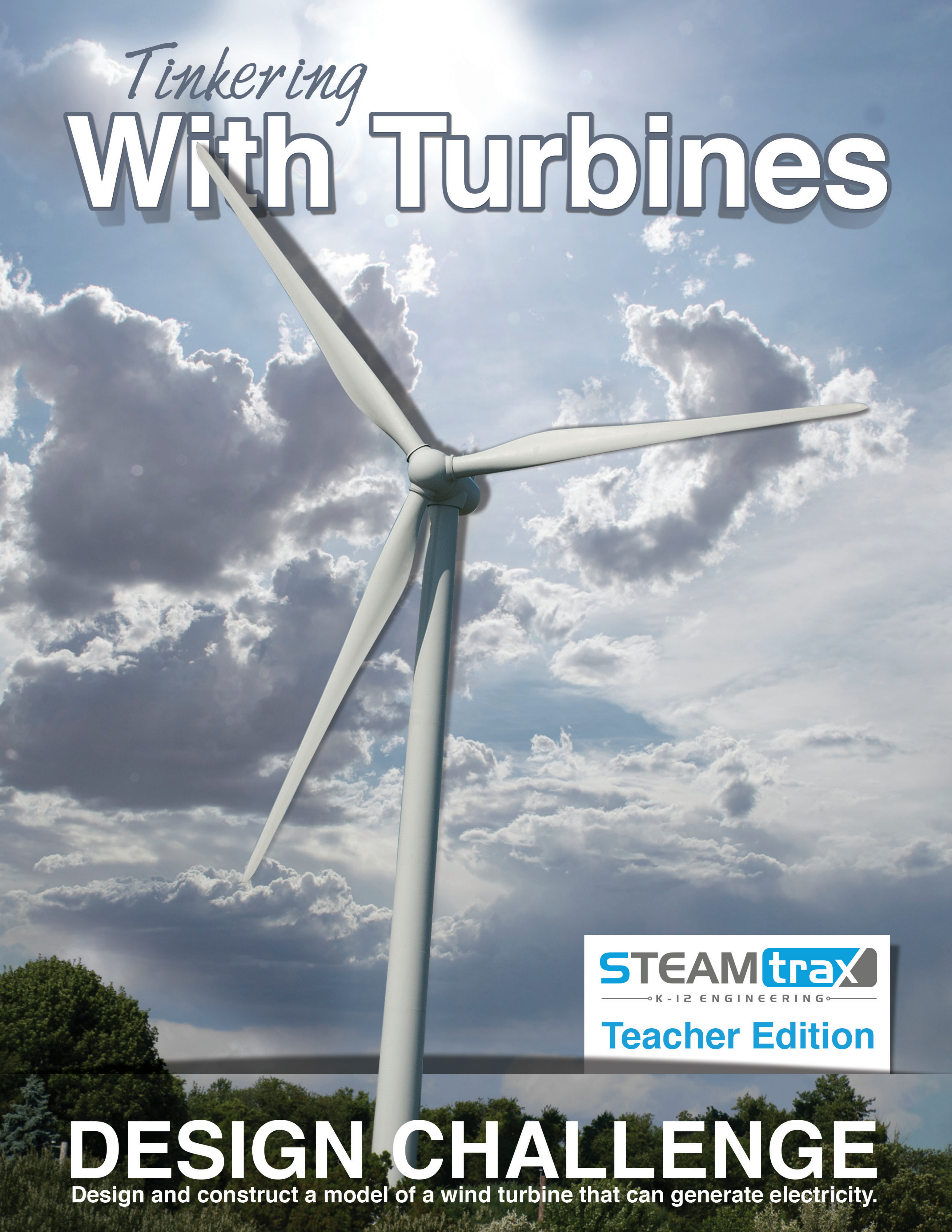
Tinkering With Turbines



STEAMtrax
K-12 ENGINEERING
Teacher Edition

DESIGN CHALLENGE

Design and construct a model of a wind turbine that can generate electricity.

WHAT is STEAMtrax?

STEAMtrax is an innovative new curriculum that integrates engineering and 3D printing technology with core academic knowledge in science, math, language arts, social studies, and art. In the true spirit of the Framework for 21st Century Learning skills, students are engaged in relevant learning scenarios that encourage the essential skills of problem solving, collaboration, clear communication, and critical thinking as well as developing core academic knowledge. Each lesson guides the students through the STEAMtrax Engineering Project Design Process shown below and in the flowchart.

STEP ONE: DEFINE THE PROBLEM

Set the Stage - The class reporter, Stacy STEAMtrax, investigates and relays information back to the team about a relevant problem from another country, culture, or setting. The problem may be in an engaging story, animation, or video.
Identify the Problem - Facilitation questions guide student discussion to identify the problem in the story and create a class problem statement.
Identify the Constraints and Criteria - Using evidence from the story; discuss design requirements and possible limitations or constraints.
Discuss and Guide -Identify math, science, engineering, and technology concepts and skills that must be researched or learned before solving the problem.
Research and Explore - Students rotate through the explore stations and group learning activities with their engineering teams. Facilitation questions assist in debriefing the stations and clarifying the concepts learned.

STEP 2: DEVELOP A SOLUTION

Brainstorm - Each student creates a labeled 2D sketch of the solution.
Debate and Decide - Students share 2D designs, and list constructive feedback.
Prototype - Build and test a 3D prototype model using common classroom materials.
Justify - Students present prototype for approval to scan or CAD the design for printing.
3D Create and Print - Students scan or CAD the design for printing.

STEP 3: TEST THE DESIGN

Test Model - Design a fair test, which controls all variables except the one tested.
Communicate - Groups present their design and CER to the class for constructive feedback on the merits of the model and improvements needed.

STEP 4 IMPROVE THE DESIGN

ReDesign - Based on the class feedback, students sketch an improved model.
Defend - Students discuss which improved designs should be reprinted.
***3D Recreate and Print** – Reprint of the best model design with class input.
***Write and WrapUp** - Students complete a write up of what they have learned.

*****_if time permits_

STEAMtrax ENGINEERING
Project Design Process

STEP 1: Define the Problem
- Set the Stage
- Identify the Problem
- Identify the Constraints and Criteria
- Discuss and Guide
- Research and Explore

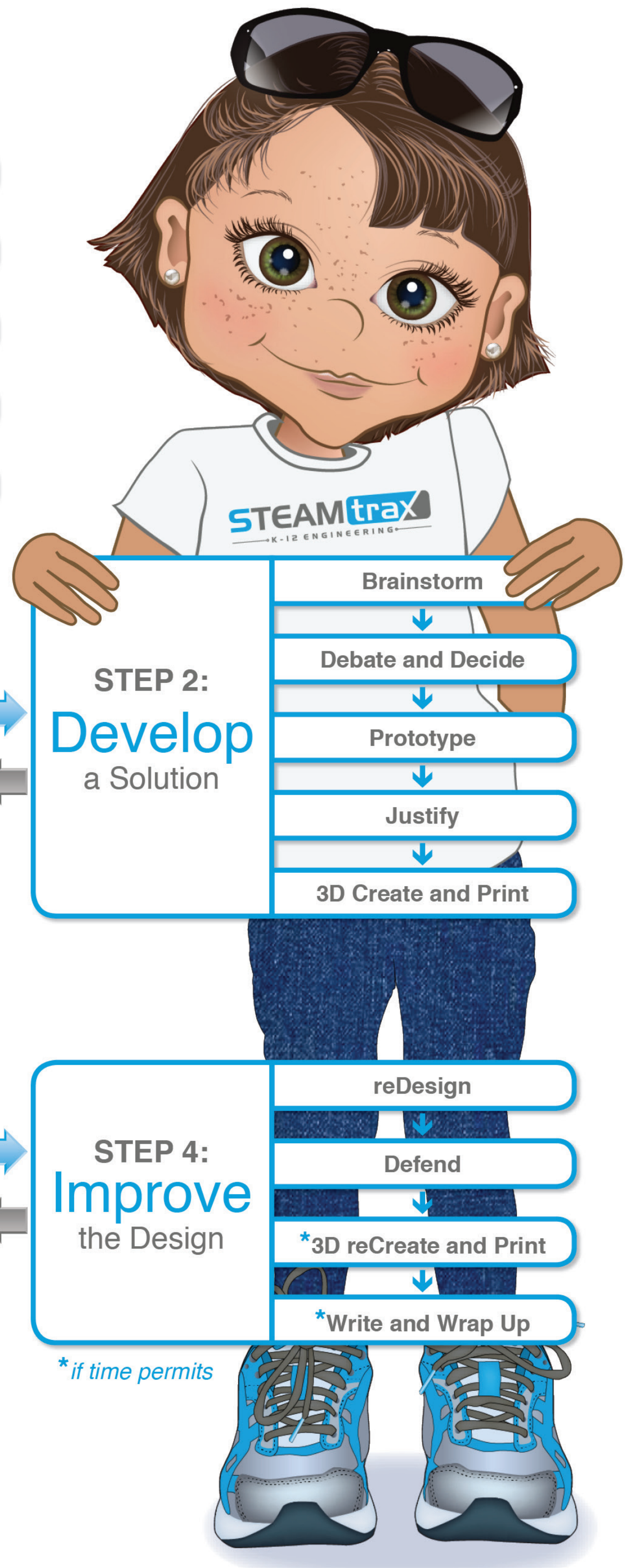
STEP 2: Develop a Solution
- Brainstorm
- Debate and Decide
- Prototype
- Justify
- 3D Create and Print

