REVIEWED & RECOMMENDED
National 4-H Curriculum

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Product Number 08384

THE POWER OF THE *Wind*

FACILITATOR'S GUIDE

18 USC 707

Acknowledgments

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The Office for Mathematics, Science, and Technology Education (MSTE) is a division of the College of Education at the University of Illinois at Urbana-Champaign. The goal of MSTE is to serve as a model-builder for innovative, standards-based, technology-intensive mathematics and science instruction at the K–12 levels. The Office serves as a campus-wide catalyst for integrative teaching and learning in mathematics, science, and technology education.

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Contents

THE POWER OF THE *Wind*

The 4-H Youth Development Program promotes learning by doing and focuses on developing skills for a lifetime. This project is designed to teach youth about the wind and its uses while introducing them to engineering and engaging them in doing and reflecting on the activities. See Experiential Learning Model on page 5.

What is 4-H SET?
What Are the Curriculum Components?

4-H SET is 4-H's response to the needs of youth to develop curiosity, abilities, and deepened learning in the areas of science, engineering, and technology (**SET**). Steeped in over 100 years of experience in working with youth in a variety of non-formal science education settings, 4-H plays a leading role in engaging youth to explore **SET** with trained and caring adults in a positive youth development environment. 4-H works from a common framework, including National Science Education Standards, to increase literacy and improve abilities in science, engineering, and technology. **4-H SET** is preparing today's youth and America's future workforce.

An Effective 4-H SET Experience Engages Youth Through:

Content

- Science, Engineering, and Technology content based on the National Science Education Standards
- SET Abilities

Context

- The Essential Elements of Positive Youth Development, fundamental to 4-H:
    - o mastering life challenges
    - o cultivating independence with guidance from caring adults
    - o developing a sense of belonging within a positive group
    - o sharing a spirit of generosity toward others
- Reliance on trained, caring adult staff and volunteers acting as mentors, coaches, facilitators, and co-learners
- Perspective that youth are partners and resources in their own development
- Inquiry-based, hands-on, experiential approach to learning that fosters the natural creativity and curiosity of youth

Delivery

4-H SET engages 6.5 million youth each year through a variety of settings, including clubs, camps, special interest groups, online, in- and out-of-school programs.

For additional information regarding SET Concepts, standards and abilities, please refer to: SET Programming in the Context of 4-H Youth Development located at: ***www.4-H.org***

Important components of *The Power of the Wind* curriculum include: engineering design process, goals, unifying concepts, SET Abilities, experiential activities, engineering design notebook, questioning, scientific terms, careers, and online component.

Engineering Design Process

Throughout this project book youth are guided to use the engineering design process to find solutions to problems related to wind power. Youth work on teams to analyze problems and find solutions that balance options and constraints. They test what they've made to see how it works, then make adjustments and test further, as necessary. Although designed for groups, this project could be adapted for individual project work with an adult. Throughout the design process, adult facilitators cultivate independence and mastery by guiding and asking questions in a caring environment. The challenges are designed to assist youth to learn by doing and apply findings to local community needs.

Goals

As youth construct wind powered devices, they:

- learn about the wind and how its energy is used to do work and produce electricity
- become aware that all energy comes originally from the sun and that it can be transformed in many ways
- learn how geography affects available wind power capacity
- explore wind power projects in various parts of the United States
- consider the factors necessary for a successful wind power project
- share what they've learned with leaders in their communities
- are introduced to scientific habits of mind and scientific ways of knowing

Unifying Concepts

The unifying concepts of this curriculum align with *National Science Education Standards*:

<u>Science as Inquiry</u>
- · Abilities necessary to do scientific inquiry
- · Understandings about scientific inquiry

<u>Physical Science</u>
- · Motion and forces
- · Transfer of energy

<u>Earth and Space Science</u>
- · Earth in the solar system

<u>Science and Technology</u>
- · Abilities of technological design

<u>Science in Personal and Social Perspectives</u>
- · Science and technology in society

<u>History and Nature of Science</u>
- · Nature of science

Activities

There are three different types of activities in the Wind Power youth guide. Although designed specifically for groups, they can be used as individual project activities with support from a facilitator/leader. The **Challenge** activities require youth to use and practice engineering and design skills to produce a wind powered machine or vehicle, test the device, and adjust the device as necessary. Almost all the devices the youth construct will differ but many will be successful. These activities require youth to use many SET abilities including build/construct, compare/contrast, and design solutions.

In the **Investigation** activities youth are often required to build a wind powered device but everyone builds the same device in order to observe an important concept in a consistent way. These activities require youth to use a different group of SET abilities including observing, measuring, recording, and use of tools.

Third are the **Exploration** activities. Here, youth examine important national, state, and local issues surrounding wind power and the scientific concepts behind those issues. These activities require youth to practice SET abilities that include researching a problem, categorizing/ordering/classifying and interpreting/analyzing/reasoning.

Engineering Design Notebook

Youth use the engineering design notebook as an integral part of the curriculum. It can be used as a place to design prototypes, document observations and thoughts, sketch components of designs, answer questions and write more questions. Entries in the notebook can help youth think, process, direct their inquiry, and can be used as an assessment tool. Encourage youth to log in the date and time with each notebook entry, as engineers do.

Questioning

The discussion questions ask youth to analyze their data and synthesize the main idea while encouraging them to learn from each other. Facilitators provide support through effective communication, including open-ended questioning. They remind youth that it is the design that is important and redirect them as needed, encouraging them to question themselves and each other, reflect on the questions, and use their ideas to try a new strategy or re-test an idea.

Scientific Terms

Different systems of measurement are used for different purposes. Scientists usually use the metric system. (NSES). Scientific terms are introduced within the context of the activities and the first instance of these words can be found in **bold**. Using the glossary, you can provide youth with a better understanding of word meanings as they apply to a specific activity while youth are engaged. Become familiar with the words and their relevance to a particular activity. Restate the definition or reframe it as needed to give additional exposure to the terminology.

Careers

Throughout the curriculum, youth are encouraged to make connections to careers related to science, engineering and technology.

The Power of the Wind online component

www.4-H.org/curriculum/wind

Online resources support, extend, and enrich the learning experience for youth and facilitators.

How Can We Think Like an Engineer?

Overview

This Engineering Design activity introduces the design process and gives youth an opportunity to "think like an engineer." These first examples involve thinking about design issues related to familiar situations in daily life. Throughout the project book youth are reminded to use the design process as they construct wind powered devices.

