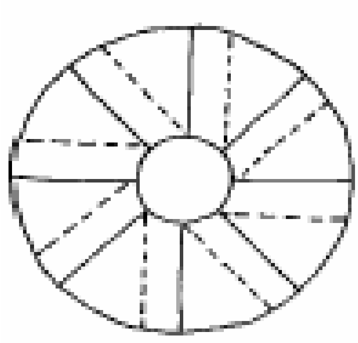
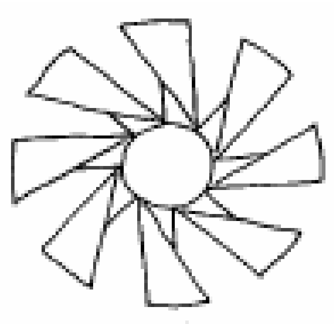


Another possible design is shown below:

Step 1: Draw a small circle within a larger circle; cut out the larger circle

Step 2: Mark solid and dotted lines as shown

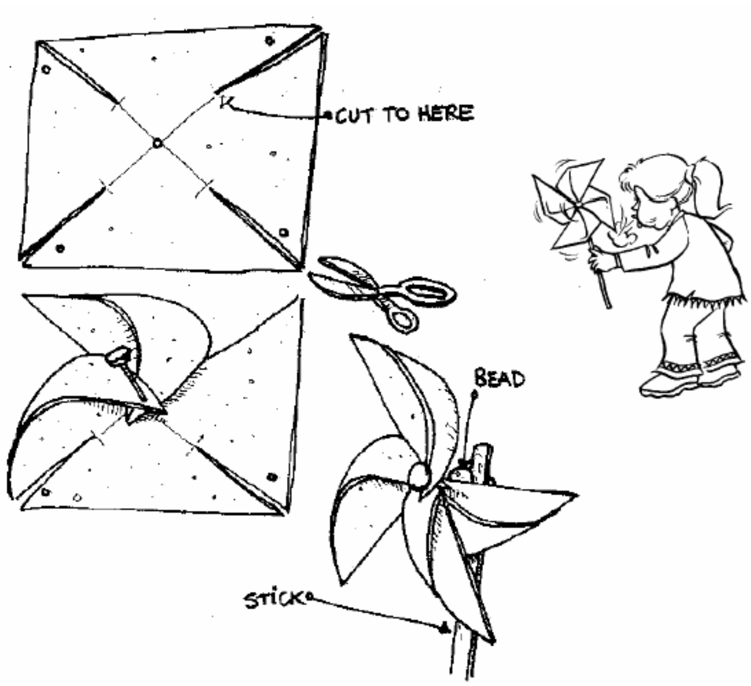
Step 3: Cut on the solid lines and fold on the dotted lines as shown

Step 1 Step 2 Step 3

Try out some of these designs (or your own) and find which ones spin best. You might hold a competition for the mechanically most efficient, or the best workmanship, and/or the best appearance.

Have the students determine how the efficiency of the models could be tested. One way would be to have an electric fan provide a standard wind speed, and counting the revolutions per 10 seconds. (You will need to colour or mark one blade in order to do this.)



Workshop 2: Building a horizontal axis wind turbine

Context

Wind turbines are classified into two main categories, depending on whether the blades rotate around a horizontal or vertical axis. A horizontal axis wind turbine (the most common type fro wind farms) will usually have a tail or a motor to make it turn to face into the wind. As the wind hits the propeller blades, the air is deflected to one side, causing the propeller to move in the opposite direction, thus causing the turbine to rotate.

Curriculum Links

Science, Energy and Change: level 3+

Equipment needed

- a cork from a wine or champagne bottle
- a drinking straw
- a bike spoke or straight piece of stiff wire
- an aluminium can or a plastic drink bottle (In this project, you can make your propeller blades from either the drink can or the plastic bottle. If you decide to use the can, be careful, as cutting the can will leave sharp edges and sometimes small needle-like points of metal.)
- snips or scissors
- a knife

What to do

To start with, you need to cut both the top and bottom off of the can and bottle. The easiest way to do this is to poke a hole through the bottle or can and then cut around so that you end up with straight-sided tubes.

