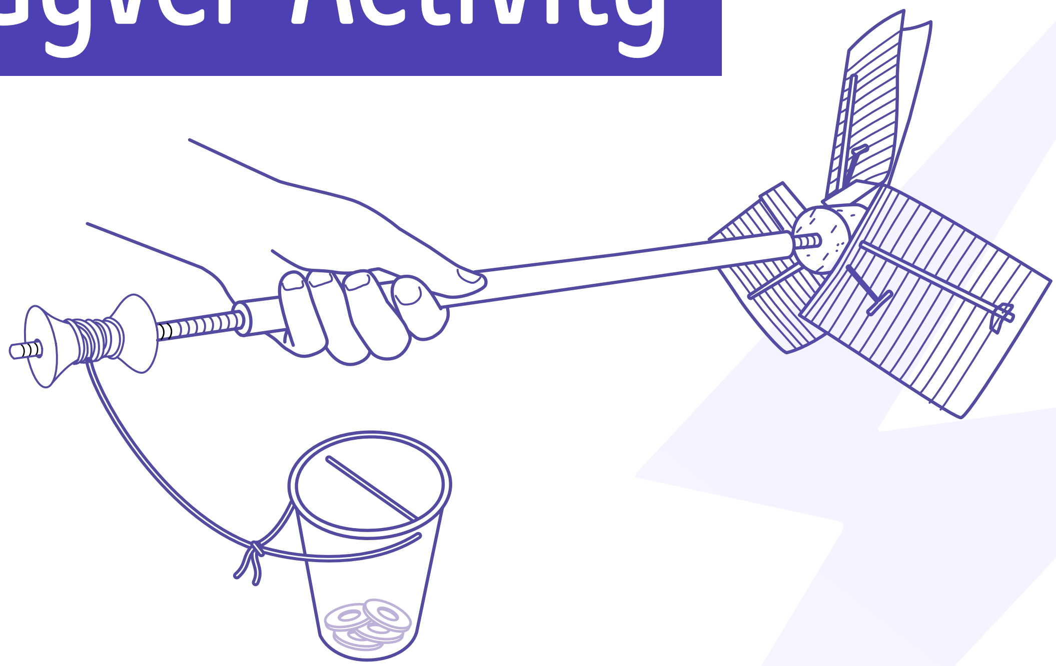
MacGyver Activity



Grades

3–8

Concepts

- Math
- Forces and Motion
- Earth Science
- Energy and Transformations
- Engineering, Art, and Design
- Using Basic Tools
- Collecting and Interpreting Data

Disciplinary Core Ideas

- PS2-A, PS2-B, PS3-A, PS3-B, PS3-C, ETS1-A, ETS1-B, ETS1-C

Time Required

45 minutes - 1 hour

Science and Engineering Practices

- Planning and carrying out investigations
- Analyzing and interpreting data
- Asking questions and defining problems

Cross Cutting Concepts

- Cause and effect
- Energy and matter
- Patterns

Objectives

At the end of the lesson, students will:

- Know the fundamental parts of a wind turbine
- Be able to use the engineering design process and the scientific method to isolate and adjust variables while designing and testing wind wheels
- Understand energy conversions and transfers, and how a wind turbine converts moving air into electrical energy
- Design a Wind Wheel for the firefly wind turbine that can light up an LED

This activity guide was adapted from a prior REcharge lesson.

Click here to check out the NGSS Website, Full NGSS Standards, or Science and Engineering Practices in the NGSS

Materials

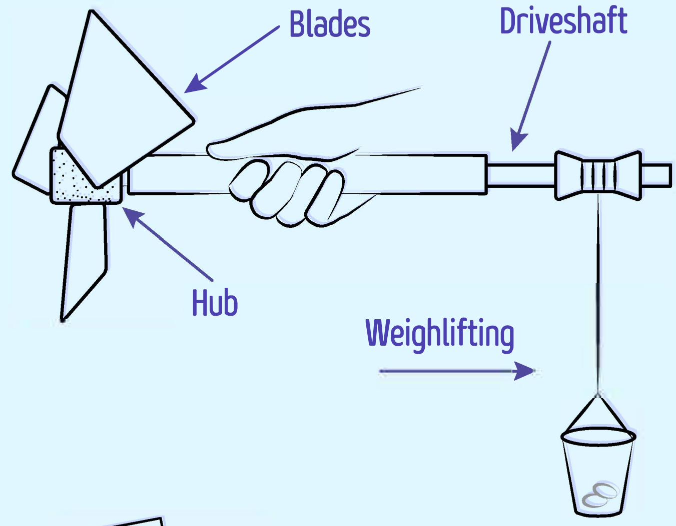
There are as many different ways to build your MacGyver Windmill as you can think of. Here we show you some suggested applications for the materials in this kit, but don't let that limit you. Most of the materials are reusable, which means you can build and rebuild your MacGyver again and again. We strongly encourage you to provide additional blade-making material to introduce even more variables for your students to test.