Getting Ready

- Read the activity in the youth guide.
- Prepare for a discussion that will generate a large number of ideas.

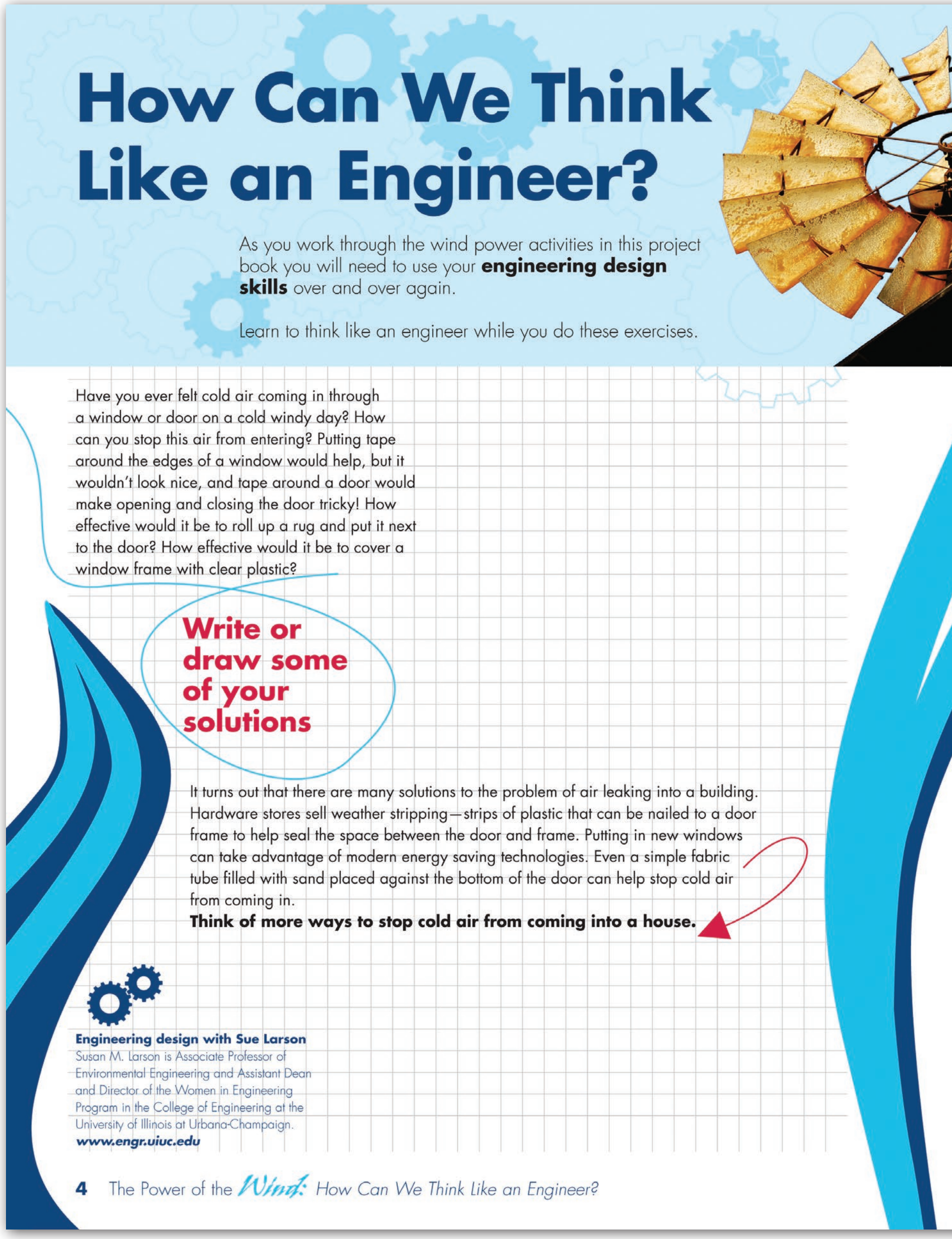
Facilitating the Activity

Introduce the youth to the engineering design process and to Sue Larson, of the College of Engineering at the University of Illinois at Urbana-Champaign. Point out that her remarks about engineering and design are found throughout the project guide.

Introduce the air infiltration problem and ask the youth for solutions. Give them a few minutes to brainstorm and make note of a few ideas. Ask individuals to share their possible solutions to this problem with the group. Keep a list of ideas as they are proposed and post them where everyone can see. The first goal is to generate a large number of ideas without judging them.

Next, return to the list and add possible advantages and disadvantages to the proposed solutions.

After the group has discussed a variety of solutions to the air infiltration problem, direct the youth to their engineering notebooks. Remind them that this notebook is for thoughts and ideas, sketches and photos. Take a few minutes for each young person to make some notes about possible solutions to the air infiltration problem in their engineering notebooks.



How Can We Think Like an Engineer?

As you work through the wind power activities in this project book you will need to use your **engineering design skills** over and over again.

Learn to think like an engineer while you do these exercises.

Have you ever felt cold air coming in through a window or door on a cold windy day? How can you stop this air from entering? Putting tape around the edges of a window would help, but it wouldn't look nice, and tape around a door would make opening and closing the door tricky! How effective would it be to roll up a rug and put it next to the door? How effective would it be to cover a window frame with clear plastic?

Write or draw some of your solutions

It turns out that there are many solutions to the problem of air leaking into a building. Hardware stores sell weather stripping—strips of plastic that can be nailed to a door frame to help seal the space between the door and frame. Putting in new windows can take advantage of modern energy saving technologies. Even a simple fabric tube filled with sand placed against the bottom of the door can help stop cold air from coming in.

Think of more ways to stop cold air from coming into a house.

