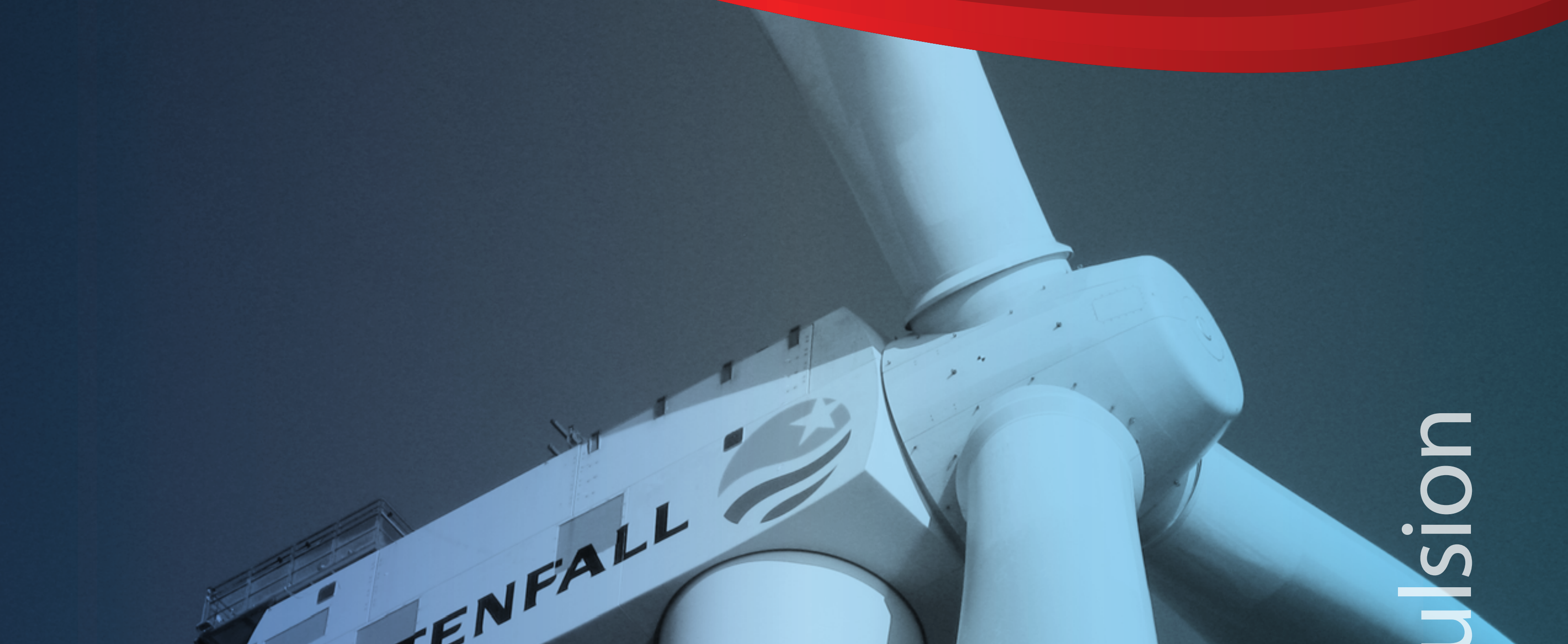
National Aeronautics and Space Administration

GRADES **9-12**

Wind Power



propulsion

Aeronautics
Research
Mission
Directorate

Museum in a BOX Series

www.nasa.gov

Wind Power

Lesson Overview

In this lesson, students will explore the power of the wind. Initially students will learn how wind is created by the phenomenon known as convection. Then they will put the power of wind to use with the creation of a wind turbine.

Objectives

Students will:

1. Learn through demonstration how the phenomenon known as convection produces wind.

2. Compete by designing different styles of turbine blade, with the winner being the team that can produce the highest power output.

Materials:

In the Box:

Plastic box
Food coloring
Plastic dropper (1 per group)
PVC Turbine Kits
Balsa wood strips (4 per group)
Coroplast strips (4 per group)
¼" Dowels (100 total)
Multimeters (1 per group)

Provided by User:

Water (hot and cold)
2-4 Risers (thin books or wood blocks)
Tape or glue
Cardboard
Styrofoam cups
Scissors / craft knives
Large fan

GRADES **9-12** **Time Requirements:** 4 hours 40 minutes minimum

Background

Early Use of Wind Power

The power of the wind has been put to work for thousands of years, powering the first ships and allowing explorers to discover the hidden corners of the globe. It was Hero of Alexandria (10AD – 70AD) though that invented the first wind powered machine. His device, simply known as "Hero's Organ", was exactly that – a wind powered organ similar to the many church organs in use today (Fig. 1).

Over the centuries, people have learned how to put wind power to far greater use than simply for playing music. It has been used to grind wheat for bread, pump water and most recently, generate electricity. The timeline in Figure 2 demonstrates how the technology has evolved over the years.

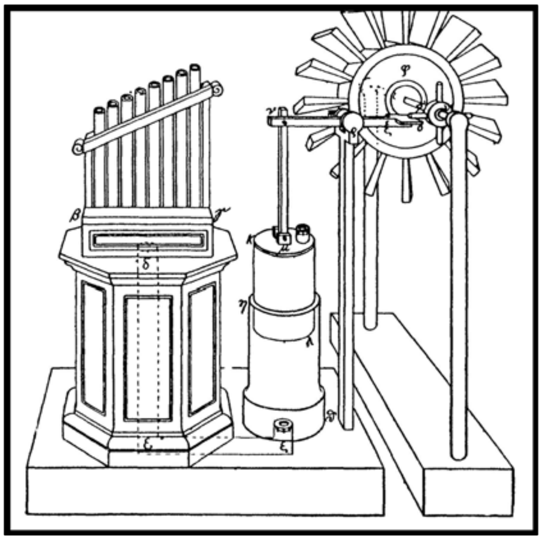


Fig. 1 Hero's Organ

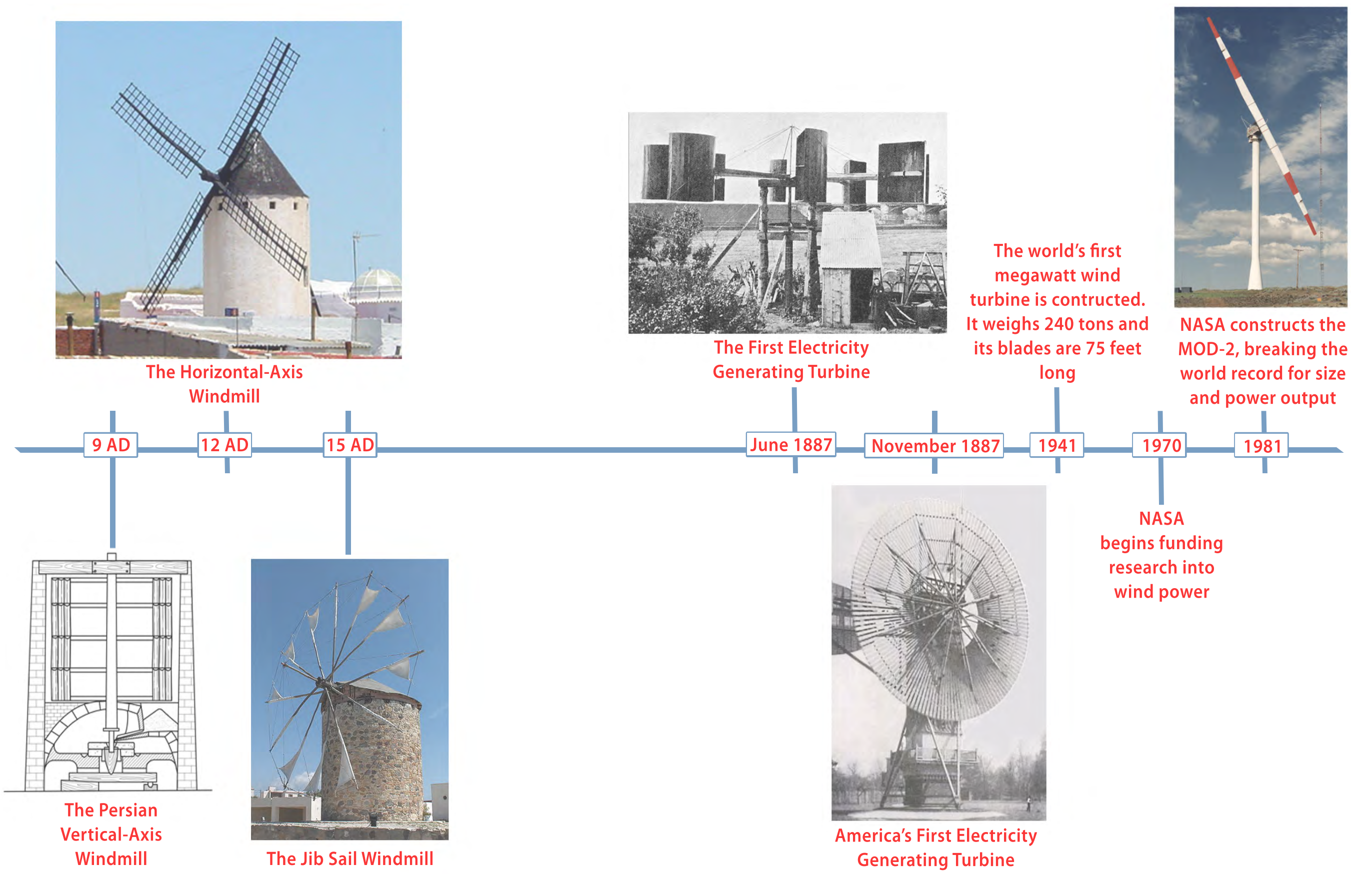


Fig. 2 Wind Power Technology Timeline

The Creation of Wind

Wind is nothing more than the movement of air due to a difference in air pressure and temperature.

