Roping the Texas Breezes

RENEWABLE ENERGY
THE INFINITE POWER OF TEXAS

For Grades 6, 7 and 8

OVERVIEW

In this unit, students will learn that wind power in Texas is a fast growing energy source with great potential. By constructing a wind-powered pinwheel, which creates the energy to perform work, students will gain an understanding of how electricity can be generated by the wind. Students will see value in renewable energy sources for Texas and be able to locate the most viable geographic regions of Texas for wind energy. Students will understand that the sun is the ultimate source for the wind.

OBJECTIVES

See Middle School Teacher Resource Guide for TEKS objectives and additional information regarding this and other middle school units.

SUGGESTED TIMEFRAME

Teacher will need to determine how many class periods to devote to each activity, based on the suggested timeframe and length of classes.

Time	Activity	Content Area
10 minutes	**Activity 1** – Teacher Introduction	Science
15 minutes	**Activity 2** – Assessment of Current Student Knowledge	
45 minutes	**Activity 3** – Reading Passage and Vocabulary **Homework Assignment** – Sentences with Vocabulary	Reading Vocabulary Language Arts
30 minutes ***60 minutes***	**Activity 4** – Pre-Lab **Activity 5** – Lab	Science
30 minutes	**Activity 6** – Post-Lab	Science
30 minutes	**Activity 7** – Assessment	Science

REQUIRED MATERIALS

- copy of the Reading Passage and Student Data Sheets (includes reading comprehension questions, vocabulary and Lab Activity) for each student
- copy of the Assessment Questions for each student
- graph paper
- an equipment kit for each group containing the following:
  - 1 liter plastic bottle (empty) with sipper top
  - 1 pair of scissors
  - 1 hobby knife (or other cutting tool capable of cutting a square in the plastic bottle)
  - 1 piece of cover stock or a manila folder
  - 1 pushpin
  - 1 smooth, round painted pencil with eraser (pencil should slide through opening of sipper top)
  - 1.1 meters of sewing thread
  - 1 ea. 10 gram mass; (1 bottle stopper or other suitable 10 gm object, such as a fishing weight)
  - 1 meter stick
  - 2 small pieces of masking tape
  - 1 rubber band
  - 1 stopwatch or timer
  - 1 floor fan, which can be shared, or a breezy day
  - goggles

BACKGROUND INFORMATION

Wind is formed by the sun's uneven heating of air, which results in the air's movement. The potential for using wind is excellent in West Texas and along ridges in the Panhandle. There is a continuous supply of wind in coastal areas as well, where the land is heated, causing hot air to rise, and cold air rushes in from ocean areas to fill the spaces. The rising hot air causes convection currents. Global convection currents in combination with the rotation of the Earth create constant predictable wind

patterns. Early sailing ships used the predictable wind patterns, called the "trade winds," to establish sailing routes.

Windmills can be used by themselves to do work, such as pumping water for cattle, or larger, multiple wind turbines can be built in a group called a "wind farm," which can generate electricity that can be transported to homes and businesses via the power grid. Wind turbines change the wind's kinetic energy into mechanical power and then change the mechanical power to electric power.

SUMMARY OF ACTIVITIES

Activity 1 – Teacher Introduction (10 minutes)

Explain to the class that for the next unit of study, they will be learning about wind energy in Texas. Students will work in groups to construct a simple model of a wind turbine.

Activity 2 – Assessment of Current Student Knowledge (15 minutes)

To assess what students already know, prompt a class discussion based on the 3 questions listed below. Based on this discussion, create and display a graphic information organizer of the points that were discussed, which can be displayed throughout the unit of study. Sample organizers are included in the Teacher Resource Guide.

1. Does anyone know what causes wind?
2. Has anyone ever seen wind turbines before in Texas? Where?
3. What is wind power used for?

See Teacher Resource Guide for alternative or additional assessment activity.