Next, you will need to cut three strips from the bottle or can, each strip about two centimetres wide, and as long as possible. You can see how this is done in Figure 1.

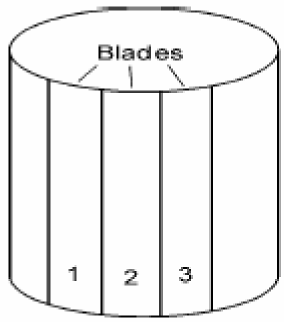


Figure 1. You cut out your blades from the can or bottle like this.

Now mark the centre of each end of the cork and push the bike spoke through the cork so that it goes straight down the centre of the cork.

Using the knife (and a good deal of care so as to not cut yourself) make three evenly spaced cuts in the cork. These are where the blades will fit, so they need to be angled at about 30 degrees to the bike spoke.

Now carefully slide each blade into place in its slot, making sure that the curved side of the blade is toward the front. Place a small dab of glue on each blade where it meets the cork, so that the blades will not come out when the turbine is turning.

When the glue is dry, you just place the straw over the bike spoke and you have a finished wind turbine. You can see how to assemble the turbine by looking at figure 2.

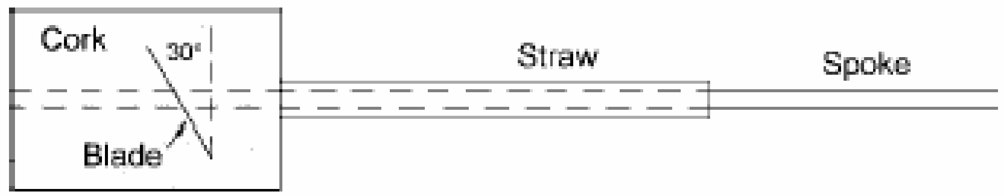


Figure 2. This is how you assemble the turbine.

To make the turbine rotate, you can blow on it, hold it into the wind, or even run along with it.

Other things to try

If you have used metal blades on your wind turbine, you can twist them so that their angle at the end of the blades is less than the 30 degrees at the base. If you do this, the wind turbine will rotate faster for the same wind speed. Why does this happen?

. . . .

. . . .

Another thing you may want to try is tying a small weight onto the bike spoke at the other end from the cork, and then dropping the turbine from a height. What do you think will happen?

. . . .

. . . .

Workshop 3: Building a vertical axis windmill (a Savonius windmill)

Context

Savonius Rotors are high torque, low speed vertical axis wind turbines that can be simple to construct. The plans presented here use some aluminium cans and cardboard, a piece of coat hanger wire and a soft drink bottle. A wide variety of other materials are also suitable.

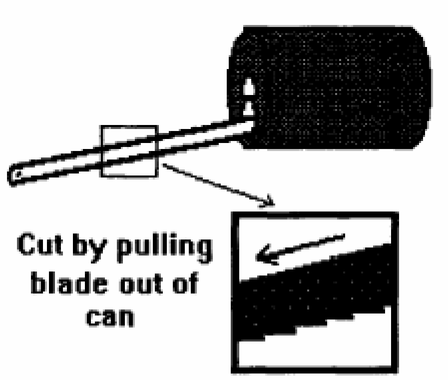
Curriculum Links

Science, Energy and Change: level 4+

Equipment needed

- An aluminium can
- A coat hanger or a bike spoke
- Strong epoxy glue (e.g. Araldite)
- Some thick cardboard
- A small (375ml) drink bottle and a cork
- Tools (drill, hacksaw or hacksaw blade, wire cutters or tin snips, scissors, small hammer)
- A compass and a protractor
- A nail

Fig 1.



What to do – Making the cups

Draw a line around the middle of the can vertically, so that it is divided into two equal halves. Using a hacksaw blade, you need to cut the can in half, using the line as a guide. (Start from the open side of the can. Insert the blade with the teeth pointing downwards and cut by drawing the blade out of the can - Figure 1). Each half will look like a trough with one open end.

