

1 Build a Lattice Tower

For one lattice cube you need:
16 sheets of A4 paper
8 bolts (5 mm x 20 mm), washers and nuts (5 mm)
a wooden stick for rolling the paper bars (35-40 cm long, 5-6 mm diameter)

For the whole lattice tower (3 cubes) you need:
40 sheets of A4 paper
16 bolts (5 mm x 20 mm), washers and nuts (5 mm)
a wooden stick for rolling the paper bars (35-40 cm long, 5-6 mm diameter)

Furthermore, you need:
paper punch (hole puncher)
glue stick
screwdriver
wrench (spanner)

Note on measures:

- A4-paper has the dimensions 297 mm x 210 mm. The important feature used is that the height-to-width ratio of the paper is equal to the square root of 2 (1.4142).
Sheets of US-legal paper can be cut down to 12 inches to have the A4 format.
- Metric units are used, e.g.:
1000 mm is equal to 1 m
10 mm is equal to 1 cm
1 inch is equal to 2.54 cm
- The M5 x 20 mm bolts are roughly equivalent to bolts 3/4-inch in length and 3/16-inch in diameter.



1. Fold a sheet of paper in portrait format so that the back edge still protrudes about 3 cm. Now use the wooden stick to roll the paper to a tube. Start rolling the paper at the edge with the fold.



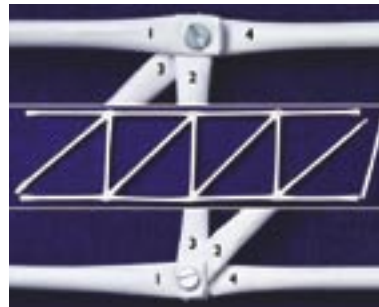
2. Put some glue along the top edge of the paper and finish rolling the bar. It is best to use a glue stick for this task. Press tight for a few seconds. Now you should have a slim and strong bar.



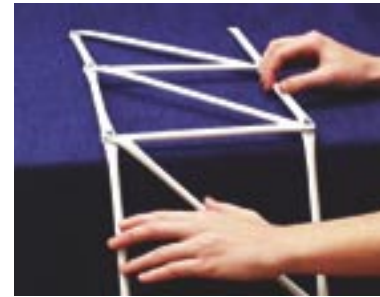
3. Flatten both ends of the bar and punch them with a strong paper punch. Make sure that there is at least half a centimeter of paper between the bar's end and the hole.



4. This is how your bar should look. To make a lattice cube you need 16 of these bars: 12 short bars and 4 long bars. You will get short bars if you roll the paper in portrait format. For long bars you simply turn the paper and roll it in landscape format.



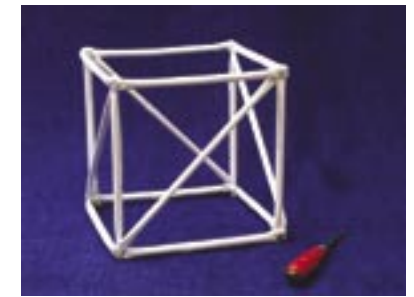
5. Put the bars together to form a lattice, as shown in the centre image: the 12 short bars are used for the edges, the 4 long ones for the diagonals. A node is made by placing bars no. 1-4 on top of each other. Insert the bolt through the holes of each of the bars. (Note: The order of bars is different for top and bottom nodes!) Finally, put a washer and a nut on the bolt and tighten it with a screwdriver.



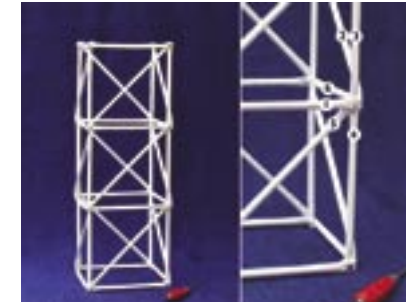
6. Use a sharp (table) edge to bend your lattice. Make sure that you can see the bolts' heads while bending.



7. Now you can finish your cube. Use the remaining two bolts to attach the last vertical bar to the cube. The bolts' heads must again point outwards.



8. This is your lattice cube. Try to test it by putting a rigid board on top of it. (Note that the board must be bigger than the cube, so that only the nodes will carry the load.) Then put a heavy weight on the board. If you have built the cube properly, you should be able to support 20 kg or more!



9. If you make more cubes you can use them to assemble a tower. Here we have used 3 cubes to form a lattice tower. Make sure you get the order right when you attach the bars of two cubes (you will have to remove 4 horizontal bars per cube). The correct order is shown in the right image.