The generation of wind begins when energy from the Sun heats a parcel of air. As the air is heated, its molecules become excited and move farther apart, causing the air mass to become less dense than its neighboring cold air mass. This difference in temperature and pressure resulting from the heating process creates instability. In an attempt to return to equilibrium, the colder, denser air moves underneath the warmer, lighter air in order to equalize the pressure between the two air masses. It is this movement of air that we refer to as wind.

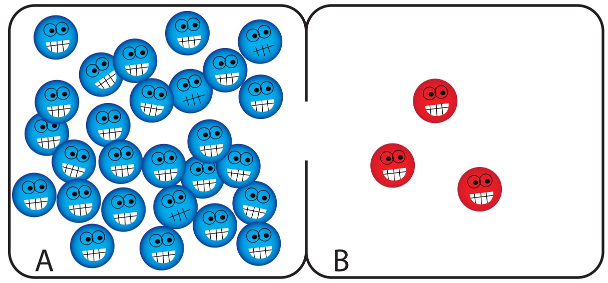


Fig. 3

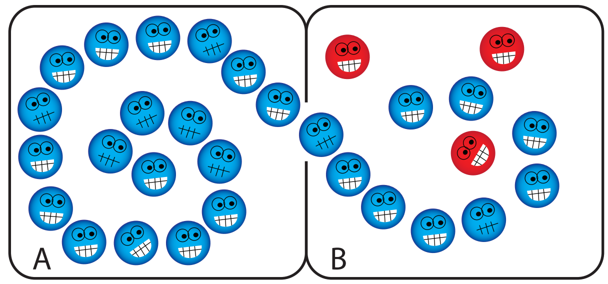


Fig. 4

To further explain, consider the following analogy. Imagine you are at a party. Room "A" is getting very crowded while the adjacent room "B" is nearly empty (Fig. 3). Some of the people in the crowded room will naturally begin to move to the sparsely occupied room, which in turn brings both rooms to equilibrium (Fig. 4). In this example, the flow of people from one room to the other represents the wind.

Measuring Wind Speed

Prior to 1805, there was no consistent way to measure the speed of the wind. One man's "strong gust" was another man's "light breeze". That all changed however when Sir Francis Beaufort, an Irishman in the Royal Navy, developed the Beaufort scale. Initially the scale went from 0 to 12 and measured the effects of the wind on the sails of a ship. This type of scale is classified as an "empirical" scale, meaning that it is based upon observation or experimentation, rather than calculated data. A 0 equated to no movement even with fully extended sails, whereas a 12 required the sails to be completely stowed for safety.

Img. 2 The Robinson Anemometer

In 1850, the scale was updated to include numbers that corresponded to the number of rotations of an Anemometer (Img. 2), a device with cups to catch the wind. An Anemometer activity is available in the Weather to Fly By lesson of the Museum in a Box series. Another change to the scale was made in 1916, when the use of sails diminished due to the increase in popularity of steam powered ships. People instead began to observe the effects of the wind on waves and land-based phenomena, such as the movement of trees or the smoke from chimneys. Figure 5 shows how the Beaufort scale matured over time.

Beaufort number	Description	Wind speed	Wave height	Sea conditions	Land conditions
0	Calm	< 1 km/h (< 0.3 m/s) < 1 mph < 1 kn < 0.3 m/s	0 m 0 ft	Flat.	Calm. Smoke rises vertically.
1	Light air	1.1–5.5 km/h (0.3-2 m/s) 1–3 mph 1–2 kn 0.3–1.5 m/s	0–0.2 m 0–1 ft	Ripples without crests.	Smoke drift indicates wind direction and wind vanes cease moving.
2	Light breeze	5.6–11 km/h (2-3 m/s) 4–7 mph 3–6 kn 1.6–3.4 m/s	0.2–0.5 m 1–2 ft	Small wavelets. Crests of glassy appearance, not breaking.	Wind felt on exposed skin. Leaves rustle and wind vanes begin to move.
3	Gentle breeze	12–19 km/h (3-5 m/s) 8–12 mph 7–10 kn 3.4–5.4 m/s	0.5–1 m 2–3.5 ft	Large wavelets. Crests begin to break; scattered whitecaps.	Leaves and small twigs constantly moving, light flags extended.
4	Moderate breeze	20–28 km/h (6-8 m/s) 13–17 mph 11–15 kn 5.5–7.9 m/s	1–2 m 3.5–6 ft	Small waves with breaking crests. Fairly frequent whitecaps.	Dust and loose paper raised. Small branches begin to move.
5	Fresh breeze	29–38 km/h (8.1-10.6 m/s) 18–24 mph 16–20 kn 6 8.0–10.7 m/s	2–3 m 6–9 ft	Moderate waves of some length. Many whitecaps. Small amounts of spray.	Branches of a moderate size move. Small trees in leaf begin to sway.
6	Strong breeze	39–49 km/h (10.8-13.6 m/s) 25–30 mph 21–26 kn 10.8–13.8 m/s	3–4 m 9–13 ft	Long waves begin to form. White foam crests are very frequent. Some airborne spray is present.	Large branches in motion. Whistling heard in overhead wires. Umbrella use becomes difficult. Empty plastic garbage cans tip over.

Beaufort number	Description	Wind speed	Wave height	Sea conditions	Land conditions
7	High wind, Moderate gale, Near gale	50–61 km/h (13.9-16.9 m/s) 31–38 mph 27–33 kn 13.9–17.1 m/s	4–5.5 m 13–19 ft	Sea heaps up. Some foam from breaking waves is blown into streaks along wind direction. Moderate amounts of airborne spray.	Whole trees in motion. Effort needed to walk against the wind.
8	Gale, Fresh gale	62–74 km/h (17.2-20.6 m/s) 39–46 mph 34–40 kn 17.2–20.7 m/s	5.5–7.5 m 18–25 ft	Moderately high waves with breaking crests forming spindrift. Well-marked streaks of foam are blown along wind direction. Considerable airborne spray.	Some twigs broken from trees. Cars veer on road. Progress on foot is seriously impeded.
9	Strong gale	75–88 km/h (20.8-24.4 m/s) 47–54 mph 41–47 kn 20.8–24.4 m/s	7–10 m 23–32 ft	High waves whose crests sometimes roll over. Dense foam is blown along wind direction. Large amounts of airborne spray may begin to reduce visibility.	Some branches break off trees, and some small trees blow over. Construction/temporary signs and barricades blow over.
10	Storm Whole gale	89–102 km/h (24.7-28.3 m/s) 55–63 mph 48–55 kn 24.5–28.4 m/s	9–12.5 m 29–41 ft	Very high waves with overhanging crests. Large patches of foam from wave crests give the sea a white appearance. Considerable tumbling of waves with heavy impact. Large amounts of airborne spray reduce visibility.	Trees are broken off or uprooted, saplings bent and deformed. Poorly attached asphalt shingles and shingles in poor condition peel off roofs.
11	Violent storm	103–117 km/h (28.6-32.5 m/s) 64–72 mph 56–63 kn 28.5–32.6 m/s	11.5–16 m 37–52 ft	Exceptionally high waves. Very large patches of foam, driven before the wind, cover much of the sea surface. Very large amounts of airborne spray severely reduce visibility.	Widespread damage to vegetation. Many roofing surfaces are damaged; asphalt tiles that have curled up and/or fractured due to age may break away completely.
12	Hurricane force	≥ 118 km/h (≥ 32.8 m/s) ≥ 73 mph ≥ 64 kn ≥ 32.7 m/s	≥ 14 m ≥ 46 ft	Huge waves. Sea is completely white with foam and spray. Air is filled with driving spray, greatly reducing visibility.	Very widespread damage to vegetation. Some windows may break; mobile homes and poorly constructed sheds and barns are damaged. Debris may be hurled about.

Fig. 5 The Beaufort scale

Wind Turbine Operation

Figure 6 shows the workings of a basic horizontal wind turbine. The blades are connected to a device, known as a governor, which serves two purposes. The first is to adjust the pitch (twist) of the blades to improve performance in varying wind conditions. The second is to control the speed and prevent a dangerous over-speed condition.

The governor is connected to the main shaft which in turn connects the blades to the gearbox. Its purpose is to amplify the speed of the main shaft by converting its immense torque, or turning forces, into additional rotor speed.

The gearbox is finally connected to the generator, a combination of magnets and copper wire. Using the principal of magnetic induction, the copper wire rotates inside a magnetic field, which shifts electrons and ultimately produces electricity (Fig. 7).

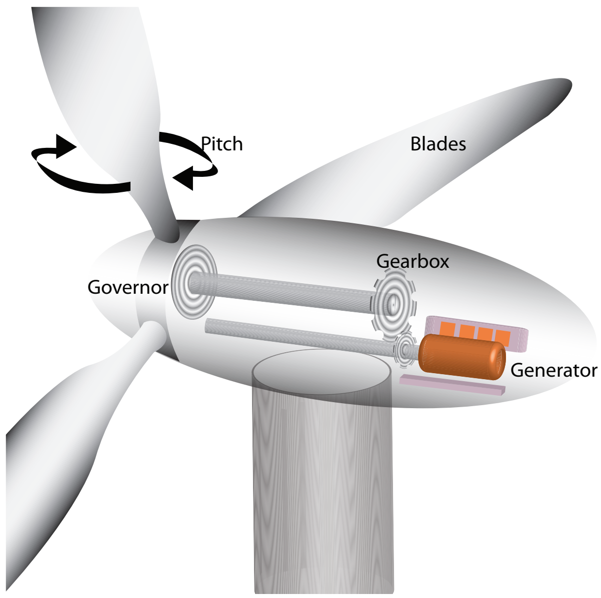


Fig. 6 Wind Turbine Diagram

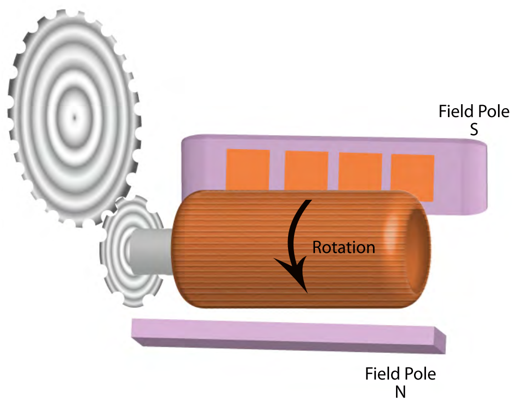


Fig. 7 Turbine Generator Diagram

Blade Design

The design of the wind turbine has changed remarkably over the years. The earliest designs were nothing more than simple pieces of cloth woven between canes. Today though, the use of computers and a better understanding of dynamics have helped us to create much more effective, efficient blade designs.

