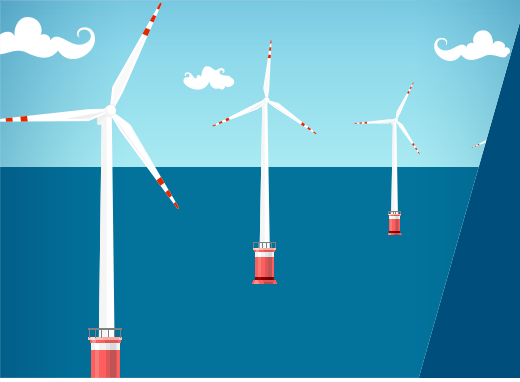


GRADES 3-5

How Windy is It? Making Anemometers to Measure the Wind

Key Concepts

Students will learn about why wind exists in the first place, and how to measure its speed and energy capacity.

Time Required

115–135 minutes

Standards

Disciplinary Core Ideas

- ESS3.A Natural Resources
- ETS1.B Developing Possible Solutions

Cross Cutting Concepts

- Cause and Effect
- Systems and System Models

Science & Engineering Practices

- Developing and Using Models
- Analyzing and Interpreting Data
- Using Mathematics and Computational Thinking
- Constructing Explanations and Designing Solutions

OVERVIEW

In this activity, students will learn about the wind, how wind turbines work, and why it's important to know how fast and frequently the wind tends to blow in an area before installing wind turbines there. Students will then construct a simple anemometer and use it to collect data on wind speed around their school. Students will analyze their wind speed data, and consider how the local environment affects wind speed and siting decisions.

LEARNING OBJECTIVES

At the end of the lesson, students will be able to:

- Explain how wind arises as a natural weather phenomenon that occurs on Earth.
- Identify features on Earth that can impact wind speed and direction such as landforms, surface materials, and manufactured structures.
- Recognize that wind can be measured and harnessed by wind turbines to generate electricity.
- Describe how the ability to measure and predict wind activity using data helps inform where wind turbines should be located, or sited.

ADDITIONAL RESOURCES

Additional resources for this lesson can be found at https://kidwind.org/activity/

BACKGROUND

Wind is caused by differences in air pressure in different areas of the atmosphere, primarily due to temperature differences. The Sun warms some areas of Earth more than others. In warmer areas, warm air rises and lowers the air pressure; cooler air then moves in to replace the warm air, causing wind. On the global scale, areas closer to the equator are warmer than polar areas, causing winds to tend to move toward the equator over much of the Earth. The rotation of the earth around its axis also impacts the movement of air globally.

An anemometer is an instrument that measures wind speed. Describing the weather as "windy" is subjective; it can mean different things to different people based on their experiences. Measuring the speed that wind is traveling allows us to compare actual wind conditions in different places. A "cup anemometer" is

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

KidWind® PROJECT

MATERIALS

For the class [optional]:

- ☐ Chart paper, space on the board, or table for presentation on a smart board or projector in order to record student data for the class.
- ☐ Materials to test and measure windspeed
  - · 3-4 different fans (if testing or demonstrating how to test indoors)
  - · Handheld digital anemometer (approximately $15; see image)

For each student group (may be packaged into kits; multiply construction items by the number of students if you want each student to make their own):

- ☐ Student Worksheet
- ☐ 1 Pencil (new, not sharpened)
- ☐ 5 paper snow cone cups (see image)
  - · Note: small paper cups (e.g., "Dixie®" cups) can also work for this activity, but will be slightly more difficult to use.

- ☐ 1 straight pin (T-pin or quilting pin)
- ☐ 2 extra-long straws
- ☐ Masking tape
- ☐ Hole punch
- ☐ Scissors
- ☐ Marker
- ☐ Ruler

one of the most basic tools for measuring wind speed. It consists of a vertical pole with three or four cups attached to it that spin when the wind blows. Wind speed is measured by the number of times the cups spin around in a given amount of time.

GETTING READY (30 MINUTES)

The following should be done prior to the start of the class. You should plan for at least 30 minutes to complete the set-up.

Take a look at the three videos in the Resources Section of this activity guide. Decide which videos work best for giving your students the necessary background knowledge to complete this activity. Queue them up to be ready to play.

Review and download or queue the videos:

- → Nature Works: To Make Clean Energy (video timing: 0:00 to 1:47)
- → The Future of Energy – Wind Power (video timing: 0:00-2:08)

Work through the activity yourself, this will allow you to understand what students are likely to have trouble with. Construct an anemometer and use it to test wind speed.

