CHALLENGE

How Can We Design a Wind Powered Boat?

Design and Build

a "sailboat" that will travel in a straight line a minimum of 75 cm on a smooth surface. Your **constraints** are to use a Styrofoam tray (see below for examples) for the body, and to attach a mast with a sail to the tray.

You Will Need:

- Small Styrofoam tray (part of an egg carton or a supermarket tray)
- Flexible straws
- Cardboard or index cards
- Tape
- Straight pins
- Scissors
- Tape measure
- Box fan

Other Possible Materials:

- Pencils
- Stop watch with second hand
- String
- Paper cups
- Paper clips
- Pennies
- Miscellaneous hardware and office supplies

Try It

- Simulate the wind with a fan.
- Position the fan on the floor or a table top.
- Mark a starting line about 30 cm from the base of the fan.
- Fasten a tape measure to the table or floor.
- Place your boat at the starting line with the fan on low.

These photos show one possible design for this project, but it is probably not the best design. Use your engineering skills to invent and perfect a design of your own.

In Your Engineering Notebook

write or sketch answers to questions you find important or interesting.

What forces influence your boat?

Where should you put the mast? How do you know?

Think about the best shape and size of the sail. Where should you attach it to the mast?

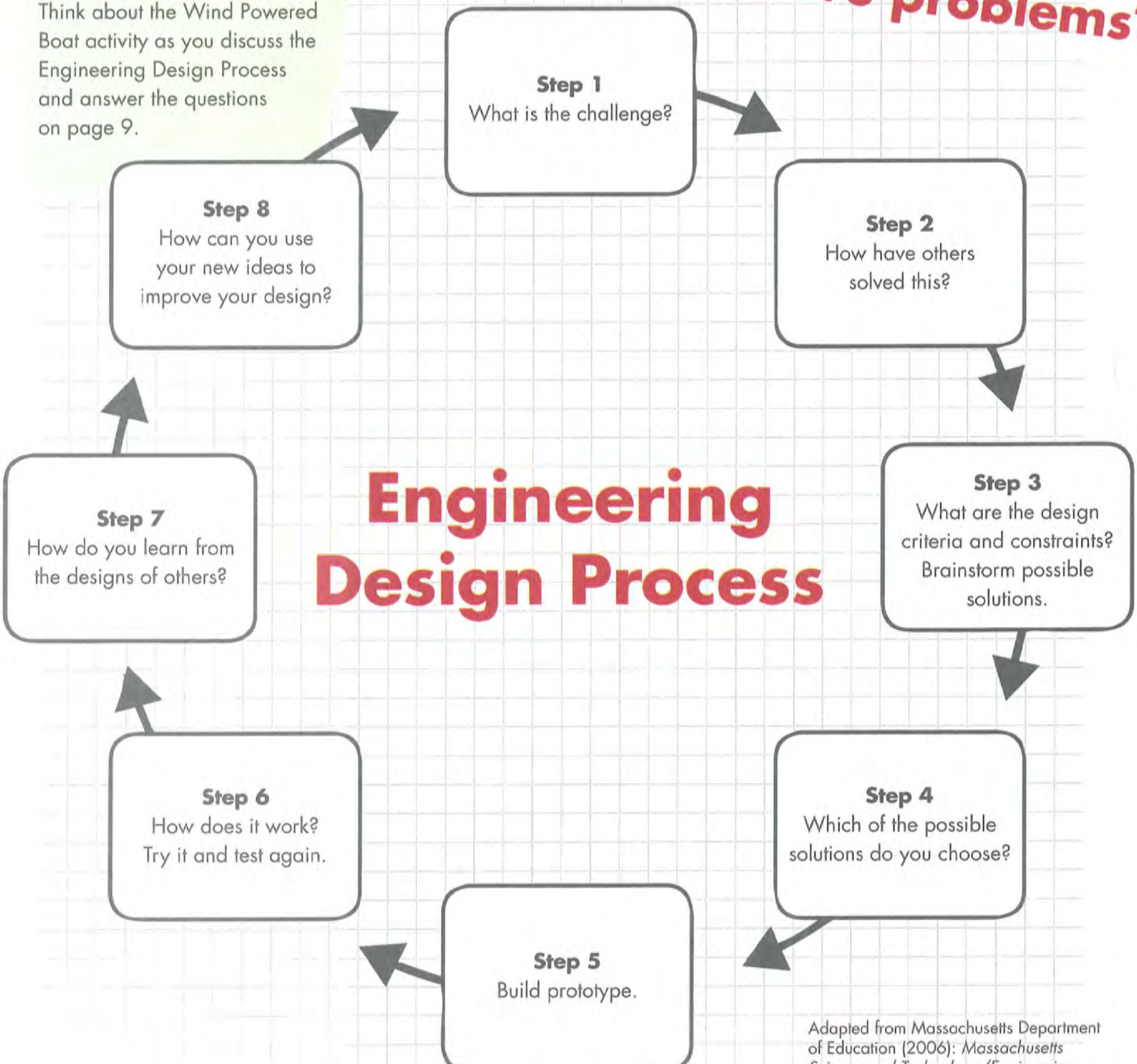
Take a picture of your best design and include it in your notebook.

