Wind-O-Meter

Measure wind speed and power with an anemometer built from recyclable materials!

Curriculum topics

- Natural and Renewable Resources
- Energy Conversion
- Science Investigations
- Weather & Climate

Subjects

- Earth & Space Science
- Engineering
- Physical Science

Grade range: 6 – 12

Who we are: Resource Area for Teaching (RAFT) helps transform the learning experience by inspiring joy through hands-on learning.

The development of this kit was funded in part by Electrify America

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http://bit.ly/RAFTkitsurvey

The Wind-O-Meter is a cup-style anemometer that uses recyclable materials to measure the speed of the wind.

The energy of an even relatively slow wind is considerable. This energy can be harvested by a type of windmill to generate electric power. But high-speed wind, as in a storm or tornado, can be very destructive. The computers that control windmill generators use an anemometer to measure the wind speed. Wind speed is used to adjust the blades to generate electricity efficiently and safely from the wind without breaking apart during windstorms.

You will build a cup anemometer and use it to measure the speed of air generated by a fan or by a natural source of wind. You will experiment with how the wind speed varies by testing your anemometer with multiple fan speeds and with the anemometer at various distances from the fan blades.

You will change the diameter of the anemometer to learn how the rotation speed changes with diameter and determine how to account for anemometer size when calculating wind speed.

Scan this QR code or visit https://bit.ly/49GJe16 to view the assembly video!

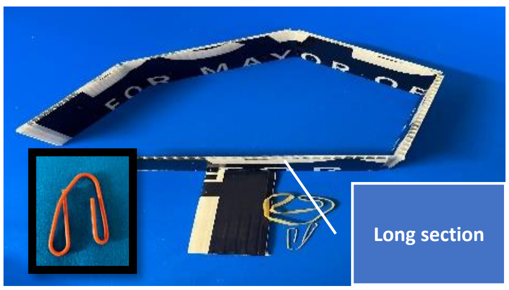
Materials

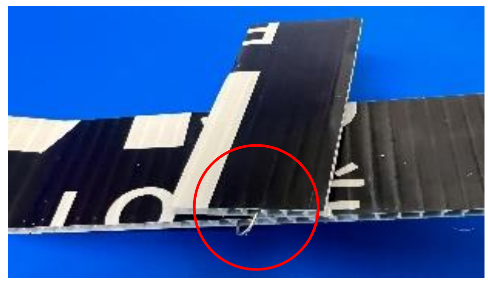
Materials in this kit may vary. This kit contains the following components or equivalent substitutes:

- Corrugated plastic strips
  - Large (1)
  - Medium (1)
  - Small (1)
- Applicator stick, wood, 6” (1)
- Binder clip, small (1)
- Paper cone-shaped cups, with 2 holes (4)
- Paper clips (3)
- Straw, jumbo (2)
- Straw, fat, 2” long (1)
- Rubber band, latex free (1)
- **Optional:** Stir stick, plastic, 1¼” (1)
- **Not included:** Marker, electric fan, or other source of wind, stopwatch

To Do and Notice (Link to assembly video https://bit.ly/49GJe16)

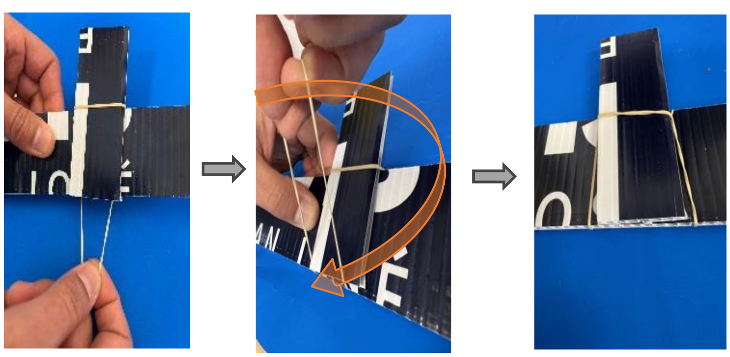
1. Lay out the large and small size plastic strips, and the rubber band as shown. Bend all 3 paper clips into the shape shown in the inset figure, (below left), and place 2 of the bent clips aside for later use. The plastic strips will form the anemometer base and tower. Identify the one section of the large plastic strip that is longer than the others.