Engineering design with Sue Larson
Susan M. Larson is Associate Professor of Environmental Engineering and Assistant Dean and Director of the Women in Engineering Program in the College of Engineering at the University of Illinois at Urbana-Champaign.
www.engr.uiuc.edu

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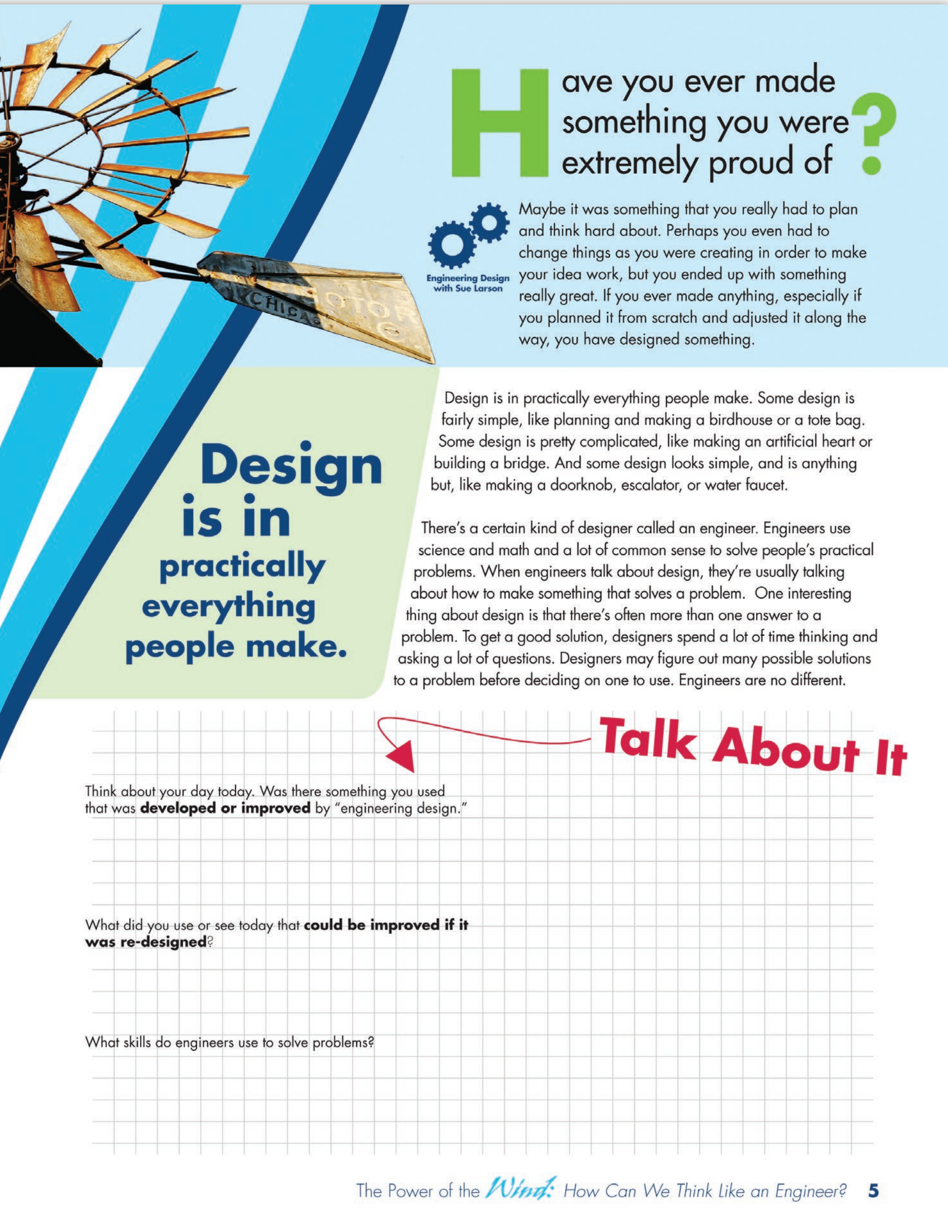
Notes



Have you ever made something you were extremely proud of?

Engineering Design with Sue Larson

Maybe it was something that you really had to plan and think hard about. Perhaps you even had to change things as you were creating in order to make your idea work, but you ended up with something really great. If you ever made anything, especially if you planned it from scratch and adjusted it along the way, you have designed something.

Design is in practically everything people make.

Design is in practically everything people make. Some design is fairly simple, like planning and making a birdhouse or a tote bag. Some design is pretty complicated, like making an artificial heart or building a bridge. And some design looks simple, and is anything but, like making a doorknob, escalator, or water faucet.

There's a certain kind of designer called an engineer. Engineers use science and math and a lot of common sense to solve people's practical problems. When engineers talk about design, they're usually talking about how to make something that solves a problem. One interesting thing about design is that there's often more than one answer to a problem. To get a good solution, designers spend a lot of time thinking and asking a lot of questions. Designers may figure out many possible solutions to a problem before deciding on one to use. Engineers are no different.

Talk About It

Think about your day today. Was there something you used that was **developed or improved** by "engineering design."

What did you use or see today that **could be improved if it was re-designed**?

What skills do engineers use to solve problems?

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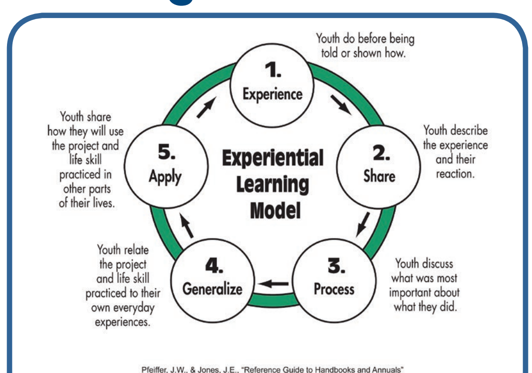
The Engineering Behind the Activity

Engineers use science, math, and problem solving skills to solve people's practical problems. There could be many good design solutions to a problem. Engineers try a lot of possible solutions before choosing one.

Introduce the idea that anything an engineer designs will be the result of choices and trade-offs. They are always balancing criteria and constraints. Engineering design involves learning from what went wrong, fixing it, and trying again. Engineers are good players; they understand how to solve problems and communicate solutions. Engineers think it's best to learn-by-doing.

What is the Experiential Learning Model?



Pfeiffer, J.W., & Jones, J.E., "Reference Guide to Handbooks and Annuals"
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The Experiential Learning Model of Instruction provides learners an opportunity to become familiar with the content (Experience), explore a deeper meaning of the content (Share and Process), connect the learning to other examples or opportunities (Generalize), and apply it in real world situations.

The facilitator will guide youth through this process by helping them to focus on the activities, provide support and feedback for the learning, and debrief with them about their learning experience: what went well, what they could have done differently, what they could do next. This debriefing process fits hand-in-glove with the engineering design process used throughout the curriculum.

CHALLENGE

How Can We Design a Wind Powered Boat?