Activity 3 – Vocabulary and Reading Passage (45 minutes)

Each student will need a copy of the Reading Passage and the Student Data Sheets, which include reading comprehension questions, vocabulary words and the Lab Activity. (As an alternative to making copies, the Study Data Sheets can be displayed so the entire class can view them and copy the information into their science notebook.) Instruct students to study the Reading Passage and complete the questions and vocabulary. This activity will help them learn about wind energy and prepare them for the Lab Activity in which they will construct a simple model of a wind turbine. Key vocabulary words in the Reading Passage will assist them in understanding the Lab Activity instructions. For students who wish to learn more of the detailed principles about wind energy, direct them to the appropriate resources. Suggested resources are included in the Teacher Resource Guide. At the end of this activity, collect and grade the student's work. Return their graded work the following day.

Homework Assignment – Key Vocabulary List

1. Instruct students to create in their science notebooks meaningful sentences that reflect an understanding of the definition of each vocabulary word. Students should have written the definition of the words in their science notebooks during class. See Teacher Resource Guide for alternative vocabulary homework.
2. Collect and grade this assignment the next day.

Activity 4 – Pre-Lab (30 minutes)

1. Explain to the class that the purpose of the Lab Activity is to demonstrate that the movement of pinwheel blades caused by the wind is capable of creating energy. Students will move a mass over a particular distance as a result of the pinwheel blades moving, by either the wind or a fan, and calculate the kinetic energy resulting from this movement. The movement of the pinwheel blades and resulting kinetic energy can be compared to blades of a large wind turbine, allowing students to speculate on the amount of energy it is capable of producing. For teachers interested in expanding the scientific inquiry more fully as it applies to this Lab, see the Teacher Reource Guide for guidelines. Before performing the lab, students should be given the lab instructions to read and summarize the steps involved. The summary can be in the form of a brief chart. Review safety guidelines before students conduct the lab. See Teacher Resource Guide for general safety guidelines. Demonstrate proper use and care of the equipment used in the activity.
2. The Lab Activity instructions also include a section explaining kinetic energy and include its relationship to velocity. If students are not familiar with these terms, review them carefully with the class.
3. Divide the class into small groups to build their pinwheel and conduct the activity.

Activity 5 – Lab Activity (60 minutes)

1. Instruct each group to obtain the materials for one Lab Activity kit. The Lab Activity involves pouring sand into a bottle; teacher may elect to pour sand into the bottles rather than allow students to complete the task.

2. Instruct students to follow the directions outlined in the Lab Activity. To ensure that all students participate, instruct the groups to assign who will be responsible for each step in the activity before beginning.
3. Confirm that the students have recorded their time measurements on their Lab Report Form, as well as answers and calculations to the lab questions.

Suggestions and Expected observations

Students should be able to measure in centimeters for this activity. The 10 gm mass used should be taped securely. When students perform 5 trials and record the time measurements, they will enter the measurements on the Data Table. For example:

Trial #:	Time:
1	2.5 seconds
2	3.0 seconds
3	3.1 seconds
4	2.7 seconds
5	2.9 seconds
Total Time	**14.2** seconds

AVG (average) = sum of the measurements (total time) / number of trials
= 14.2 / 5
= 2.8

Since in this example the measurements are recorded to one decimal place, the average should be rounded to one decimal place: 2.8 seconds.

Activity 6 – Post-Lab (30 minutes)

After students have completed their Lab Report Forms, discuss their results. You may ask each group to summarize to the class their results or post their data on the chalkboard or other display for the entire class to view and compare.

Activity 7 – Assessment (30 minutes)

Distribute a copy of the Assessment Questions to each student. Instruct each student to work alone and answer the short answer and multiple-choice questions. Collect the handouts, grade and return them to the students and review answers with the class when time permits.