2 Build a Small Wind Turbine

For a sail rotor you need:

14 sheets of A4 paper (12 for the rotor, 2 for the shaft bearing)
6 sheets of thin paper (max. 50 g/m²) (for the sails: A4 for big rotor, A5 for small rotor)
7 bolts (5 mm x 20 mm)
14 nuts (5 mm)
8 small washers (5 mm)
2 big washers (5 mm)
a threaded rod (the shaft, 5 mm, 40-50 cm long)
8 cable ties (6 for the rotor, 2 for mounting the shaft)
a wooden stick (35-40 cm long, 5-6 mm diameter)
a cork or rounded plastic button (as a safety stop at the end of the shaft)
string
sticky tape (Scotch tape)

For a nacelle you need:

7 sheets of A4 paper
2 bolts (5 mm x 20 mm), washers and nuts (5 mm)

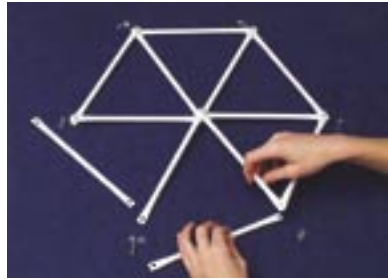
For a rigid rotor you need:

a sheet of strong paper (min. 250 g/m²) (A4 or A3)
a paper pin
2 corks (one as a safety stop at the end of the shaft – you may use a rounded plastic button)
a threaded rod (the shaft, 5 mm, 40-50 cm long)
2 sheets of A4 paper (for the shaft bearing)
6 nuts (5 mm, for the shaft)
2 small washers (5 mm, for the shaft)
2 cable ties (for mounting the shaft)

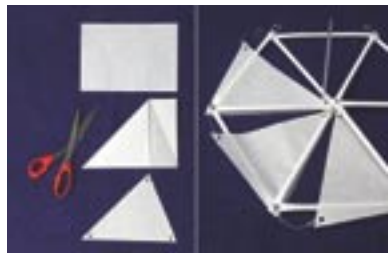
Furthermore, you need:

scissors, glue, 4 mm drill, glue stick, 2 wrenches (spanners) and screwdriver, paper punch (hole puncher)

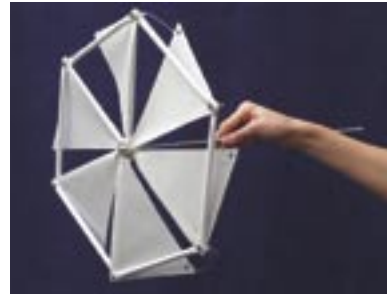
SAIL ROTOR



1. To build a sail rotor you need the same kind of paper bars used for the lattice tower. The sail rotor requires 12 long bars (for a big rotor) or 12 short bars (for a small rotor). During assembly the rotor put a bolt into the centre hole.



2. The sails consist of 6 sheets of very thin paper: A4 for the big rotor, A5 for the small rotor (you get A5 paper if you cut A4 in half). The left part of the picture shows how to fold, cut, and punch the paper to get a triangular sail. Before you punch the sails you may put some sticky tape around the edge, where the holes will be, to reinforce the paper. The right image shows the correct order of assembly.

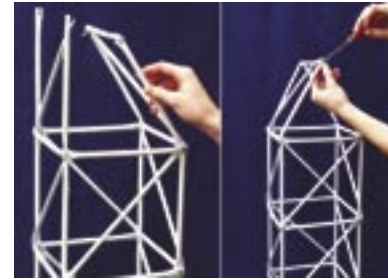


3. Put the threaded rod through the rotor's centre hole and fix the rotor using a big washer and a nut on either side. Use a wrench (spanner) to tighten the nuts. The sails are fixed to the rotor lattice using cable ties (centre), bolts, and strings (edge). You can simply sling the string around the nearest bolt and make a knot.

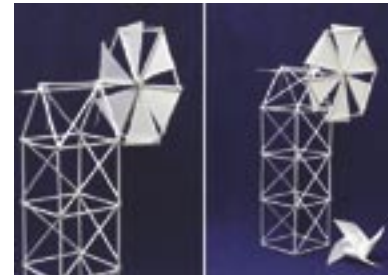


4. As you want the rotor to turn smoothly, the shaft (threaded rod) must run in a bearing. Use two sheets of A4 paper (landscape format) to roll a rigid tube with the wooden stick. Put the shaft through the tube (top picture). On the left end you can mount the sail rotor (centre), on the right end you may squeeze a string between the two nuts for lifting objects with the rotor. Place a cork or rounded plastic button on the protruding end of the shaft for safety.

NACELLE



5. If you have already built a tower you can now add a nacelle which will hold the rotor. For this you need 5 short and 2 long paper bars which you screw onto the top of the tower, as shown in the pictures.



