Module 2: Wind Turbines

4th Grade

About the Instructions:

This document is intended for use by classroom teachers, SciTrek leads, and SciTrek volunteers. The document has been composed with input from teachers, leads, volunteers, and SciTrek staff to provide suggestions for future teachers/leads/volunteers. The instructions are not intended to be used as a direct script, but were written to provide teachers/leads/volunteers with a guideline to present the information that has worked in the past. Teachers/leads/volunteers should feel free to deviate from the instructions to help students reach the learning objectives of the module. Places in which you can be creative and mold the program to meet your individual teaching style, or to meet the needs of students in the class are: during class discussions, managing the groups/class, generating alternative examples, and asking students leading questions. However, while running the module make sure to cover all the material each day within the scheduled 60 minutes. In addition, no changes should be made to the academic language surrounding procedures or the procedure activity.

Activity Schedule:
There are no scheduling restrictions for this module.

Day 1: Technique/Observations/Variables (60 minutes)*
Day 2: Question/Materials Page/Experimental Set-Up/Procedure Activity (60 minutes)
Day 3: Procedure Activity/Procedure (60 minutes)
Day 4: Results Table/Experiment/Graph (60 minutes)
Day 5: Results Summary/Poster Making (60 minutes)
Day 6: Poster Presentations (60 minutes)
Day 7: Draw a Scientist/Tie to Standards/Content Assessment (60 minutes)*
*This schedule assumes the teacher has given the procedure assessments before SciTrek comes in on Day 1 and Day 7.

The exact module dates and times are posted on the SciTrek website (scitrek.chem.ucsb.edu/elementary) under the school/teacher. The times on the website include transportation time to and from the SciTrek (Chem 1204). Thirty minutes are allotted for transportation before and after the module. Therefore, if a module was running from 10:00-11:00, then the module times on the website would be from 9:30-11:30.

Student Groups:

For the initial observation (Day 1), students work in three groups of approximately ten students each. After Day 1, the groups of approximately ten students are further subdivided into two subgroups, approximately five students each, for the rest of the module. One volunteer is assigned to help each group (which is made up of two subgroups). We find groups/subgroups work best when they are mixed levels and mixed language abilities.

NGSS Performance Expectation Addressed:

4-PS3-4 Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.

Common Core Mathematics Standards Addressed:

4.NF-6 Use decimal notation for fractions with denominators 10 or 100.

4.MD-6 Measure angles in whole-number degrees using a protractor. Sketch angles of specified measure.

Learning Objectives:

1. Students will know that electricity is a form of energy.
2. Students will know that energy can be transferred from one form to another.
3. Students will be able to state which value of a changing variable would be most optimal for constructing a wind turbine, given a data set or graph.
4. Students will be able to annotate controls, changing variables, and/or data collection within a procedure.
5. Students will be able to determine whether a statement could be a correct step for a procedure from a given question and experimental set-up.
6. Students will be able to list at least two ways they behaved like scientists.

Classroom Teacher Responsibilities:

In order for SciTrek to be sustainable, the program needs to work with teachers on developing their abilities to run student-centered, inquiry-based science lessons on their own in their classrooms. As teachers take over the role of SciTrek lead, SciTrek will expand to additional classrooms. Even when teachers lead the modules in their own classrooms, SciTrek will continue to provide volunteers, and all of the materials needed to run the module. Below is a sample timeline for teachers to take over the role as the SciTrek lead.

*Groups are made up of approximately ten students, and are subdivided into two subgroups (approximately five students each) after Day 1 of the module.