A turbine blade though can never be 100% efficient. Albert Betz, a German physicist, demonstrated back in 1919 that a blade that is too efficient, or that collects too much of the air, simply cannot turn. He proved, in what became known as Betz's Law, that a blade efficiency of about 59% is the theoretical maximum. In actuality, most commercial devices operate at around 40% efficiency as the 59% theoretical limit is almost unobtainable (Fig 8).

There are many ways to reach this limit but it becomes increasingly more difficult as the size of the blade increases.

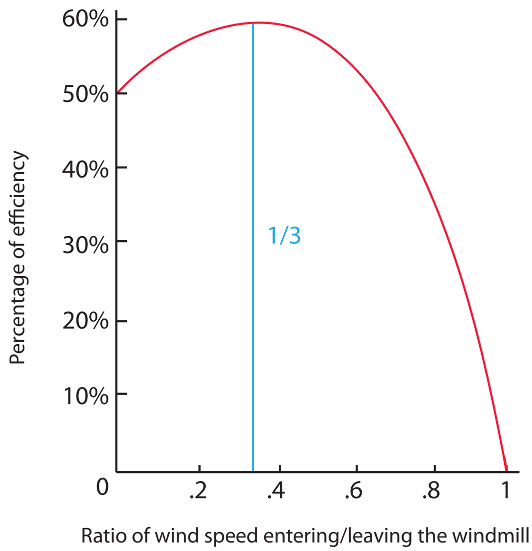


Fig. 8 Betz's Law

Some of the ways engineers are striving towards this 59% goal however are:

- **Aerodynamic blades.** By making a turbine blade in a similar way to an airplane's wing, it not only reduces the drag on the blade as it moves through the air, but uses the areas of high and low pressure to physically pull the blades around.
- **Blade Twisting.** Another technique also used on aircraft is twisting the blade, similar to an airplane's propeller. As the blades turn, the outer edges move significantly quicker than the inner, or root part of the blade due to the greater distance that the outer edge of the blade has to travel. In order to make each part of the blade most effective for its speed, it's twisted to give the tips of the blade a finer pitch and therefore produce less drag.
- **Horizontal / Vertical blades.** For large scale designs, the horizontal blade is a far more efficient design. For smaller locations, or in areas where the direction of the wind changes frequently, a vertical design works better. Similar to an old fashioned barbershop sign, the vertical blade design can collect wind from any direction. Also, due to its aerodynamics, it can be turned by much slower wind speeds, even in just a slight breeze. The drawback however is its inefficiency, with even the best designs capturing a mere 20-30% of the wind's available energy.

Activity 1

Convection Demonstration

GRADES 9-12

Time Requirement: 40 minutes

Materials:

In the Box

Plastic box
Food coloring
Plastic dropper

Provided by User

Very hot water
2-4 Risers (thin books, woodblocks)
5 Styrofoam cups

Worksheets

None

Reference Materials

None

Key Terms:

Convection
Density
Pressure
Wind

Objective:

In this activity, students will learn through demonstration how the phenomenon known as convection produces wind.

Activity Overview:

Using a combination of hot and cold water, students will learn how the Sun's uneven heating of the Earth creates air masses of varying density and pressure. These air masses move from the high pressure areas to the low pressure areas, creating what is more commonly known as wind. Liquid reacts to these changes in the same manner as air, always trying to maintain a state of equilibrium and in this demonstration, the food coloring will show how these masses move to maintain equilibrium.

WARNING: This activity requires extremely hot water. As such, it should be performed as a demonstration only.

Activity:

1. **Begin by setting up the demonstration.** First, take four Styrofoam cups and place them upside-down on the risers. The cups should be spaced so that they can fully support the plastic box.
   Select risers that are just high enough to allow the fifth cup to slide under one corner of the box.

2. **Using the Background information provided, discuss with the students how wind is created.**

3. **When ready to begin the demonstration, fill the box with at least 6 cm of very cold or refrigerated water and place it on the four Styrofoam cups.**

4. **Next, take the dropper and place a few drops of food coloring on the base of the box in opposite corners.** *Be very careful to not cause any turbulence in the water when doing this!*

5. **Lastly, fill the fifth Styrofoam cup with the hottest water available and place it under one of the corners with the food coloring.**

6. **Have your students watch what happens** (Img. 2)**.**

(Photo courtesy of Lost Tribe Media, Inc.)

Img. 2 The Convection Phenomenon

Be patient; depending on the temperature of the water, it can take several minutes to see the results.

Discussion Points:

1. **What caused the food coloring to move?**
   When the hot water was placed underneath the box, it gave off energy in the form of heat, which heated the water in the box. As the water heated it became less dense, which meant that it could be displaced by the adjacent cold water. It is this displacement you saw as the food coloring travelled around the box.

2. **How does this relate to wind?**
   The air around us reacts in the exact same way as the water in the box. As the air is heated by the sun it becomes less dense and is displaced by colder, denser air. This movement of air is what we refer to as wind. If we were somehow able to add food coloring to the air and look down from space, we would see the exact same thing happening with the air as we did with the water in the box.

3. **What would happen if we didn't use both extremely hot and cold water?**
   While the experiment would still work, the effect is most apparent when the temperature differences are greatest. It is no different with air. Larger differences in temperature, and therefore pressure, cause the wind that is created to be stronger.

NATIONAL SCIENCE STANDARDS 9-12

SCIENCE AS INQUIRY

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

PHYSICAL SCIENCE

- Structure and properties of matter
- Interactions of energy and matter

SCIENCE AND TECHNOLOGY

- Abilities of technological design
- Understanding about science and technology

Activity 2 Wind Turbine Design Competition

GRADES 9-12

Time Requirement: 4 hours minimum

Materials:

In the Box

3 PVC Turbine Kits

Balsa wood strips (4 per group)

Coroplast strips (4 per group)

100 ¼" Dowels

3 Multimeters

Provided by User

Tape or glue

Cardboard

Styrofoam cups

Scissors / craft knives

Large fan

Worksheets

Wind Turbine Power (Worksheet 1)

Reference Materials

Wind Turbine Assembly Instructions (3 copies, one per group)

Using The Multimeter (3 copies, one per group)

Sample Turbine Blade Designs

Key Terms:

Voltage

Wind Turbine

Objective:

Students will compete by designing different styles of turbine blade, with the winner being the team that can produce the highest power output.

Activity Overview:

Wind turbines come in a variety of shapes and sizes. By creating and experimenting with different blade styles, students will learn what blade characteristics harness the greatest wind potential.

Activity:

1. **Using the Background information as needed, discuss with the group how wind turbines create electricity and how there are various styles of turbine blade, each with their own unique qualities.**

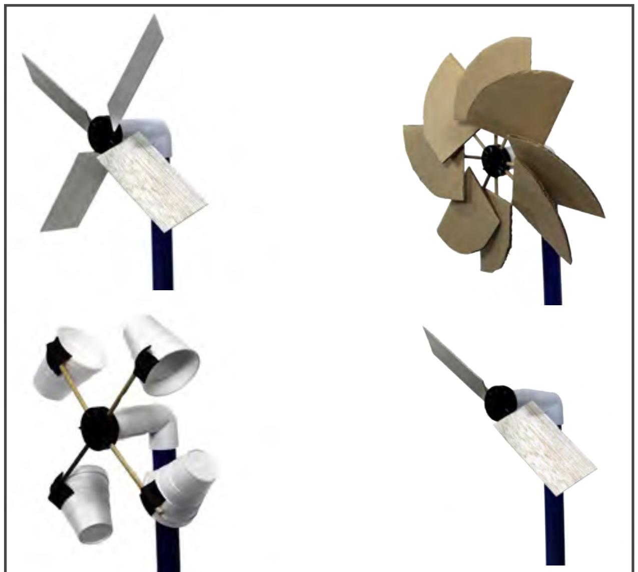
2. **Divide the students into three teams and provide each with their own wind turbine kit and a multimeter.**

3. **Have each team assemble their wind turbine using the instructions provided in the Reference Materials section.**

4. **Provide each team with a selection of coroplast strips, balsa wood strips, Styrofoam cups, cardboard and any other materials you have available for the creation of the turbine blades.**

WARNING: Do not use any sharp or metal materials for turbine blade creation.

5. **Ask the students to design their own turbine blades by cutting, gluing and taping as desired.**
It may be necessary to help younger students get started on this point. You can use the templates provided in the Reference Materials section or Image 3 below for ideas on blade creation.

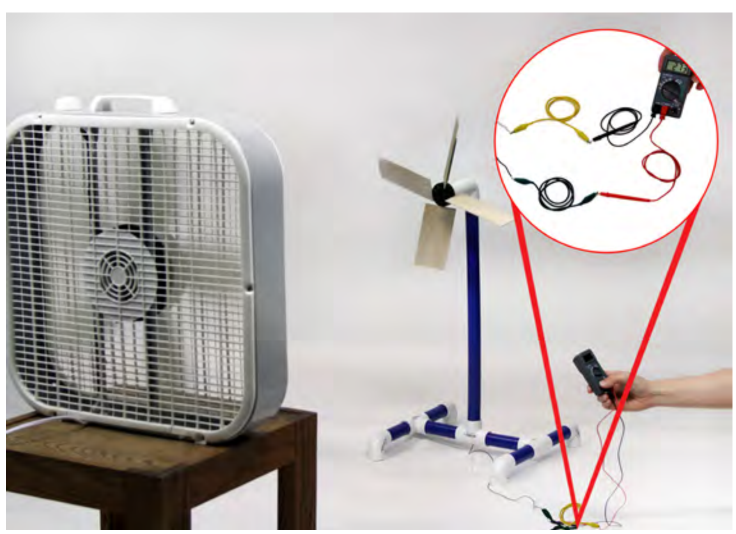


(Photo courtesy of Lost Tribe Media, Inc.)