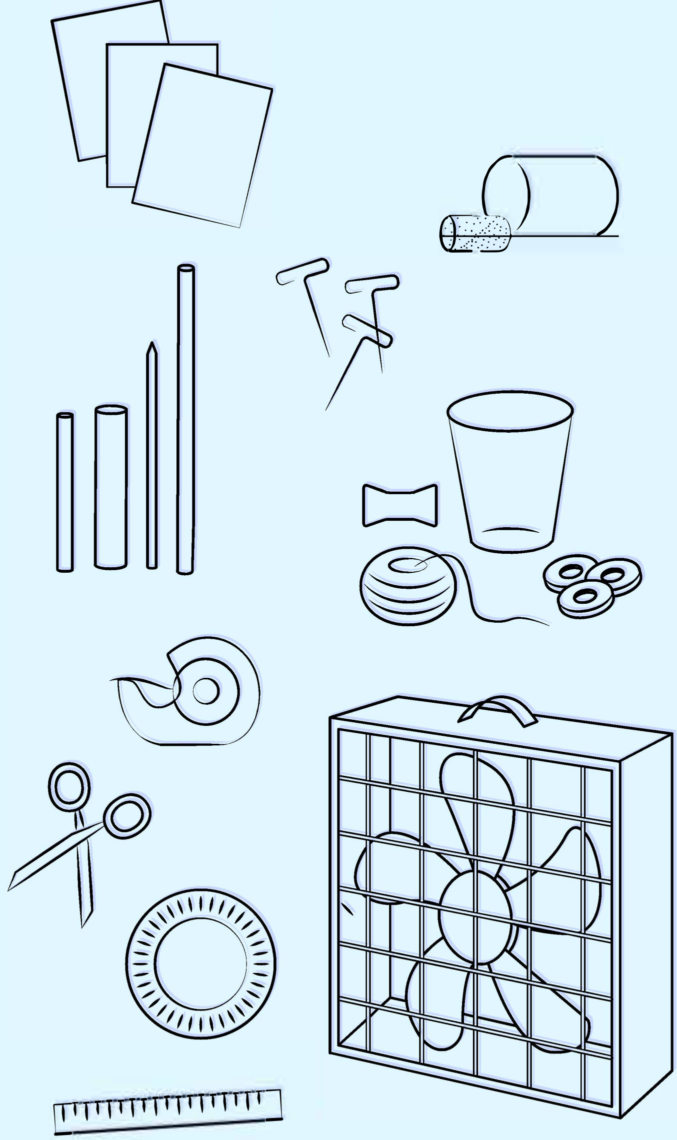
- Blades
  - Index cards
- Hubs
  - Foam cylinder
  - Cork
- Driveshafts
  - Skewers
  - Straws
  - Cardboard tubes
  - Dowels
- Attachments
  - T-pins
- Weightlifting
  - String
  - Cup
  - Washer
  - Spool

Classroom materials to share

- 20"x20" standard box fans
- Ruler
- Tape
- Scissors
- Alternative blade material such as paper plates, scrap cardboard, lawn signs, pie pans, etc. Anything that catches the wind will work!

REcharge Labs & KidWind have been leaders in K-12 renewable energy education for over 15 years. Their library of materials and programming are now a part of Gale Force Education. Gale Force Education is a non-profit focused on fostering opportunities for students, educators, and the public to explore a future powered by renewable energy.





Learning Goals

Students will use a limited amount of materials to design and build functioning windmill models. They will use these models to convert wind into mechanical energy in order to lift weights. Using the scientific method, they will conduct trials, change variables, and work to improve the performance of their windmills.

Safety Guidelines

Always wear safety glasses when the rotor is spinning! You could be hit if your blade flies off during testing.

Getting Ready

- It is strongly suggested that teachers try to build their own windmills before the class begins. This is a valuable preview to the challenges and problems that students will face.
- Separate the materials to distribute to each group. Remember that materials for this activity are intentionally limited, as this inspires creative problem solving and discourages waste. Use common box fans (20” by 20”) to encourage the students to build efficient designs. Using the fan on a low speed is recommended.
- Have students do some background reading on windmills and wind power.

Activity

During the first class period, students focus on getting their prototypes to spin when placed in front of the fan. During the second class period, students participate in the Weight-Lifting Challenge to get their windmill to lift a cup of weights (washers).