6. Finally mount the rotor onto the tower. Insert the shaft into the nacelle, just underneath the top horizontal bar. Use two cable ties to attach the shaft to the two corners.

That's it! Now try how much weight your turbine can hoist. Attach a load to the back end of the shaft, using a string, and see if the turbine can wind it up. Try different rotor types and sizes and compare them.

RIGID ROTOR



7. For the rigid rotor you need a square sheet cut from A4 paper (small rotor) or A3 paper (big rotor). Now cut the four slots as shown.



8. Drill a hole (4 mm in diameter) halfway through one end of the cork – this is for the shaft. Put some glue on the other end of the cork. Use the pin to fix the four corners of the paper to the centre of the paper. Affix the pin and the rotor to the centre of the end of the cork with the glue.



9. Put the threaded rod into the cork's hole, and you are finished. Place a cork or rounded plastic button on the protruding end of the shaft for safety.

3 Build a Gearbox for the Wind Turbine

For the gearbox you need:

- 26 sheets of A4 paper
- a wooden stick (35-40 cm long, 5-6 mm diameter)
- 2 rubber belts or leather belts (transmission belts, diameter 7-10 cm, 2 cm wide)
- a long threaded rod (the shaft, 5 mm, 40-50 cm long)
- 2 short threaded rods (5 mm, 32-35 cm long)
- 6 corks or rounded plastic buttons (as safety stops for the threaded rods)
- 44 nuts* (5 mm)
- 14 big washers* (5 mm)
- 2 small washers (5 mm)
- 2 hooks
- a key ring
- 17 cable ties
- 2 pieces of string (2 x 60 cm)

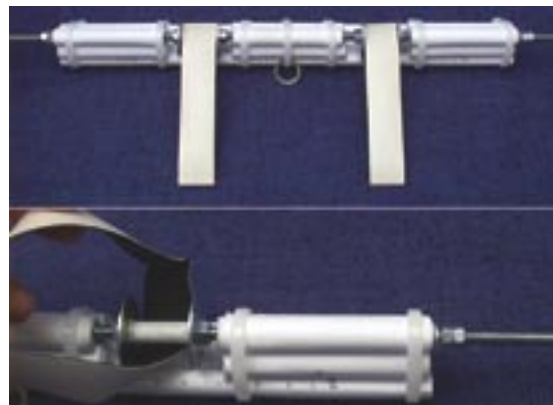
Furthermore, you need:

- glue stick, glue, 2 wrenches (spanners), scissors

*) Note: 2 big washers and 2 nuts for a sail rotor are included in the part list above



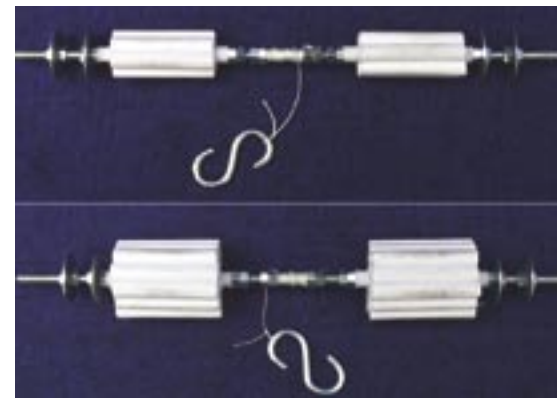
1. Here we see the main shaft in the middle of the picture, and the two belts up front. In the background we see the beam, which will carry the main shaft. The beam consists of three strong paper tubes, rolled around a wooden stick using two layers of paper in landscape format, cut to three equally long sections. The main shaft (a threaded rod) carries three paper tubes which are used as bearings. They are made from two layers of paper in portrait format. As they act as bearings, they must be able to turn freely – so do not fix them to the shaft.



2. Assemble the beam by gluing the tubes together and fix them using 7 cable ties (top picture). Note that the centre tie also carries a key ring. Do not forget to put the belts on the shaft before you glue the shaft bearings to the beam. The bottom image shows how the wheels for the belts are mounted on the shaft: A piece of paper tube is squeezed in between two big washers and fixed by two nuts. At the ends of the beam the shaft carries a small washer and two nuts. You tighten one nut against the other in order to keep the nuts in place. The shaft must be able to turn freely.



3. Build these 4 gear wheels for the slow shafts. First make 9 paper rolls by rolling a paper in landscape format very tightly around one of the threaded rods. It has to be tight, otherwise the wheels may slip very easily. Cut 8 tubes into 6 sections of equal length, and the last tube into 4 sections. Now glue them together to form gears as shown. Use the 4 longer tubular sections for the centre.