Img. 3 Sample Blade Designs

Caution: Blades with a diameter larger than that of the fan will not function.

6. **As each team finishes a blade design, have them test its ability to harness the wind's energy by connecting the multimeter to the turbine and blowing on the blades using the fan.** See the Multimeter Guide in the Reference Materials section for information on how to use it correctly.



7. **Have the students record the voltage produced by the turbine as well as a sketch of the blade design on the Wind Turbine Power worksheet.**

8. **Encourage the students to modify or redesign their blades as needed in order to increase the power output.**

9. **After each team has had sufficient time to adjust their blades, compare the results and declare one team the winner!**

Discussion Points:

1. **Why did some designs work better than others?**
   It is commonly assumed by students that bigger is always better which is not always the case. Bigger blades may capture more of the airflow but they also require more force in order to move. Smaller, lighter blades may be less effective but also barely need a light breeze in order to start rotating.

2. **What converted the wind into electricity?**
   The turbine in our design was a simple electric motor. If electricity was applied to the leads, the motor would have turned the blades. Motors are able to work in more than one way however. By turning the shaft, as we did using the blades, it generated electricity. In real world designs though, the generator is specifically designed for converting mechanical energy into electricity.

3. **What else could have been done to generate more electricity?**
   In commercial designs, the turbine blades are connected to a gearbox. This gearbox allows the pitch of the blade to change, just like an airplane propeller, in order to improve its performance. Additional things such as twisting the blade or shaping it more like an aircraft wing would have also yielded improved performance.

NATIONAL SCIENCE STANDARDS 9-12

SCIENCE AS INQUIRY

• Abilities necessary to do scientific inquiry

• Understandings about scientific inquiry

PHYSICAL SCIENCE

• Structure and properties of matter
• Interactions of energy and matter

SCIENCE AND TECHNOLOGY

• Abilities of technological design

• Understanding about science and technology

Reference Materials

Glossary

Convection:
The circulation or movement of a liquid or gas, caused by the transfer of heat

Density:
The compactness of the molecules within a body of matter; a body that is more dense has more tightly packed molecules

Pressure:
The application of a force against an object

Wind:
The name given to the movement of an air mass

Voltage:
The force produced by an electrical energy, expressed in volts

Wind Turbine:
A device designed to capture the kinetic energy of wind and convert it into electrical or mechanical energy