STEP 3: Test the Design
- Test
- Communicate

STEP 4: Improve the Design
- reDesign
- Defend
- *3D reCreate and Print
- *Write and Wrap Up

*if time permits

Extend and Apply
- Entrepreneurship
- Art
- Community



Set-up and Management

- Gather the necessary materials in a central location.
- Duplicate copies of the printed materials for each student:
  - » *Student Notebook*
  - » *Parent Letter*
  - » *Standards-Based Assessment*
- Duplicate a copy of the printed materials for each group:
  - » *Evaluation Rubric*
  - » *Self and Group Evaluation*
- Print out several copies of each of the wind turbine blade templates on card stock.
- Print out a copy of each station card on card stock and laminate.
- Assemble the TeacherGeek Wind Lift model.
- Assemble Wind Turbine materials in zip bags for each group.
- Assemble station materials. Cut apart a string of small holiday tree lights. Strip about 2-3 cm of the plastic off the wires so that they can be attached to the hand crank generator.
- **Read the Quick Start Guide instructions carefully.**
- **Be sure to set the print jet gap before beginning printing.** (See Quick Start Guide.) It is suggested that this be done prior to every printing job.
- Clean the Print Pad under tap water and dry with a lint-free cloth. Just before printing, remove the Print Pad from the Cube. Apply a thin, even coat of CubeStick glue on the entire Print Pad. Check to make sure there are no gaps without glue. Place Print Pad on the platform.

Materials Needed

Non-consumable Materials

- TeacherGeek Wind Lift model, assembled
- 20 washers
- 3 hand crank generators
- 2 battery holders
- 2 lightbulbs and holders
- 2 small electric motors (can be purchased at science or electronic websites or supply stores)
- 10 alligator clips
- TeacherGeek Wind Turbine model parts for each group, in zip bag
- electric fan
- 1 DC Voltmeter or voltage probe
- 1 wire stripper
- ruler, 1 per group
- triple beam or electronic balance

Consumable Materials

- card stock
- graph paper, cm squares
- plastic and foam disposable plates
- set of small holiday tree lights
- string
- wires with ends stripped

For Every Lesson:

- CAD Software (download here)
- 3D CUBE Printer (purchase here)
- PLA cartridge (purchase here)
- Cube Stick (purchase here)

Engineering Toolkit

- calculator
- calipers
- glue sticks
- large paper clips
- markers
- multi-cutter tool
- pencils
- Phillips screwdriver, small head
- rubber bands
- ruler
- scissors

Printed Materials on Cardstock

- *Wind Turbine Blade Templates*
- *Learning Station Cards,* laminated

INTRODUCE THE 3D PRINTER

Place the 3D printer in a central location to demonstrate its use. Explain that a 3D printer can transform a digital message from a computer, scanner, or file into a 3D object using filament as "ink."

- Turn on the printer as directed in the first step of *Cube Printer Quick Start Guide*, and then follow each step of the *Cube Printer Quick Start Guide* as your facilitator demonstrates how to prepare the Cube for printing.
- Hold up examples of geometic shapes and a USB drive, explaining that the digital code for the shapes are stored on the USB. Demonstrate how to insert the USB into the printer, and choose the shape each group wants to print from the file. Explain that the printer will take at least 30 minutes to print the shape, and that we will be checking it several times during the printing process as the class works on other related activities.

STEP 1: DEFINE THE PROBLEM

SETTING THE STAGE

- Read the story of William Kamkwamba, and how he overcame challenges to build a wind turbine to provide electricity for his family and village.
- Lead the students in a discussion to identify the problem in the story, and ask them to complete the CLOZE sentence below in their *Student Notebook*.
- The challenge is to design a *wind turbine* that will *transform wind energy to electrical energy*.

IDENTIFY THE CRITERIA/CONSTRAINTS

Lead the students in a discussion to elicit information about the challenges of designing a wind turbine and list their responses on chart paper or the board.

CRITERIA OR DESIGN REQUIREMENTS (POSSIBLE ANSWERS FROM STUDENTS)

- *Wind turbine structure must be tall enough to allow the blades to spin freely in the wind and stand on its own.*
- *Blades must be light enough to spin.*
- *Blades have to be connected to a device that can change or transform the movement of the blades into electricity.*

CONSTRAINTS OR LIMITS ON THE DESIGN (DUE TO RESOURCES AND ENVIRONMENT)

- *Finding materials to design and build the wind turbine in the junkyard.*
- *Learning how to use the materials to generate electricity.*

DISCUSS AND GUIDE

Lead the students in a discussion to elicit other questions or concepts they may need to research or learn about before solving the problem.

- What is a complete electrical circuit?
- How do generators work?
- How can we transform wind to mechanical or electrical energy?
- How do windmills and wind turbines work?
- How can we make plastic blades?
- Which blade shape will catch the most wind?

RESEARCH AND EXPLORE

Explain to students that they will explore the skills and concepts they need to help them solve the problem at learning stations about electrical energy, energy transformation, generators, motors, and wind turbines.

- Remind students to record observations while visiting the stations, and explain that they will have 8 minutes at each station to follow the instructions on the station card and record their observations on the *Station Data Sheet*.
- Facilitate the rotation to the stations using a timing device that emits a sound when it is time to straighten up and move to the next station.
- Debrief stations with students by allowing each group to report their observations of the stations, and clarify understanding of the concepts using the facilitation questions and possible answers from students in blue text:

Station 1: Exploring Electrical Energy

- How did you make the bulb light up using energy from the batteries? *We placed the batteries in the holders and connected the alligator clips to the metal on the battery holders and the bulb holder to make a complete circuit to light the bulb.*
- Does it matter which way the batteries are placed in the holder? *The batteries must be placed in the holders by matching the + and – signs on the battery and holder to insure that electricity flows from the negative to the positive end of the battery. If the batteries are backwards, the electricity will not flow.*
- How was energy transformed or changed in this system? *The chemical energy in the battery was transformed to electrical energy that traveled through the wires to the bulb, where it was finally transformed into light energy.*

Station 2: More Than One Way to Light a Bulb

- How can you make the bulb light up using the hand generator? *Connect the alligator clips to the metal parts on the holiday bulb and the bulb holder to create a circuit, and then turn the hand crank on the generator until the bulb lights.*
- How are the holiday bulb and the bulb in the bulb holder similar? *They both have metal to conduct electricity from the alligator clips to form a complete circuit.*
- How was energy transformed or changed in this system? *Turning the crank of the generator converts the mechanical energy of moving parts of the generator into electrical energy, which flows down the alligator clips to the bulb, where it is transformed into light energy.*

Station 3: Is It a Generator or a Motor?

- What do you observe inside the hand generator as you turn the crank? *We see moving gears connected to a small motor.*
- How was energy transformed or changed in this system? *Turning the crank of the generator converts the mechanical energy of moving parts of the generator into electrical energy, which flows down the alligator clips of the second hand generator, which acts as a motor by transforming electrical energy into the mechanical energy that we observe as the handle turns.*

Station 4: What is a Windmill?

- What happens to the Wind Lift when you place it in front of the fan? *The blades spin as they catch the wind, which turns the dowel where the string and cup are connected.*
- What happens to the Wind Lift when you add washers to the cup and place it in front of the fan? *The Wind Lift transforms wind energy into mechanical energy to lift a load of washers.*

Station 5 What is a Wind Turbine?

- How is the wind turbine like the Wind Lift Windmill? *Both a windmill and a wind turbine transform energy from the wind into other types of energy. If the energy is used directly to do work (like the Wind Lift), the device is called a windmill. If the mechanical energy is transformed to electrical energy, (like the hand generator), then it is called a wind turbine.*
- Did William build a windmill or a wind turbine in the story? *A wind turbine, because it generated electricity.*

Station 6: Which Blade Measures Up?

- Why is the shape of the blades for a wind turbine important? *Different blade shapes may be more efficient in catching wind to turn the turbine depending on the surface area, mass, and thickness of the blade.*
- Why is the surface area of the blades for a wind turbine important? *The blades catch the wind, so a larger surface area may help to catch more wind.*
- Why are the mass and thickness of the blades for a wind turbine important? *Blades need to be strong and light – blades that are too heavy and thick may be hard to move with wind energy.*

GROUP LEARNING ACTIVITY: WHICH ROTOR WORKS BEST?

Direct students to follow the instructions on *Which Rotor System Works Best?*, to gather more data on how each blade affects the rotation of the wind turbine.

- Allow each group to choose one of the pre-printed tagboard blade shapes for their rotor system. Have several of each blade pre-printed in case a group decides to change to a different blade shape based on results of their tests.
- Remind students about proper safety when working with electrical motors. Never touch any bare wires or exposed metal when generating electricity!
- Set up a station to measure how much electricity each rotor system generates. This measuring station should have a DC voltmeter or voltage probe and a small electric fan.
- As each group finishes their rotor system, let them test the voltage that each rotor generates, and record the data in their engineering journals.
- Give students time to discuss what they discovered during their research and exploration time.
- Discuss and compare the electricity produced by each blade design.