Learn More About Engineering Design

How do engineers use design to solve problems?

Think About It

Think about the Wind Powered Boat activity as you discuss the Engineering Design Process and answer the questions on page 9.



Adapted from Massachusetts Department of Education (2006): *Massachusetts Science and Technology/Engineering Curriculum Framework.*

EXPLORATION

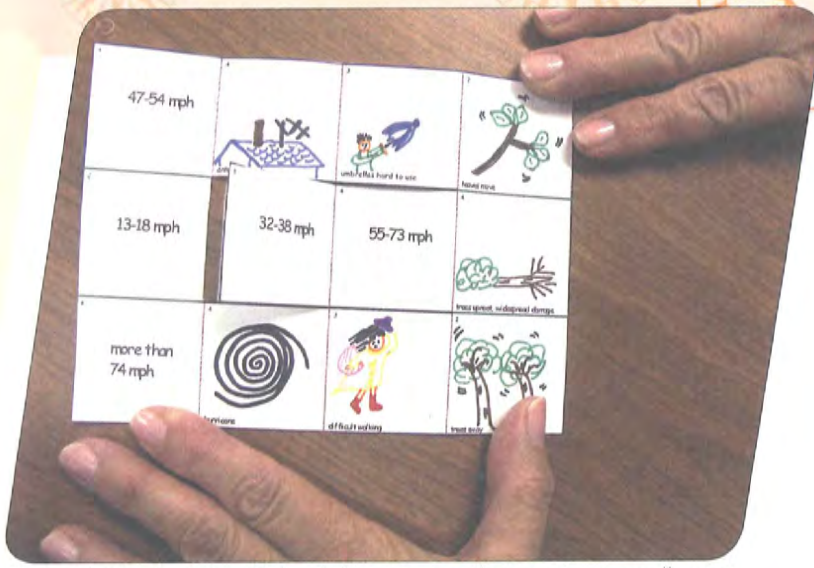
How Do We Observe and Measure the Wind (Part I)?

A method for estimating wind speed based on observations was developed in 1805 by Sir Francis Beaufort.

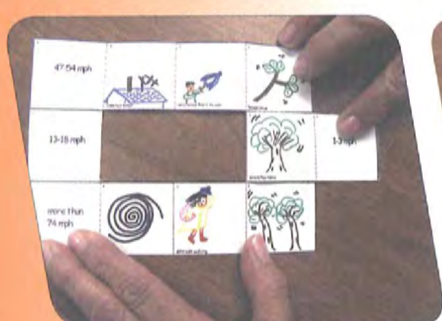
Learn about and use the Beaufort Scale

by making this tool. Cut out the tetraflexagon in Appendices D and E. Cut on the heavy black lines and crease on the red vertical lines.

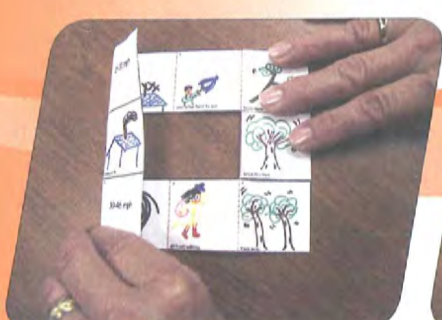
After you cut out the **tetraflexagon**, follow the instructions under the photos.



Draw illustrations in each of the squares that contain small print.



Fold the center flap over and under the right-most vertical column.