ADDITIONAL ACTIVITIES

1. **Analyze Effect of Speed**
   Repeat the activity using a fan that has variable speeds. Instruct students to take time measurements and calculate the kinetic energy at the different speeds. Discuss the results and how it pertains to locations with different wind speeds.

2. **Internet Research**
   Students can research information available on the Internet about wind energy. Suggested resources are included in the Teacher Resource Guide. You may divide the class into 4 groups and assign each group to a particular topic. Each group can create a display of the information that they found and provide a short summary of their findings. Suggested group topics include:
   1. Comparison of wind energy usage in the following countries: U.S., Germany, India and Japan
   2. Research and prepare a summary about a Texas wind farm development project. Points to consider in the summary should include: the region/location in Texas, total megawatt (MW) capacity of the wind farm, the type of wind turbines and where they are manufactured.
   3. What are some of the conditions that need to be readily available for wind turbine energy to be used?
   4. Research and summarize the components of a wind turbine. Students can prepare a drawing of a wind turbine and label the components.

3. **Map of Texas Wind Energy Potential**
   Instruct students to practice drawing a map of Texas a few times from memory. Then have them do the following: place an X where they live and label the name of the town; place a dot and label each of these cities on their map: Houston, Dallas, San Antonio, Austin, Lubbock, Amarillo, El Paso, and Corpus Christi; shade in the areas where wind power potential is the greatest. Instruct students to answer the following the question:

   Based on information provided in the Reading Passage about where wind resources are the greatest, near which cities on your map could wind turbines be located?

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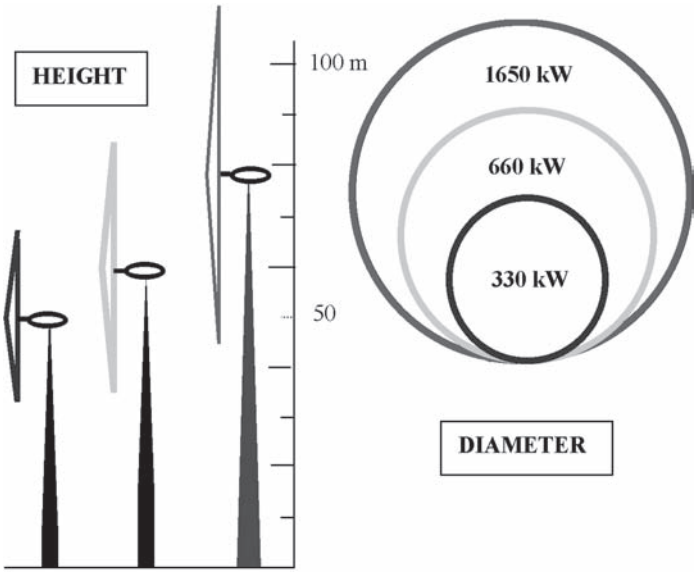
HIGHLIGHTS

- **Wind power has been used in Texas for more than a century**
- **Texas has a large wind resource, but we are only using a small part of it for wind energy**
- **Texas wind farms are now making electricity for Texans**



SIZES OF WIND TURBINES INSTALLED ON TEXAS WIND FARMS *The 1650 kW turbine is taller than the Statue of Liberty.*