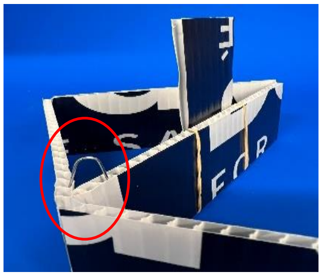
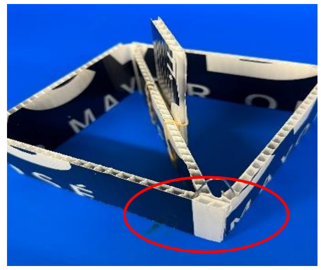
2. Clip on the tower. Place the small plastic strip over the longest section of the large strip as shown above (right). The small strip will form the tower. Align and center the narrow end of the small strip on the long section. Insert one leg of a bent paperclip into a corrugation (flute) of the large strip and the other leg into the bottom center of the small strip, as shown above (circled). Hint: Find the center flute of the tower by counting the openings.

3. Complete mounting the tower. Secure the small plastic strip to the long strip with the rubber band (below left). Then stretch the rubber band up and over the top of the tower. Follow the steps in the figures, below, from left to right.

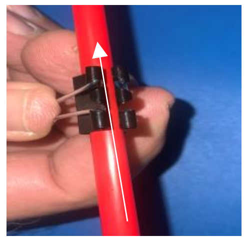
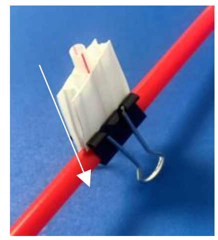


4. Clip together the base’s diagonal. Fold the longest section of the large base strip (with the tower attached) to form a triangle. Secure the loose end of the longest section to the opposite corner of the triangle by inserting one leg of a bent paper clip into a flute on the loose end and the other leg into the bent corner, as shown and circled, (below, left).

5. Complete the base. Fold the remaining base section to form a square with the tower mounted on the diagonal base section. Insert a bent paperclip into the flutes on each of the 2 segments at this corner of the square (circled, below right).

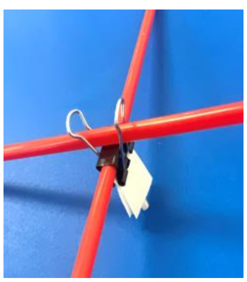
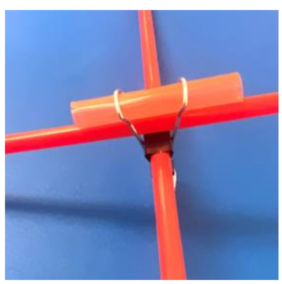
 

6. Layout arms, axle, hub and cups. Place the wood applicator stick, 2 long straws, short fat straw, short stir stick (optional), small plastic strip, binder clip, and 4 cups as shown, (below left). Use a marker to clearly mark just **one** of the cups so it is easy to see and use for counting the number of revolutions around the axle stick when driven by the wind.

7. Assemble the hub. Pinch the binder clip handles together so that the jaws open about ¼ inch. Slide a long straw into the binder clip as shown, (above middle). Next, insert the small plastic strip into the binder clip so that the holes are perpendicular to the straw, as shown, (above right). Make sure the long straw is centered in the clip, then push the strip firmly into the clip so that the straw is slightly flattened between the strip and the clip. Then, firmly insert the short stir stick (optional) into the center of the plastic strip.

8. Install and secure the second arm. Insert the 2nd straw into the wire loops of the binder clip handle and push the straw down against the black metal, (below, left). The middle of the straw's length should be centered. Pinch the short straw and insert it into the wire loops in the handle, (below, 2nd from left).

