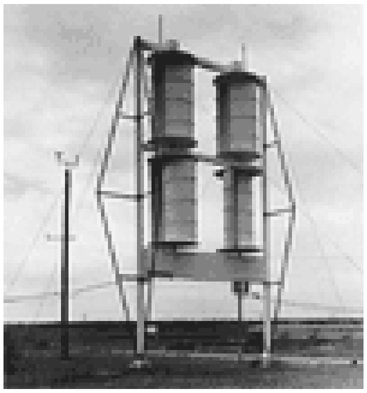
Background

The Savonius Wind Turbine

These plans are for the construction of a machine called a Savonius wind turbine. Wind turbines come in two general types, those whose main turning shaft is horizontal and points into the wind, and those with a vertical shaft that points up. The Savonius is an example of the vertical axis type. It consists of two simple scoops that catch the wind and cause the shaft to turn.


A Savonius wind turbine.

This type of turbine is simple to build, but is not nearly as efficient as a well-designed horizontal axis turbine. The Savonius turbine relies solely on drag to produce the force that turns their shaft. One side of the turbine catches the moving air more than the other, causing the turbine to spin. This design does not allow the turbine to spin faster than the oncoming wind, which makes them a poor choice in areas where winds are light.

Horizontal axis turbines are by far the most common kind of wind turbine. They can be seen at several places across Canada and the United States. They are also becoming common in Europe and many other countries around the world. These turbines feature wing-like blades that generate aerodynamic lift as the wind blows past them, causing the central shaft to turn. To operate at peak efficiency, this type of turbine must always face directly into the wind. Many horizontal turbines have a large wind vane that acts like a sail, helping them to stay pointed in the right direction.


A horizontal axis turbine.
Courtesy Vision Quest Wind Electric Inc.

Making electricity

We are surrounded by hundreds of appliances that use electricity to do work. But what is electricity? Basically, electricity is a flow of electrons in a metal wire, or some other conductor. Electrons are tiny particles found inside atoms, one of the basic building blocks of all matter. We call the flow of electrons through any conductor a "current of electricity."

Each electron carries a tiny negative charge. When they move through a conductor, they produce an invisible field of magnetic force, similar to that found around a magnet. The strength of that field depends on how many electrons are in motion. You can concentrate this field by winding the wire in which the electrons move into a tight coil with many turns. This causes many more electrons to be in motion in a small space, resulting in a stronger field. If you then place a piece of iron in the middle of the coil, the electromagnetic field will turn the iron into a powerful magnet.

While it is true that electrons moving through a conductor produce a magnetic field, the reverse is also true. You can make electrons move in a wire by "pushing" them with a moving magnet. This is in fact how an electrical generator works. Electrical generators usually contain powerful magnets that rotate very close to dense coils of insulated wire. The coils develop a flow of electrons that becomes an electrical current when the generator is connected to an electric circuit.

You will be building an electrical generator as part of this project. It uses moving magnets to create a current of electricity in coils of wire. This generator is technically called an alternator because the electrons move back and forth in the wire, rather than flowing in just one direction as they do from a battery. A meter connected to the wire would show that the charge of the wire switches or alternates between positive and negative as the electrons change directions. Such an electrical current is called alternating current or AC. Household electrical current is alternating current. Appliances have to be specially designed to use it. The other type of current is called direct current, because the electrons move in one direction only. Most battery-powered appliances such as calculators and portable CD players use direct current.

Safety Precautions

Utility knives and scissors can be dangerous! Use caution when cutting materials using them. The blades of most utility knives can be extended and locked in place. Extend the blades only far enough to cut all the way through the material, no farther. Be sure they are locked in position while cutting.

For a safe and easy cutting make sure the blades of your utility knives are always sharp (ask your teacher for assistance in breaking off dull blades)

Hot glue guns can cause serious burns, as can the glue if it comes in contact with your skin.

The magnets you will be using can cause serious damage to computers or other electronic devices. Be sure to keep them away from credit cards, computer disks, audio tapes, or any other materials on which information is stored magnetically.

Tools

- Scissors
- Utility knife
- Hot glue gun and glue sticks
- Metal or plastic ruler
- Robertson screwdriver, no. 2
- Pencil
- Electrical tape
- Digital voltmeter with probes equipped with alligator clips
- Pencil sharpener
- Sand paper or emery cloth
- 4 rare earth magnets
- push pin

Build It!