Wind Power Skill:	Designing and engineering a sailboat
SET Abilities:	Observe, record, build/construct, compare/contrast, design solutions, evaluate, interpret/analyze/reason, measure, redesign, troubleshoot
Education Standards:	NSES: Science as Inquiry; Transfer of Energy; Motion and Forces
Life Skills:	Critical thinking, Problem solving, Teamwork
Success Indicator:	Designs and engineers a sailboat that travels forward, straight, and at least 75 cm; describes how the wind moves the boat

Overview

This Challenge is a design problem. In this activity, youth build their own sailboat and test it to see how far and straight it goes when they use a fan as a source of wind. Youth should be encouraged to test, adjust their designs, and test again.

Getting Ready

- Read the activity in the youth guide and gather the necessary materials.
- Provide table top or floor space for groups to design and test their boats.
- Remind youth that they will use their engineering notebook for planning and recording this activity. Youth may want cameras to take pictures of their designs.

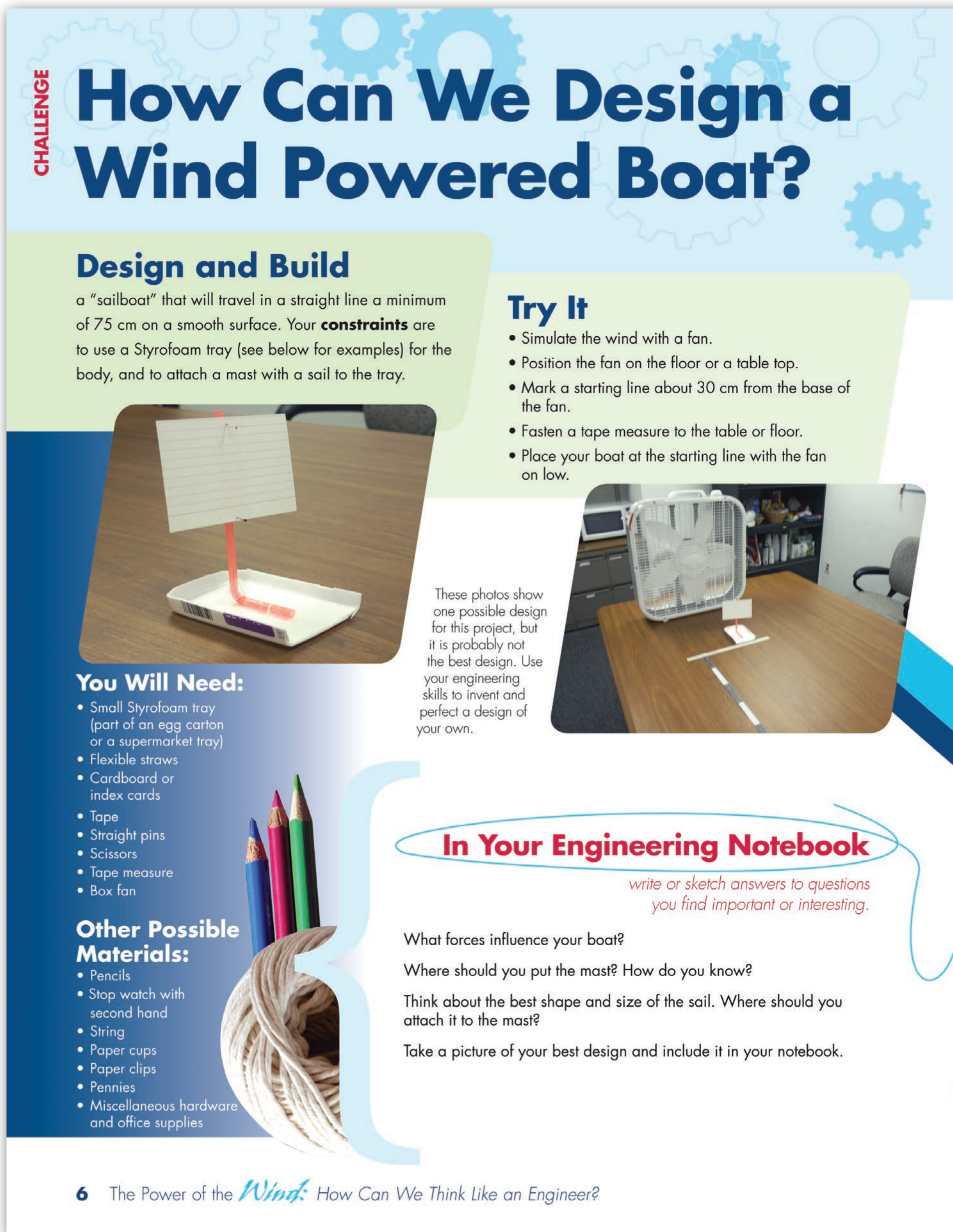
Facilitating the Activity

Explain to the youth that their challenge is to design a sailboat that will travel in a straight line a minimum of 75 cm on a smooth surface. Talk to the youth about the engineering design process. Engineers make a plan, build a prototype (first attempt), test it, make adjustments, test it again, and continue to adjust and test again. Make sure the youth have plenty of time to work and discuss their designs.

As a facilitator, you may impose limitations on materials or add a time constraint. You may allow only paper sails or you may want to suggest trying cloth sails.

When youth have had enough time to perfect their designs, conduct a group test so everyone can see and discuss all the sailboats.

You may want to use a stopwatch and conduct a timed test.


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.

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.

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

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.