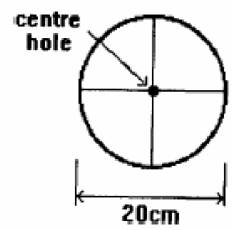
Using a small hammer, flatten each side of the half-cans so that the cans can be glued to a flat surface. Cut a small "V" in the top and bottom of each half can, about 1cm in from the side opposite the opening.

Making the rotor

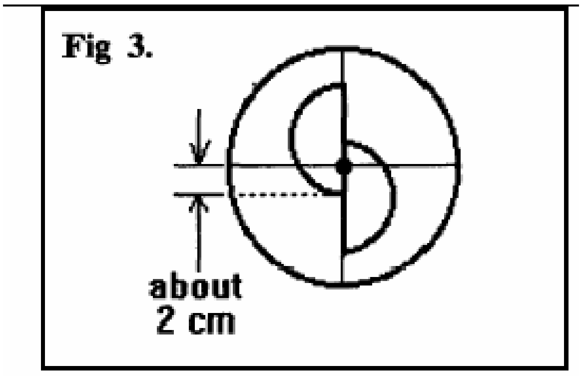
First make the shaft. Use wire cutters or tin snips to cut a length of bike spoke or wire coat hanger about 30cm long.

Using a compass, draw two circles, each 20cm in diameter, on your cardboard. Now mark out where the cups are going to go by drawing on one of the circles two diameters at right angles from each other (Figure 2).

Fig 2.



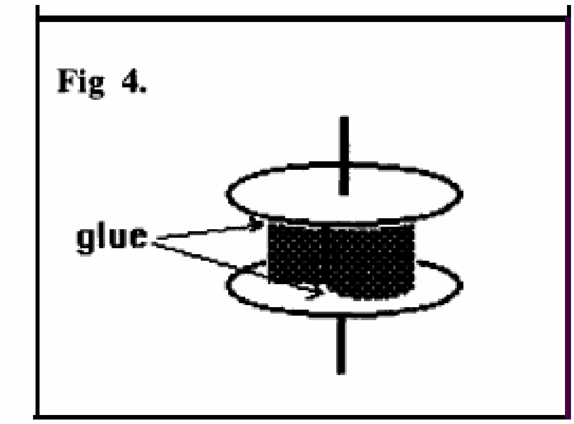
Graphics by James Hamlyn-Harris



Cut out the circles and use the shaft or nail to poke a hole through the centre of each circle.

Use a strong glue to glue the cups to the cardboard, lining them up along one of the lines, with the inside edges overlapping by about 2 cm, as in Figure 3. It is best to have the two open sides of the can on the outside of the circle, so one half will have to be upside down.

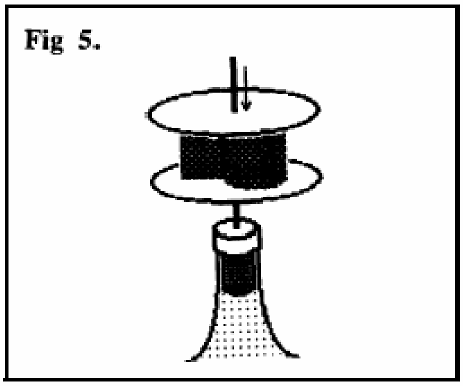
Next, glue the other circle to the tops of the cans, making sure that the edges of the top circle line up with the edges of the bottom one (Figure 4).



Making the base

Fill the drink bottle with water (to make it heavy and stable), leaving enough room for the cork to go in the top. Wedge the cork firmly into the neck of the bottle. Poke the shaft (the piece of spoke or coat hanger) into the centre of the cork. Take the lid of the bottle and, using the nail, tap a hole in it. Slide it onto the shaft, so it sits upside down on top of the cork, to make a bearing for the rotor to spin on (Figure 5).