Fig. 1 Hero's Organ

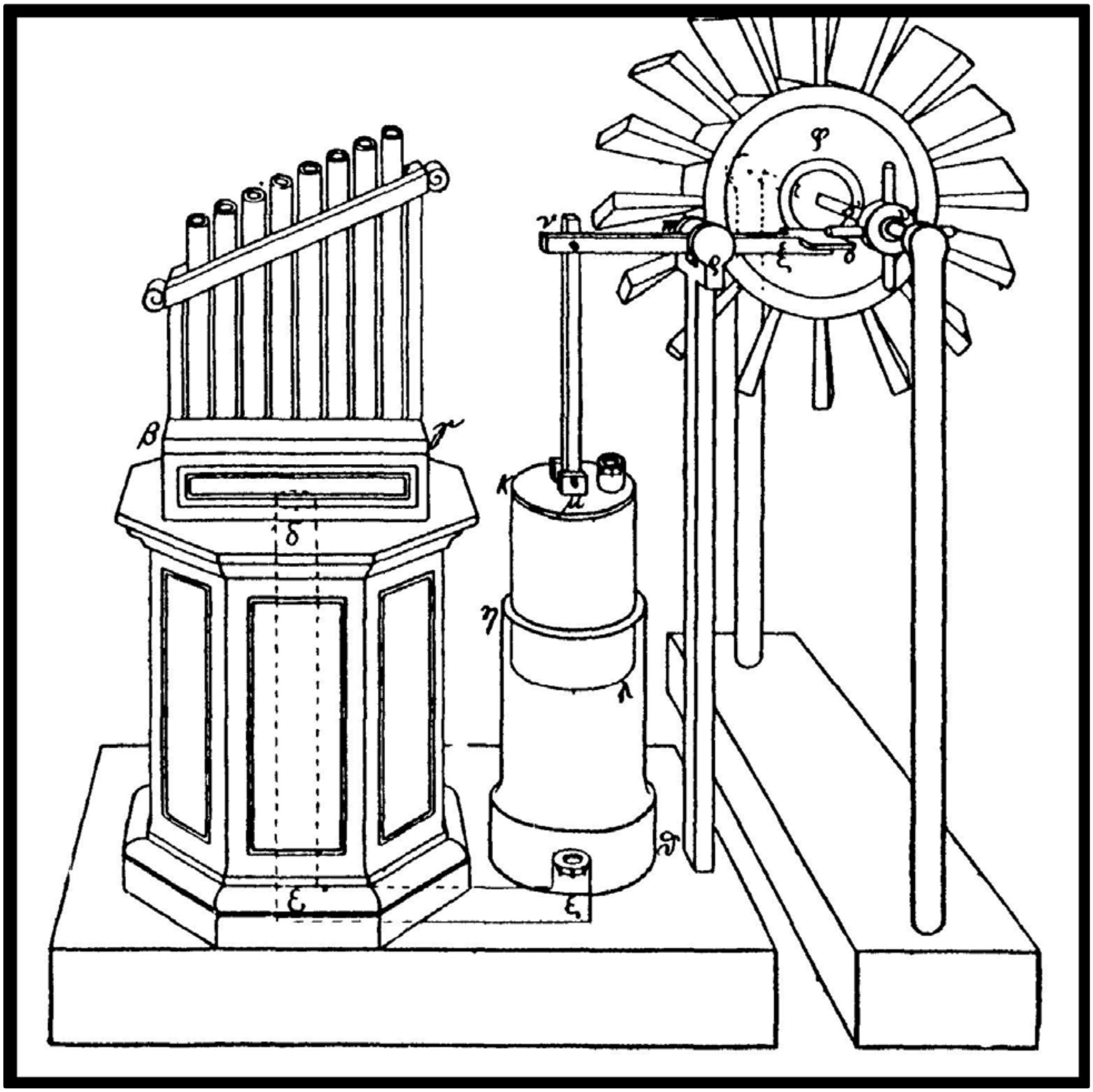


Fig. 2 Wind Power Technology Timeline

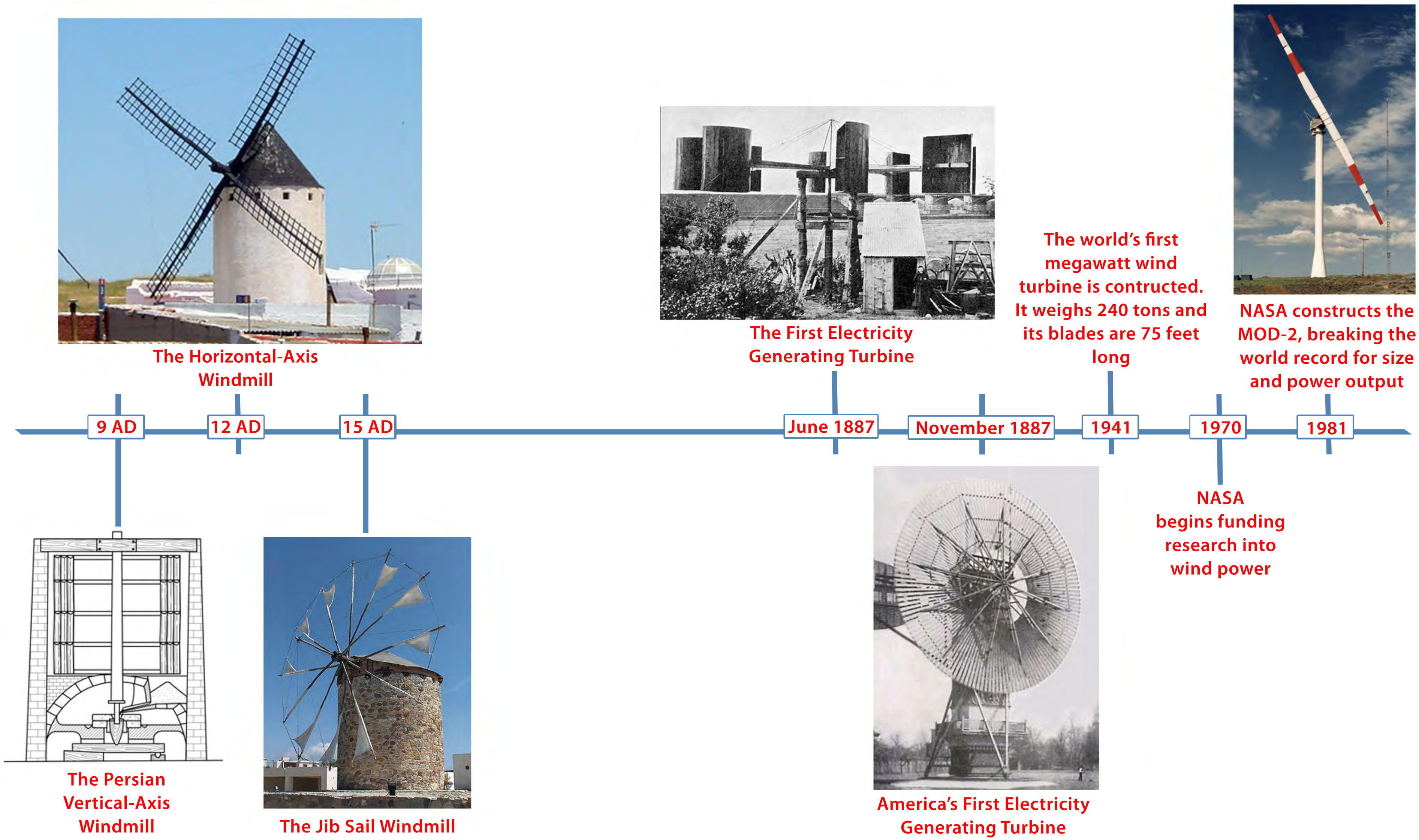


Fig. 3

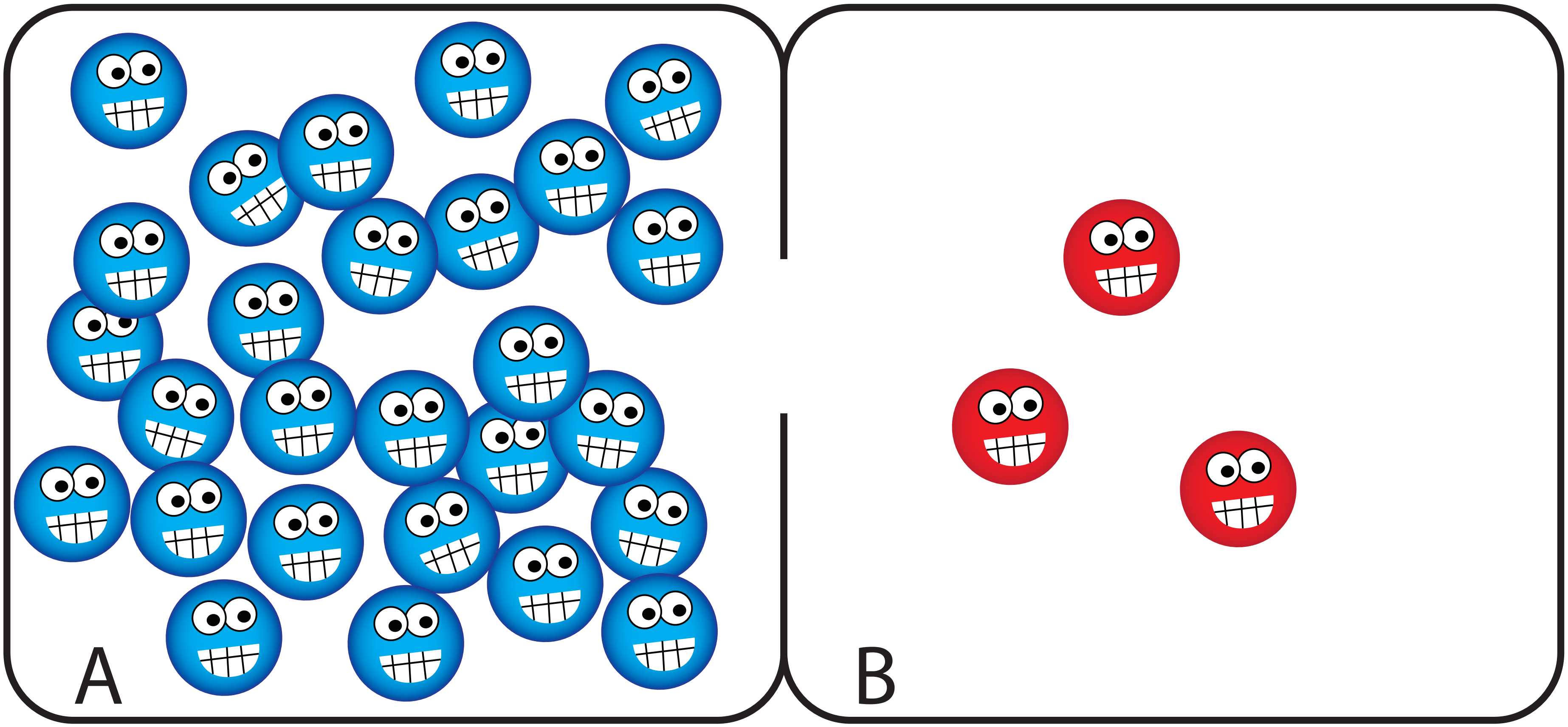


Fig. 4

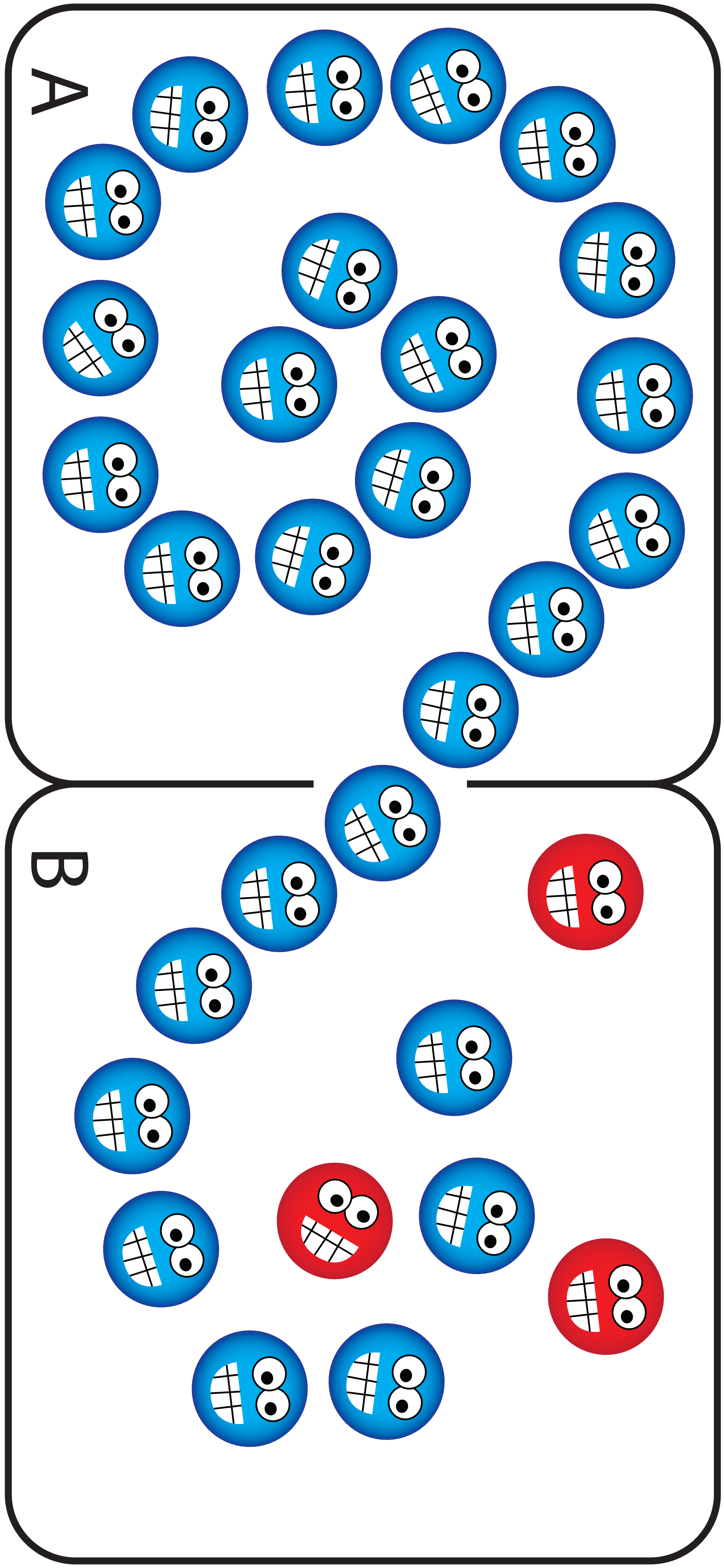


Fig. 5 The Beaufort scale

Beaufort number	Description	Wind speed	Wave height	Sea conditions	Land conditions
0	Calm	< 1 km/h (< 0.3 m/s) < 1 mph < 1 kn < 0.3 m/s	0 m 0 ft	Flat.	Calm. Smoke rises vertically.
1	Light air	1.1–5.5 km/h (0.3-2 m/s) 1–3 mph 1–2 kn 0.3–1.5 m/s	0–0.2 m 0–1 ft	Ripples without crests.	Smoke drift indicates wind direction and wind vanes cease moving.
2	Light breeze	5.6–11 km/h (2-3 m/s) 4–7 mph 3–6 kn 1.6–3.4 m/s	0.2–0.5 m 1–2 ft	Small wavelets. Crests of glassy appearance, not breaking.	Wind felt on exposed skin. Leaves rustle and wind vanes begin to move.
3	Gentle breeze	12–19 km/h (3-5 m/s) 8–12 mph 7–10 kn 3.4–5.4 m/s	0.5–1 m 2–3.5 ft	Large wavelets. Crests begin to break; scattered whitecaps.	Leaves and small twigs constantly moving, light flags extended.
4	Moderate breeze	20–28 km/h (6-8 m/s) 13–17 mph 11–15 kn 5.5–7.9 m/s	1–2 m 3.5–6 ft	Small waves with breaking crests. Fairly frequent whitecaps.	Dust and loose paper raised. Small branches begin to move.
5	Fresh breeze	29–38 km/h (8.1-10.6 m/s) 18–24 mph 16–20 kn 6 8.0–10.7 m/s	2–3 m 6–9 ft	Moderate waves of some length. Many whitecaps. Small amounts of spray.	Branches of a moderate size move. Small trees in leaf begin to sway.
6	Strong breeze	39–49 km/h (10.8-13.6 m/s) 25–30 mph 21–26 kn 10.8–13.8 m/s	3–4 m 9–13 ft	Long waves begin to form. White foam crests are very frequent. Some airborne spray is present.	Large branches in motion. Whistling heard in overhead wires. Umbrella use becomes difficult. Empty plastic garbage cans tip over.