Class Period 1

Step 1: Beginning questions for students

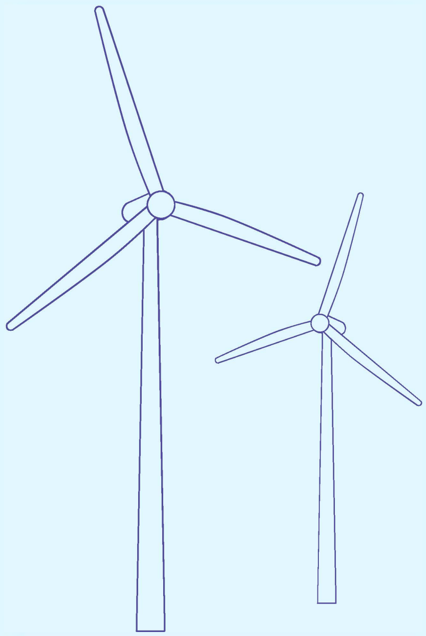
- Who has seen a real windmill (mechanical or electrical)?
- What are the parts and features of a windmill?
- What is the purpose of a windmill?
- How does the wind cause the windmill to rotate?

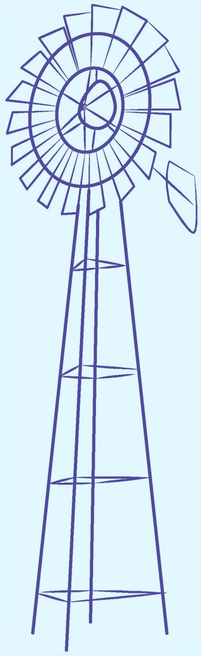
Step 2: What is the difference between a windmill and a wind turbine?

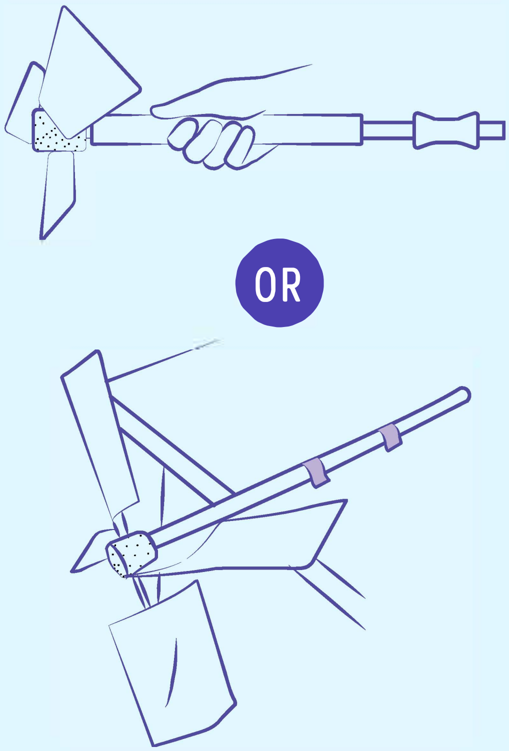
Ask a couple of students to draw a windmill on the blackboard. Ask the other students to describe how these windmills work and what they are used for. Generate a brief discussion about what differentiates the windmills from modern wind turbines.

Step 3: Distribute materials

Present the windmill design activity to the students and organize them into groups of 3 to 5. Give each group the required materials. Do not pass out the string, cups, or washers yet, as these will be distributed at the beginning of the second class period when the Weight-Lifting Challenge is presented. As you distribute the materials, be sure to mention some ground rules for safety.







Step 4: Spin in the wind

Instruct the students to assemble a mechanism that will rotate when placed in the wind. Tell them not to worry about lifting weight yet. The first challenge is just to get the windmill to spin. Note: there are not enough materials to build a tower. These windmills should be held by hand or attached to the desktop.

Step 5: Design and test

Give the groups some time for initial designing and construction. Each group should have a chance to test their windmill with the fan at least once during this first class period. Three tests per group is ideal. There is no right answer here and many designs are possible. Students will feel confused. That is okay!

Step 6: Discussion

At the end of class, show students pictures of real windmills and wind turbines. Discuss how windmills work and the fundamental parts of a windmill. How do these real windmills differ from student designs? What new ideas do the pictures give them?

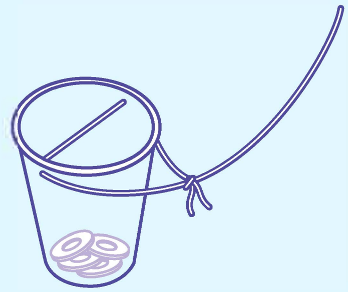
Other possible questions:

- What windmill designs worked best?
- What is holding it back/preventing spin?
- What parts were most difficult to design and make functional?
- How did you attach your blades?
- Where is there friction in your design?
- How did you reduce friction in your windmill?
- How did you pitch or angle the blades?
- Were your blades changing pitch frequently?
- Did the fan work better from the front of the blades or the side?