Decide how to distribute construction materials and prepare: either (1) create student kits ahead of time or (2) have the students gather materials from a common store during class, then set up the kits or the materials store.

Decide whether and how to structure student groups for measuring the wind.

With 2 students per group, one student should hold the anemometer and manage the stopwatch while the other counts and then records.

With 3 or 4 students per group, one student can hold the anemometer in place while another acts as timekeeper, and another acts as a recorder; all students not watching the stopwatch can count.

Consider whether you want to let students choose how to get mutliple observations, or if you want to assign what they will do. Here are some options:

- → Organize groups of 3-4 students, and ask multiple students count at the same time.
- → Direct groups to repeat the same measurement multiple times.
- → Assign multiple groups to measure the same location.

Determine what outdoor locations on campus you will use for measuring the wind speed. Here are some important considerations:

Pick areas that are more and less windy.

You may need to have a backup plan to conduct the measurement part of the activity (Part 2) on a day with inappropriate weather! One possibility is to have 3-4 fans of different sizes and/or speeds to represent different outdoor locations.

Consider how you will monitor students. If you can't observe all the sites at once, you may wish to enlist the help of another adult, or pair up with another class and teacher to do the activity together.

You should have at least 3 locations to measure. You may wish to have multiple groups assigned to each site or, if there's time, have each group rotate to each site.

Prepare a chart to record data from student groups for the class.

Choose from a variety of ways to collect student data into a chart to share with the class:

- On easel paper
- On a computer spreadsheet (share with a smart board or projector)
- On a white board or blackboard

Adjust the example chart to fit your decisions about what/how many locations, groups, and repeated measures per group to have in this lesson (see example).

Location	Group	Average Rotations	Average Wind Speed
Basketball hoop	1		
	2		
	3		
	4		
Class Averages			
Swing set	3		
	4		
	5		
	6		
Class Averages			
Cafeteria door	**1**		
	2		
	5		
	6		
Class Averages			

ACTIVITY PART 1: INTRODUCE ANEMOMETERS (40-50 MINUTES)

Step 1: Step 1: Introduce the essential questions (10 minutes)

Post the questions below on the board or in some other prominent place.

- *What is wind?*
- *What is wind power?*

Step 2: Ask students consider the essential questions. For example, you could tell students to write down or talk about everything they can think of about the question:

- In a notebook or on a handout for later reference
- On sticky notes for later placement and organization on the board
- In a joint file, again to make it possible to organize and possibly save them
- Have students turn-and-talk in pairs

Step 3: Engage students.

Students should record their prior knowledge before beginning the activity. Ask students to share what they know or believe about the essential questions and record the contributions in the "K - What I Know" section of a KWL chart. For example, you could:

- Lead a class discussion about the essential questions, while you or students record the major points in the KWL chart.
- Ask students (with your help) to organize the class responses on sticky notes or in a joint file into categories, to be summarized for the KWL chart.

PART 2: BUILD BACKGROUND KNOWLEDGE (15 MINUTES)

Step 1: Group learning

Ask students what they know about the wind. What is the wind? What causes the wind?

Watch a video about the wind, or if you prefer, review or introduce the topic with a book or slideshow. See example video resources in the "Resources" section.

Review wind content. Here are some questions you could ask:

- *Where does the wind come from?* Answer: The Sun warms the air, air rises, and then cooler air rushes in. The turning earth affects which way the winds tend to flow.

- *Is the wind the same in all places all the time? Why not?* Some things to consider that can affect the wind: the shape of the land, hills and valleys, the color of the surface, and what that surface is – for example, water, sand, buildings, pavement, trees, plants, or dirt. If students don't come up with these ideas themselves, you might talk about them and ask students to make educated guesses about how each might affect how the Sun makes wind and how strong the winds are.

Ask students what they know about wind turbines. Has anyone seen one? What does a wind turbine look like? What does it do? Accept all answers.