Beaufort number	Description	Wind speed	Wave height	Sea conditions	Land conditions
7	High wind, Moderate gale, Near gale	50–61 km/h (13.9-16.9 m/s) 31–38 mph 27–33 kn 13.9–17.1 m/s	4–5.5 m 13–19 ft	Sea heaps up. Some foam from breaking waves is blown into streaks along wind direction. Moderate amounts of airborne spray.	Whole trees in motion. Effort needed to walk against the wind.
8	Gale, Fresh gale	62–74 km/h (17.2-20.6 m/s) 39–46 mph 34–40 kn 17.2–20.7 m/s	5.5–7.5 m 18–25 ft	Moderately high waves with breaking crests forming spindrift. Well-marked streaks of foam are blown along wind direction. Considerable airborne spray.	Some twigs broken from trees. Cars veer on road. Progress on foot is seriously impeded.
9	Strong gale	75–88 km/h (20.8-24.4 m/s) 47–54 mph 41–47 kn 20.8–24.4 m/s	7–10 m 23–32 ft	High waves whose crests sometimes roll over. Dense foam is blown along wind direction. Large amounts of airborne spray may begin to reduce visibility.	Some branches break off trees, and some small trees blow over. Construction/temporary signs and barricades blow over.
10	Storm Whole gale	89–102 km/h (24.7-28.3 m/s) 55–63 mph 48–55 kn 24.5–28.4 m/s	9–12.5 m 29–41 ft	Very high waves with overhanging crests. Large patches of foam from wave crests give the sea a white appearance. Considerable tumbling of waves with heavy impact. Large amounts of airborne spray reduce visibility.	Trees are broken off or uprooted, saplings bent and deformed. Poorly attached asphalt shingles and shingles in poor condition peel off roofs.
11	Violent storm	103–117 km/h (28.6-32.5 m/s) 64–72 mph 56–63 kn 28.5–32.6 m/s	11.5–16 m 37–52 ft	Exceptionally high waves. Very large patches of foam, driven before the wind, cover much of the sea surface. Very large amounts of airborne spray severely reduce visibility.	Widespread damage to vegetation. Many roofing surfaces are damaged; asphalt tiles that have curled up and/or fractured due to age may break away completely.
12	Hurricane force	≥ 118 km/h (≥ 32.8 m/s) ≥ 73 mph ≥ 64 kn ≥ 32.7 m/s	≥ 14 m ≥ 46 ft	Huge waves. Sea is completely white with foam and spray. Air is filled with driving spray, greatly reducing visibility.	Very widespread damage to vegetation. Some windows may break; mobile homes and poorly constructed sheds and barns are damaged. Debris may be hurled about.

Fig. 6 Wind Turbine Diagram

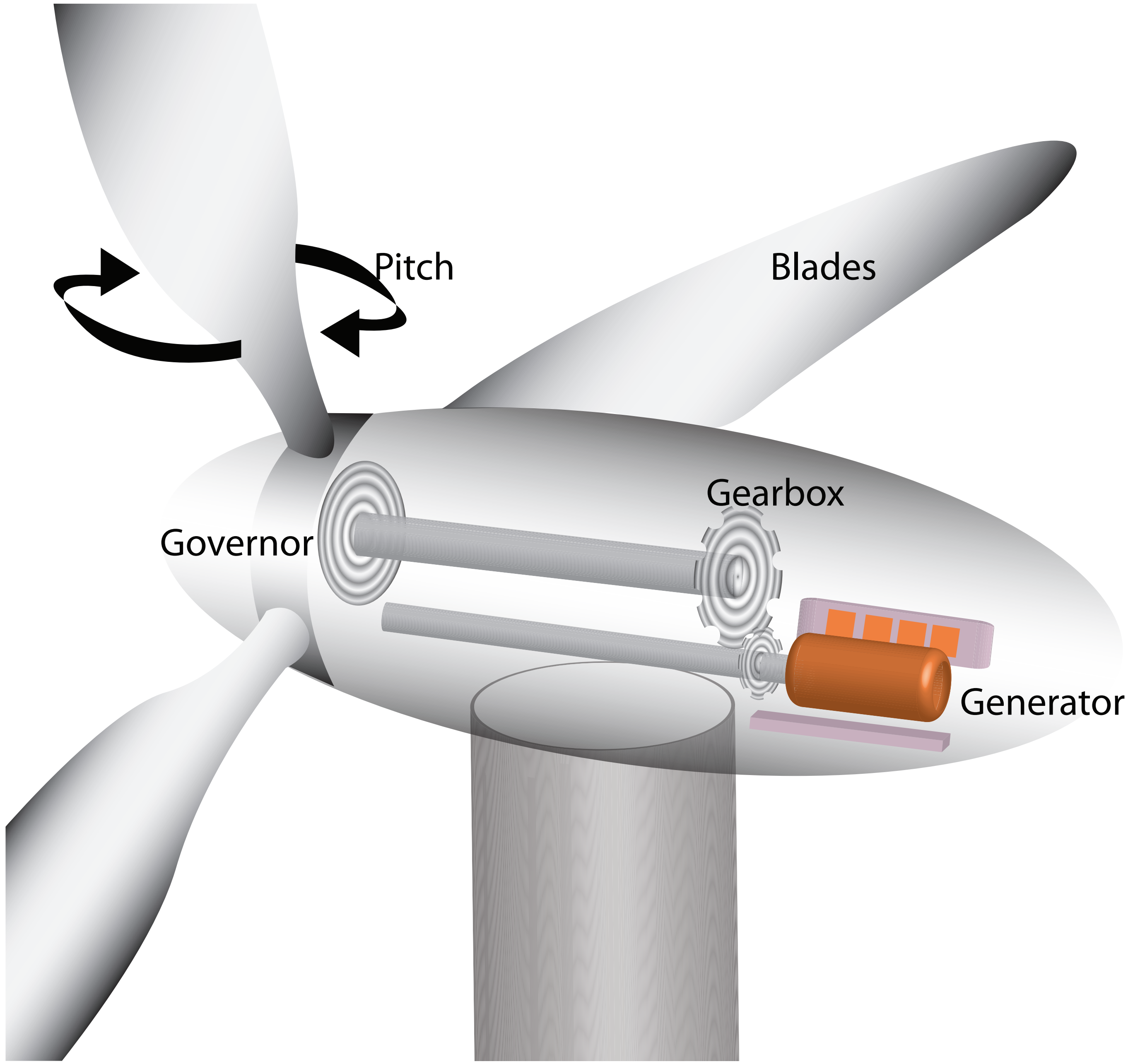


Fig. 7 Technology Generator diagram

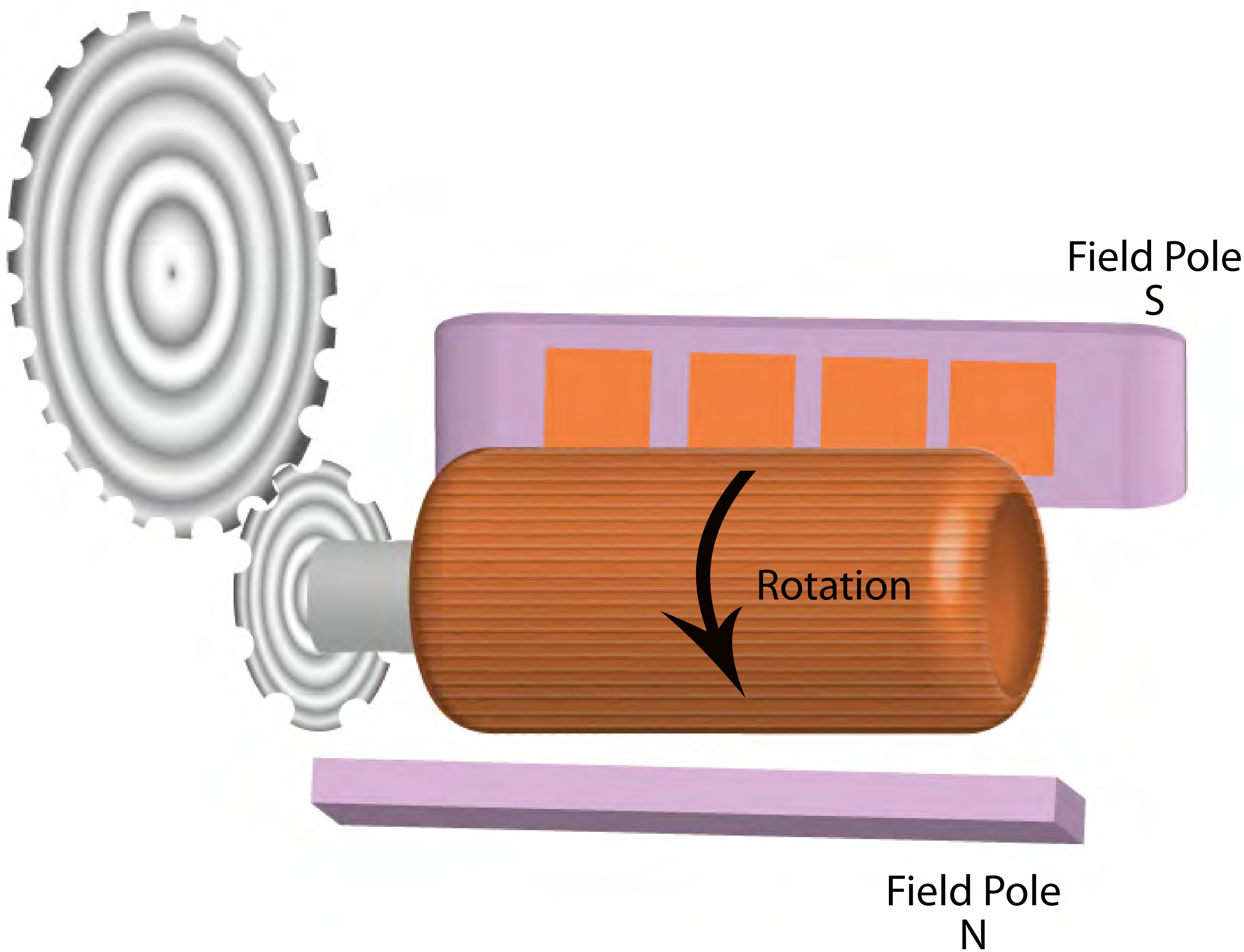
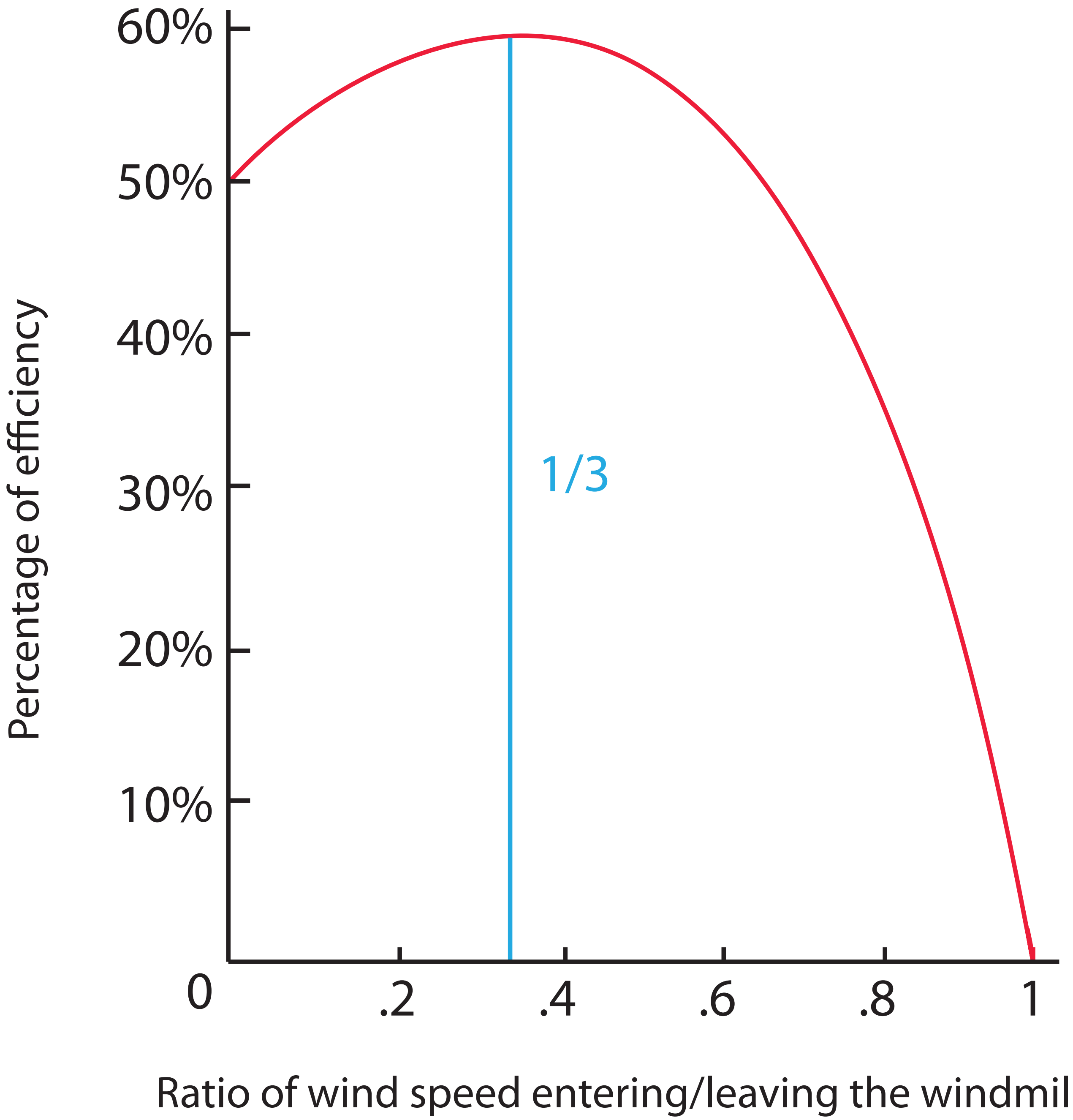