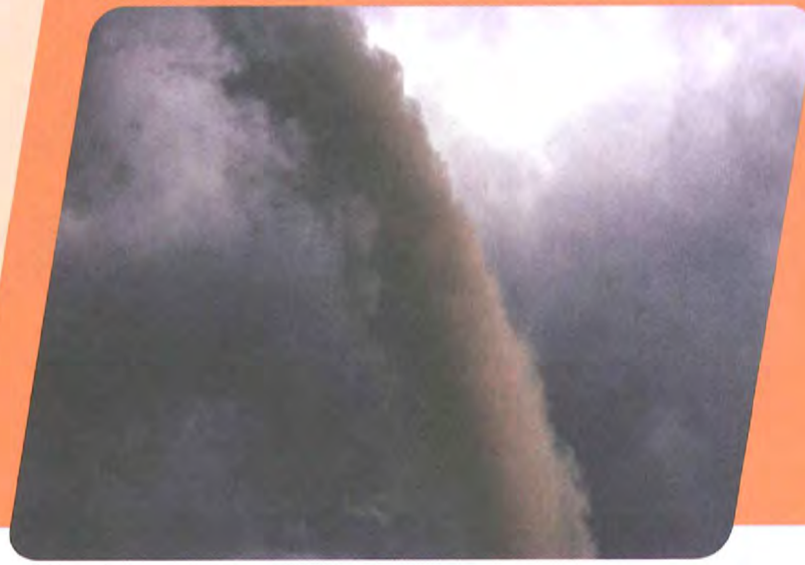
Fold the left-most column over the second column.

Fold both over onto the third column.

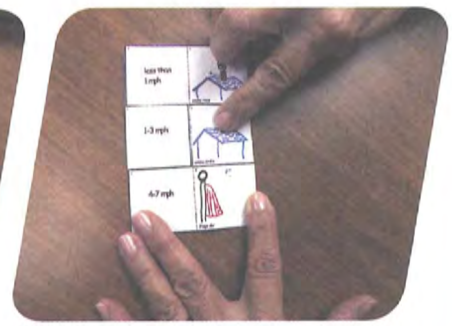
Now the wind speeds from the **Beaufort Scale** are matched up with their illustrations.

WIND FACT

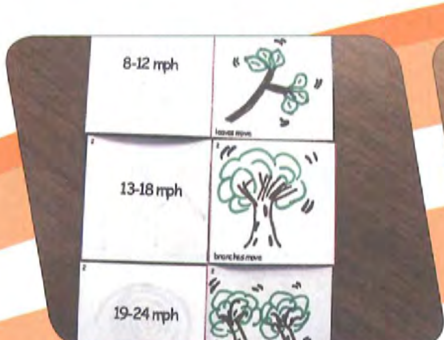
Tornadoes make the highest wind speeds. **Scientists think some tornadoes may produce 400 mph winds**, but they don't know for sure because the tornadoes destroy their wind instruments.



Flip the whole tetraflexagon over and tape.

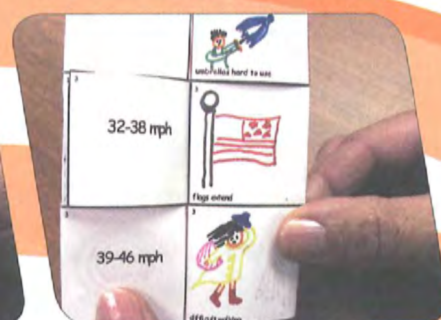


The Beaufort Scale showing the least wind speeds is face up.



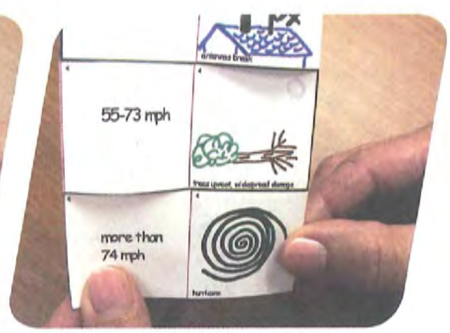
Turn the tetraflexagon over to show the next higher group of wind speeds.

Now the flexagon is ready to flex. Bend it in the middle.



Let the next group of wind speeds fall open.

Bend it in the middle again.



Open to see the highest group of wind speeds.

Flex your tetraflexagon to see all four sides showing the twelve Beaufort Scale categories and their illustrations.

How Do We Observe and Measure the Wind (Part 2)?