Important note: Please read and follow these instructions carefully, step by step! Have one member of your group read each step aloud to be sure the instructions are clearly understood. Do not proceed until each step has been completed.

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Materials

- 1.5-litre plastic water bottle
- Large piece of corrugated cardboard (approx. 60 cm by 40 cm, cut with corrugations running its length)
- Wooden base (plywood, particle board, or solid wood, approx. 14cm by 30 cm, at least 15mm thick)
- 1 wood screw (#8, 3/4" Robertson)
- white glue
- nail or awl
- Wooden dowel, 30 cm by 6 mm (1/4")
- Magnet wire (100m, 24 gauge enamel coated)
- Rectangle of corrugated cardboard, 4cm by 16 cm cut with corrugations running perpendicular to the long axis of the rectangle
- Paper Templates: please download the following templates separately and print according to printing instructions.

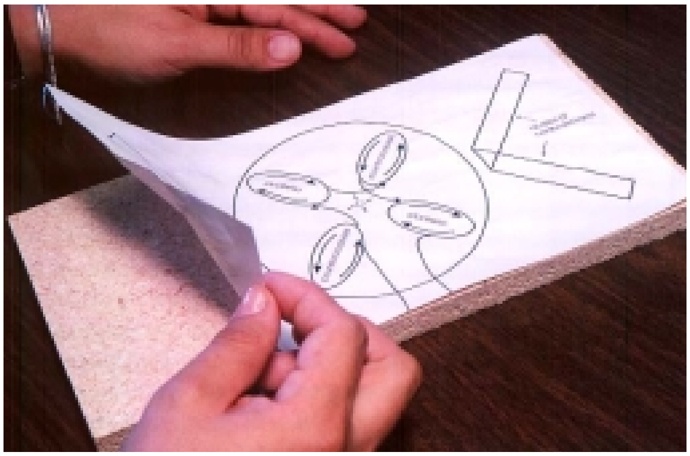
Printing Instructions (37K) Frame (179K)
Base (131K) Rotor (113K)

A. Prepare the Templates

Included with these instructions are three paper templates, labeled "Base, Frame, and Rotor". These need to be glued down on either cardboard or wood before you can proceed with the assembly of your turbine.

1. Cut out the "Base Template" to fit the rectangular base board using your scissors.

2. Apply a very thin, even layer of white glue to the back of the paper "Base template", being sure to cover the entire back surface of the template. Apply the template to the wooden board, and set it aside to dry.



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3. Cut out the 3 pieces of the frame template and the parts from the "Rotor templates" sheet.

4. Apply a thin layer of white glue to the back of the paper "Frame templates" and "Rotor templates", carefully place on cardboard, and let dry. As you glue down the frame templates, be sure their long axis is parallel to the corrugations in the cardboard.

B. Assemble the Frame

The frame of your turbine consists of 4 parts: the top and two side pieces made of corrugated cardboard, and the base, which is from a short piece of plywood or 2 by 6 lumber.

CAUTION! The utility knife is sharp, and can cause serious cuts. Extend the blade only as far as needed to cut through the cardboard, and lock the blade in place!

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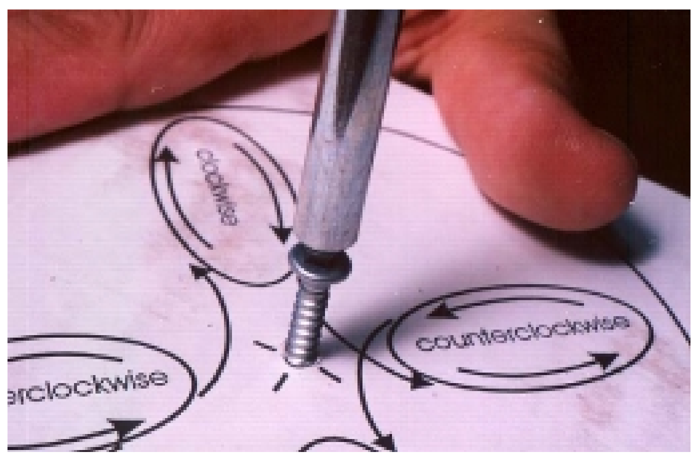
1. Cut out the sides and tops of the frame pieces using the utility knife. The metal ruler can be used to help make the cuts straight. You may use the bottom surface of the board as a cutting board to prevent damage to the tabletop.