Fig. 8 Betz's Law



Wind Turbine Assembly Instructions

Assembling The Base:

1. Assemble the PVC pieces according to the diagram on the right.

2. Use the T-pieces without holes to join the sides of the base to the center. In the very center of the base, use the T-piece with the hole drilled in it. This hole will allow the wires from the motor to pass through.

Assembling The Hub:

1. Wrap a 1/2 inch by 18 inch piece of tape around the motor to ensure a snug fit.

2. Push the three pieces of PVC pipe together to form one solid piece.

3. Run the wires of the motor through the pipe as shown.

4. Secure the motor in the coupler, it should fit very snuggly; you may add or remove tape to attain the best fit.

5. Press the crimping hub onto the drive shaft, this should also fit snugly.

Using The Multimeter

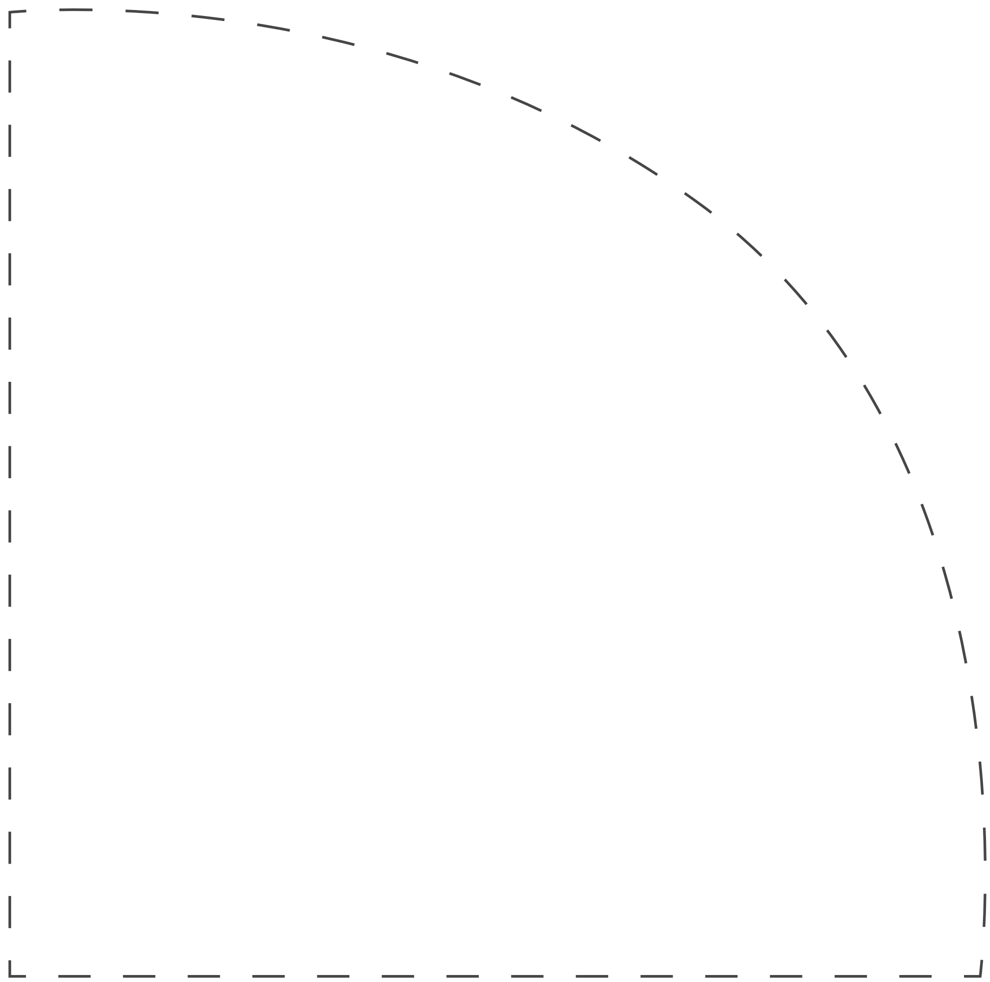
1. Attach the leads to the multimeter. To measure voltage, attach the black lead to the COM port and the red lead to the VΩMA port.

2. Using alligator clips, attach the multimeter leads to the wind turbine's motor wires (the wires emerging from the base of the structure). Attach the black lead to the red wire and red lead to the white wire.

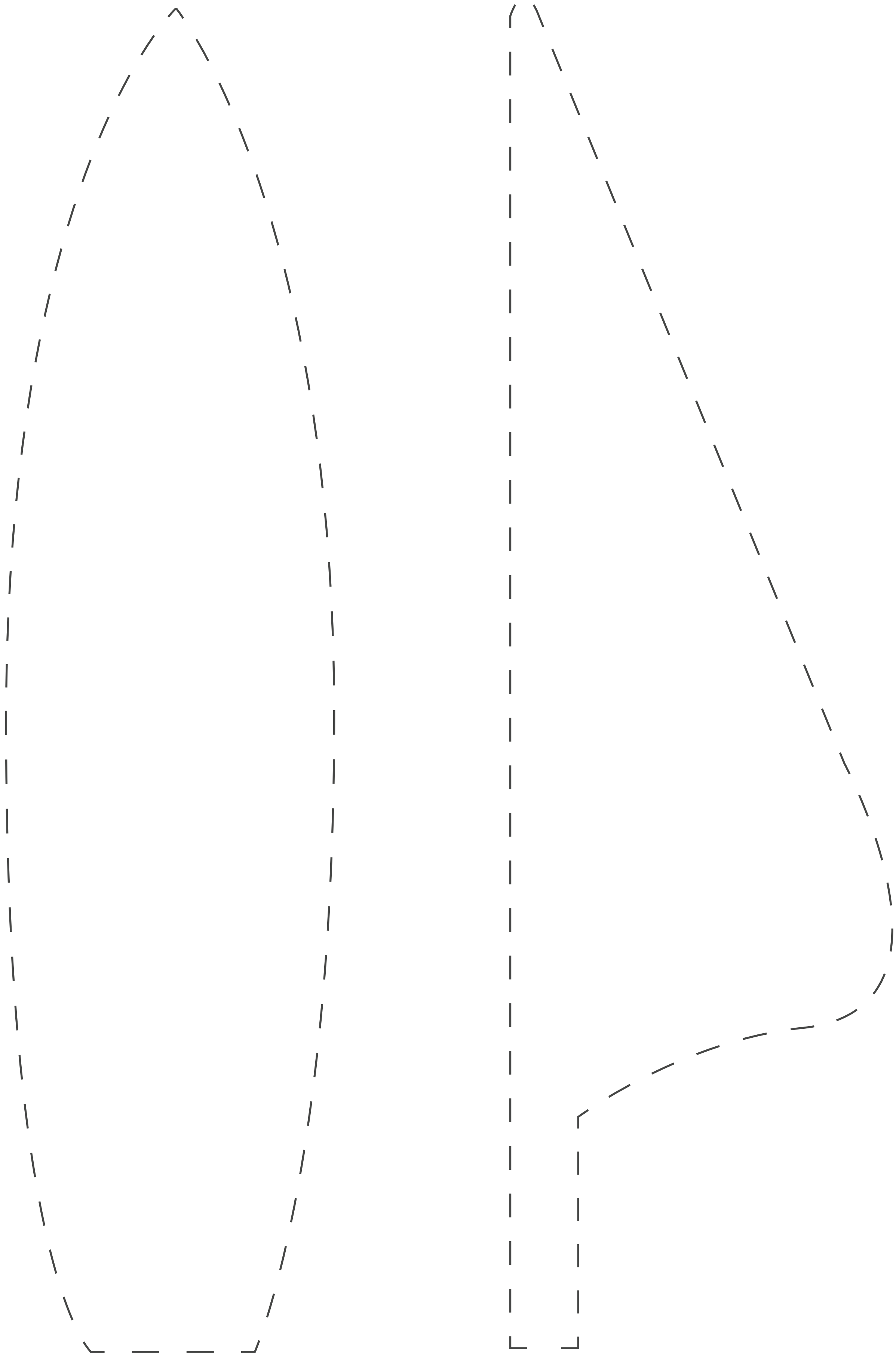
3. Turn the multimeter dial counterclockwise to the 2000 m position. This will display measurements in thousandths of a volt.