SUMMARY

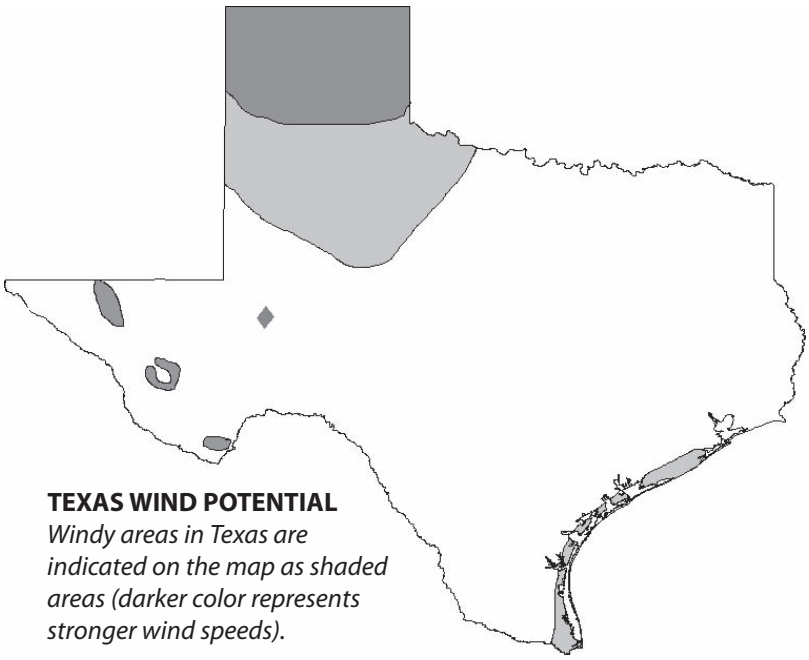
Did you know that more than 80,000 windmills are still in use in Texas? For decades, these simple, rugged machines have pumped water for homes and livestock. Recently, wind power for electricity has become cheaper and more common. Large commercial wind turbines can create electrical power between 500 kilowatts to over a megawatt, which could provide power for over 200,000 homes in Texas. Wind turbines can create electricity for less money than electricity created from new coal-fired power plants. And if we consider costs like air pollution and greenhouse gases, wind power may be the least expensive source of electrical power available today.

ROPING THE WIND *Even using a small portion of available wind power can help meet Texas' electricity needs.*

WIND TURBINES

Wind turbines convert the kinetic energy that is present in wind into a more useful energy

such as electricity. Windmills were common on farms and ranches several decades ago before electricity became more available in rural areas. These small units were rated at 100 Watts to 1 kilowatt (kW), with blades 1 meter to 3 meters in diameter. Today wind turbines are being installed in the windiest locations of the state. These large wind turbines have long, thin blades that are 30 meters to 70 meters in diameter. Each wind turbine can produce 300 kW to over a megawatt (MW) of power. And they are mounted on top of towers 40 to 80 meters tall.



TEXAS WIND POTENTIAL
Windy areas in Texas are indicated on the map as shaded areas (darker color represents stronger wind speeds).

TEXAS-SIZE POTENTIAL

Texas has a large wind energy potential. The main regions where wind resources are the greatest are in west Texas, the High Plains and along the Gulf coast from Mexico to Matagorda. Studies have shown that the annual wind power available is approximately 250,000 MW. This amount of energy potential is around four times the amount of electricity that is being created in Texas right now. Lands that are considered good sites are areas where the ground can hold a wind turbine and where the average wind speed is at least 12 miles per hour measured at a height of 33 feet.

Utilities and groups that develop wind farms look for the windiest places in Texas. The best locations – on top of mountains and mesas in West Texas and along ridges in the Panhandle – are being developed first.

WIND-DRIVEN MEGAWATTS

At of the end of 2003, the US had 6,374 MW of wind power in use. Much of the recent growth in the U.S. wind power industry has occurred in Texas. Electric utilities are using wind power because of its cost-effectiveness. By being cost-effective, wind power is attractive to both the homeowner and the electric companies that want to lower the cost of producing electricity. Wind turbines are modular. They can be installed rapidly and will produce electricity that is less expensive than electricity produced in new coal fired plants. Even so, it costs about $1,000,000 per Megawatt to build a wind farm.

WIND PROJECTS IN TEXAS

As of 2003, Texas had 1,292 MW of wind turbines. Projects are located in or near the Delaware Mountains, Fort Davis, McCamey, King Mountain, Big Spring, Trent and the Texas Panhandle.