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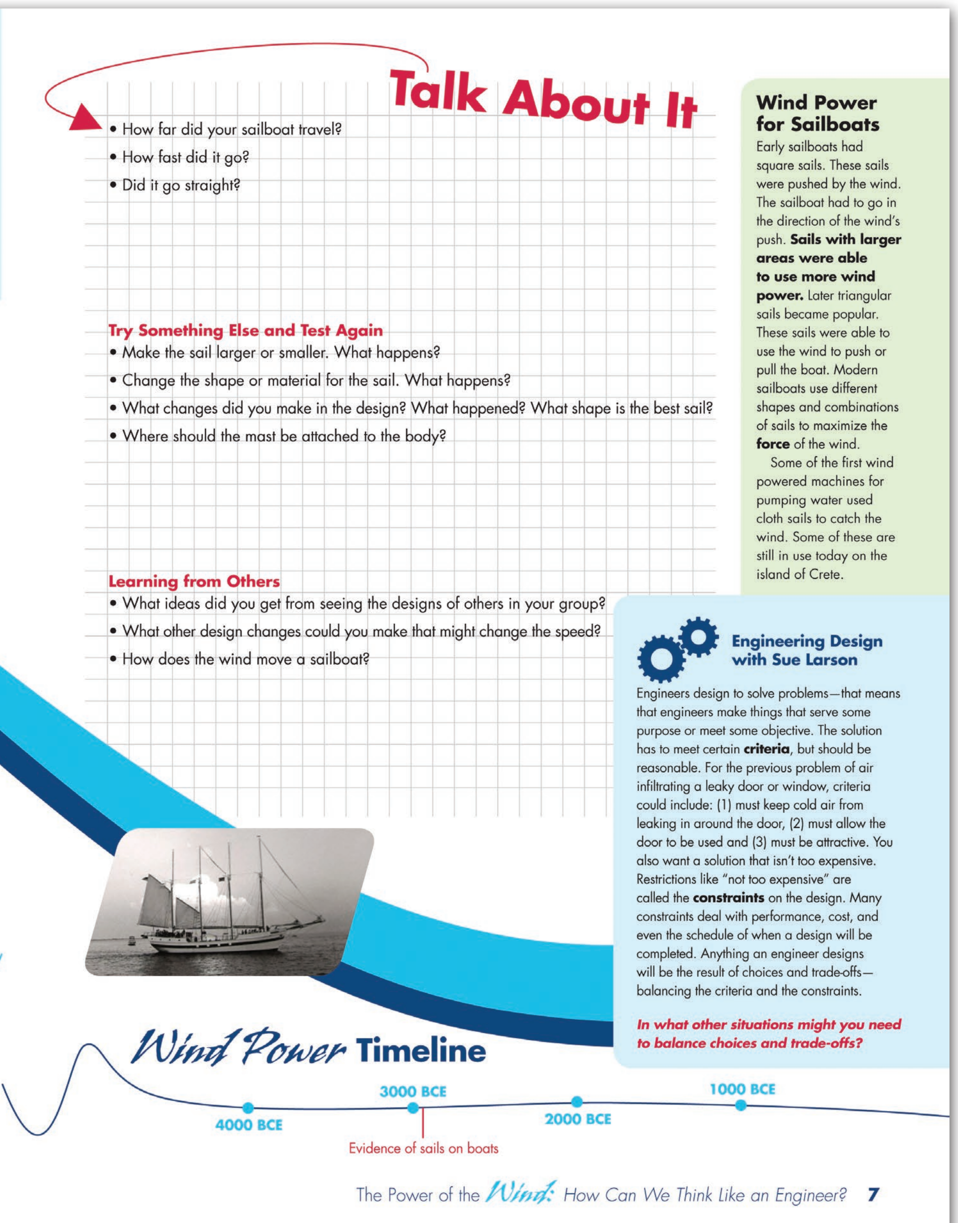
Encourage Group Thinking

Materials Needed

- Styrofoam trays
- Pencils *(optional)*
- Straws
- Cardboard
- String *(optional)*
- Paper cups *(optional)*
- Paper clips *(optional)*
- Tape
- Straight pins
- Scissors
- Pennies *(optional)*
- Tape measure
- Box fan with low setting
- Stopwatch with second hand *(optional)*

Historical Perspective

Sailboats were early users of wind power. The activities in this book parallel the historical development of wind powered machines. Take time to have youth examine the timelines throughout.



Talk About It

- How far did your sailboat travel?
- How fast did it go?
- Did it go straight?

Try Something Else and Test Again

- Make the sail larger or smaller. What happens?
- Change the shape or material for the sail. What happens?
- What changes did you make in the design? What happened? What shape is the best sail?
- Where should the mast be attached to the body?

Learning from Others

- What ideas did you get from seeing the designs of others in your group?
- What other design changes could you make that might change the speed?
- How does the wind move a sailboat?

Wind Power for Sailboats

Early sailboats had square sails. These sails were pushed by the wind. The sailboat had to go in the direction of the wind's push. **Sails with larger areas were able to use more wind power.** Later triangular sails became popular. These sails were able to use the wind to push or pull the boat. Modern sailboats use different shapes and combinations of sails to maximize the **force** of the wind.

Some of the first wind powered machines for pumping water used cloth sails to catch the wind. Some of these are still in use today on the island of Crete.

Engineering Design with Sue Larson

Engineers design to solve problems—that means that engineers make things that serve some purpose or meet some objective. The solution has to meet certain **criteria**, but should be reasonable. For the previous problem of air infiltrating a leaky door or window, criteria could include: (1) must keep cold air from leaking in around the door, (2) must allow the door to be used and (3) must be attractive. You also want a solution that isn't too expensive. Restrictions like "not too expensive" are called the **constraints** on the design. Many constraints deal with performance, cost, and even the schedule of when a design will be completed. Anything an engineer designs will be the result of choices and trade-offs—balancing the criteria and the constraints.

In what other situations might you need to balance choices and trade-offs?

Wind Power Timeline

4000 BCE — 3000 BCE: Evidence of sails on boats — 2000 BCE — 1000 BCE

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The Science Behind the Activity

Energy and its forms is an idea that is developed throughout this booklet. In this activity, youth should begin to understand that wind energy is transformed into energy of motion—called kinetic energy by scientists—as the sailboat travels. Youth should see that wind pushes the sail, causing the boat to move, and larger sails catch more wind. Youth might want to discuss the problem of friction—the force between the table and the parts of the boat that touch the table that works against the forward motion of the boat.

Trade-offs are a very important part of the Engineering Design Process that need to be considered when comparing different possible designs, and again when a prototype is being designed. For example, increasing performance often results in higher costs. Or an increase in the speed of a boat often results in a decrease in stability. An excellent example later in this unit is that higher speed of a rotor means lower torque. It is a prominent part of the choices that youth make in deciding between different wind turbine rotor designs in the next activities.

Going Further

Speed of travel on the sea or in the air is measured in knots (1 knot ≈ 1.15 mph). One knot or one nautical mile per hour is faster than one mile per hour.

The nautical mile is based on the circumference of the earth at the equator (or any great circle). There are 360 degrees of latitude in the whole circumference of the earth. Each of those degrees is sub-divided into 60 minutes. One nautical mile is one minute of latitude at the equator. So a ship or airplane traveling at one knot covers one minute of one degree of latitude in one hour. The distance around the earth at the equator is 360 x 60, or 21,600 nautical miles.