PLAN AND CREATE A DESIGN BRIEF

- Review the design challenge and constraints/criteria.
- Show students the materials available for constructing their wind turbines from the wind turbine kit. Discuss the physical properties of the remainder of the materials and how they might affect the performance of the wind turbine.
- Develop a rubric to guide the students in their design.

STEP 2: DEVELOP A SOLUTION

BRAINSTORM

- Remind students of the materials available for constructing their wind turbines, including plastic blades that will be printed on the 3D printer.
- Instruct students to create a labeled 2D sketch of their design solution individually, then to share their design with their group.

DEBATE AND DECIDE

- Allow time for members of the groups to identify the strengths and weaknesses of each design using the *Engineering Improve It Plan*.
- Monitor as each team creates a final wind turbine design sketch. Make sure students label the parts of the sketch and tell what materials they will use in constructing their model.

BUILD A PROTOTYPE

- Have each group choose a blade shape for the blades for their wind turbines. They may use their rotor system from the learning station or build another rotor with a different blade type.
- Allow at least 30–40 minutes for groups to assemble their wind turbine bases.
- Assist the students in assembling the model wind turbines, as needed. Make sure the students have the motor securely attached to the rotor system before testing.

TEST AND ANALYZE PROTOTYPE OR MODEL

- Ask students to record all data on the *Test and Analyze Your Wind Turbine* page of their *Student Notebook*.
- Have the DC voltmeter or voltage probe and the fan set up in an area large enough for testing the wind turbines. Let each group test their wind turbine models at the three different speeds. Make sure they fill in the data table as they test their systems.
- Instruct groups to calculate the average voltage produced at each speed.
- Give each student a sheet of graph paper to create a bar graph depicting the average voltage produced at each fan speed.
- Direct students to answer the questions following the data table.

COMMUNICATE AND JUSTIFY

- Draw a large data table on the board to collect average voltage data from each group. Have a column on the table in which the students will draw the shape of their blade.
- Let each group demonstrate their wind turbine models for the class and share the data they collected. Have one member from each group add their data to the class data table.

After each group has shared, ask the following questions:

» What shape of blade worked best at low speeds? High speeds?

» Why do you think these blades worked best?

» What energy transformations were taking place as the blades of the wind turbine were spinning?

» What problems did you encounter as you constructed and tested your model wind turbine?

» Did you decide to revise your original design or change materials while constructing and testing your model? Explain.

» If you had access to materials other than those allowed, what might you have chosen to use to construct your model? Why?

» If you were to make another model wind turbine, what would you do differently? Why?

- Let students from other groups ask relevant questions. Allow them to make positive comments and critiques, if desired.

3D CREATE AND PRINT

- Review the use of the Cube printer, and how to choose from the file on the USB for blade shapes.
- Review the *3D scanner Quick Start Guide* and the *Tinkercad* instructions so students may either scan or CAD blade designs.
- Begin printing the blades chosen on the Cube to insure that all groups will have the printed

blades needed to construct their wind turbine.

STEP 3 TEST THE DESIGN

TEST

- Distribute another copy of *Test and Analyze Your Wind Turbine* handout for each group to record results on the Wind Turbine
- Have the DC voltmeter or voltage probe and the fan set up in an area large enough for testing the wind turbines. Let each group test their new wind turbine models at the three different speeds. Make sure they fill in the data table as they test their systems.
- Instruct groups to calculate the average voltage produced at each speed, and compare to their prototype model with cardstock blades.

COMMUNICATE

- Ask each group to present their wind turbine model to the class.
- As a class, discuss merits of the model and suggestions for improvements that could be made to each model as constructive feedback, and list on the *Engineering Improve It Plan*.
- Monitor as each team sketches their group's design. Make sure the students label the parts of the sketch and what materials will be used to construct their model.

STEP 4: IMPROVE THE DESIGN

REDESIGN

- Ask students to reconvene in groups to create a drawing or write up of the planned redesign of their model based on feedback from the class.

DEFEND

As groups complete their drawings of improvements, the teacher and the class can decide if the best design can be reprinted on the printer.

3D RECREATE AND PRINT

- If time permits, let students make changes to their wind turbines, and allow them to retest their models to see if the changes were effective.

WRITE AND WRAP UP

Review what students have learned about the science, technology, engineering, art, and math concepts during the lesson wind turbines using a Stand and Deliver review strategy.

- Ask students to find a partner they have not had the opportunity to work with during the lesson. Allow each student to speak without interruption about what was learned during the lesson, as their partner listens. Then, students reverse roles.
- After the oral review, ask students to "Write Up" what they have learned.

STEAM trax
K-12 ENGINEERING

NEED TO KNOW:
Science Concepts

NGSS
- **3-5-ETS1-2:** Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- **ETS1.B:** Developing Possible Solutions
- **5-ESS3-1:** Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.
- **ESS3.C:** Human Impacts on Earth Systems

TEKS SCIENCE CONCEPTS
5.6A: Explore the uses of energy, including mechanical, light, thermal, electrical, and sound energy.
5.6B: Demonstrate that the flow of electricity in circuits requires a complete path through which an electric current can pass and can produce light, heat, and sound.
5.7C: Identify alternative energy resources such as wind, solar, hydroelectric, geothermal, and biofuels. (Readiness Standard)

TEKS SCIENTIFIC REASONING AND INVESTIGATION
5.1B: Make informed choices in the conservation, disposal, and recycling of materials.
5.2A: Describe, plan, and implement simple experimental investigations testing one variable.
5.2C: Collect information by detailed observations and accurate measuring.
5.2D: Analyze and interpret information to construct reasonable explanations from direct (observable) and indirect (inferred) evidence.
5.2E: Demonstrate that repeated investigations may increase the reliability of results.
5.2F: Communicate valid conclusions in both written and verbal forms.
5.2G: Construct appropriate simple graphs, tables, maps, and charts using technology, including computers, to organize, examine, and evaluate information.

NEED TO KNOW:

Math Concepts & Skills

COMMON CORE MATHEMATICS

- **5.NBT6:** Find whole-number quotients of whole numbers with up to four-digit dividends and two-digit divisors, using strategies based on place value, the properties of operations, and/or the relationship between multiplication and division. Illustrate and explain the calculation by using equations, rectangular arrays, and/or area models.
- **5.G2:** Represent real world and mathematical problems by graphing points in the first quadrant of the coordinate plane, and interpret coordinate values of points in the context of the situation.

MATHEMATICS TEKS

- **5.1A:** Apply mathematics to problems arising in everyday life, society, and the workplace.
- **5.1D:** Communicate mathematical ideas, reasoning, and their implications using multiple representations, including symbols, diagrams, graphs, and language as appropriate.
- **5.3C:** Solve with proficiency for quotients of up to a four-digit dividend by a two-digit divisor using strategies and the standard algorithm.
- **5.3K:** Add and subtract rational numbers fluently.
- **5.9A:** Represent categorical data with bar graphs or frequency tables and numerical data, including data sets of measurements in fractions or decimals, with dot plots or stem-and-leaf plots.

LEARNING STATION 6

Cube Printer Quick Start Guide

CUBE PRINTER: SETUP

1. Plug Cube into wall using supplied power cord; turn on by pressing circle button underneath the touch screen. Turn on the printer by pressing the circle button underneath the touch screen.
2. Load print cartridge
   a. Click the "Load Cartridge" button and follow the directions as prompted by the printer
   b. Click new cartridge in, and thread filament through "Cube Tube"
   c. Feed filament into the print head, and wait until filament is extruded out of the print head on the bottom
   d. Once filament is being extruded, exit by clicking the circle button
3. Calibrate the print gap
   a. Touch the screen to start the printer
   b. Click the "Setup" button on the touch screen and click "next"
   c. Place a piece of paper on the clean printbed
   d. Click the "Set Gap" button
   e. Level the print gap on the touch pad, so that the paper can freely move between the printbed and the extruder, but that decreasing the print gap one step more would wedge the paper between the two
   f. Exit by clicking the circle button

CUBE PRINTER: PREPARING A 3D FILE FOR THE CUBE PRINTER

1. Install the Cube software on either Windows or Mac, downloaded from http://cubify.com/en/Products/Cube2TechSpecs
2. Open the Cube software

3. Import the .STL 3D file that you would like to print
    a. If the program asks if the file is in inches, click NO unless you know that your print file is scaled in inches
4. Click the 3D part, so that the part is highlighted in yellow (and not blue).
5. Click the “Heal” button and click “OK”
6. Click the “Orient and Scale” button. Using this dialogue box, you can scale, rotate or translate the 3d print file as needed.
7. Next, click the “Center” button, to center the item on the build plate.
8. Click the “Settings” button at the bottom, to set up the 3D printing settings. Below are default settings and explanations:
    a. Raft – Off (this setting places a printed raft underneath the object. For the most case, this is not needed, but if there are issues with complex objects sticking to the build plate, it can be turned on)
    b. Supports – Off (this settings generates supports for objects with overhangs. If your 3d printing file has overhangs, turn this option on)
    c. Print mode – Strong (this prints with crosshatched infill inside the print)
    d. Print material – PLA
    e. Cube model – Cube 2^{nd}
9. Click the “Build” button and save the .cube file for printing

CUBE PRINTER: PRINTING A 3D FILE

1. Place the .cube printing file on a USB in the main directory, and plug USB into the Cube printer
2. Click the print button
3. Apply CubeStick to the printbed across the entire printbed
4. Select the print file you want to print, and touch the name of the print to start the print
5. The file will then print; status and time remaining will be shown on the touchscreen.
6. Allow for the print to finalize before removing and removing the printer
7. Any supports or rafts can be removed from the raft by hand or with small pliers
8. The printbed may be cleaned by running under water; the CubeStick solution is water soluble.