The first large-scale wind farm was installed in the Delaware Mountains in Culberson County in 1995; it has 112 turbines. The first phase of the project, consisting of 35 MW, was developed on land leased from the

State's Permanent School Fund. The project pays about $100,000 per year to the fund, which is used to help educate the youth of Texas.

SOURCE: ALTERNATIVE ENERGY INSTITUTE

TEXAS WIND POWER *In the Delaware Mountains, south of Guadalupe Mountains National Park, this wind farm's turbines are 330 kW each.*

FARMING & RANCHING WITH THE WIND

Large utilities are getting the most attention for using wind power. But Texas agricultural producers and rural homeowners have been using wind power for decades. Windmills, such as the 1930's Aeromotor, continue pumping water for cattle and crops. But many are at the end of their lives. Some are being replaced with solar photovoltaic (PV) units in sunny areas. New water pumping systems, which combine wind and PV, are now available as well. In rural areas, Texans are also installing small-scale wind power systems (from 300 W to 5 kW) for their electric needs where there are no power lines nearby.

SOURCE: ALTERNATIVE ENERGY INSTITUTE

LARGE MODERN WIND TURBINES *In foreground is the 1.65 MW wind turbine at Big Spring; in the background are 660 kW units.*

A WINDY FUTURE

New wind farms are being developed today throughout Texas. A state law that was signed in 1999 made it possible for these new wind farms to be developed. The law set a goal to install 2,000 MW of new renewable energy resources by 2009. Because of the cost-effectiveness of wind turbines, it is expected that most of this 2,000 MW will be from wind farms. These new wind farms will be a major factor for developing rural areas in Texas.

Understanding the Reading Passage

1. What were windmills used for in earlier days? _____

   _____

   What are modern wind turbines used for today? _____

   _____

2. How much power can wind turbines produce today (in megawatts)? _____

3. List the areas in Texas with the most wind energy potential.

   1 _____

   2 _____

   3 _____

4. How much power from wind farms did Texas have as of 2003? _____

5. What happened in 1999 that made it possible for more wind farms to be developed?

   _____

   _____

Vocabulary

Based on the Reading Passage, write down your understanding of these words or word pairs and verify your definitions in a dictionary, on the Internet if available or with your teacher:

atmosphere _____

blade _____

bushing _____

commercial _____

convection current _____

cost-effective_____

generator _____

kilowatt _____

kinetic energy _____

meter _____

megawatt _____

modular _____

potential _____

rural _____

velocity _____

wind _____

wind turbine _____

work _____

LAB ACTIVITY – TESTING A PINWHEEL TURBINE

Introduction
The purpose of this activity is to build a pinwheel as a simple model of a wind turbine and calculate the amount of kinetic energy it generates.

Before You Start
Review the vocabulary words from the Reading Passage. Ask your teacher if you are unsure of any of the meanings. Divide up all the steps in the Lab Activity first, so that everyone has a clear job to do.

Materials
Obtain an equipment kit from your teacher. Check that it contains the following materials:
- 1 liter plastic bottle
- 1 pair of scissors
- 1 hobby knife
- 1 piece of cover stock or a manila folder
- 1 pushpin
- 1 smooth, round painted pencil with eraser
- 1.1 meters of sewing thread
- one 10 gram (gm) mass
- 1 meter stick
- 2 small pieces of masking tape
- 1 rubber band
- 1 stopwatch or timer
- 1 floor fan, to be shared with other groups, or a breezy day
- goggles

Constructing the pinwheel and elevator
(wear goggles)
1. Cut a 22 x 22 cm square from cover stock paper or a manila folder.
2. Draw 2 lines diagonally on your square from corner to corner. Your square now has 4 triangles drawn on it, connected in the middle (see Figure a).