The world water speed record is just over 275 knots. How long would it take a ship traveling at 275 knots to go around the world at the equator? Actually, the record was set in 1980 on a one kilometer straight-away, so do you think a boat could keep going at this speed for very long?

Learn More About Engineering Design

Overview

These pages offer youth an opportunity to reflect on the engineering design process that they used in the previous activity and will continue to use.

Getting Ready

Review the Engineering Design Process and the chart that compares scientific inquiry and engineering design found on page 9.

Facilitating the Activity

Step 1: What is the challenge or problem to solve? In the previous activity, the challenge was to design and build a sail boat that will travel in a straight line for a minimum of 75 cm on a smooth surface. Throughout *The Power of the Wind* curriculum, there are several design challenge activities for youth to solve.

Step 2: How have others solved this? What is the current state of the issue? Encourage youth to look for ideas from others who have solved this challenge or similar challenges. There are many resources such as the internet, books, or the photos in the curriculum that can be used as springboards to innovative thinking and new ideas.

Step 3: What are the design constraints? In the previous activity, the constraints were distance and limited materials (youth had to use a styrofoam tray, for instance). What solutions did they brainstorm, given their constraints? Did they try different shapes, sizes, or placement of the sails? The activities throughout the curriculum provide possible designs and suggestions, but youth brainstorm many others. Encourage them to draw on principles of mathematics and science.

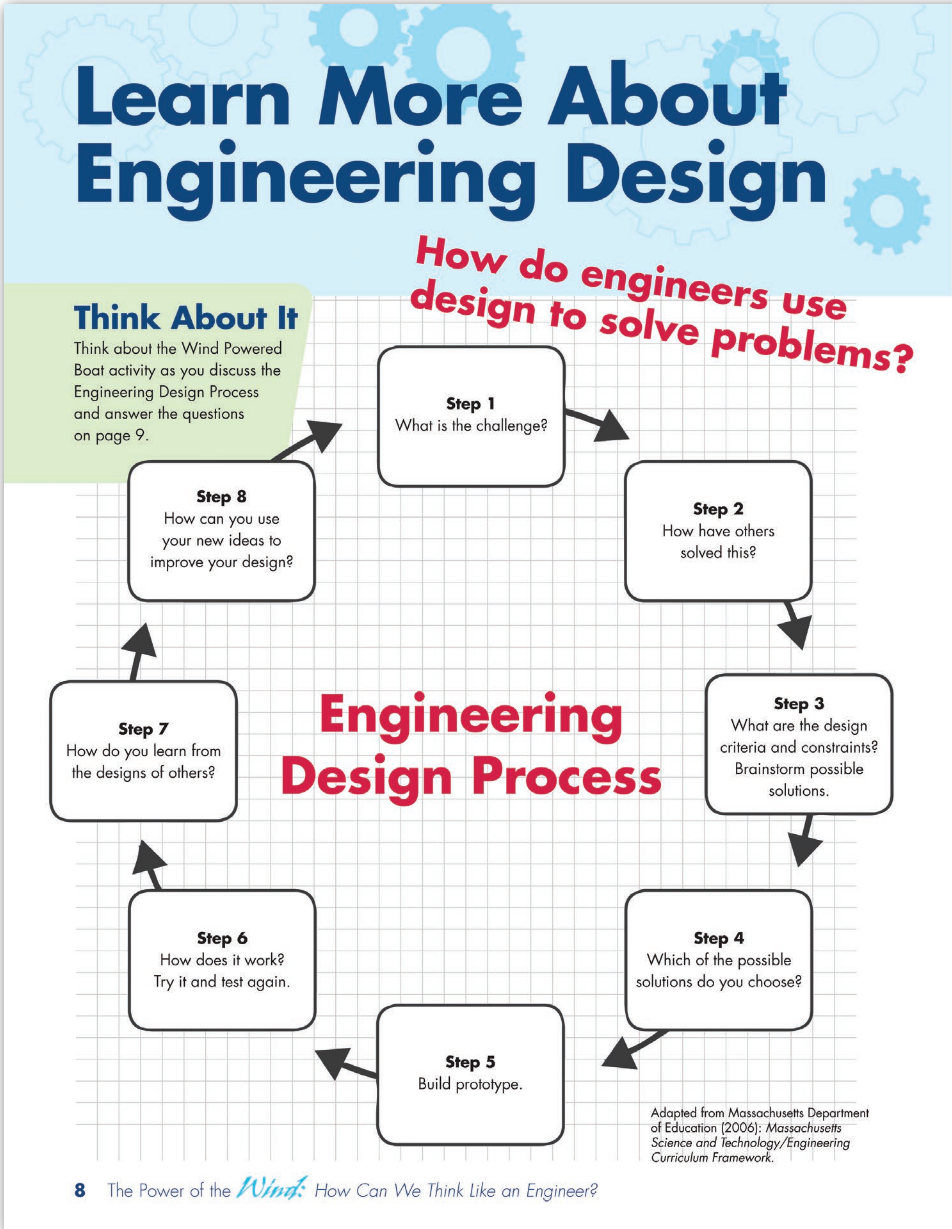
Step 4: After considering multiple options youth narrow the choices based on what they think will work best.

Step 5: Build a prototype. The prototype is a first attempt at constructing a workable solution. This solution can can be in two or three dimensions.

Step 6: How does it work? Does it meet the original design constraints? Try it and test again. Youth assess their prototype by trying it. They evaluate what is working and what is not working and think about how to fix it. They make changes in the prototypes and then test again.