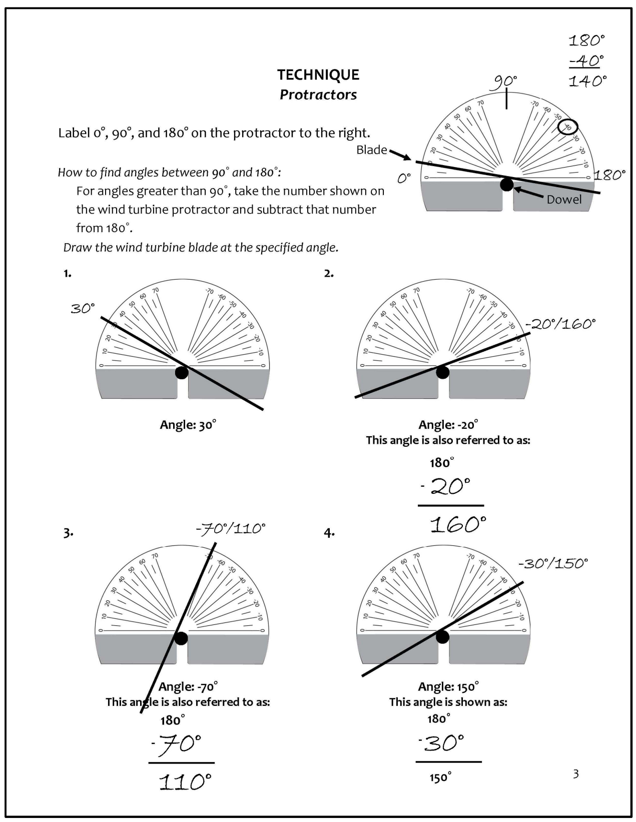
1. Year 1
    a. Classroom teacher <u>leads a group</u> (Role: Group Lead; this is referred to as a volunteer in these instructions)
2. Year 2
    a. Classroom teacher <u>co-leads the modules</u> with a SciTrek staff member (Role: Co-Lead)
        i. Classroom teacher will be responsible for leading entire class discussions (Ex: procedure activity).
        ii. Classroom teacher will be responsible for time management.
        iii. Classroom teacher will be responsible for overseeing volunteers and helping any groups who are struggling.
        iv. Classroom teacher will be responsible for all above activities. The SciTrek co-lead will only step in for emergencies.
        v. The SciTrek co-lead will run the tie to standards activity.
3. Year 3 and beyond
    a. Classroom teacher <u>leads the modules</u> (Role: Lead)
        i. Classroom teacher will be responsible for leading entire class discussions (Ex: procedure activity).
        ii. Classroom teacher will be responsible for time management.
        iii. Classroom teacher will be responsible for overseeing volunteers and helping any groups who are struggling.
        iv. For year 3 a SciTrek staff member will co-lead the tie to standards activity with the classroom teacher, for subsequent years they will run the tie to standards independently.

SciTrek staff is counting on teacher involvement. Teachers should notify the SciTrek staff if they will not be present on any day(s) of the module. Additional steps can be taken to become a SciTrek lead faster than the proposed schedule above. Contact scitrekelementary@chem.ucsb.edu to learn more.

In addition, teachers are required to come to UCSB for the module orientation, approximately one week prior to the start of the module. Contact scitrekelementary@chem.ucsb.edu for exact times and dates, or see our website at scitrek.chem.ucsb.edu/elementary under your class's module times. At the orientation, teachers will go over module content, learn their responsibilities during the module, and meet the volunteers who will be helping in their classroom. If you are not able to come to the orientation at UCSB, you must complete an online orientation. Failure to complete an orientation for the module will result in loss of priority registration for the following year.

Prior to the Module (at least 1 week):

1. Come to the SciTrek module orientation at UCSB.
2. Inform SciTrek staff if your class uses any method of subtraction other than what is shown below.



Note for Teachers During the Module:

Note: We **highly recommend** you give the initial procedure assessment prior to **Day 1**, and the final procedure assessment prior to **Day 7** of the module.

If possible, have a document camera available to the SciTrek lead every day of the module. If you do not have a document camera, please tell a SciTrek staff member at orientation.