2. Using a nail or awl, make a small hole in the center of the wooden base. Turn the screw into the wood so that it projects above the board by about 4mm.
3. Set the blade of the utility knife so that it



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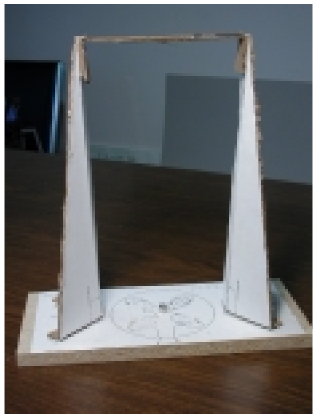
projects about 2 mm from the handle, and make shallow cuts along the dotted lines on the frame parts where shown. The cuts allow the cardboard to bend smoothly along straight lines.



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4. Gently bend the frame parts as shown.

5. Glue the uprights to the board at the locations shown on the base template using hot glue.

6. Score and bend the top frame support so that it spans the distance between the two side pieces. The pinhole should be centered directly over the screw. Use a drop of hot glue on each side support to hold the top support in place.

C. Assemble and Mount the Coils

1. Make a winding jig by folding a small piece of corrugated cardboard in half and securing with tape. The jig should measure 3cm by 8 cm when completed.

2. Cut 8 short (4 cm) strips of electrical tape, and set them aside.

3. Leaving a wire lead of about 5 cm, start winding the first coil on the jig. Form a compact coil with 200 turns of wire, ending with another 5 cm lead. Cut the wire with wire cutters or scissors.

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4. Carefully slip the coil off the jig, and secure it on each side using the two strips of electrical tape.

5. Using a piece of sandpaper, remove the enamel insulation from the ends of each lead, exposing about 1 cm of bare wire.

6. Repeat steps 1 through 5 to make three more coils.

7. Loosely position all 4 coils on the base, according to the “clockwise” / “counterclockwise” markings on the base template. It helps to trace the path an electron might take through the coils, starting at one end. Ensure each coil is arranged so that an electron moving through the wire follows each coil, alternating between clockwise or counterclockwise directions.

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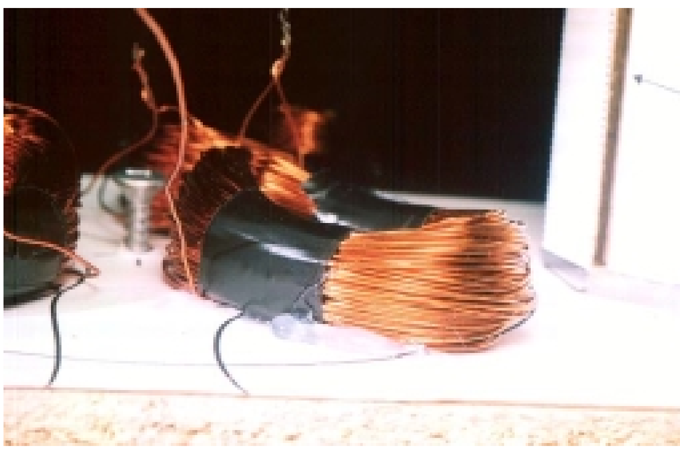
8. When you are sure you have oriented the coils correctly, connect the ends of the wire coils by twisting the bared ends together tightly.

9. Check your connections: Set a multi-meter for measuring electrical resistance (Ohms). Connect the probes to the two free ends of the wires from the coils. A good connection should yield a resistance reading of 7 to 10 Ohms (a lower reading indicates an even better connection). A large reading means that you have a poor connection between two or more of your coils. You may need to check each connection individually, and re-sand the wires before reconnecting to ensure all the insulation has been removed.

10. Once you are confident the coils are properly positioned and connected, glue them down on the stator disk. Use a blob of hot glue under each to ensure they will not shift.



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D. The Rotor

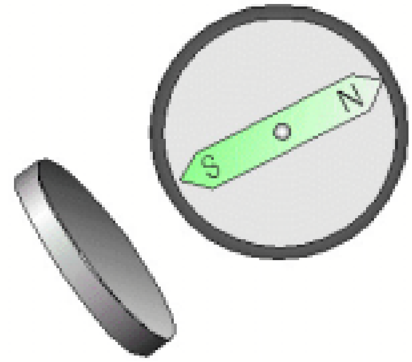
The rotor is a rotating disk equipped with magnets. This disk will spin near the coils to induce an electrical current.