CUBE SENSE 3D SCANNER
Quickstart Guide

You can use the Sense 3d scanner to scan objects and people of various sizes into 3d-printable files.

1. Install the Cubify Sense software on either Windows or Mac, downloaded from http://cubify.com/en/Products/SenseTechSpecs
2. Plug in the Sense scanner to your computer via USB port, and open the Cubify Sense software
3. Position your object in an area that allows 360-degree clearance (so that you can scan the object from all angles) and make sure that your object is well lit.
4. On the Cubify Sense software, select what you would like to scan
   a. Select either object or person
      i. For object, select the appropriate object size (small, medium, large; examples of these sizes are provided in the software)
      ii. For person, select either head or full body
5. Aim the scanner at the object or person you are scanning, approximately 15 inches away from the target
6. Click start scan; you will have approximately 3 seconds until the scan starts
7. Move the scanner slowly and steadily around the target, using the image depicted in the screen as a guide
   a. Keep the image centered on the screen and follow directions to change distance as directed.
   b. To fill gaps, hold the scanner still on unfilled areas; multiple passes are allowed.
   c. For small items without many distinct features, place other small objects around it to help the scanner with tracking (these can be removed in the software processing step)
8. The scan can be paused with the pause button; when the scan is finished, click the next button.

9. Edit the scan using the built in editing workflow
   a. First, the scan can be cropped using the crop tool to select the area of the scan you would like to keep
   b. The erase tool can be used to remove particular areas that need to be removed
   c. The solidify tool makes the scan print-ready, filling in any holes or gaps in the model
   d. The trim tool allows you to slice away unwanted areas
   e. Finally, the touch up tool can be used in particular areas to smooth out low quality scanning
10. Finally, save the scan to your computer as a .STL file. This file can then be uploaded into the Cube software for printing; if you click the “print” button, the Cube software will open automatically and load the file.

Designing Blades with Tinkercad

Based on previous findings, students can design new printed blades using the Tinkercad CAD design software. Tinkercad is an easy-to-use, free, online CAD software.

- First direct students to create an account on the Tinkercad website at http://www.tinkercad.com. A personal or school email is required.
- Students can then take the Tinkercad online tutorials to become familiar with the software. These can be found under the "Learn" tab.
  - **Lesson:** Learning the moves
  - **Lesson:** Camera controls
  - **Lesson:** Creating holes
  - **Lesson:** Scale, Copy & Paste
  - **Lesson:** Key ring, letters!
  - **Lesson:** Die on the workplane
- Direct students to create a new design for the windmill blade, incorporating their findings from the previous days of experimentation. This design should first be sketched out on paper.
- Next, this paper design can be replicated in Tinkercad.
  - **HINT:** combinations of boxes and cylinders (either additive, or acting as holes) can be used to design the new blade
  - **HINT:** the maximum size should be approximately 120mm horizontally, as the build platform is 5 inches (127mm) squared.
  - **HINT**: an ideal height for the blade is 1.5 mm
    This can be achieved by setting the "snap-grid" to 0.5
- Once students have finalized their designs, direct them to click the Design->Download for 3D printing option
- This will download a .STL file to the computer
- Import that .STL file into the Cube software and prepare for printing as directed in the Cube printer guide and tip-sheet.
- Windmill blade designs can then be tested & compared

Reproducible Masters

DEFINE THE PROBLEM
Setting the Stage

"This is Stacy STEAMtrax reporting to you as I fly to Malawi, Africa. I am traveling to a village called Wimbe to investigate a story about a fourteen year old boy called William Kamkwamba , who designed and built a wind turbine to help his village.

William grew up in the poor village of Wimbe in Malawi, Africa. Like the other villagers, William's family raised corn on their small farm for food. When William was fourteen years old, a severe drought with no rain and strong winds dried up the corn crop. The people of Malawi began to starve, and William felt fortunate to have one handful of corn meal each day for dinner. His family could no longer afford to pay his $80 yearly fee for school, so William had to drop out of school.

Luckily, the school allowed William to borrow books so he could continue to study science. William borrowed a 5th grade book called Using Energy with windmills and wind turbines on its cover. He studied the book to learn about electricity, electrical circuits, generators, and how to build a wind turbine.

The villagers who did not understand science laughed when William began to visit the junk yard to gather materials to build a windmill. He dragged home rusty tractor fan, plastic pipe, wire, bolts, and a broken bike with a small generator headlight and bulb. To build thin blades to catch wind, he melted plastic pipe over a fire, flattened the pipe, and then shaped the blades with a saw. William's friends helped him to build a strong tower out of wood from trees and raise the plastic fan blades up to the top of the tower. William connected the generator from the bike, and everyone waited for the winds to come that evening.

When the winds came, the blades started to turn. William connected the wires from the bike headlight generator to the bulb, and the bulb lit! The villagers cheered, and praised William for discovering "electric wind," which could provide power for a home.

Soon William designed and built another a wind mill from junkyard materials, and found a way to use the power of the wind to draw water up from a small well near his home to water the parched crops on his family' farm.

Journalists in Africa wrote about William's story, and how he taught himself how to build a windmill to save his family from drought and famine. People from all over the world were moved by the story of William's determination and courage, and donated money to send him back to school to keep learning about science and engineering. Money was also donated to improve the wind turbines in his village to irrigate the maize crops and prevent famine from droughts in the future. William is now an engineering student at Dartmouth College in New Hampshire. After he graduates, he plans to return to Malawi to continue his work to use wind as a renewable energy source to generate electricity and to pump water to African villages.

SETTING THE STAGE

- Read the story of William Kamkwamba, and how he overcame challenges to save his family and village from starvation.
- Complete the CLOZE sentence below about William's problem:

The challenge is to design a ___________ that will ____.

CRITERIA OR DESIGN REQUIREMENTS

List the criteria or what the design requires and the constraints or limits on the design due to resources and environment below.

Criteria:____

____

____

Constraints or Limits on the Design: ____

____

____

____

What are other questions or science concepts you need to learn before solving the problem? ____

____

____

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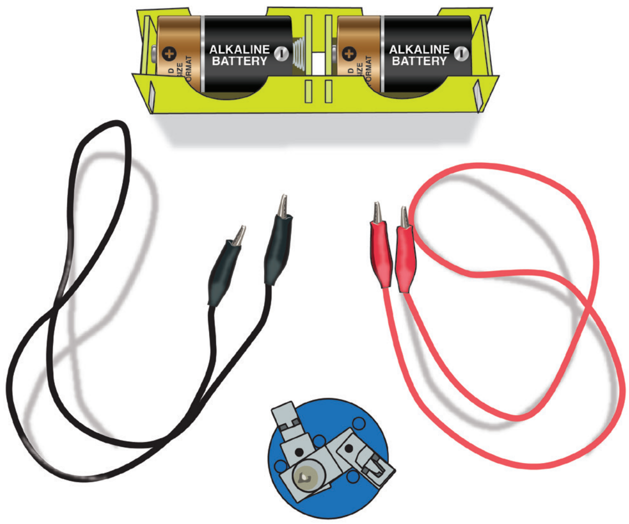
____

STEAMtrax K-12 ENGINEERING

LEARNING STATION 1

Exploring Electrical Energy



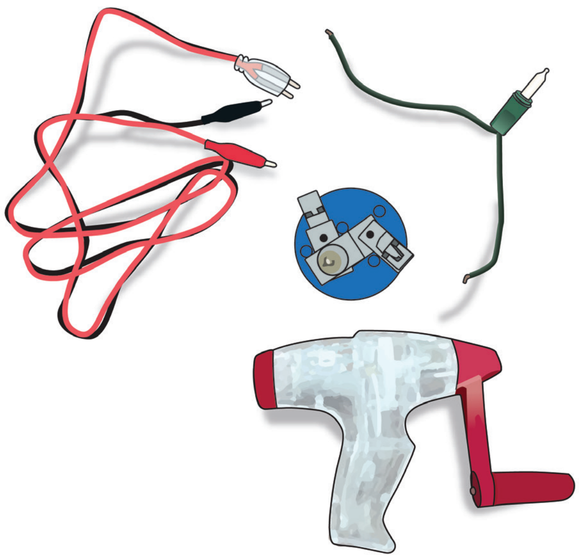
1. Place the battery in the battery holder, being sure it is positioned correctly by matching the + and – signs on the battery and holder.
2. Insert the light bulb into the bulb holder.
3. Test ways to connect the alligator clips to make the bulb light.
4. Draw a diagram of the model in your journal.