Day 1:

Have three floor spaces available for students to perform the initial observation. Each group will need a place to plug in one fan and a ~1 ft x 3 ft floor space for the experimental set-up, as well as additional space for approximately ten students to sit. The desks/tables do not need to be moved into groups.

Days 2 - 5:

Have students' desks/tables moved into six groups and cleared off.

Day 4:

Have six floor spaces available for students to perform experiments. Each subgroup will need to plug in one fan, have a ~1 ft x 3 ft floor space for the experimental set-up, as well as have additional space for approximately five students to sit.

Days 6 - 7:

Have students' desks/tables cleared off. The desks/tables do not need to be moved into groups.

Scheduling Alternatives:

Some teachers have expressed interest in giving the students more time to work with the volunteers throughout the module. Below are options that will allow the students more time to work with the volunteers. If you plan to do any of the following options, please inform the SciTrek staff no later than your orientation date (approximately one week before your module, exact orientation times are found at: scitrek.chem.ucsb.edu/elementary). This will allow the SciTrek staff to provide you with all needed materials.

Day 1:

If you would like to have more time for your students to make observations and generate variables, you can do one or both of the following activities with your class, ***before*** SciTrek arrives:

1) Procedure assessment **(highly recommended)**
2) Technique activity

Day 2:

If you would like to have more time for your students to design their experiments, you can do one or both of the following activities:

1) Example question and experimental set-up outlined in the Introduction, ***before*** SciTrek arrives.
2) The first part of the procedure activity with your class, ***after*** SciTrek leaves (pages 10-11, notebook).

Day 3:

If you would like to have more time for your students to write their procedures, you can do the second part of the procedure activity (pages 12-13, notebook) with your class, ***before*** SciTrek arrives.

Day 4:

If you would like to have more time for your students to perform their experiments, you can do the example graph and go over how to put together the wind turbine hubs with your class, ***before*** SciTrek arrives.

Day 5:

If you would like to have more time for your students to analyze their experiments and make posters, you can do the example results summary with your class, ***before*** SciTrek arrives.

Day 6:

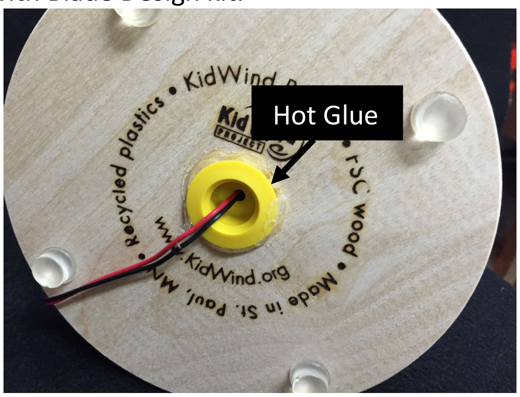
If you would like to have more time for your students to discuss their experiments during poster presentations, you may take more time for each presentation and finish the presentations with your class, ***after*** SciTrek leaves.

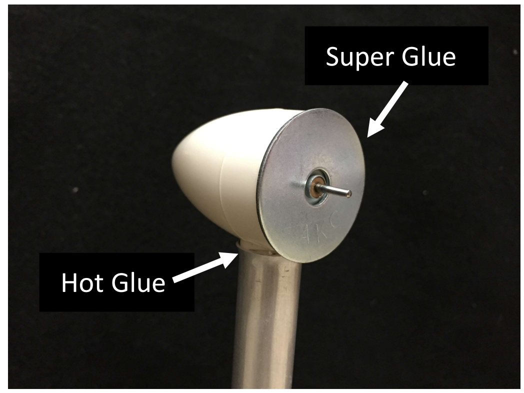
Day 7:

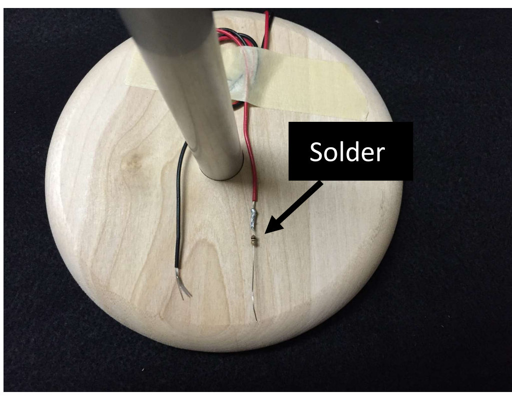
If you would like more time for the tie to standards activity, you may give the procedure assessment to your class, ***before*** SciTrek arrives. **(highly recommended)**

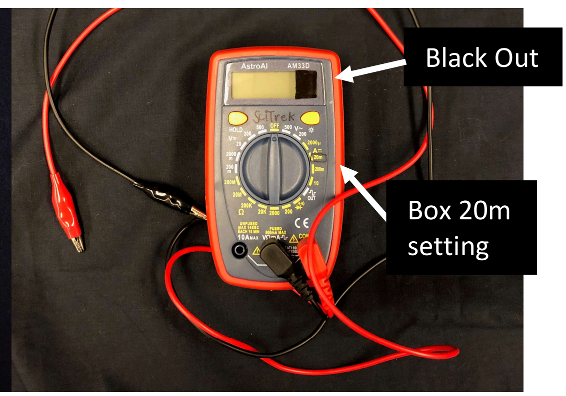
Materials Used for this Module:

1. KidWind Mini Wind Turbine with Blade Design kit (Vernier Part Number: A0043). This kit comes with a multimeter, however, this multimeter is unreliable, and we do not use it. To keep the wind turbine from falling apart, the turbine head is hot glued to the metal shaft, and the bottom plastic piece is hot glued to the wooden base and the metal shaft. In addition, a $\frac{5}{16}$ in. x $1\frac{1}{2}$ in. washer (Home Depot Part Number: 804800) is super glued to the front of the turbine head to keep the motor from pulling out when the hub is removed. In order to measure current, a 100 Ω resistor (RadioShack Part Number: 2710005) is soldered to one of the wires coming from the wind turbine. Using this resistor, you should get current values between 0-12 mA. See pictures below for the modifications that are made to the KidWind Mini Wind Turbine with Blade Design kit.