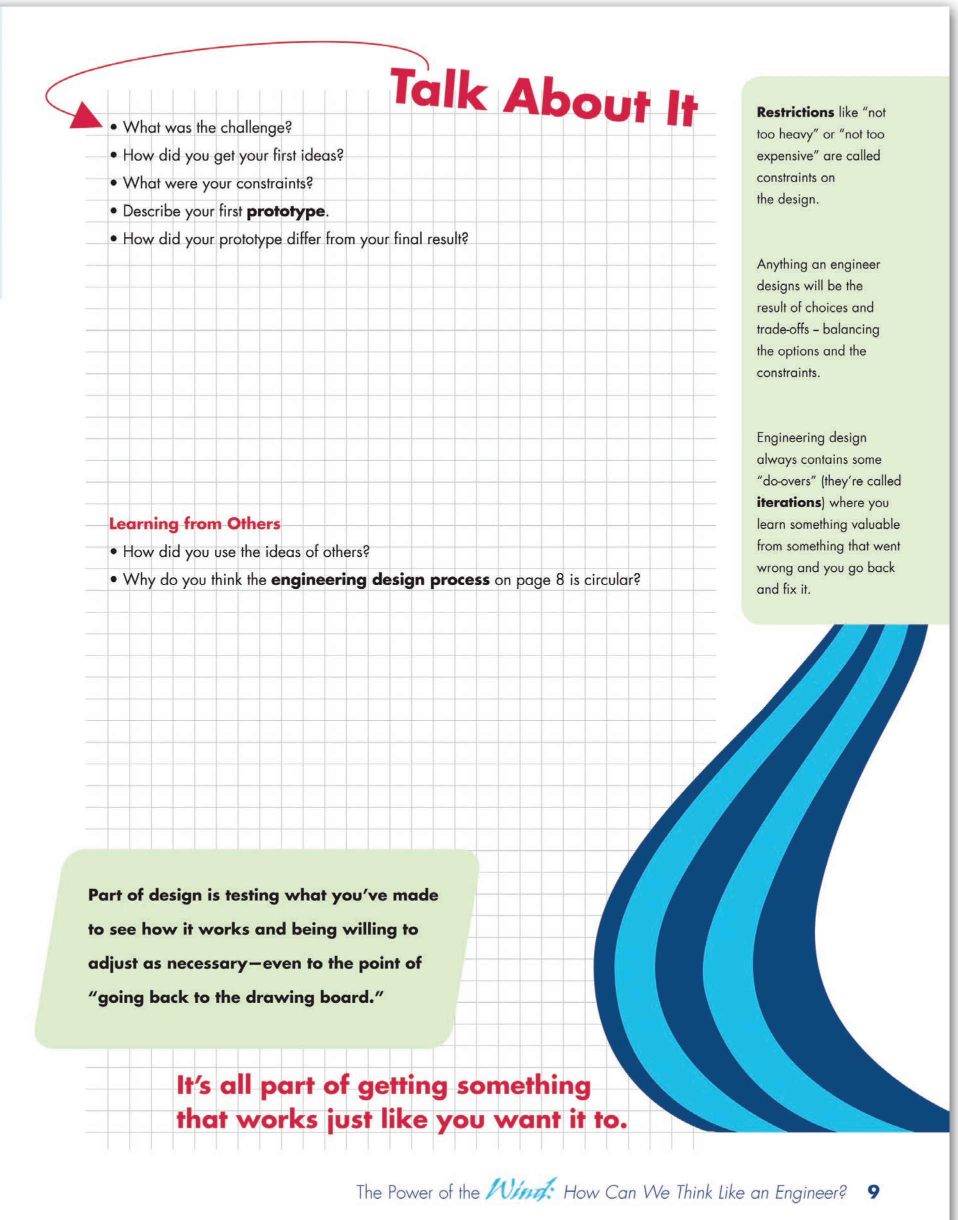
Step 7: How did you learn from the designs of others? Arrange for a whole group trial test so everyone can see all the prototypes and how they perform.

Step 8: How can you use your new ideas to improve your design? The large group trial allows each person to benefit from the ideas of others and have opportunity to see a variety of prototypes and use the information to re-design their original solution. Encourage team work. A successful group trial will result in several solutions for the same problem. Discuss impacts and tradeoffs of the solutions.



Discussion Questions

- How are the processes of science and engineering similar?
- How are they different?
- How does the result of a scientific inquiry differ from the result of an engineering project?
- How many different kinds of engineers do you know about? Reseach careers in engineering and engineering technology.



Talk About It

- What was the challenge?
- How did you get your first ideas?
- What were your constraints?
- Describe your first **prototype**.
- How did your prototype differ from your final result?

Learning from Others

- How did you use the ideas of others?
- Why do you think the **engineering design process** on page 8 is circular?

Restrictions like "not too heavy" or "not too expensive" are called constraints on the design.

Anything an engineer designs will be the result of choices and trade-offs – balancing the options and the constraints.

Engineering design always contains some "do-overs" (they're called **iterations**) where you learn something valuable from something that went wrong and you go back and fix it.

Part of design is testing what you've made to see how it works and being willing to adjust as necessary—even to the point of "going back to the drawing board."

It's all part of getting something that works just like you want it to.

The Power of the *Wind:* *How Can We Think Like an Engineer?* **9**

Notice another variation of the Engineering Design Process as compared to the Scientific Inquiry Process. This can be used as a talking point throughout the curriculum.

The Scientific Inquiry Process	The Engineering Design Process
Formulate a question.	Define a problem.
Research how others have addressed it.	Research how others have solved it.
Brainstorm hypotheses and choose one.	Brainstorm solutions and select one.
Conduct an experiment to test the hypotheses.	Create and test a prototype.
Modify hypothesis based on experiment.	Redesign solution based on test results.
Draw conclusions; write paper.	Finalize design; make drawings.
Communicate findings orally and in writing.	Communicate design in words and drawings.
Investigate new questions.	Define new problems.

Sneider, Cary I., and Brenninkmeyer, Julie (2007). "Achieving Technological Literacy at the Secondary Level: A Case Study from Massachusetts," Professional Development for Engineering and Technology.

EXPLORATION

How Do We Observe and Measure the Wind (Part 1)?

Wind Power Skill:	Creating a tetraflexagon for gauging wind speed
SET Abilities:	Measure, use tools
Education Standards:	NSES: Science as Inquiry NCTM Geometry Standard: Use visualization and spatial reasoning
Life Skill:	Acquiring and evaluating information
Success Indicator:	Creates a tool for gauging wind speed

Overview

In this Exploration, youth create a tetraflexagon to use for gauging wind speed. This is a paper folding activity that introduces the Beaufort Wind Scale. Folding the tetraflexagon requires youth to illustrate the wind scale and read and follow a schematic diagram. The completed tetraflexagon is used in other activities.

Getting Ready

- Read the activity in the youth guide.
- Locate the flexagon template in Appendix D and E and make enough two-sided copies for each person.
- Tell the youth that they will be using their tetraflexagons in other activities.