Now slide your finished rotor onto the shaft, and make it spin! If the holes in the cardboard are too tight, and the rotor doesn't spin properly, wiggle the rotor gently to make the holes a little bigger.



Put a fan near the windmill, and notice that it will spin in the same direction regardless of which way the air is moving.

Extension Activity

Use your knowledge of motors and windmills to design and build a small Savonius windmill to power some garden lights at home or at school. You may find some designs on the Internet.

Workshop 4a: Calculating the efficiency of turbine blades

Context

One common type of windmill blade is the simple curved metal plates seen on windmills (wind pumps). The propeller blades of modern wind turbines used to generate electricity, however, tend to be shaped much more like aircraft wings, producing both lift and drag forces. Blade design and manufacture is complex, but affects the efficiency of the turbine.

Curriculum Links

Science, Energy and Change, level 5+

Senior Physics, Geography, Multistrand Science

Equipment needed

- Wind turbine propellers (make your own from a variety of materials and/or use examples of 3,4 and 6 bladed plastic propellers available from science education suppliers)
- Blu Tac or similar
- Motor A: 1.5 V, 200mA DC Motor (from Solar Energy Education Kit - number 689 - available from electronics and hobby stores)
- Motor B: 2.0 V, 50mA DC Motor
- Multimeter
- Fan
- Set of connecting leads (e.g. Alligator Clips)

What to do

Connect a two blade propeller to motor A by carefully inserting the axle of the motor through the small hole in the centre of the propeller. Secure the propeller by placing a small amount of Blu Tac over the axle and the propeller. Carefully insert the motor into the plastic motor stand (You may need to loosen the screw on the stand to allow the motor to easily slide through) (Figure A)

Connect the multimeter to the motor by clipping one of the alligator clips to one of the pins at the back of the motor. Connect the other alligator clip to the other pin at the back of the motor (Figure B).

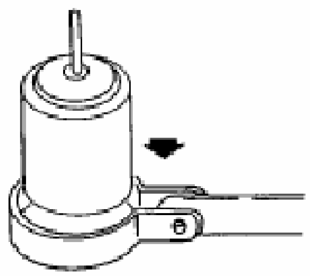


Figure A

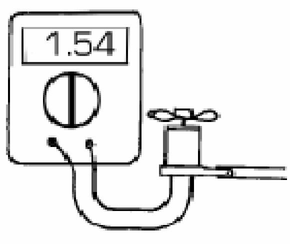


Figure B

Place your wind turbine model in front of the fan and turn the fan on. Move the turbine around in front of the fan until you find the maximum current output. To ensure that you are carrying out a *fair test*, mark this spot so that you can return the turbine to this spot each time. Using the *Results Table* below and the multimeter, record the current and voltage being generated by this propeller. Next, record the current and voltage being generated when you switch the fan to the highest setting.

Number of propeller blades	**Low Speed**		**High Speed**	
	Current (I)	**Voltage (V)**	**Current (I)**	**Voltage (V)**
2				
3				
4				
6				

Results Table

Repeat the experiment using other types of propellers.

When you have completed the table, calculate the amount of power being generated for each of the blades and the different wind speeds. For fixed resistance in a circuit, power is proportional to both current and voltage according to the relation: $P = VI$

Use the following table to record your calculations.

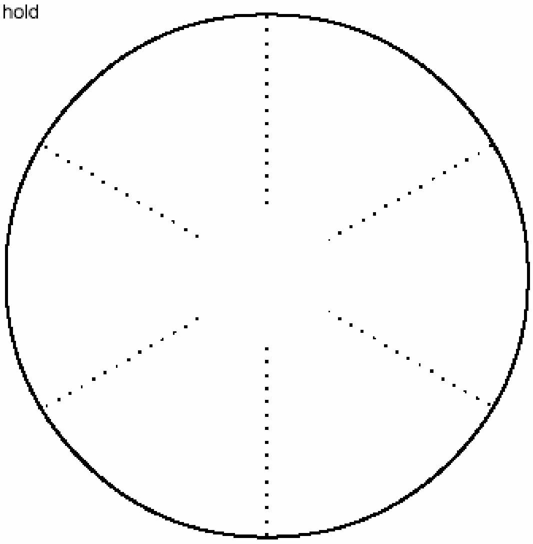
Blades on Propeller	**Power Generated**	
	Low Speed	**High Speed**
2		
3		
4		
6		