Record

observations in your engineering notebook.

Go outside to observe the wind. Although you can't see the wind, what can you observe that tells you how windy it is?

What do your other senses tell you about the wind?

Observe the wind at regular time intervals for several days. Make a chart and record your wind observations. Include the date and time of day. Use your Beaufort Wind Scale tetraflexagon to estimate the wind speed.

How does a wind vane work like the **rudder** on a wind mill?

Beaufort Wind Scale
Developed in 1805 by Sir Francis Beaufort

Force	Wind Speed (miles per hour)	WMO Classification	Appearance of Wind Effects On Land
0	Less than 1	Calm	Calm, smoke rises straight up
1	1-3	Light Air	Smoke moves in the direction of the wind, wind vanes don't move
2	4-7	Light Breeze	Leaves rustle, wind can be felt on face, wind vanes begin to move, flags stir
3	8-12	Gentle Breeze	Leaves and small twigs are constantly moving, light flags blow out
4	13-18	Moderate Breeze	Dust, leaves, and loose paper lifted off ground, small tree branches move, flags flap
5	19-24	Fresh Breeze	Small trees in leaf begin to sway, flags ripple
6	25-31	Strong Breeze	Larger tree branches move, umbrellas are hard to use, flags beat
7	32-38	Near Gale	Whole trees moving, hard to walk against the wind, flags extended
8	39-46	Gale	Twigs break off trees, walking is very difficult
9	47-54	Strong Gale	Slight structural damage occurs, shingles blow off roofs
10	55-63	Whole Gale	Whole trees are uprooted, severe damage to buildings
11	64-73	Violent Storm	Widespread damage
12	74+	Hurricane	Violent destruction

HOW DO WE OBSERVE & MEASURE THE WIND? PART 1

Talk About It

- What indicators of wind speed do you observe today?
- What is the speed of the wind today?
- How do your observations compare with the official weather information?
- Can you observe different wind conditions in different areas of your neighborhood at the same time? Explain how that is possible.
- Where does the wind blow at the steadiest speeds? The fastest speeds? The slowest speeds?
- Is today a good day to fly a kite? How do you know? Use the Beaufort Scale to determine the wind speed.

Learning from Others

- What members of your community need to know the speed of wind?
- How can you teach others to observe the speed of wind?
- What projects could you do together to observe the wind and gauge its speed?

Use the Beaufort Wind Scale to determine the approximate wind speed in these photos of flags.

Wind Facts

June 5, 1805 a massive **tornado** started in Missouri and then crossed the Mississippi River into Illinois. Fish were scattered all over the countryside of Illinois. Reports were that clothing from one home that was hit was carried 8 miles.

Jet streams form more than 9 km above the Earth. They travel at speeds of 92 km/hr or more.

High Winds

All of these are names of storms that have high winds. What are the characteristics of each? How do they differ from each other?

Hurricane

Tornado

Cyclone

Tropical Storm

Typhoon

Tsunami

Investigate other tools for measuring the wind.

How do they compare to using the Beaufort Scale?

How Does a Pinwheel Use Wind Power?