9. Install the axle, hub, and arms onto the tower. Insert the applicator stick into the center flute on the tower. This should be the same flute that you inserted the paper clip into at the bottom of the tower.
10. Mount the cups. Gently squeeze each cup to align the holes, then insert the ends of each straw through the holes on each of the cups, as shown (above, right). Orient the cups in the same direction, with the openings hanging below the straws (see title page for completed assembly photo).

Experiment and Observe

Outdoor wind speed can be estimated by observing how our skin feels, watching how smoke rises and how leaves and trees move when blown by wind. The US National Weather Service publishes a chart called the Beaufort Scale which classifies wind speeds based on observations.

- Try looking outside and use the Beaufort Scale to estimate the wind speed.
- Your anemometer can be placed outside on a day when the wind speed is less than 10 MPH (miles per hour), when leaves and small twigs are constantly moving.

Professional anemometers are designed and tested using wind tunnels. Experiment with your anemometer using a source of wind that can be controlled, such as an electric fan or blower.

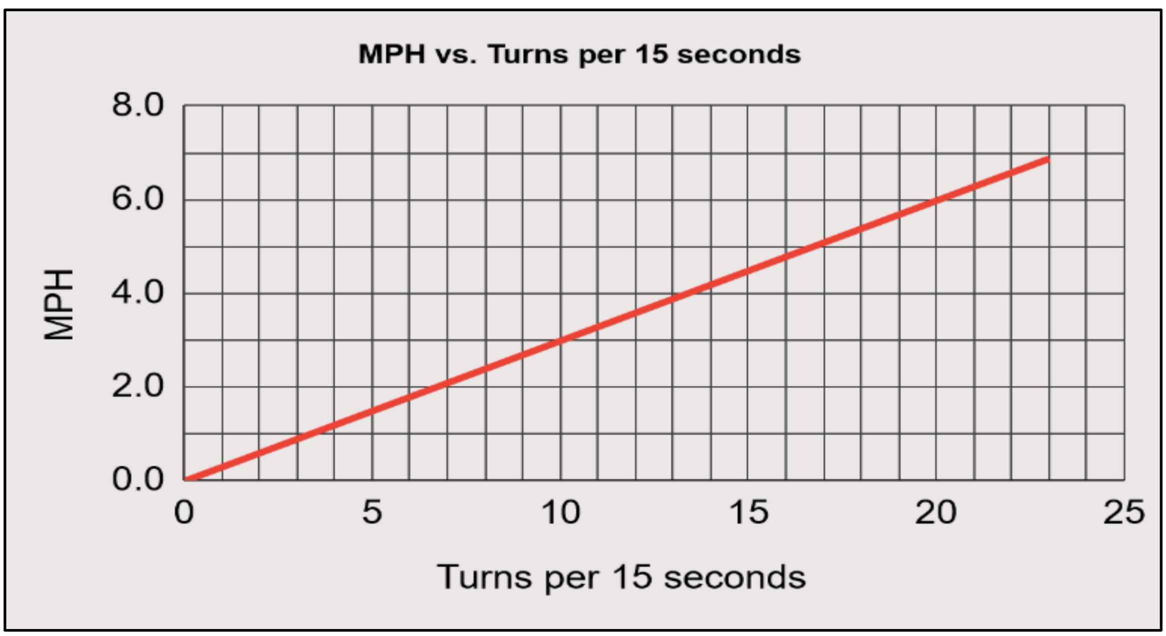
1. Predict and observe. Before you place your device in blowing air, try to predict the direction that the anemometer cups will rotate. Next, place the anemometer about 2 feet in front of a fan. If the base moves in the breeze, place a book or other heavy object on the base. Do the cups turn in the direction you predicted? Predict, then observe what happens to the rotation speed if someone stands between the front of the anemometer and the fan. What will happen to the speed if someone stands behind the anemometer? Explain both phenomena and sketch the airflows for each case.

2. Measure wind speed. With the anemometer in front of the fan, count and write down the number of times the marked cup rotates around the axle in 15 seconds. You can use a stopwatch/timer app, wall clock or watch, or have a partner count out the seconds. Record the number of revolutions per 15 seconds, along with the fan speed, (if using a multi-speed fan), and the distance between the fan and anemometer. Make sure that there are no objects blocking the air stream. **Teacher:** Consider providing a data table for students to record their measurements/observations or have them draw their own table.