Complete the blanks in this sentence based on your observations:

Chemical energy in a battery can be transformed into ____________________ energy to light a bulb in a complete circuit.

LEARNING STATION 2

More Than One Way to Light a Bulb



5. Hold the clear hand grip of the hand generator, and slowly turn the handle in a clockwise direction. Record your observations of the motor and gears inside the generator as you turn the handle.
6. Insert the output cord into the hand generator.
7. Attach one lead of the output cord to each of the stripped ends of the holiday lights.
8. Slowly turn the handle with increasing speed until the bulb lights. Be careful not to turn the handle too fast, which will burn out the bulb.
9. Create a another complete circuit using the bulb, bulb holder, and hand generator. Slowly turn the handle with increasing speed until the bulb lights.
10. Draw a diagram of both circuits in your journal.

Complete the blanks in this sentence based on your observations:

1. A generator transforms ________________ energy into ________________ energy to light a bulb.

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LEARNING STATION 3

Is It a Generator or a Motor?

1. Label one generator A and the other B.
2. Attach the black leads of the generators to each other, and then attach the red leads to each other.
3. Have one person from the group hold the clear hand grip of generator A, and another person hold the clear hand grip of generator B.
4. As the person holding generator A slowly turns the handle in a clockwise direction, the person holding generator B should hold just the hand grip and observe the motion of the handle on generator B.
5. Draw a diagram of the model in your journal.

Complete the blanks in this sentence based on your observations:

1. A generator transforms ________________ energy into electrical energy, while a motor transforms ________________ energy into mechanical energy.

LEARNING STATION 4

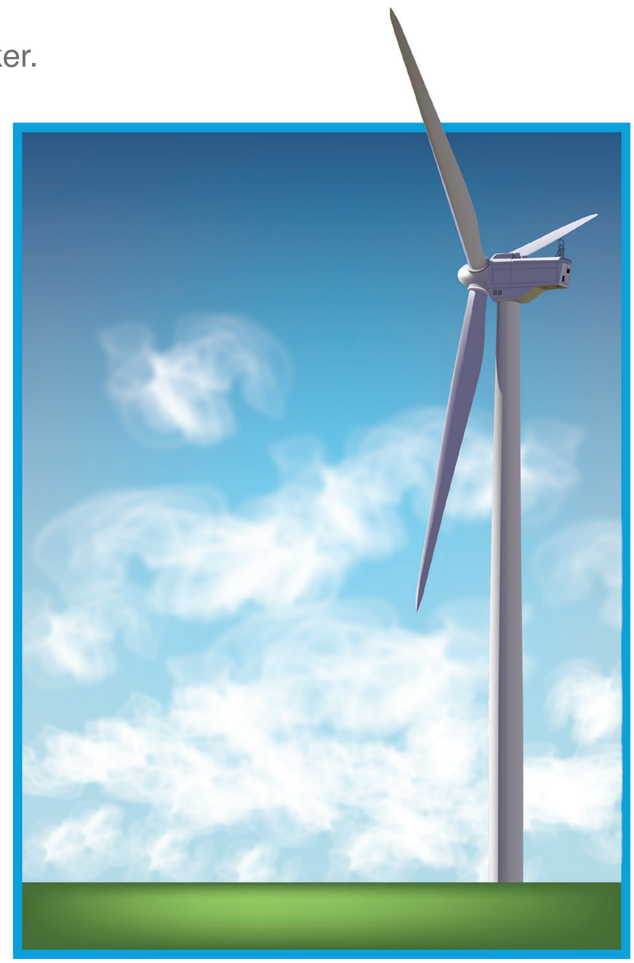
What is a Windmill?

The blades of a windmill transform wind energy into mechanical energy that that can mill or grind grain or draw up groundwater to the surface.

Test the windmill model to observe how a windmill transforms wind energy into mechanical energy to lift a load of washers.

PROCEDURE

- Place the windmill in front of the fan at the marker.
- Load the cup with 5 large washers.
- Hold the base of the Windlift and turn on the fan.



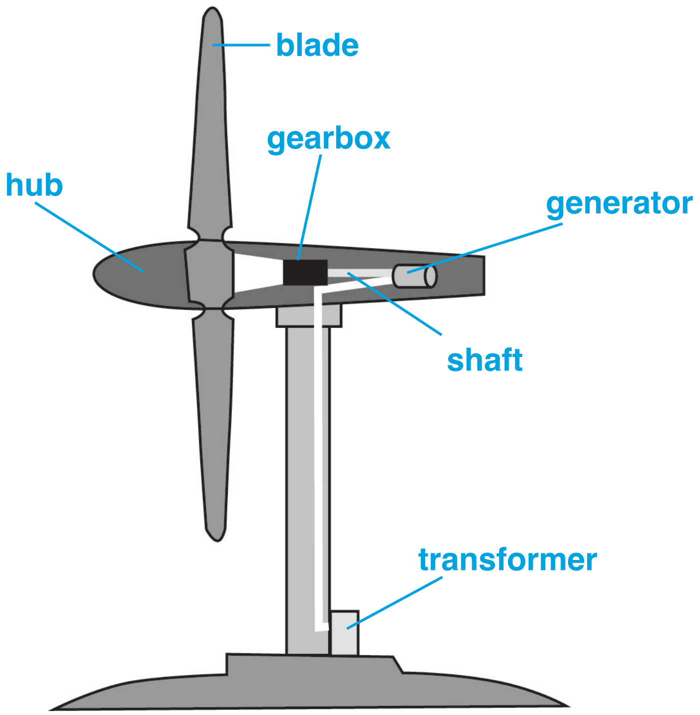
LEARNING STATION 5

What is a Wind Turbine?

Most of the energy used in our country today comes from fossil fuels. Natural gas is used for cooking and to heat our homes. Oil is used in our cars and in the manufacturing of plastics. Coal is burned to produce electricity. Renewable energy resources, such as solar, wind, or geothermal are good alternatives to fossil fuels. Unlike fossil fuels, these resources can be replaced within a relatively short period of time.

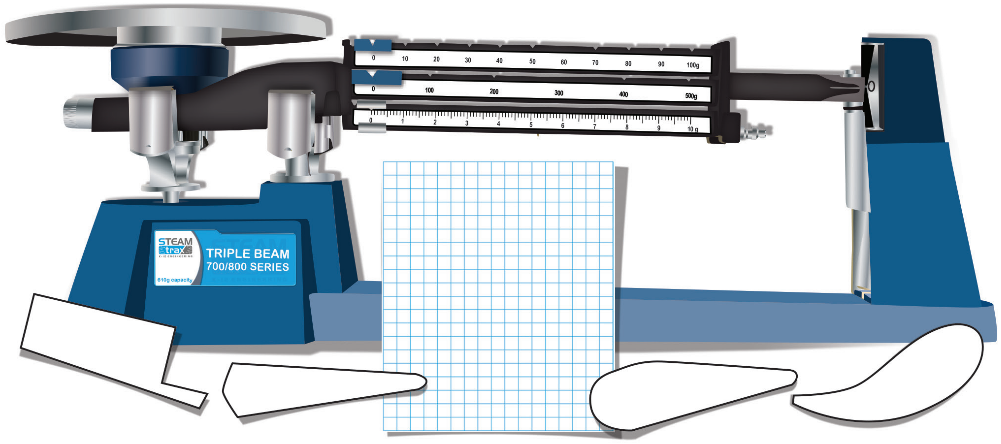
Due to recent developments in wind technology, wind energy has become one of the most promising ways to reduce our use of fossil fuels. Wind turbines capture energy from the wind. Like the windmills used in the past, today's wind turbines use blades to collect the wind's kinetic energy. Wind flowing over the blades creates lift, causing them to turn. The blades are connected to a drive shaft that turns an electric generator to generate electricity. Watch the video about wind turbines on the tablet at the station at **http://youtu.be/tsZITSeQFR0**.

1.



LEARNING STATION 6

Which Blade Measures Up?



Gather measurement data on each of the pre-printed plastic wind turbine blade templates to predict how each blade may be able to catch wind to transform it into electrical energy if used in a wind turbine.

PROCEDURE

- Estimate the surface area of each blade by tracing the four blades on centimeter graph paper carefully with a pencil.
  - Count up the whole cm squares and record on the data sheet.
  - Estimate the number of partial squares and record on the data sheet.
  - Add the whole squares and partial squares to find the estimated surface area of each blade.
  - Discuss and try methods to measure blades using a metric ruler to calculate surface area.
- Measure the mass of each blade using a triple beam balance or digital scale and record on the data sheet.
- Measure the thickness of each blade with the calipers, and record on the data sheet.

Which Blade Measures Up? Continued

Dear Parents:

We are excited to let you know that for the next ____________________ your student will be exploring civil and environmental engineering using 3D printing resources from

____.
DATES

He/she will be doing this by creating a model of a wind turbine to show how alternative energy resources can be used to produce electricity. This project will include learning objectives from all of the major STEAM areas of focus: Science, Technology, Engineering, Arts, and Math (STEAM).

From this project-based learning activity, your student will be learning the following skills:

Science:

- Identify alternative energy resources such as wind, solar, hydroelectric, geothermal, and biofuels.

Technology:

- Use CAD (computer-assisted drawing) software to design and print a designated object.