Class Period 2

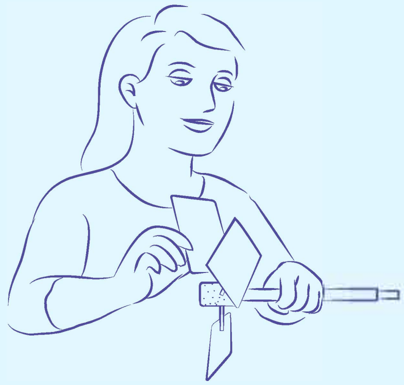
Step 1: Weight-Lifting Challenge

By the beginning of this class period, most groups should have succeeded in getting their windmills to spin in the wind. Now introduce the Weight-Lifting Challenge. Give each group the string, cups, and washers. Their goal is to use the power of the wind to lift as many washers as possible. As students work toward this goal, they will have to isolate and improve certain variables in their designs.



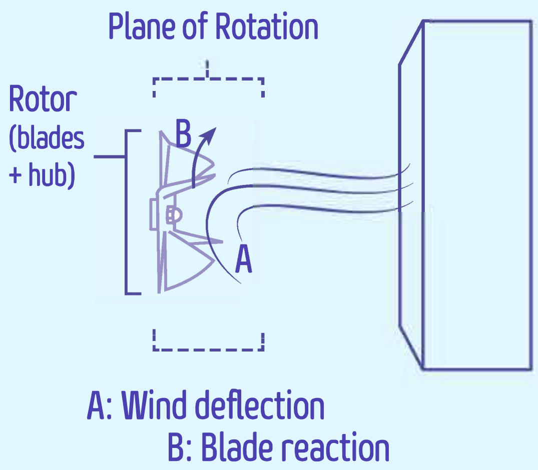
Step 2: Test variables, improve designs

As students test their weight-lifting windmills, give them guidance and tips on how to improve their designs. Encourage them to focus on one variable at a time; conduct a trial, measure the results, make changes, and repeat the trial. The size, shape, pitch, and number of blades can be explored. The variables of fan setting (speed) and distance from the windmill should be kept constant. Remind students to use the scientific method as they design and test their prototypes.



Some groups may struggle to get the windmill to lift any weight. Urge them to look at other groups that have been successful. What techniques work well and what does not seem to work? Remind students that this activity is not a competitive contest, but rather a class effort. Students can learn from and support each other.

Blade pitch is the angle of the blades with respect to the plane of rotation. The pitch of the blades dramatically affects the torque of the rotor. Pitch also affects the amount of drag encountered by the blades. Efficient blades will provide maximum torque with minimum drag.



Step 3: Discussion

- How many blades worked well for lifting weight?
- Did more blades mean you could lift more weight?
- What blade pitch was best for lifting weight?
- Where did you attach the string? Why?
- How did your design change after the attempt to lift weight?
- How were you able to get more turning force from your blades?
- What ideas seemed to work well?
- What problems did you encounter?
- What parts of your windmill broke or failed?

Extension Activity

For grades 9-12

For a quantitative analysis of your MacGyver windmill, you can ask students to calculate the energy required to lift the bucket of washers and determine the average power of their windmill as it lifts that mass.

Energy is measured in joules (J). Power is measured in watts (W). Power is a measurement of how fast energy is converted. In this case, power is a measurement of how fast the mass is lifted.

To calculate how much energy is required to lift the washers, students will first need to measure the mass (kilograms) of the washers they are lifting and how high they are lifting the washers (meters).

Energy (J) = Mass (kg) × Acceleration of Gravity (9.8 m/s^2) × Height (m)

To measure power, they must also measure how long it takes to lift the mass to that height (seconds). Standardize the height so that every group must lift to the same height (0.5 meter or so).

Power (W) = Energy (J)/Time (s)

Vocabulary

Blades

The aerodynamic surface of the turbine that catches the wind.

Blade pitch

The angle of the blades with respect to the plane of rotation. For example: blades perpendicular to the oncoming wind would be zero degrees; blades parallel to the wind would be 90 degrees.

Drag

The friction of the blades against air molecules as they rotate. For a wind turbine, this is also called wind resistance. Drag works against the rotation of the blades, causing them to slow down.

Driveshaft

The rod or shaft connected to the hub; it rotates with the rotor.

Force

A push or pull.

Friction

A force that resists the relative motion of two bodies in contact.

Hub

Central component connecting blades to driveshaft.

Plane of rotation

The area directly in line with the rotor. It is dangerous to stand in this area because a blade that is not securely fastened to the hub and detaches could hit any person standing in this zone.

Rotor

The rotating section comprised of blades projecting from a hub.

Torque

A force times a distance that causes rotation. In a windmill, each blade acts like a lever arm rotating around an axis. The more surface area the blade has, the more torque the wind applies to the blade.

Windmill

Technology that uses the wind to accomplish a task (ie. mill grain or drive machines).

Wind turbine

Technology that converts wind into electrical energy by turning a turbine.