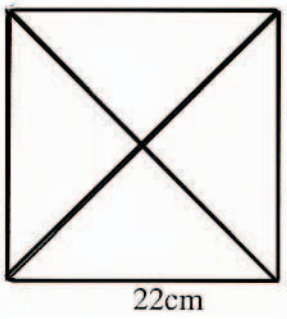


Figure a

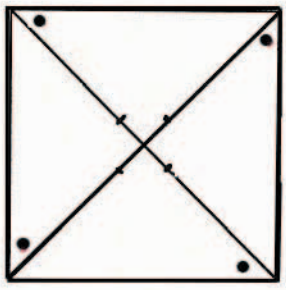


Figure b

Figure e

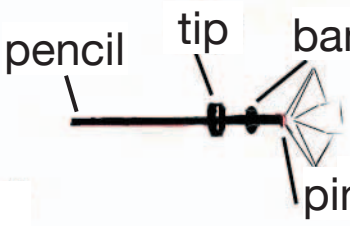


Figure c

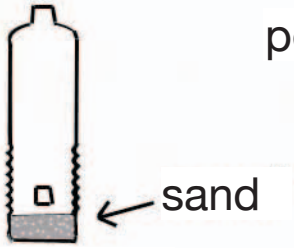
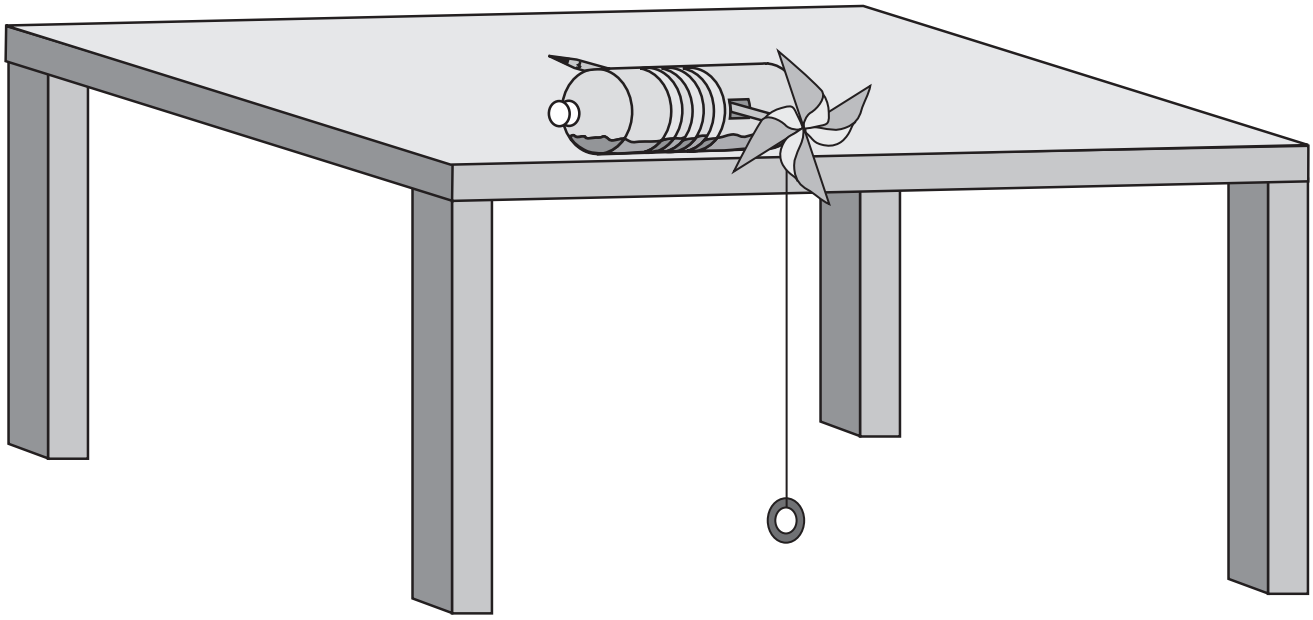