3. For fans with multiple speed settings, change the fan speed and count the number of revolutions in 15 seconds again. Record the number of revolutions along with the fan speed for each trial. If you have a single-speed fan, you can move the anemometer further away from the fan in regular increments (e.g., 1-2 ft), in place of changing the fan speed. What happens to the anemometer rotation speed as the fan runs more slowly or as the anemometer is placed further from the fan? Explain both phenomena.

4. Using the graph below, find the number of turns per 15 seconds that you wrote down for each trial along the X axis. Extend vertical lines up from these points to the diagonal line on the graph, then find the corresponding speed in miles per hour (MPH) on the Y axis. Write down these measured speeds next to the rotation speeds, fan speeds, and distance from the fan that you recorded in steps 2 and 3.

5. Slide each of the cups about 1 inch closer to the hub and repeat steps 1 and 2. Before turning on the fan, predict if and how the rotation speed will be affected. Turn on the fan and compare your observations with your predictions. Were your predictions correct? Explain.



Core Content Skills:

Science & Engineering, Mathematics (NGSS, CCSS Math)

Developing and Using Models, Planning and Conducting Investigations, Analyzing and Interpreting Data, Constructing Explanations and Designing Solutions; Definition, Transfer, and Conversion of Energy, Weather and Climate, Earth's Systems, Quantitative Relationships between Dependent and Independent Variables

Social Emotional Learning

- Self-awareness
- Self-management
- Responsible decision-making

The Science Behind the Activity

The sun provides most of the earth's energy. Wind and weather are just two of many observable phenomena on the earth that are powered by solar energy. People have harnessed wind power to mill grains and to pump water since ancient times. Today, wind power is also used to generate electricity. Wind can also be destructive. Since the power of the wind increases dramatically as its speed increases, high winds can cause catastrophic damage.

Wind and air speed data, measured by anemometers, provides information for many purposes:

- Predict weather system movement
- Issue extreme wind event warnings
- Help boat captains maneuver
- Control windmill power generators
- Choose wind farm locations
- Assist aviators
- Predict & report ocean wave conditions
- Design HVAC systems & hair dryers

Wind speed measurement: A cup anemometer can measure the speed of wind independent of direction. The force of the wind pushes against the open end of the cups, causing the anemometer to rotate. The indicated wind speed is proportional to the distance traveled by a cup over a time period. The travel distance is equal to the circumference of the circle traced by the pointed end of the cups as they rotate about the axle. The circumference = $2\pi r$, where r is the radius of the anemometer arms measured from the axle to the pointed end of a cup. Conversion factors can be used to report wind speed in the desired units, typically miles per hour or meters per second.

Wind speed indicated by anemometers must be adjusted using a correction factor to account for real-world physical effects. Real anemometers are affected by friction and inertia. Another significant factor is the anemometer's own effect on the wind. Ideally, wind flow is smooth and steady, but wind often swirls and tumbles about when it interacts with objects and when it combines with other winds coming from different directions. The anemometer itself introduces this type of turbulence.

Reuse

This kit uses reusable materials designed for other uses. To continue making a positive impact in reducing waste, reuse these materials in other projects. Additionally, any unused materials can be collected and delivered back to RAFT.

Feedback

Please comment on this kit by taking this short survey: http://bit.ly/RAFTkitsurvey. Let us know of any material concerns (missing, broken, or poorly fitting parts) as well as any suggestions for improvement.

Resources

Wind-O-Meter assembly (YouTube, 2:33) - https://bit.ly/49GJe16
How are wind speeds measured? (YouTube, 1:38) - https://bit.ly/3LYtxIl
Measure wind speed at home. (Scientific America) - https://bit.ly/3SDXDoE
How to read a windsock (Pilot Institute) - https://pilotinstitute.com/reading-windsocks/
The power of the wind. (Danish Wind Industry) - https://bit.ly/49sXx9r
Ping Pong Ball Anemometer - https://bit.ly/3QYc85a