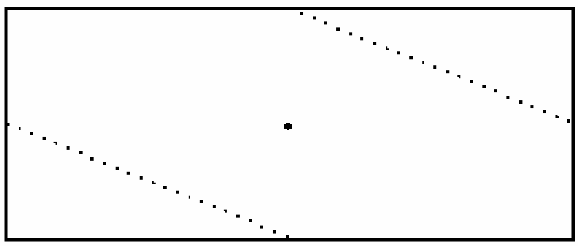
Use the results to graph the number of blades versus power for both wind speeds.

Discussion

Which turbine produced the largest current? How do you think it was able to produce more current?

6 BLADE PROPELLOR
1. Cut along dotted lines and fold one corner of each flap in towards the centre.
2. Staple centre to hold blades in place.



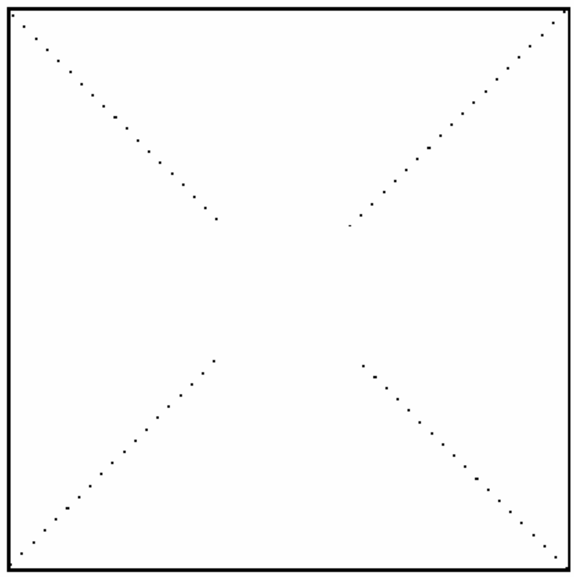


2 BLADE PROPELLOR
1. Fold along dotted lines so that one fold is on each side of the of the blade

Which turbine produced the largest voltage? How do you think it was able to produce more voltage?

Which turbine gave more power at the high wind speed? Which turbine gave more power at the lower wind speed?

If you were asked to design a Wind Turbine which could be used to generate electricity for a remote community on the north east coast of Queensland, what would it look like?



4 BLADE PROPELLOR
1. Cut along dotted lines and fold one corner of each flap in towards the centre.
2. Staple centre to hold blades in place.

Workshop 4b: Calculating the efficiency of turbine generators

Context

Another important part of a wind turbine is the generator, with different generators being suited to use in different conditions. This activity will look at the characteristics of two different generators under different operating conditions.

Curriculum Links

Science, Energy and Change, level 5+

Senior Physics, Geography, Multistrand Science

Equipment needed

As for workshop 4a.

What to do

Using the set up from activity 4a, connect the propeller blade of your choice to the motor A (1.5 V, 200mA DC). Place your turbine in front of the fan and turn the fan on to the low setting.

Using the table below, record the current and voltage being generated by this propeller using the multimeter. Now record the current and voltage being generated when you switch the fan to the medium and high settings.

Repeat the experiment using motor B (2.0 V, 50mA DC)

Generator	**Low speed**		**Medium speed**		**High speed**	
	Current (amps) I	**Voltage (volts) V**	**Current (amps) I**	**Voltage (volts) V**	**Current (amps) I**	**Voltage (volts) V**
Motor A (1.5 V, 200mA)						
Motor B (2.0 V, 50mA)						

When you have completed the table, calculate the amount of power being generated for each of the generators at different wind speeds. (Note: your turbine may not spin with the fan on the low setting.)