> **CAUTION!** In this section you will be using the hot glue gun. Be careful not to get the hot glue on your skin--it burns!

1. Use a nail or an awl to punch a hole through the center of the cardboard rotor disk. Be careful not to bend or deform the cardboard while you are doing this.

2. Carefully separate the magnets (some magnets may very strong and may require a ruler to pry them apart.)

3. Identify the north pole on each magnet, and mark it with a felt pen. Some magnets may have a mark (a red dot or some other mark) to identify which surface is the north pole. If there is no mark, you may need to use a magnetic compass to help identify the poles.



Using a compass to identify the pole of a magnet.
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4. Put a generous blob of hot glue on the center of the first circle and press a magnet down firmly onto the blob. Be sure mount the magnets so that their poles alternate, as shown on the template.

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5. Do not mount the next magnet until the glue holding the first one is cooled properly.

E. The Turbine

1. Using a nail or awl, punch a hole in the middle of each turbine end piece as marked (this is where your wooden dowel will slide through).

2. Using the utility knife or scissors carefully cut the top and bottom off the plastic pop or water bottle, to make a cylinder with open ends.

3. With the scissors, cut the plastic cylinder lengthwise into two equal halves. These bottles usually have faint lines on their surfaces that show the edges of the mould used to make them. These lines make an excellent guide for cutting the bottle into two perfectly equal halves.

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4. Check the fit of the end pieces of the turbine with the plastic cylinder halves. You may need to trim either the plastic or the cardboard to get a better fit.

5. Apply a "bead" of hot glue onto the curved edge of one of the cardboard end pieces. Quickly position one of the cylinder halves onto this edge, holding it steady for about 20 seconds while the glue cools and hardens.

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CAUTION! Be sure to apply the glue to the cardboard and not the plastic! The hot glue will deform the plastic if applied directly, and make it difficult to assemble the turbine.

6. Apply glue to the second end piece, and position it onto the cylinder you glued in step 5.

7. Use the glue gun to apply hot glue to the remaining halves of each end piece, then add the second cylinder. This operation may take two people, one to hold the partially assembled turbine, the other to position the plastic half-cylinder onto the hot-glued end piece.

8. Use a pencil sharpener to make a point on one end of the wooden dowel. Round off the point using the sandpaper.

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9. Check the fit of the turbine shaft in the frame by placing its sharpened point in the center screw and standing it inside the frame. The top of the dowel should just fit under the top frame support. Cut the doweling as necessary using the utility knife.

10. Insert a push pin through the pinhole location and into the top of the dowel. The dowel should turn easily and freely inside the frame.

11. Remove the push pin, and remove the dowel from the frame. Carefully push the dowel through the nail holes in the end pieces of the turbine. Slide the turbine on the dowel so that about 3 cm of the dowel sticks out above the turbine end pieces.

12. Recheck the turbine vanes and shaft for fit inside the frame. The turbine vanes should spin easily without hitting the sides of the frame. Add a bead of hot glue to the top and bottom of the end pieces where the dowel comes through to fix the turbine vanes to the shaft. You are now ready for the final assembly and testing of your wind turbine!

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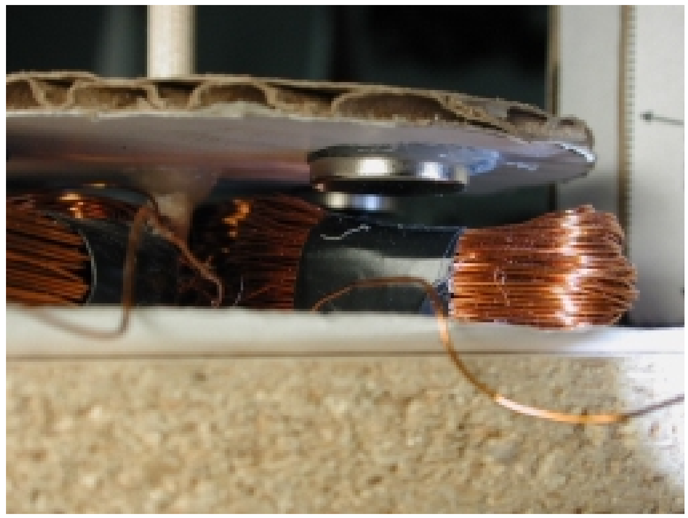
F. Final Assembly

The object of this stage is to position the magnet-equipped disk so it spins smoothly, and as close to the coils as possible. The closer they are to the coils, the more electricity they will make.