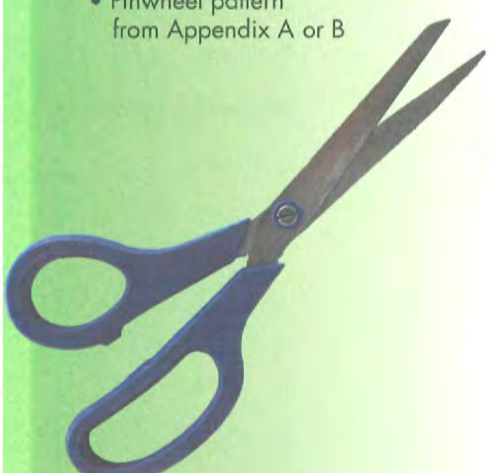
Try It

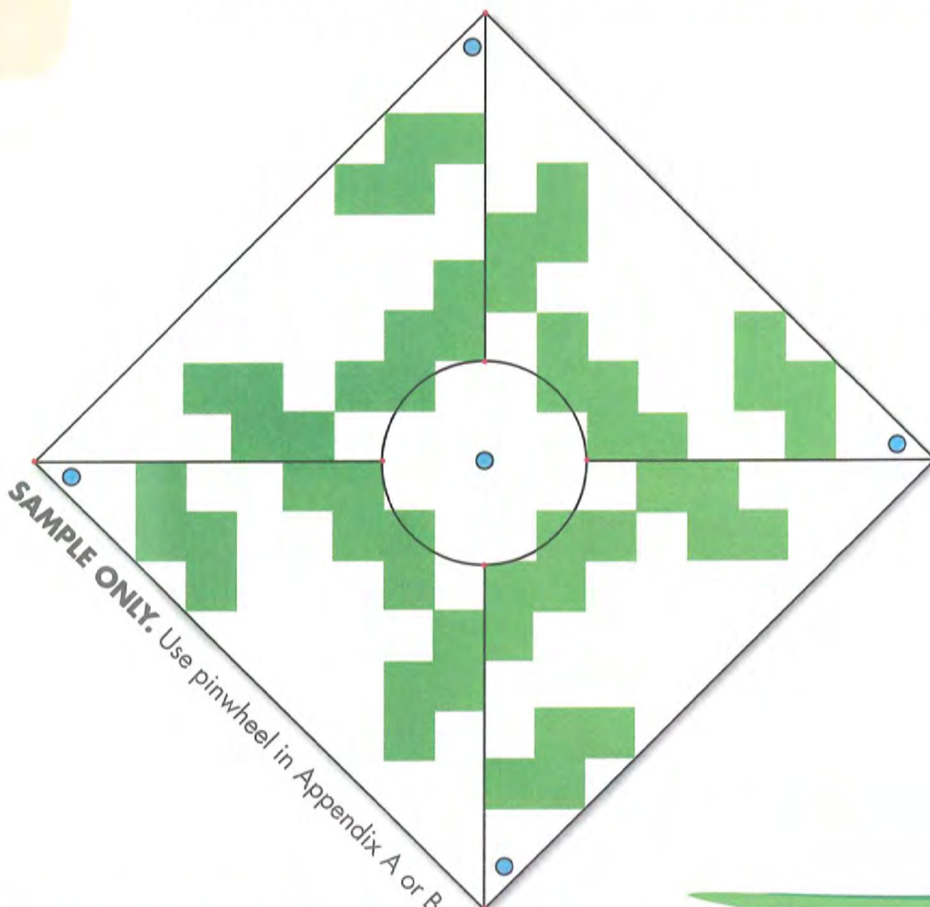
- Cut out one of the square pinwheels in Appendix A or B.
- Cut on the lines from the corners to the center circle.
- Curl the dots at the corners to line up with the dot in the center circle.
- Push the pin through all five dots and into the eraser of a pencil.
- Blow straight into the front of the pinwheel and see it turn.

Pinwheels are easy to make and are fun toys that turn when air blows on them. A pinwheel is a turbine. The energy of the moving air becomes **mechanical energy** when the pinwheel turns.

You Will Need:

- Scissors
- Straight pins
- Pencils with erasers
- Pinwheel pattern from Appendix A or B





HOW DOES A PINWHEEL USE WIND POWER?

PART 2

Talk About It

- When the wind blows straight into the front of the pinwheel, it turns. What happens when the wind blows into the back of the pinwheel or if it blows into the sides? Try both sides.
- Does your pinwheel turn easily?
- What could be improved? How could you alter your pinwheel design?

Try Something Else and Test Again

- Make another pinwheel from a larger square. What happens? Does it turn faster or slower?
- What other changes could you make to the design that might change the speed? What happens when you try out your changes?
- What adjustments can you make in the design to make your pinwheel turn better?

Learning from Others

- What determines the direction of the turning?
- How is your pinwheel like the working **windmill** in the picture?
- How does the pinwheel use the power of the wind?
- Your pinwheel and your boat both use wind power. How are they alike? How are they different?
- How can you help younger children learn to design pinwheels? How can you teach them how pinwheels work? Create a short lesson for children in your neighborhood.