Generator	**Power**		
	Low Speed	**Medium Speed**	**High Speed**
Motor A			
Motor B			

Which generator produced the most power at each of the wind speeds?

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Wind Farms

Wind farms are in areas that use a number of wind machines to convert wind energy to electricity. Use the Internet to find out how many wind farms are in Queensland / Australia. Are there any planned for your region? Why / why not?

. . . .

. . . .

What is the power rating of the turbines used on these wind farms?

. . . .

. . . .

How much power can these turbines individually produce?

. . . .

. . . .

What is the total 'installed capacity' of wind turbines in Qld / Australia?

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If a typical household uses 20kWh per day, how many homes can they power?

. . . .

Workshop 5a: Measuring wind speed

Context

How do wind farm developers decide where to build a wind farm? The first task of a wind prospector is to gather accurate wind speed data. It is not enough to simply know how fast the wind is blowing at any particular point in time. A record of wind speed over a period of time is required, as well as a record of maximum wind gusts, s these can damage wind generators. As well as these technical requirements, the output of any wind turbine is related to the cube of the wind speed, so even minor differences in wind speed can significantly affect the output of a wind farm and hence its economic viability. What are the indicators of wind speed? A combination of methods is often used, including

- the deformity of plant species can be one useful indicator initially (e.g. look for bent trunks and foliage growth away from the prevailing winds)
- Isovent maps / wind maps: another initial indicator, these contour maps provide an approximate estimation of wind speeds in an area, without taking into account local topography.
- Measurement: serious developers, after selecting a general area to 'prospect', will monitor the wind speed and direction of specific sites.

Different units are often used to measure the speed of the wind. Often wind speed readings for over water are given in knots, and over land, in kilometers per hour (km/hr). Wind farm developers, however, use the figure of meters per second (m/s). The conversion rates are:

1 knot = 1.853 km/hr

1 km/hr = .278 m/s

1 m/s = 3.6 km/hr

Three types of anemometers are used to measure wind speed

Hand-held anemometers take instantaneous readings of wind speed at any given time. This method is used by many Met. Bureau recording stations. It is a very crude measurement and of limited value for analysis of a potential wind farm site.

A **wind-run anemometer** averages the wind speed over a specified duration (e.g. 1 day, 1 month). It is used by some Met Bureau recording stations, but, as the counter must be read manually, it tends to be read only monthly, giving average monthly wind speeds.

A **data-logging anemometer** records and stores hourly mean wind speed and direction data. It records the frequency distribution of each day, month and year. This provides the most accurate profile of the wind resource at any particular site and is used extensively by serious wind farm developers.

What to do

The Beaufort Wind Scale is sometimes used to estimate and/or describe wind speeds. Complete the table below by calculating the speed in meters per second.

Beaufort Wind Scale			
Description	**Speed (km/hr)**	**Speed (m/s)**	**Common signs**
Calm	Less than 1		Smoke rises vertically; flags hang limp
Light air	1-5		Smoke drifts slowly; flags flutter
Slight breeze	6-11		Leaves rustle; flags flap
Gentle breeze	12-19		Leaves and twigs constantly move, light flags extended
Moderate breeze	20-30		Dust and loose paper blown about; small branches move; flags fly straight
Fresh breeze	31-39		Small trees sway
Strong breeze	40-50		Umbrella hard to hold; large branches sway
Moderate gale	51-61		Walking difficult; whole trees swaying
Fresh gale	62-74		Twigs break off
Strong gale	75-87		Branches may break off; some structural damage e.g. roof off
Whole gale	88-102		Trees uprooted; considerable structural damage
Storm	103-116		Widespread damage
Cyclone	117-132		Extreme danger

Workshop 5b: Building an data-logging anemometer

Context

A simple anemometer (wind speed meter) is easy to make, but it will generally only tell you the speed of the wind at the time you read it. A bicycle computer can be used to provide more useful information: it is a small electronic device that measures the speed and distance of a bicycle by counting how often a magnet on the spokes passes a sensor attached near the wheel. It also records the maximum speed attained and the average speeds for the recording period. All of this information is provided by an LCD display and the various functions are operated by a couple of buttons on the front of the device. The sensor for the datalogger is similar to anemometers on top of weather stations, and is made from a brushtype DC motor mounted inside a watertight enclosure, with the familiar cup and arm arrangement attached to the shaft of the motor.