Engineering:

- Create and compare solutions to a problem.
- Research and analyze ways individual communities use science ideas to protect the Earth's resources and environment.

Art:

- Explore a variety of art materials while learning new techniques and processes.

Math:

- Solve division problems up to a 4-digit number divided by a 2-digit number.
- Add and subtract numbers with proficiency.
- Create graphs based on data collected during a science investigation.

We will have a challenge to test the different designs from each of the groups on ____________.
DATE

Please don't hesitate to email or call me if you have any questions, and I cannot wait for your student to let you know about the wonderful learning experiences happening in our class!

Best,

____

Teacher

____

Contact Information

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RESEARCH AND EXPLORE

Station Data Sheet

Draw a diagram of the setup at each station. Describe your observations in the space on the right of the diagram. Complete the blanks in each sentence based on your observations:

EXPLORING ELECTRICAL ENERGY

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Chemical energy in a battery can be transformed into ______________ energy to light a bulb in a complete circuit.

MORE THAN ONE WAY TO LIGHT A BULB

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A generator transforms ______________ energy into ______________ energy to light a bulb.

IS IT A MOTOR OR A GENERATOR?

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A generator transforms ______________ energy into electrical energy, while a motor transforms ______________ energy into mechanical energy.

WHAT IS A WINDMILL?

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____

____

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WHAT IS A WIND TURBINE?

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WHICH BLADE MEASURES UP?

surface area: ______________________________

mass: ______________________________

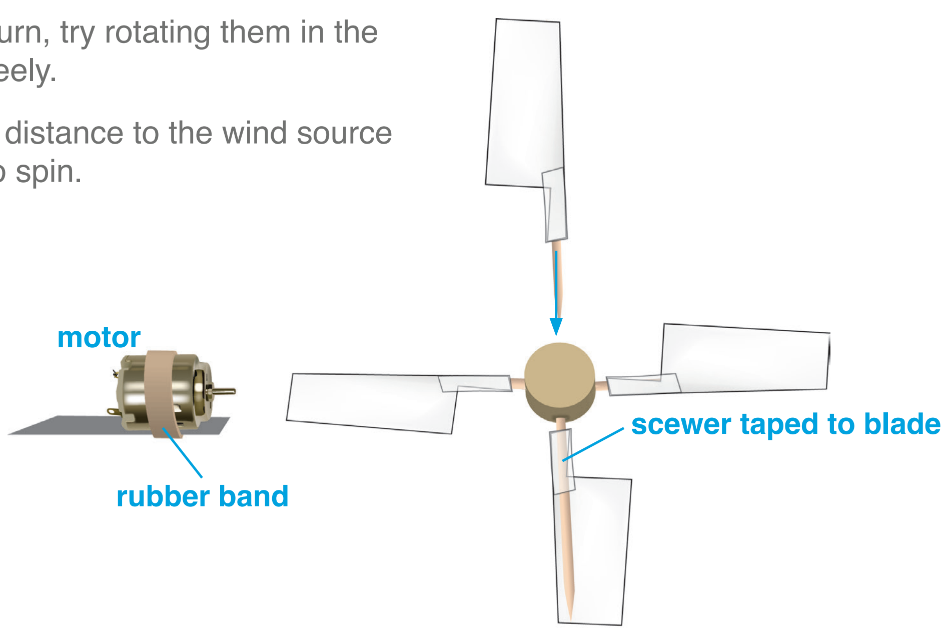
thickness: ______________________________

Which Rotor System Works Best?

Follow the directions below to construct a wind turbine rotor. This rotor will be used to test how much electricity your model can generate. If you don't understand a direction or have trouble deciding what to do, study Figure 1 following these directions.

1. Attach two alligator clips to the flat end of the motor.
2. Use a rubber band to attach the electric motor to the end of a ruler. Be sure the shaft of the motor sticks past the end of the ruler.
3. Use tape to attach the skewers to the cardstock wind turbine blades that your group selected. Think carefully about where the skewer should be taped to the blade.
4. Insert the scewers into the hub to attach the blades. Push the hub onto the motor shaft.
5. Rotate the ends of the skewers to get the blades to the desired angles in the hub, and place the cover on the hub.
6. Take your rotor system to the voltage measuring station.
7. Attach the alligator clips from the motor to the alligator clips on the DC voltmeter or voltage probe.
8. Place the rotor system about 25 cm away from the fan (the wind source). Turn on the fan and measure the voltage produced.
9. If the blades do not turn, try rotating them in the hub until they spin freely.
10. If needed, adjust the distance to the wind source to allow the blades to spin.