MSTE photo, Ji-Young Kim

Rotational Symmetry

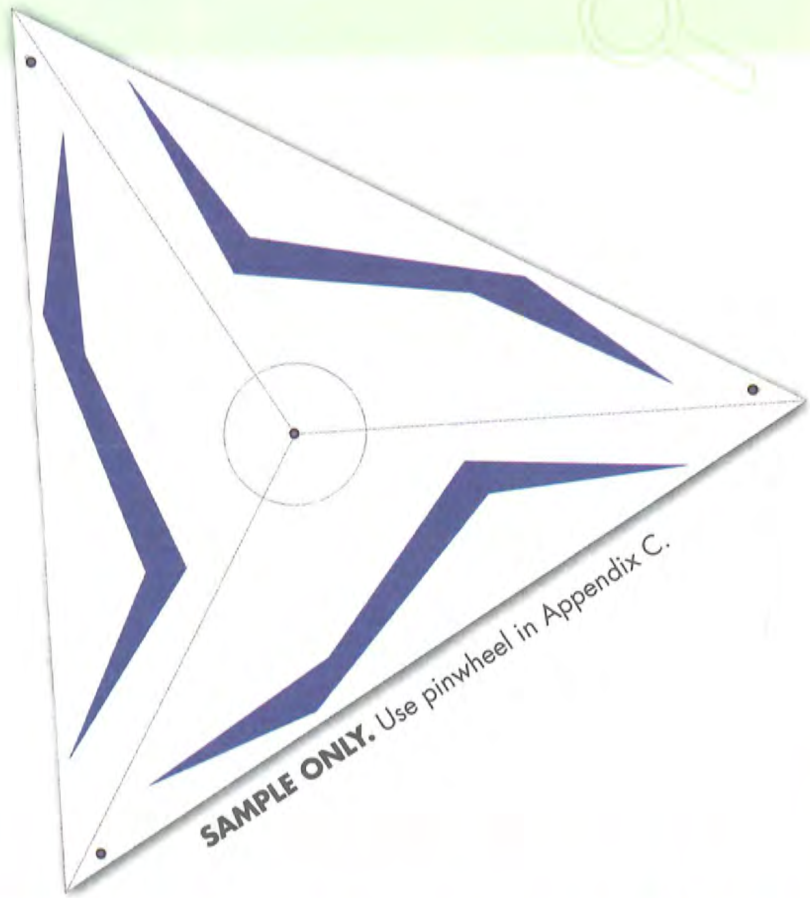
The pinwheel pattern looks the same in multiple positions as it turns. This is an example of **rotational symmetry**. The windmill blades in the photo also have rotational symmetry.

INVESTIGATION

How Can We Design a Better Pinwheel?

Try It

- Cut out the triangular pinwheel in Appendix C.
- Make a design on the pinwheel that has rotational symmetry.
- Cut on the lines from the corners to the center circle.
- Curl the dots at the corners to line up with the dot in the center circle.
- Push the pin through all three dots and into the eraser of a pencil.
- Design and build another pinwheel with more blades. Start with a hexagon, octagon or other polygon.



You Will Need:

- Scissors
- Straight pins
- Pencils with erasers
- Paper (various weights—construction paper, index cards, cardboard)
- Pinwheel patterns from Appendix C

Other Possible Materials:

- Paper plates
- Aluminum pie plates
- Paper clips
- Coffee stirrer
- Popsicle sticks
- Miscellaneous hardware and office supplies

In Your Engineering Notebook

write or sketch answers to questions you find important or interesting.

Make several pinwheel variations.
What other aspects of the design change the way the pinwheel works?

How well do other pinwheel shapes work?

Vary the number, shape, and size of the blades.
What materials work best? Is stiffer paper too heavy?

Record your observations about the various designs in your engineering notebook.

Make sketches or include photos.

How Can We Design a Better Pinwheel? (Discussion) PART 3

Talk About It

- How did your group define "best?"
- Why is it important to change only one thing or variable at a time?
- Which pinwheel designs turn faster using wind energy? How do you know?

Learning from Others

- Which pinwheel designs does the entire group think are the best? What does your entire group mean by "best?"
- What other changes could you make to the design that might change the speed?
- Why might speed be important in working windmills and wind turbines?
- What do you observe about the blades of working windmills and wind turbines? Think about their shape, length, and speed.

Wind Facts

- Normal breathing causes a 5 mph "wind."
- Sneezes can travel at a speed of 100 mph.
- The ancient Greeks thought wind was the breath of the earth.

CHALLENGE

How Can We Use Wind Power to Produce Electricity?

Design and Build

a wind turbine that uses wind power to create electricity.