Watch videos about wind power. With students now thinking about wind turbines and wind power, pause and watch one or both of the following videos:

- Nature Works - To Make Clean Energy (video timing: 0:00–1:47)
- The Future of Energy – Wind Power (video timing: 0:00–2:08)

Lead a discussion about wind power. Here are some questions you could ask to get the conversation going:

- *What is a wind turbine? What does it do?* Answer: it uses the energy from the wind to generate electricity.
- *What are some advantages to using wind turbines to generate electricity?* Potential answers: they are pollution-free, the energy is renewable, and they can generate a lot of electricity.
- *What is renewable energy? Why is renewable energy important?* Answers: Renewable energy is electricity that is produced from natural resources that never run out. Examples include electricity harnessed from wind, solar, water, or biomass.
- *What are some problems with using wind turbines to generate electricity?* Potential answers – make sure the first two get mentioned: (1) there needs to be enough wind in a place for a wind turbine to work and not every place is windy enough; (2) the wind doesn't always blow; (3) not everyone wants to live near wind turbines; (4) minimal bird mortality is possible; other responses are possible.[1]

Direct student to talk to their neighbor about where to build wind turbines, and then share what they discussed with the class. Ask: *What do you think are the best places to build wind turbines? Why? How can people know what the best places are?*

Record what students learned from the videos and the discussion about wind, wind power, and the importance of wind speed for generating electricity with wind turbines. Write student contributions into the KWL chart.

Record what students "Wonder". Ask students what they don't understand and want to know more about. Record their contributions in the "W-Wonder" section of the KWL chart.

PART 3: INTRODUCE THE EXPERIMENT (5 MINUTES)

Step 1: Setting up.

Explain that students will measure wind speed around their school. Ask: *Does anyone know what an anemometer is?* Show a simple anemometer. Explain that students will first construct a simple anemometer, and then use it to measure wind speed around their school.

Review the student guide. Provide a brief overview of the activity and then review and "walk through" the Measuring the Wind Instruction Guide step by step with students. Draw attention to any particular steps where you feel your students may struggle.

Point out the "Work Checklist" on the Measuring the Wind Instruction Guide, and instruct students to check off the items as they complete the steps.

Direct students assemble into their teams. If they haven't already done so, they should do so now.

Check for questions. Answer any questions students have.

Distribute materials. Either pass out the kits you prepared, or allow teams to come to the "materials store" that you set up to pick out the materials listed in their Measuring the Wind Instruction Guide.

PART 4: CONSTRUCT AN ANEMOMETER (10-20 MINUTES)

Step 1: Build time.

Remind students of team expectations. For example, you might remind them to ask each other when they feel stuck before coming to talk to you.

Tell student teams to begin the activity using the handout to guide them.

Circulate to check in with teams. Provide suggestions, answer questions, and make sure students understand what the different materials represent.

Let students know when they have 10 minutes and 5 minutes remaining to complete their anemometer.

ACTIVITY: PART 2 (45-55 MINUTES)

PART 1: INTRODUCE HOW TO MEASURE THE WIND (10-15 MINUTES)

Step 1: Review the activity.

Review the goal of the activity with students before bringing them outside to test the wind.

- Assign students to work in groups of 2-4.
- Each group should have their anemometers, a stopwatch, and a clipboard.
- One student will hold (use) the stopwatch, another will hold the anemometer, and a third will hold the clipboard and count the rotations. If the group includes two students, one can use the stopwatch and hold the anemometer.

Step 2: Practice the activity.

Take the class outside (or practice indoors with a fan). Ask students to gather around in a circle.

Practice as a class how to measure the rotations of the anemometer.

- Tell everyone to practice using the stopwatch to count 10 seconds by doing it together. Make sure all students know how to do it.
- Practice in groups

  Ask one student to hold up their anemometer for everyone to watch the rotations.

  Ask a second student to run the stopwatch: they should call "start" when they push the button for a 10-second countdown.

  Tell all students in the class to count the turns of the anemometer while the stopwatch is running.

- Ask students how many turns they counted. There are likely to be multiple responses.
- Count how many students in the class gave each response with a show of hands.

Make sure students understand why they need multiple trials. There are likely to be errors in measuring the rotations of the anemometer. Here are some questions you could ask and things you can say to help students think about the issue of error:

- Ask: Why did some students come up with a different count than others?
- Say: Scientists have a name for what happened. They call it "error." Error is what we call it when the same experiment leads to different results.
- Ask: What do you think we could do to figure out the best number to use for our count of rotations of the anemometer? What can we do to make error as small as possible?
- Discuss or explain: Students may come up with a variety of answers. We encourage you to take the time to help them to discuss the pros and cons of each method. Make sure that you end up talking about:

  Making multiple or repeated measurements, just as the class made multiple measurements by all counting at the same time. They could also make repeated measurements by taking turns.

  Using math to decide on a final measurement by finding an average. If your class is ready, have them calculate the arithmetic mean; otherwise, you can have them find the mode (the most common result) of the multiple trials.