4. If the multimeter does not display any numbers (including 0), when the dial is moved out of the OFF position, you may need to replace the 9V battery.

Sample Turbine Blade Designs 1



Sample Turbine Blade Designs 2 and 3



Student Worksheets

Worksheet 1 Wind Turbine Power

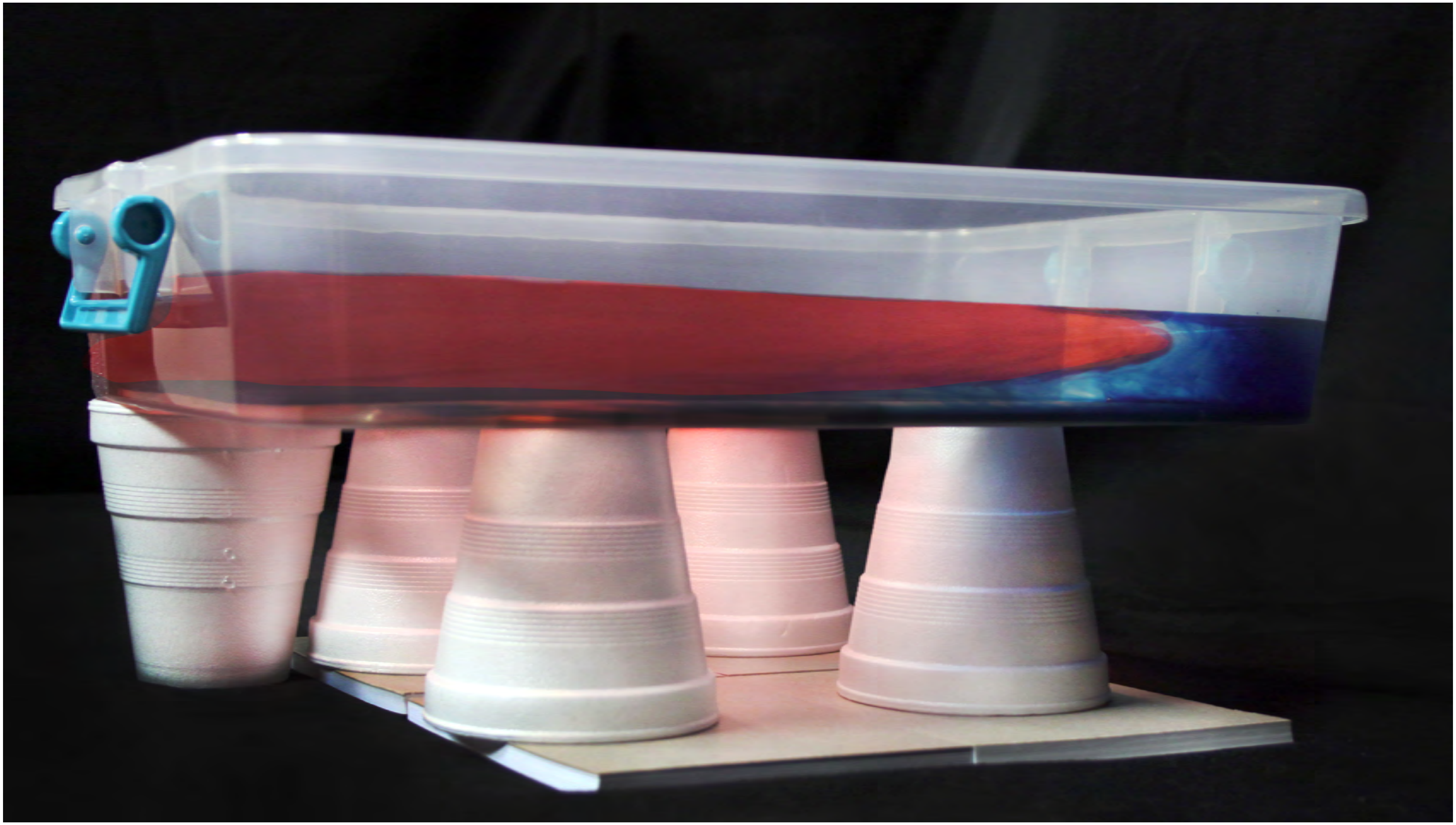
Sketch a picture of your blade design and record the voltage generated in the table below.

Blade Design 1 Volts:
Blade Design 2 Volts:
Blade Design 3 Volts:

Images

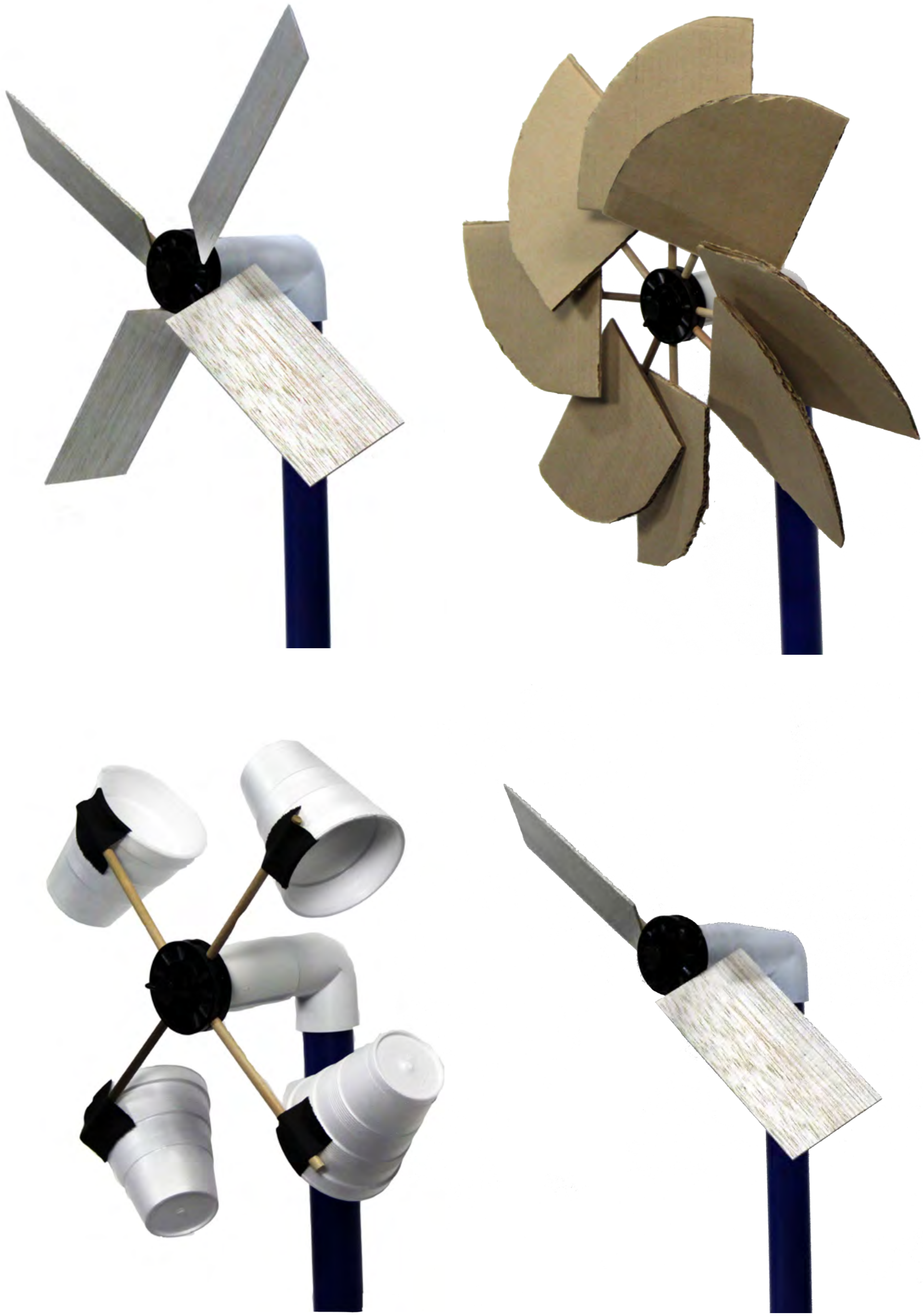
Img. 1 The Robinson Anemometer

Img. 2 The Convection Phenomenon



(Photo courtesy of Lost Tribe Media Inc.)

Img. 3 Sample Blade Designs



(Photo courtesy of Lost Tribe Media Inc.)

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