Try It

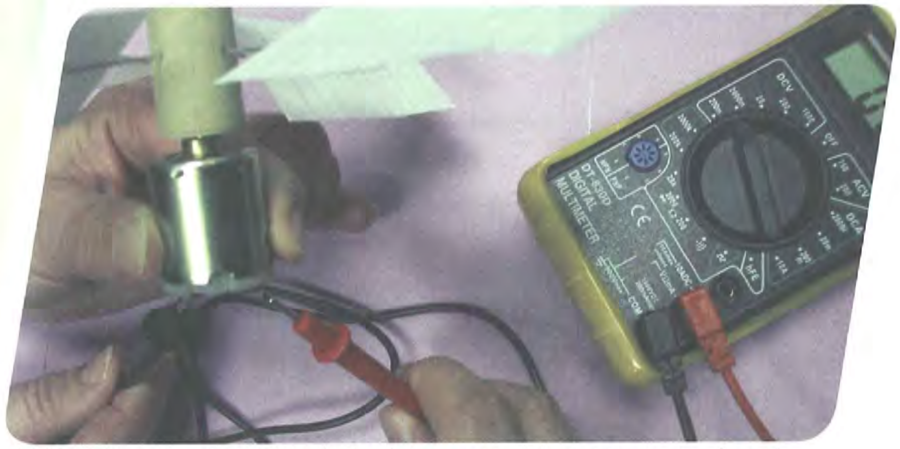
- Create **rotor** blades.
- Connect your blades to a cork hub.
- Insert the **shaft** on the **motor** into the cork.
- Attach the leads on the motor to the **multimeter**.
- Simulate the wind with a box fan.
- Position the "wind" near your device.
- Measure the electricity produced.

You Will Need:

- Cardstock or index cards
- Paper clips
- Tape
- Cork (natural or synthetic)
- Multimeter
- Box Fan
- Small motor
- **LED** (a string of tiny holiday bulbs, cut apart, works well)
- Wire stripper

Other Possible Materials:

- Plastic drink bottles or aluminum pie plates
- Rubber bands
- String
- Paper cups
- Miscellaneous junk, hardware and office supplies



When the rotor turns the shaft of the motor, electricity is produced. You can measure the amount of electricity with a **multimeter**. Try to produce at least one volt. See Appendix F for help in using your multimeter. Remember, a motor uses electricity and a **generator** produces electricity.

In Your Engineering Notebook

write or sketch answers to questions you find important or interesting.

Faster turning rotors produce more electricity. Use a systematic method for testing and developing your designs. Adjust the number, position, shape and size of the rotor blades. Refer back to the Engineering Design Process on page 8 and write about how your design evolved.

How many volts can it produce?

Can it produce enough electricity to light a small **LED**?

Take a picture of your best design and include it in your notebook.

Appendix D

Beaufort Wind Scale – Tetraflexagon (Front Template)

- Cut on the heavy black lines and crease on the red vertical lines.
- Draw illustrations in each of the squares that contain small print.
- Follow the instructions for folding on pages 10–11.

4 47–54 mph Strong gale	4 antennas break	3 umbrellas hard to use	2 leaves move
2 13–19 mph Moderate breeze	3 32–38 mph Moderate gale	4 55–73 mph Whole gale/ Violent storm	4 trees uproot, widespread damage
4 more than 74 mph Hurricane	4 hurricane	3 difficult walking	2 trees sway

Appendix E

Beaufort Wind Scale – Tetraflexagon (Back Template)

4 less than 1 mph Calm	4 smoke rises	3 8–12 mph Gentle breeze	2 25–31 mph Strong breeze
2 13–19 mph Moderate breeze flags extend	3 branches move	4 1–3 mph Light air	4 smoke drifts
4 4–7 mph Light breeze	4 flags stir	3 19–24 mph Fresh breeze	2 39–46 mph Strong breeze

Appendix F

Using a Multimeter

Measuring Voltage

You can test even a very small amount of generated electricity using a moderately priced digital multimeter. If the turbine you created is spinning, that means you can measure its voltage. The voltage is one measure of how fast the turbine is spinning.

- The multimeter has a red test lead cable and a black test lead cable. To measure voltage attach the red to the VΩmA jack and the black to the COM jack.
- Select 20V on the DCV part of the dial.
- Attach the leads to the generator and place your turbine in the test wind.
- Depending on your turbine design and the wind speed, your voltage readings should be between 0.1 and 1.0 volts.
- Turbines that generate voltage readings near 1.0 volts can light a small LED.