- Say: For this activity, I want you to make multiple measurements so you can make the error smaller.
- Decide or explain: At this point, you can either have students come up with their own method to take multiple measures, or you can tell them which method to use. Groups of 3-4 could take multiple measures at the same time, while groups of 2-3 may prefer to take sequential measurements. Or, have multiple groups test the same location.

TEACHER TIP:

Have a constructed anemometer available as a model for students to reference when building.

PART 2: CONDUCT THE ACTIVITY: STUDENTS MEASURE THE WIND (15 MINUTES)

Step 1: Beginning the activity.

Remind students of team expectations. For example, you might remind them to ask each other when they feel stuck before coming to talk to you.

Tell student teams to begin the activity using the handout to guide them.

Circulate to check in with teams. Provide suggestions, answer questions, and make sure students understand the procedure.

Remind students when they have 5 minutes remaining to complete their measurements.

PART 3: ANALYZE AND DISCUSS DATA (10-15 MINUTES)

Step 1: Data tables.

Return to the classroom.

As needed, show students how to find the average for each of their trials. Show students how to calculate the mean or determine the mode of the number of rotations they counted.

Give students time and support to complete their data tables. Once students have an average number of rotations, they can determine what wind speed that corresponds to.

You may need to demonstrate for the class and/or circulate to support students as they work.

Step 2: Group data.

Record each group's average (median or mode) values for each location in the Class Data table you prepared. Call on each group and support students to report accurately.

Solicit students to help you determine, for each location, the average rotations and wind speed.

Step 3: Discuss.

Lead a class discussion to analyze the data. Encourage students to contribute their arguments and evidence.

- → *Which location was the windiest? Which was the least windy? How do you know?*
- → *Where did the wind have the most energy?* Remind students that faster winds have more energy than slower winds.
- → *Why do you think some locations were windier than others (or not)?* Look for students to talk about physical attributes of each location, including nearby buildings and trees.
- → *What are some reasons that it's helpful to be able to measure wind speed?*

  Example answers may include: to prepare for extreme weather or storms, to test if materials are strong enough to withstand certain speeds (e.g., buildings, wind turbines, camping tents, telephone poles, etc.), and to see if there's enough wind to make building a wind turbine worthwhile.

Step 4: Connecting the dots.

Connect back to what students learned about how wind speed matters for wind turbines. Support students to make explanations that connect wind speed, energy, and transformation from mechanical energy (spinning blades) to electricity.

- → *How does wind speed matter for generating electricity with a wind turbine?*

  Faster wind has more energy, and more energy turns the turbine blades faster.

  The more frequently the wind turbine blades go around, the more electricity a turbine will generate.

  Knowing how fast the wind tends to blow enables utility companies to predict how much electricity they can produce.

PART 4: REVIEW & CLOSING (10 MINUTES)

Step 1: Clean up and review.

Have students clean up and put things away.

Revisit the essential questions.

- → Ask: *What have we learned about wind? What is wind?* Students should be able to talk about:

  The Sun warms air masses that rise, so that cooler air can move in.

  The spinning globe and more regional or local features (surfaces, altitude, landforms, structures, etc.) affect the wind.

  Wind has energy to do things (like blow your hair around, or turn turbine blades).

→ Ask: *What have we learned about wind power?* Students should be able to talk about:

The wind spins turbine blades

More spinning leads to more electricity being generated

Wind energy is "renewable" and better for the environment than burning fossil fuels

Wind power comes and goes with the wind and other problems with relying on the wind to make electricity

Revisit what students "Wonder."

→ Review the questions on the KWL chart and update those that have been answered.

→ Decide which ones students still want to answer and make a plan with students for how they will answer them [optional].

VOCABULARY

Air pressure – The force exerted by air on everything around it. Air at a higher pressure will move into areas with lower air pressure, causing wind.

Anemometer – An instrument used to measure wind speeds.

Average – A number used to summarize or characterize a set of data. Two kinds of averages are the mean and the mode.

Mean – An average of a set of numbers, found by adding all the numbers and dividing by the amount of numbers in a data set.

Mode – The most common number in a set of numbers.

Rotation – The action of rotating around an axis or center.

Renewable energy – Electricity that is generated from an energy source that will never run out, such as wind, solar, water, or biomass.

Speed – How fast something is moving.

Wind – The natural movement of air, usually in a current from one place to another.

Wind turbine – a device that converts the kinetic energy of wind into electrical energy.