Figure d

3. Mark a point 2 cm from the center on each diagonal line as shown in Figure b (you will have 4 such marks).
4. Using scissors, cut the square from each corner to the 2 cm mark. Do this 4 times, once for each corner of your square.
5. Draw a dot in the right hand corner of each of the 4 triangles as shown in Figure b. To make it easier, after marking one dot, turn your square in order to mark the next dot. Now you have a dot in each of the 4 triangles.
6. Fold each dotted corner to meet the center point and hold all four corners together at this point.
7. Using the pushpin, carefully pin all of the dotted corners together in the center to make a pinwheel.
8. Tack the pinwheel to the end of the eraser on the pencil (see Figure c).
9. On the water bottle, mark 2 points that are on opposite sides from each other and that are 10 cm from the bottom of the bottle.
10. Cut a 1 cm square hole at each of the 2 points you have marked on the bottle (see Figure d). You now have two 1 cm square holes on opposite sides of the bottle.
11. Mark a point on the bottle that is 9 cm from the bottom.
12. Your teacher may help you with this step. Remove the cap from the bottle and fill it with sand until the sand reaches the mark you made 9 cm from the bottom. The sand should not reach the height of the 2 holes as shown in Figure d.
13. Remove the sipper tip (Figure e) from the top of the water bottle cap and place the cap back on the bottle.
14. Wrap a rubber band several times around the pencil, 3 cm from the eraser end on the pencil (see Figure c).
15. Slide the free end of the pencil (the lead tip) through the sipper tip. The rubber band on the pencil will stop the sipper tip from coming close to the pinwheel. The sipper tip acts as a bushing as shown in Figure c.
13. Tie or tape one end of the thread to the 10 gm mass.
14. Tie or tape the free end of the thread to the eraser so that when the thread is extended, the total length of the thread between the mass and the pencil is 1 meter.
15. Slide the pencil through the plastic bottle, using both square holes.

Performing the Activity (wear goggles)

1. Holding the pinwheel so it will not move and covering the holes with your fingers to keep the sand inside, carefully place the plastic bottle on its side on a table so that you can see both of the holes. Do not place the bottle so that one of the holes is on the table so the sand will not spill out. When the bottle is placed correctly, the sand will flow to a level below the holes when the bottle is on its side. Allow the thread to hang down loosely, with the 10 gm mass at the end. If outside in the wind, hold the bottle securely.
2. Holding the pinwheel still, place the bottle in a position that will allow the fan or the wind to spin the pinwheel when you release it. (Suggestion: move the pinwheel setup towards the end of a table so that only the pinwheel will extend over the table.) The thread should be fully extended with the mass hanging from the pencil.
3. At the same time, release the pinwheel and start the timer. Measure the amount of time it takes for the pinwheel to reel up the 10 gm mass exactly 1 meter. This is work being done by the pinwheel.
4. Repeat five times and record the time (in seconds) for all five trials in the Data Table on your Lab Report Form.



Calculations

Kinetic energy is defined as the energy that something has because of its motion. Kinetic energy from wind is the energy that is present when air moves. Kinetic energy (KE) can be calculated by the following equation:

$KE = \frac{1}{2} mv^2$

Where m = mass and v = velocity

Velocity is another word for speed but it also includes the direction an object is traveling. Therefore velocity (v) is the distance traveled or moved over time and can be calculated by the following equation:

$v = d/t$

Where d = distance traveled (or moved) and t = time

Use these equations to complete the answers in your Lab Report Form.

Units:

m (mass) – g (grams)
d (distance) – m (meters)
t (time) – s (seconds)
v (velocity) – m/s (meters/second)
KE (kinetic energy) – g • m^2/s^2

To convert to Joules:
1 J (Joule) – 1 kg (kilograms) • m^2/s^2
(Note: to obtain a value of kinetic energy in Joules, convert grams, g, to kilograms, kg)

Lab Report Form: Building and Testing a Pinwheel

Date _____

Purpose of this lab is to _____

_____

Instructions:

Follow the instructions listed in the Lab Activity and record your measurements in the Data Table below. Once you have completed all the measurements and calculations, answer the questions at the end of this form.