Note: This is quite an involved project, so instructions should be read thoroughly before commencing.

Curriculum Links

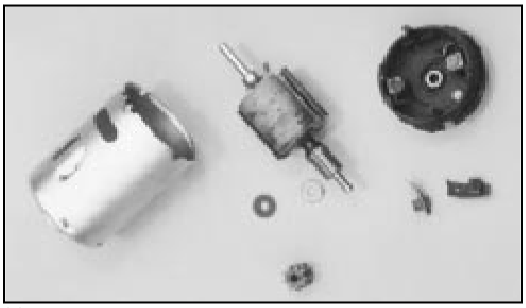
Science, Energy and Change, level 5+

Senior Physics, Geography, Multistrand Science

Equipment Needed

- 1 programmable bicycle computer (with magnet and sensor)
- 1 small electric hobby motor, with metal or plastic gear to suit (Using an old motor is a cheap way of providing a shaft already mounted in its own bearings. Try a motor from a disused remote-control model cars and boats, or cheap and simple ‘hobby motors’ available from electronics component stores.)

- 1 steel can with lid
- small gear
- 4 pieces of aluminium flatbar, 13 x 3 x 150mm
- 4 plastic spherical 'cups', or two plastic toy balls or table tennis balls cut in half
- a length of twin-core insulated hookup wire
- insulating tape or 'heatshrink tubing'
- solder and a soldering iron, or some suitable wire connectors
- paint suitable for outdoor use
- assorted small screws, nuts and bolts
- Angle bracket soldered to can
- Hub 12 x 3mm
- Coffee jar lid



The motor components. Note the armature in the middle of the photo.

What to do – preparing the motor

Start by pulling the back end of the motor and removing the armature (the bit that turns) from the case. This can take a bit of force in some motors, as the magnets inside them are very strong. Remove the magnets from the motor case to allow the armature to rotate easily when everything is reassembled. This is done by removing a spring clip between the two magnets and prising them out with a screwdriver. Some magnets may be glued in, so a fair bit of persuasion may be required. Wash the case in a detergent solution, using a paint brush to remove any accumulated gunge, rinse it and put it in the sun to dry.

Remove the brushes on the inside of the motor end cap. These are the little carbon blocks that rub on the copper section of the armature, and are usually mounted on bits of springy metal and can just be snipped off. (Some more expensive racing motors have a brush/spring system similar to larger motors, with the brush sliding in a square tube with a spring pressing on the back of it. By removing the springs and cutting the brush leads first, the brushes can just be slid out of their holders.)

Reassemble the motor and pace a single drop of light machine oil on the bearing at each end of the motor.

Making the housing

Drill three holes in the bottom of a waterproof can (e.g. a Milo can): one large one in the centre and one smaller one each side of it for the motor mounting screws (most of the motors will have threaded holes in the front end which accept 3mm metric screws). Install the motor in the can. Solder a mounting bracket to the can, then prime and paint the whole assembly to make it weather proof.

Make a rotor for the anemometer from a small gear that fits the motor shaft (these are usually available for little cost), glued into a painted wooden hub about 60mm in diameter. (The gear is used as a strong and reliable way of attaching the rotor hub to the motor shaft.)