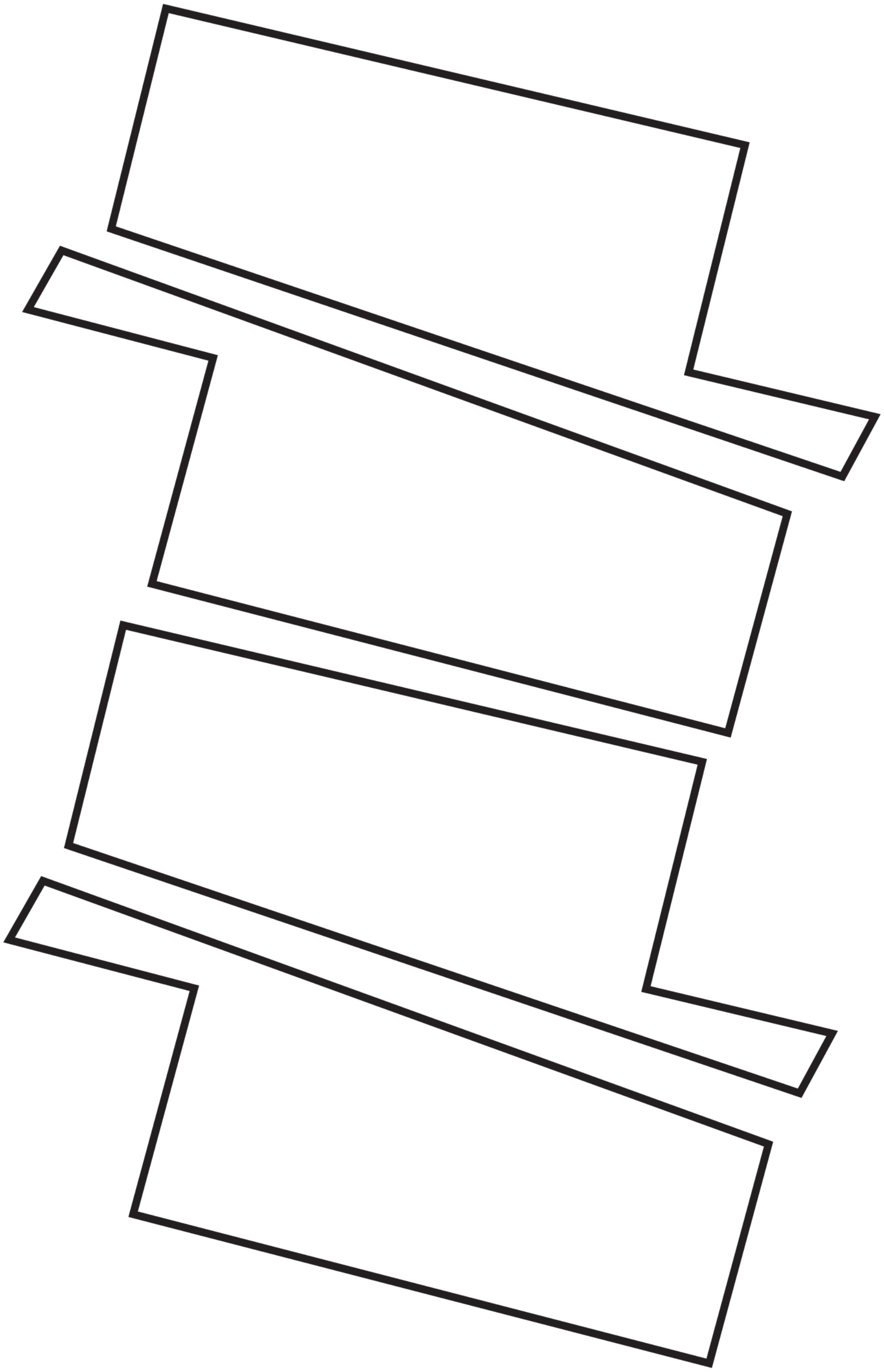
Figure 1



Voltage generated by the rotor system ________________

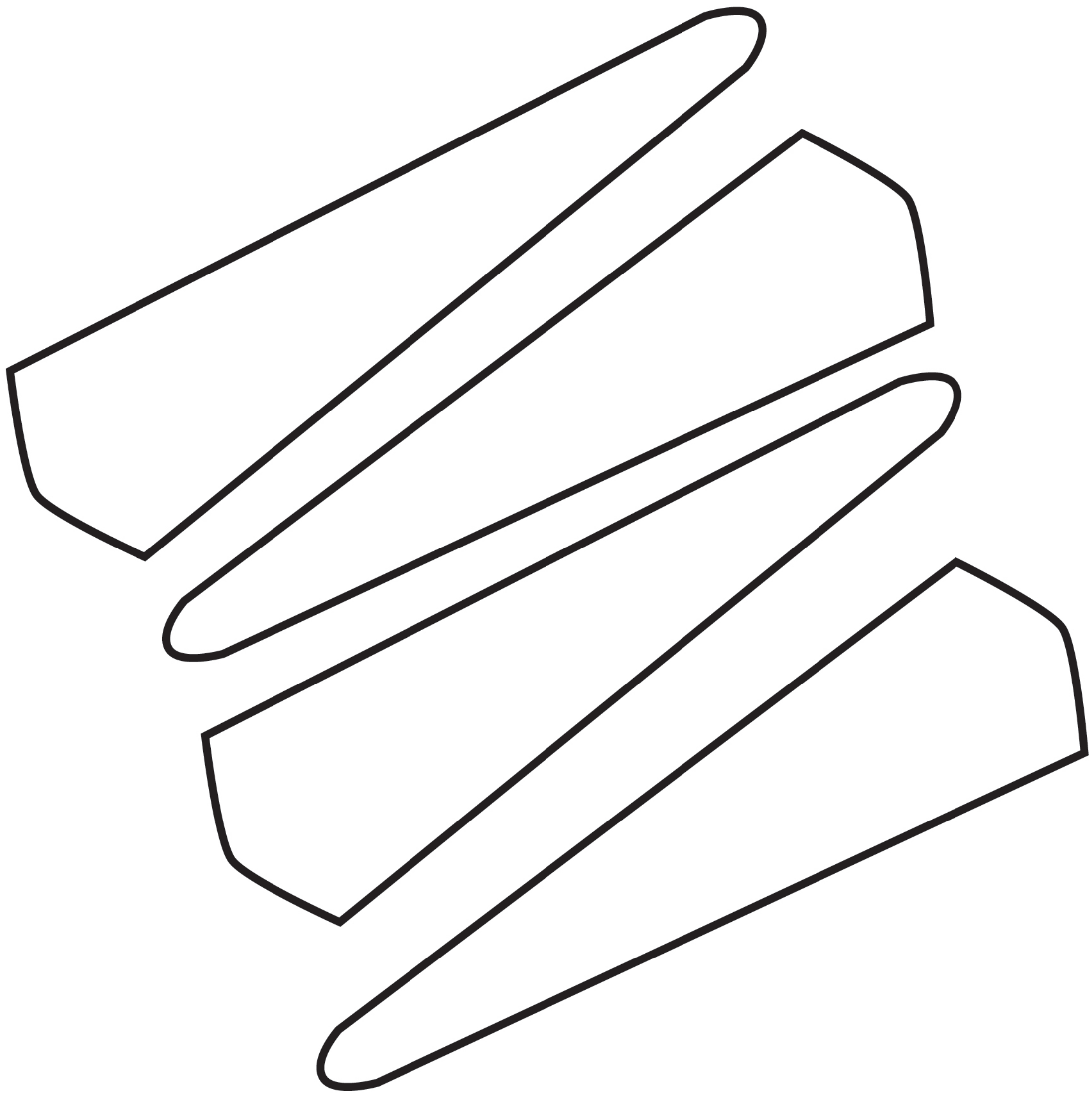
REPRODUCIBLE TEMPLATES

Wind Turbine Blade Template #1



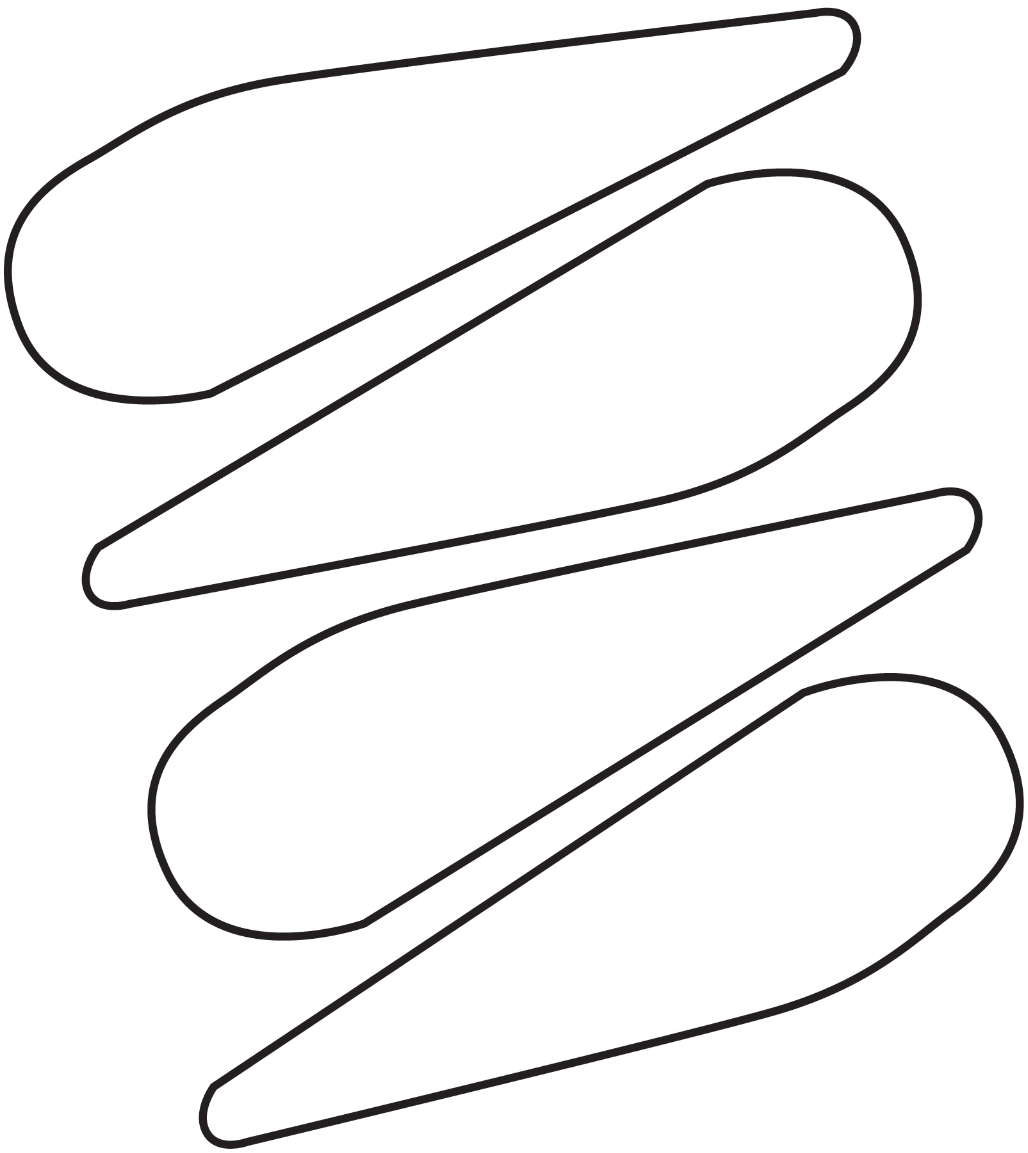
REPRODUCIBLE TEMPLATES

Wind Turbine Blade Template #2

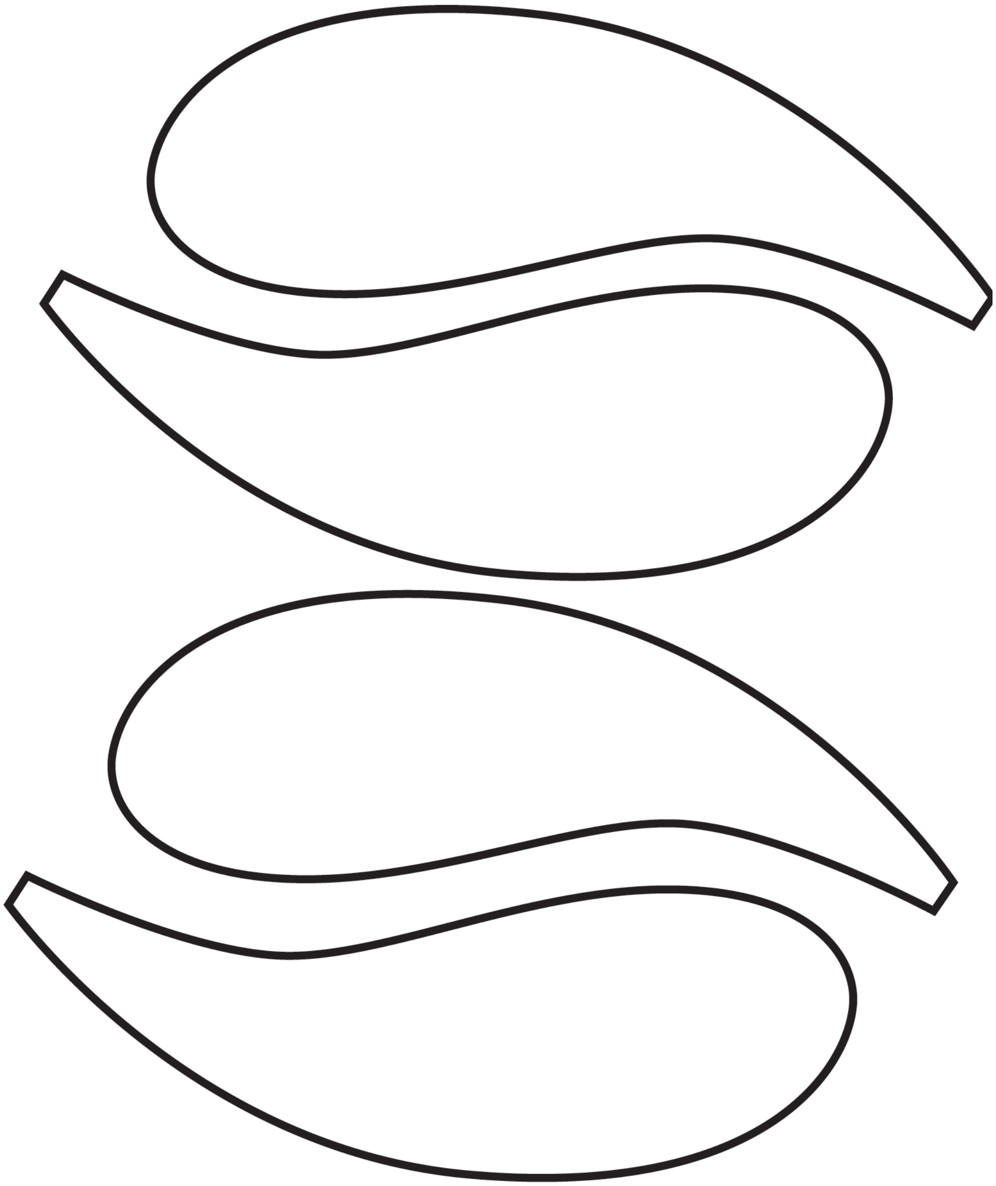


REPRODUCIBLE TEMPLATES

Wind Turbine Blade Template #3



Wind Turbine Blade Template #4



DESIGN CHALLENGE

Tinkering With Turbines

PROBLEM:

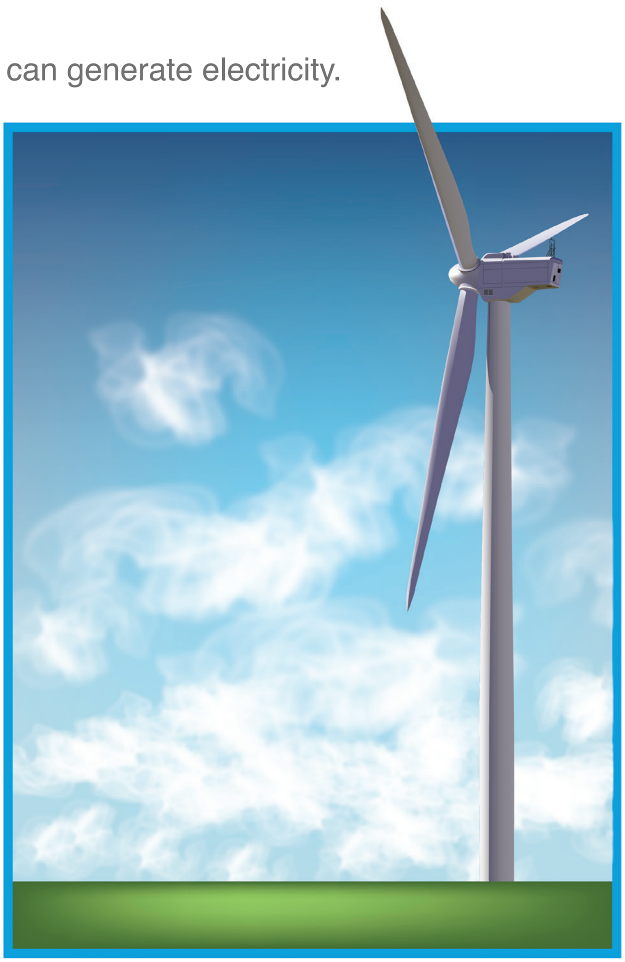
Much of the electricity we use in our homes and businesses today is generated from the burning of fossil fuels. As fossil fuels are burned to generate energy, they increase the levels of carbon dioxide in our atmosphere which can lead to climate change. Scientists agree that the Earth is getting warmer, but they disagree about the rate of warming, how this warming will affect our environments, and what should be done about it. Scientists and engineers around the world are currently exploring alternative energy sources to replace our dependence on fossil fuels. Some mechanical and environmental engineers are working together to design more efficient wind turbines that can transform wind energy into large amounts of electricity to provide energy for towns and cities.

DESIGN CHALLENGE:

Design and construct a model of a wind turbine that can generate electricity.

CONSTRAINTS/CRITERIA:

- The model must be constructed out of the given materials.
- The model must stand on its own—it cannot be held or supported during the testing period.
- The blades of the model must spin freely while withstanding the force of the wind from an electric fan on high for at least one minute.
- The model must generate a measureable amount of electricity.



DEVELOP A SOLUTION

2D Design Sketch

Think about what you learned by constructing and testing a model rotor system, and the problem statement below.

The challenge is to design a ________________ that will______________________________________ .

Make a sketch of the wind turbine design that you think will meet the challenge.

2D Sketch

Engineering Improve it Plan

List Merits of the model

List suggested improvements of the model

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Test and Analyze

Collect and record data using your model wind turbine. Record the data in the table below. Calculate the average voltage produced at each speed. (Show your work in the space below the table.)

	Voltage Produced at Low Speed	Voltage Produced as Medium Speed	Voltage Produced at High Speed
Trial 1			
Trial 2			
Trial 3			
Averages			

Answer the questions below based on the data you collected and your observations.

1. What is the difference between the average voltage generated at low speed and the average voltage generated at high speed? ______________________________

   ____

2. What most likely accounts for this difference? ______________________________

   ____

3. Is your model exactly like the sketch you chose or did you make modifications as you constructed the model? Explain. ______________________________

   ____

4. What do you think you could do to make your wind turbine generate more electrical energy? ______________________________