DATA TABLE

Trial	Time	Observations
1		
2		
3		
4		
5		
Total time		
Average time		

To calculate the average: Take the amount of total time and divide this number by the number of trials. Round your answer to one decimal point. This number is the average time in seconds for your data.

1. Using the length of the thread (the distance the mass moved) and the average time you calculated and recorded in your Data Table, calculate the velocity (v) of the mass (indicate the correct units):

   v = _____

2. Using the velocity figure you calculated above and the weight of the mass, calculate the kinetic energy of the mass when moved by the pinwheel (indicate the correct units):

   KE = _____

3. Convert the KE value you calculated to Joules: _____ J

4. What do you think would create greater kinetic energy in this activity? _____

   _____

Assessment Questions

1. Explain how the wind is really caused by the sun.

_____

_____

2. Describe 2 examples of what wind energy is used for.

1 _____

2 _____

Multiple Choice Questions

1. Do you think wind power will benefit homeowners?
   a) yes b) no
   c) depends d) never

2. If we used wind power, how would this help society?
   a) use less imported energy b) reduce pollution
   c) stabilize energy prices d) all answers, a, b, & c

3. Modern wind turbines:
   a) have short, flat blades b) are built close to the ground
   c) have long, thin blades d) are not used in Texas

4. The best wind resources in Texas are located in which regions:
   a) west Texas b) Gulf Coast
   c) High Plains d) all answers, a, b, & c

5. Windmills and wind turbines are:
   a) affordable to operate b) non-polluting
   c) using a free source of energy d) all answers a, b, and c

6. If using energy from wind turbines were suggested for your city, what would you do?
   a) you would want to use only oil for energy
   b) you would support and encourage using wind energy for electricity
   c) you would oppose wind energy
   d) you would never use electricity that was wind generated

7. Wind power is:
   a) a fossil based energy b) non-renewable energy
   c) a renewable energy d) a limited resource

Understanding the Reading Passage

1. In earlier days, windmills were used on farms and ranches to pump water for household use and for livestock. Modern wind turbines are used to generate electricity.
2. over 1 MW
3. West Texas, the High Plains and along the Gulf Coast from Mexico to Matagorda.
4. 1,292 MW
5. A state law was passed setting a goal for 2,000 MW of renewable energy resources to be installed in Texas by 2009.

Assessment Questions

1. The sun causes the heat responsible for convection currents.
2. Wind energy can be used for water pumps for livestock and other remote water needs, and it can be a source of electricity for homes.

Multiple Choice Questions

1 a (best answer); 2 d; 3 c; 4 d; 5 d; 6 accept students answers (could be used for discussion); 7 c

Vocabulary Definitions

atmosphere – composed of air, which is composed of tiny particles of gases like oxygen, hydrogen and nitrogen

blade – flat surface that rotates and pushes against air or water

bushing – a lining for a circular piece like a sleeve (the bottle top sipper acts as a bushing in this experiment)

commercial – connected with, sponsored by or used in commerce or business

convection current – air movement caused by the different weights of warm and cool air; the movement of parts of a gas or fluid differing in density and temperature

cost-effective – bringing good results or profit for lower expense

generator – machine for converting mechanical energy into electric energy

kilowatt – unit of electrical power equal to 1000 Watts

kinetic energy – energy resulting from motion

meter – a metric unit of measure that equals 39.37 inches

megawatt – unit of electrical power equal to 1,000,000 Watts

modular – units of a standard size that can be used together in a number of ways

potential – anything that may be possible but not yet in existence

rural – pertaining to the country; other than urban

wind – air in motion; when air is heated and rises and cold air rushes in to replace the warm air

wind turbine – a machine that has propeller-like blades that can be moved by wind to make electricity

work – distance an object is moved by a known force against some resisting force (friction)

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