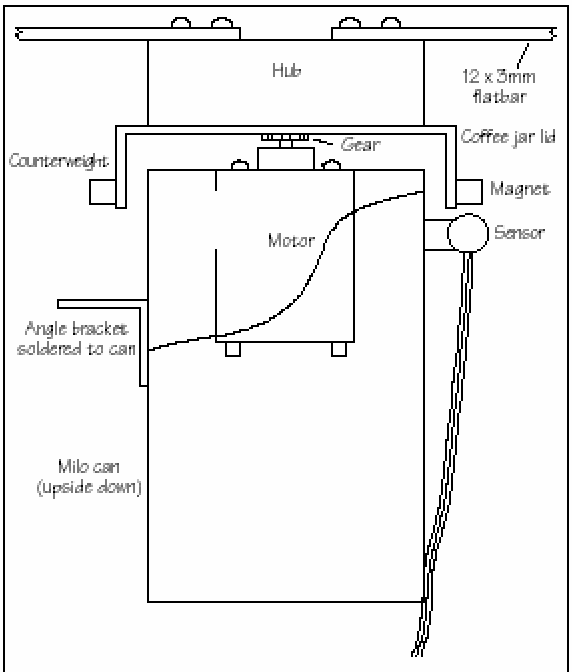


Figure 1. The anemometer for the wind speed data logger.

On the bottom of the hub mount a coffee jar lid or similar to protect the top of the motor from the weather.

Make the arms by twisting each of the aluminium flatbars 90 degrees along their length (Figure 2).

Figure 2. This is how the rotor arms are twisted along their length.

Cut each of the toy balls in half to make four 'cups'. Attach a cup to the end of each arm by a small bolt and nut. Attach the arms to the rotor.

Assembly (refer to Figure 1)

As the bicycle computer's original sensor provides the pulses to the computer, mount the sensor on the outside of the can on a small block of wood to set it at the correct height. The sensor has a small flat on one side, which needs to be the side closest to the passing magnet. The magnet (also supplied with the computer) is attached to the coffee jar lid with a couple of short self-tapping screws. A counterweight (such as a small bolt) should be attached to the opposite side of the lid for balance.

Extend the length of the wires from the sensor by cutting them and joining in an appropriate length of wire (either solder the wires or use one of the many types of connectors and splices made for this purpose. These are readily available from electronic component shops.)

Calibrating the computer

To calibrate the computer, you need to reset it by pressing the small reset button on the back, and then enter in the wheel circumference. Here are two options for calibrating your data logger.

If you have **access to a calibrated anemometer** (you don't need the data-logging type, just one that gives an accurate instantaneous wind speed), the calibration will be easy. Just program a number, say 1000, into the computer and compare the speed it shows with the speed showing on the other anemometer. If it reads, say, twenty percent low, then increase the number by that figure (giving 1200 in this example) and program it in. The data logger will now be calibrated.

The second way involves **running and using a stop watch: moving the anemometer through still air at a known speed.** Reset and then program the computer with, say 1000. The easiest way to do this is to hold it away from you and run at the same speed for a known distance (e.g. 100 metres), stopping the anemometer the instant you get to the 'finish' line. Get someone to time you, and divide the distance by that time to find your speed in m/s. You then multiply this by 3.6 to get the real speed in km/h. You would then check what the computer reads for an average speed, and work out the adjustment to the programmed number accordingly.

Calculations

There are a few of points that need to be addressed concerning the calculations and the numbers provided by the bike computer. The maximum wind speed recorded will be accurate (well, as accurate as your calibration of the computer, at least), but the average wind speed will need to be recalculated. This is because the computer only averages the speed for the period that it receives input, not for the whole time period.

Fortunately the computer also records the distance traveled by the air passing the anemometer, so the actual average speed can be easily calculated. An example would go as follows. If the computer recorded a distance of, say 138 kilometers passing the anemometer, and this distance was recorded over a time period of 24 hours, then the average speed is simply the distance divided by the time, or 138/24, which equates to 5.75km/h. Dividing this by 3.6 gives you 1.6m/s – you would need to find another site if every day was this bad!

We should also note here that it is probably best to record the data and reset the computer each week or so, as it only counts up to 9999 kilometers and then clocks over to zero again. But apart from these limitations, this device should allow you to log wind speed data over extended periods, without the cost of buying a commercial logger.