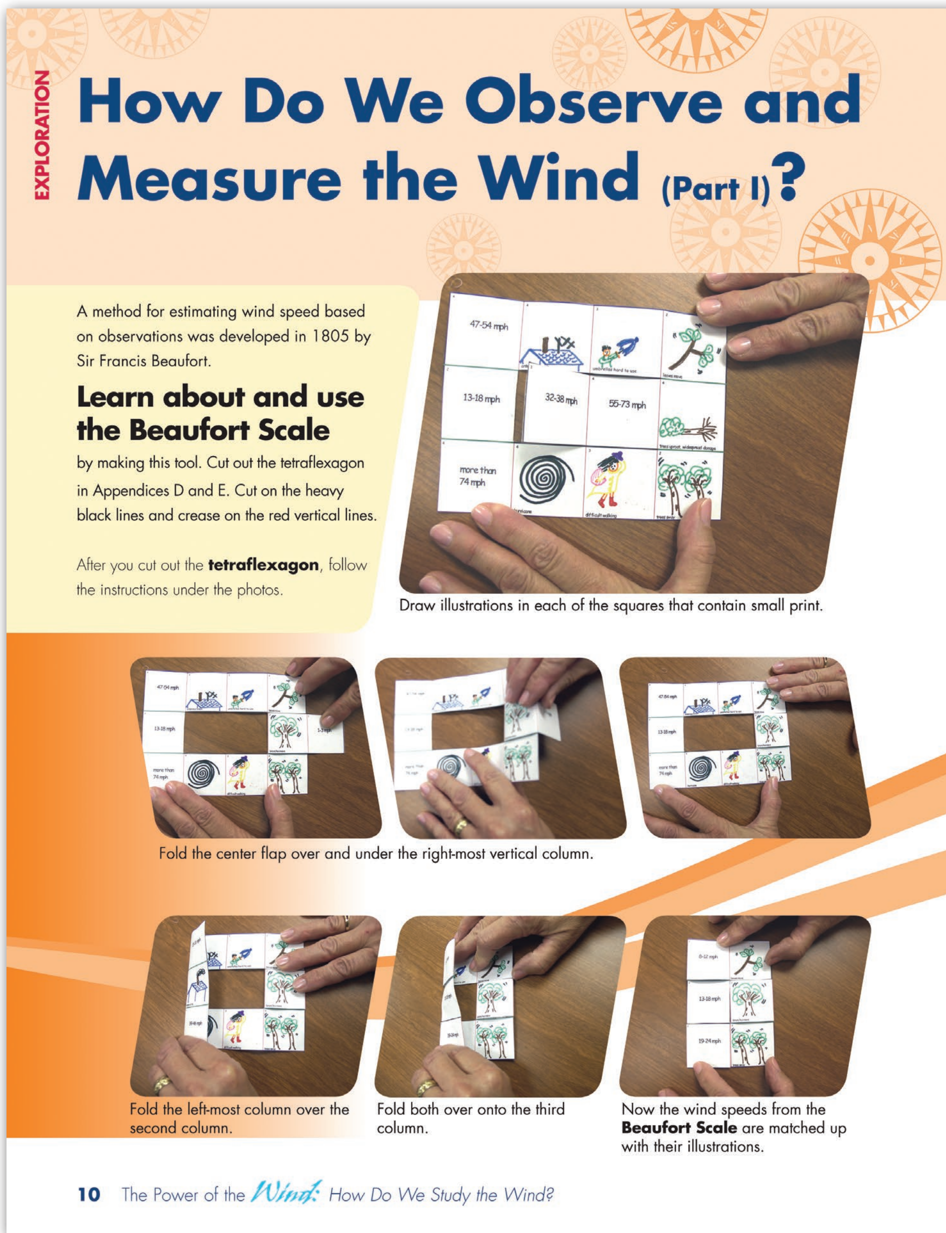
Facilitating the Activity

Explain to youth that they will be creating a tetraflexagon to use for gauging wind speed. Accurate cutting and folding are essential for the tetraflexagon to work properly.

Scientists use tools all the time to extend their senses and collect additional data. Discuss with youth the idea of using tools to provide information that cannot be gathered using only our senses. What other tools do scientists use to extend their senses? Discuss with youth the other scientific tools they have used to collect, record, and analyze data.

The Science Behind the Activity

Wind can be observed, you can hear and feel it, and you can see its effects. Wind speed can be estimated by observing its effects. Ask the youth who might need to be able to do this?


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.

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Materials Needed

Tetraflexagon template
Scissors
Colored pencils or crayons

Going Further

An anemometer is a device for measuring wind speed. A common type consists of four cups that turn in the wind. The revolutions per minute are counted and the wind speed is computed using the circumference of the circle of revolution.

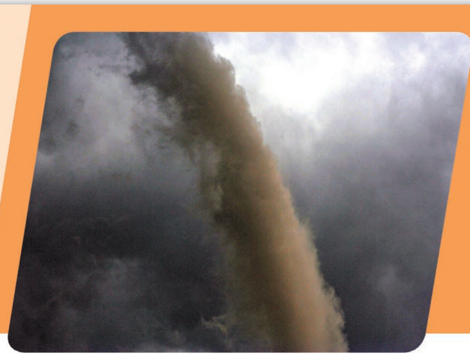
There is a type of anemometer that looks like a protractor. There are electronic digital anemometers and there are other types of anemometers that use a heated wire technology. Where do you see anemometers?

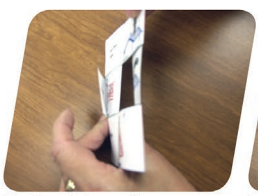
Youth can do some research and get instructions for making an anemometer.

Notes

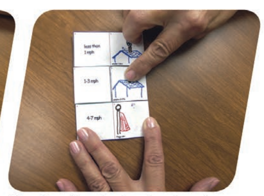
WIND FACT

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.

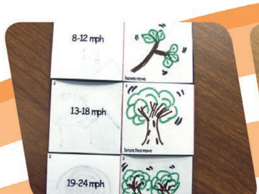




Flip the whole tetraflexagon over and tape.

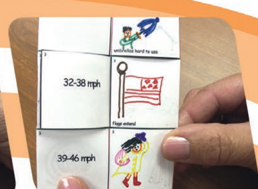


The Beaufort Scale showing the least wind speeds is face up.



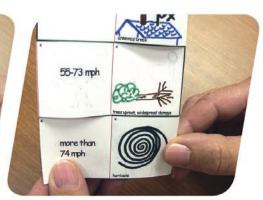
Turn the tetraflexagon over to show the next higher group of wind speeds.

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.