   ____

5. What are some advantages of using wind turbines to generate electricity? ______________________________

   ____

Presentation Checklist and Feedback

PROBLEM	TEACHER FEEDBACK
The challenge is to design a ________ that will ______________________________ .	
MERITS OF DESIGN	
SUGGESTIONS FOR IMPROVEMENT	

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SELF AND GROUP
Evaluation

1. How well did your wind turbine work? ______________________________

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2. Did your wind turbine meet your expectations? Why or why not? ______________

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3. Describe one problem you had while constructing your wind turbine. How did you solve this problem? ______________________________

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4. List two things you learned from working on this project. ______________

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STANDARDS-BASED
Assessment

Name ____________________________ **Date** _____________ **Per.** _____________

Directions: Choose the best answer for each question below. Remember to use and show your test-taking strategies!

1. Which of the following is a disadvantage of using wind energy to produce electricity?

A The wind does not blow all of the time.
B Wind energy is a renewable resource.
C Wind energy does not pollute the environment.
D Electricity produced from wind energy can be sent long distances.

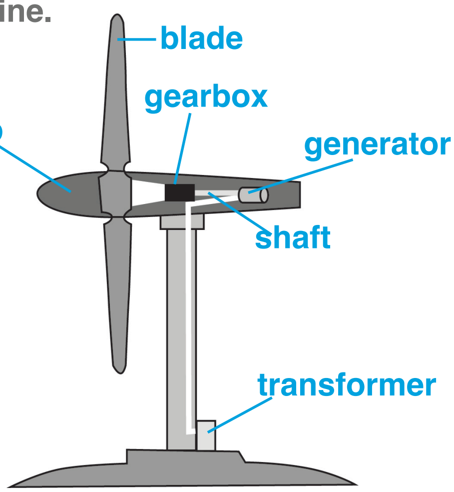
2. Why is wind energy considered a renewable resource? Wind energy—

A can be transformed directly into electrical energy
B is clean and efficient to use
C does not produce air pollutants
D can be replenished in a short period of time

3. Which of the following best describes wind energy?

A Energy produced by moving water
B Energy produced by once-living organisms
C Energy produced by moving air
D Energy that uses the sun's rays to produce power

The diagram shows the main parts of a wind turbine.



4. Which part of the wind turbine actually produces the electricity as the blades turn?

A The hub
B The generator
C The shaft
D The transformer

5. Which action below does NOT illustrate energy conservation?

A Recycling metals, plastics, and paper
B Turning off the lights when you leave a room
C Building bigger, more powerful cars
D Setting the air conditioner to a higher temperature on warm day

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Evaluation Rubric

Group Members: ____

____

Wind Turbine Rubric

Criteria Assessed	Meets Criteria with High Quality (4)	Meets Criteria (3)	Meets Little of the Criteria (2)	Does Not Meet Criteria (1)
Model is complete and realistic				
Model is constructed of given materials				
Model is self-standing				
The blades of the model spin 1 minute				
Model illustrates concepts thoroughly				
Model is effectively presented				
Model is a successful solution				
Group members worked well together				
Group members participated equally				

Group Score ________________

Grade Conversion Scale:
32–36 = A
28–32 = B
24–27 = C
22–23 = D
Below 22 = F