ADDITIONAL RESOURCES

What causes the Wind? (4:39) From FunScienceDemos YouTube Channel

Weather 101: What Causes Wind? (0:55) From Weather Channel YouTube Channel

Why Does the Wind Blow? (2:59) From NOAA SciJinks YouTube Channel

[1] Bird Mortality Statistics

Sovacool, Benjamin K., "The avian benefits of wind energy: A 2009 update." Renewable Energy, Volume 49, 2013, doi:10.1016/j.renene.2012.01.074.

Measuring the Wind Instruction Guide

Name(s) _____ Date _____

MATERIALS

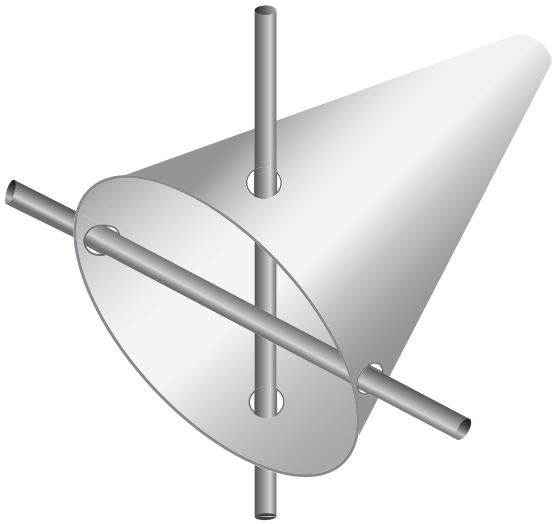
- ☐ 1 pencil
- ☐ 5 snow cone cups
- ☐ 2 extra-long plastic straws
- ☐ Masking tape
- ☐ Single hole punch
- ☐ Scissors
- ☐ 1 straight pin
- ☐ Marker
- ☐ Stopwatch or a watch with a second hand
- ☐ Ruler

PROCEDURE

CONSTRUCT YOUR ANEMOMETER[1]

1. Read through all the steps in the procedure first, and ask your teacher about anything you do not understand.
2. Use the marker to entirely color one of your snow cone cups, inside and out.
   → This will help you count the rotations (number of spins) of the anemometer later.
3. Pick up another (white) cone. Cut a tiny bit off the tip to make a just hole large enough for the pencil to slide in.
   → This will be your "base cup," which will hold the anemometer arms together on the pencil.
4. Use the hole punch to make four holes around the larger side of the base cup:
   → Two holes opposite each other close to the rim, but not on it!
   → Two holes between the first two holes, about ½ centimeter farther away from the the rim of the cup.
5. Slide the straws through the holes in the base cup, making an "X" (see Figure 1).
6. Center the straws in the base cup, so you have the same length sticking out on all four sides.
   → Use a ruler to make sure that the same amount of straw is sticking out on each side.

Figure SEQ 1: Base Cup



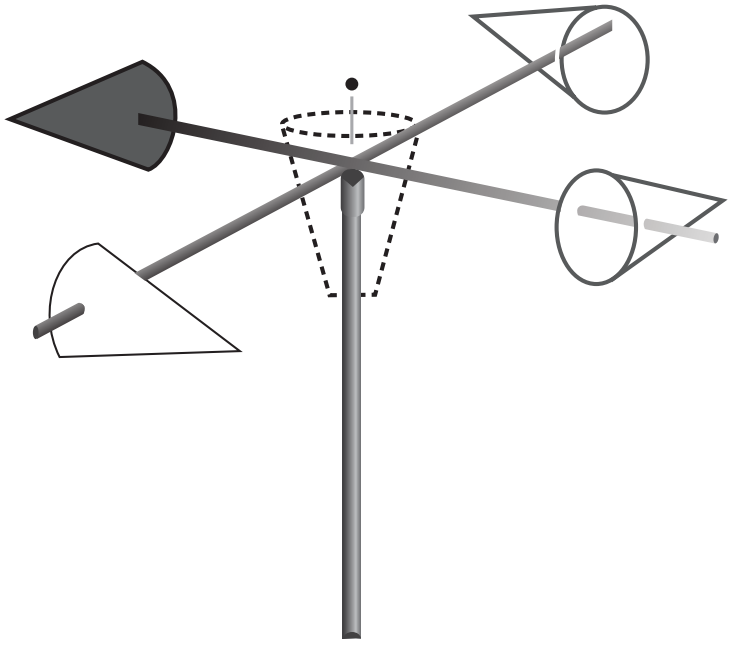
[1] ©2021 The NEED Project Floating Offshore Wind Teacher & Student Guide www.NEED.org.