4. This is how a slow shaft should look like – use the short threaded rod. The two big washers at both ends of the shaft will keep the shaft in place. They are fixed using two nuts each. The gear wheels are also fixed with nuts. One end of the string is squeezed in between two nuts, the other one is attached to a hook. The top shaft will have a transmission ratio of 1:3, whereas the bottom one has a ratio of 1:5, when the main shaft drives them.



4

Wind Turbine

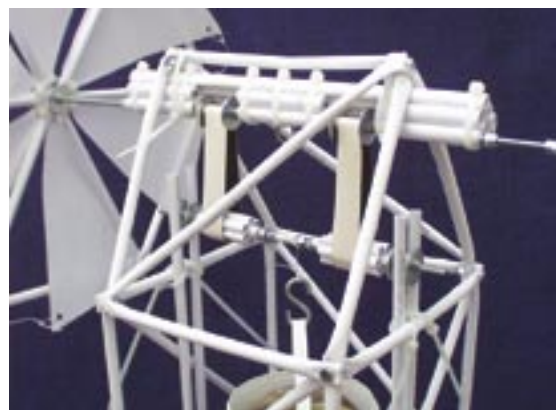
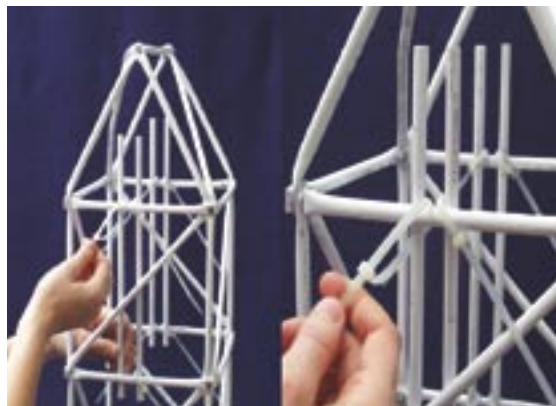
With nuts and bolts, a few tools, and the content of your paper basket you can build

- A lattice tower for a wind turbine (you need 40 sheets of (recycled) A4 paper)
- A wind turbine with a sail rotor (you need an additional 21 sheets of A4 paper)
- A 1-stage gearbox so that the turbine can hoist heavy items (you need an additional 26 sheets of A4 paper)

Wind Turbine Experiments

Turn the page for instructions

Kit developed by:
Norbert Pöcksteiner
Photos: Norbert Pöcksteiner
You can download this set of instructions, experiments and further experiments from:
<http://www.windpower.org/en/kids/assign/index.htm>



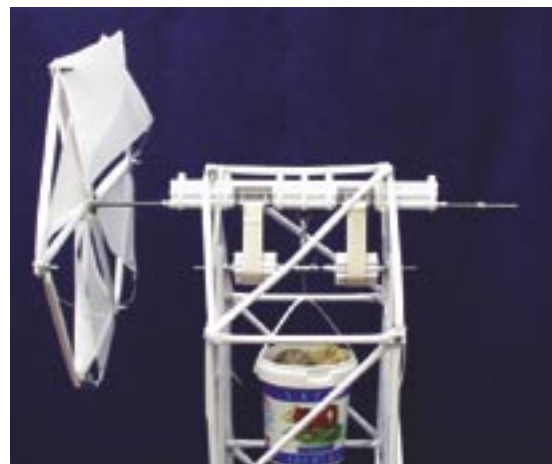
5. You need a tower to mount your gearbox. The slow shaft has to be able to move vertically in order to keep the belts tightened. Thus we need some vertical slides (bearings). Simply make 4 paper tubes out of landscape format paper and attach them to the tower as shown, using two cable ties per tube.

6. This is how the beam and the shaft is hung under the top horizontal bar of the nacelle. Use two cable ties to fix the beam to both top ends of the nacelle. As you can see, a sail rotor has already been mounted on the main shaft.

7. A view of the finished gearbox: The slow shaft with the small gear wheels (transmission ratio 1: 3) is hanging in the belts. The hook is holding a container filled with pebbles. Try how much weight you can hoist using this setup. If you want to lift more, take a look at the next image.



block and tackle technique you double the transmission ratio to 1:10, hence you get a very strong machine. But it takes some time to lift the load...



8. If you use this setup, you will be able to lift really heavy loads. Hang the slow shaft with the big gear wheels (transmission ratio of 1:5) into the belts. Do not attach the hook directly to the load, but sling it around the handle and attach it to the ring mounted in the center of the beam. With this so-called

9. This is a side view of the wind turbine. Again, you see the slow shaft with the big gear wheels. Try to lift several different loads and find out how long your turbine takes to hoist them. You can also use different rotors (sail rotor, rigid rotor, big model, small model) and compare their performance. Which is the most powerful one?