1. Carefully push the pointed end of the turbine shaft through the top of the rotor disk at its exact center. The magnets should be facing down. Avoid bending the cardboard. Slide the disk so that about 2.5 cm of the dowel projects from the cardboard.

2. Check the position of the rotor disk on the dowel by placing it inside the frame and re-inserting the push pin. The magnets should turn freely without striking the coils or snagging the wire between them. If necessary, press the wires down and out of the way, and press the coils in to a flatter shape to ensure they do not interfere with the magnets.



The magnets should pass as close to the coils as possible. *The Pembina Institute*

3. The disk should spin smoothly without wobbling. If the disk wobbles, you will have to adjust the angle a bit. Make small adjustments to the height and angle of the disk so that it spins smoothly, and as close to the magnets as possible.

4. If you are satisfied with the position of the disk, add a bead of hot glue around the dowel where it comes through the top surface of the cardboard disk. You can do this without removing it from the frame. Recheck the rotor disk by spinning it. You can make small adjustments to the disk's position and angle as the glue sets.

5. After the hot glue cools, remove the rotor and turbine assembly from the frame. Reinforce the disk

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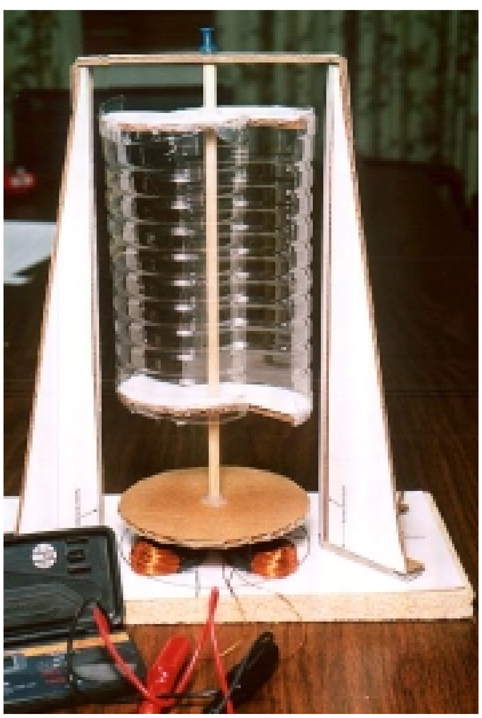
with an additional bead of hot glue applied to the shaft where it projects from the underside of the disk.

6. Reassemble the turbine and check again to make sure the clearance between the coils and magnets is correct. You can make further adjustments by turning the center screw out or in depending on whether you want to increase or decrease the clearance between the coils and the magnets.



The completed vertical axis turbine.
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Test It!

1. Set the selector on the digital volt meter to read Volts AC. At this setting, the meter will detect the number of volts of alternating current your turbine produces.

2. Attach the test clips on the volt meter to the wire leads on your turbine.

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3. Blow on your turbine to cause it to spin. Have a partner watch the readings on the display of the meter. Record your results. A well-assembled wind turbine should be able to produce between 1 and two volts by blowing on it. A more consistent way to test your turbine is to use a stream of air from an appliance such as a blow dryer (set for COOL) or a vacuum cleaner with the hose plugged into the discharge end. Measure the voltage of your turbine and compare with others.

4. You may make small modifications to improve the efficiency of your turbine. Look for sources of friction that might slow down its rotation, or find ways to bring the coils closer to the spinning magnets.

Questions

1. What changes to this design could you make to improve the efficiency of this turbine?

2. What advantages does the vertical axis turbine have over conventional horizontal axis turbines?

3. What limits or disadvantages does this design have?

4. Why must the coils be positioned in a clockwise / counterclockwise manner?

5. What is the difference between alternating current (AC) and direct current (DC)?

Notes:

Acknowledgements

The design of this turbine is based closely on the ingenious "Pico-turbine", published as a free download from http://www.picoturbine.com. PicoTurbine.com is one of the best sources of ideas and resources for renewable energy education in North America.

Sources

Magnets: Lee Valley Tools Ltd. Phone 1-800-267-8767. Part #99K32.11
Wire: In Edmonton, Electronic Connections Ltd., Ph. 780-469-7222. Ask for 24-gauge enameled magnet wire. Sold by weight.

Contact us at: education@pembina.org.