7. Slide the base cup over the pencil through the hole in the tip of the cone.
8. Push the pin through the middle of both straws and into the pencil eraser – as far as you can – to anchor the device.
9. On the four remaining cups, including the one you colored, use the hole punch to make two opposite holes in each cup, about 1 centimeter below the rim of each cup..
10. Slide one cup onto the end of each straw. Make sure that all the cups face the same direction (See Figure 2).
11. Adjust the cups on the straws so that they are all spaced equally and balanced. Check by letting them go and see if one side dips down. If it does, adjust the cups.
12. Once the cups are balanced on the straws, tape the cups to the straws.
13. Lift the straws slightly away from the eraser on the pin, so that the device spins easily.
    → You might need to stretch the pin holes in the straws by pulling gently on the straws while holding the pin in place.
14. Test your anemometer by holding it upright and blowing into one of the cups. If the cups spin freely, great job! If not, adjust the pin and straws as described in step 11 until the cups spin freely when you blow.

WORK CHECKLIST

Steps	✓
1. I have all of my supplies.	
2. I colored one of my five cups.	
3. I cut the tip of the "base" cup off, and slid the pencil through it.	
4. I punched four holes to make an X in the "base" cup, and crossed the straws.	
5. I punched two holes in each of the four other cups, so the holes went across from one side to the other.	
6. I put the four cups on the ends of the two straws.	
7. I made sure all the cups are facing the same direction.	
8. I centered the straws and cups, so all the cups are spaced equally.	
9. I pushed the pin through the spot where the two straws cross, and into the pencil eraser.	

Figure 2: Completed Anemometer



MEASURING THE WIND

We can calculate wind speed by counting the number of rotations the anemometer makes in 10 seconds. That is, we count the number of times the anemometer makes one complete spin in 10 seconds.

1. Bring your anemometer, stopwatch, and Instruction Guide (this document) to your outside location.
2. Assign one person to hold the anemometer (the Holder), one to work the stopwatch (the Timer), and one to record the data (the Recorder). If you are working in a group of two, you can share roles.
3. Decide which group member or members will count the rotations (the Counters).
4. [Holder] Hold the anemometer upright and straight.
5. [Timer] Set the stopwatch to 10 seconds.
6. [Timer] Press the stopwatch button at the same time that you say "go" aloud.
7. [Counter(s)] Count the number of times the colored anemometer cup makes one full rotation (spins completely around the pencil) until the stopwatch beeps or the person holding it says "stop."
8. [Timer] At exactly 10 seconds, say "stop."
9. [Recorder] In Table 2 on page 4, write the number of rotations that each Counter counted during the 10 seconds. If more than one group member counted, record each person's count on a separate line as a separate trial.
10. Repeat steps 2–9 each time you measure the wind speed. Make sure you get at least 3 measurements for each location you test.

AVERAGE YOUR COUNTS AND FIND THE WIND SPEED

11. Calculate the sum of the number of rotations for each location and write it in Table 2, Row A.
12. Write the number of completed trials (the number of rows you filled out) for each location and write it in Table 2, Row B.
13. Calculate the average number of rotations for each location using the method shown in Table 2, Row C (or the method your teacher shows you) and write it down.
14. Find that number of rotations in Table 1, and convert it to a wind speed.
    → For example, if you counted 11 rotations, you would record a wind speed of 4 mph.
    → Record the wind speed in Table 2, Row D.
15. Look up your average rotations in Table 1, and compare your average speed to the average speed listed in the table. Are they the same?
16. Compare your results with those of other students in the class.

Table 1. Anemometer Speed Conversion

Rotations per 10 Seconds	Wind Speed (mph)
2 – 4	1
5 – 7	2
8 – 9	3
10 – 12	4
13 – 15	5
16 – 18	6
19 – 21	7
22 – 23	8
24 – 26	9
27 – 29	10
30 – 32	11
33 – 35	12
36 – 37	13
38 – 40	14
41 – 43	15
44 – 46	16
47 – 49	17
50 – 51	18
52 – 54	19
55 – 57	20

Table 2. My Team's Data Collection Sheet

Location:				
Trial	# Rotations	# Rotations	# Rotations	# Rotations
1				
2				
3				
4				
Sum of Completed Trials				
Number of Completed Trials				
A ÷ B = C (or most common #) = Average # of Rotations				
Average Wind Speed				

Table 3. Class Data

Location	Average Rotations	Average Wind Speed
Class Averages		