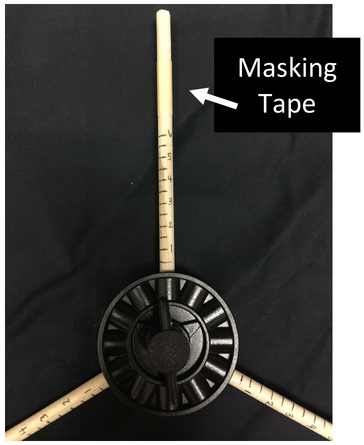




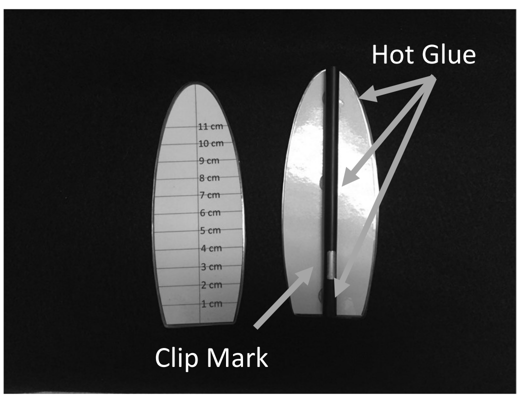




2. AstroAI Digital Multimeter with Ohm Volt Amp and Diode Voltage Tester Meter (Intelligent Anti-burn) (Amazon). Students will only read the current to the tenths place. Therefore, to make it easier for them, a Sharpie is used to black out the hundredths place. Refer to the picture above (bottom right) to see an example. Additionally, to ensure that we get appropriate current readings between 0-20 mA, a black Sharpie is used to box the 20m setting on the multimeter.
3. TOTOT Banana Plug to Alligator Clip 1 Red 1 Black Test Leads 15A Safe Plug (Amazon). When plugging the leads into the multimeter, the plugs are put in backwards (red into the *COM*, and black into *VΩMA*). This is done, because if blades are put at an angle between 0˚ and 90˚, the current read out is positive when the leads are backwards. For angles between 90˚ and 180˚, the wind turbine spins in the opposite direction, and the current read out is negative.
4. KidWind Wind Turbine Hub (10 pack) (Vernier Part Number: H0043). Extra hubs are needed so that the hubs can be given to students with dowels already in them. This is done because inserting and tightening dowels into the hubs is challenging for students, and hubs can get stripped if tightened too much. The dowels are inserted 1 cm into the hubs, and then are labeled every 0.5 cm from 0 cm to 6 cm. In addition, 2 in. of masking tape is wrapped around the end of the dowel to allow the straw to fit tighter when inserted over the dowel. See picture on next page.

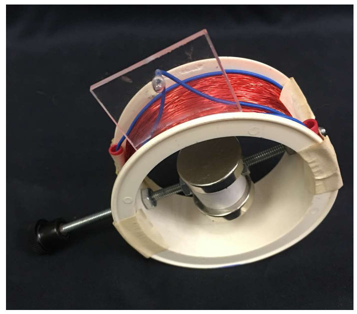


5. Wind turbine blades are printed onto cardstock and laminated. The cardboard blades that are used for the initial observation are cut from the cardboard that comes with the wind turbine kit. Marks are then drawn on the cardboard blades so that they look like the cardstock blades, and then these blades are laminated. For the template for the blades, contact scitrekelementary@chem.ucsb.edu. After lamination, straws (Smart and Final Part Number: 8 in Fat Black Straws) are cut to 13.5 cm and hot glued to the backs of the blades. Three hot glue dots are placed in the center of the back of the blade at 1 cm, 7 cm, and 12.5 cm. A silver metallic Sharpie is used to draw a 1.5 cm line on the straw starting 2 cm from the bottom (next to the flat end of the blade) of the straw. This line is used to show students where to put the 9/16" wide mini binder clip (Office Max Number: 25014243) used to affix the blade to the dowels. See pictures below.



6. Lasko 20 in Box Fan. Many different fan types were tested, and a large box fan is needed to get reliable results. (Lasko Model Number B20200)
7. $\frac{1}{8}$ in. x 1 in. Zinc-Plated Fender Washer (Home Depot Part Number: 204276365)
   Washers are super glued together to make stacks of 3, 6, 9, 12, 15, 18, 21, and 24, to be used for weights. Washer stacks are labeled with black Sharpie to make it easier to identify. These washer stacks sometimes fall apart. If you write the number of washers in the stack on both sides, it is easy to tell if they are not a complete set.
8. KidWind Blade Pitch Protractor (Vernier Part Number: H0259 Fisher Part Number: S04804ND)
9. Maglite Mini AAA LED Flashlight (Walmart Part Number: 551779062)
10. Radiometer (Educational Innovations Part Number: RAD-100)
11. 152 cm/60 in. flexible measuring tape (ETA hand2mind Part Number: IN524)
12. Ruler (Office Depot Part Number: 21215472)
13. Masking Tape

14. Magnet lightbulb demonstration is made by taking a 2.5 in. ring that previously held ribbon on it, and drilling a $^1/_8$ in. hole the middle of the side. 400 wraps (200 each side of the hole) of 30 AWG magnet wire are wrapped around the ring. Then, a 1.5 V 40 mA bulb is attached to the ends of the wire (All Electronic Corp. Part Number: LP-3) using crimp connectors. To hold the bulb in place, a 1.5 in. x 1.25 in. piece of plexiglass is superglued to the ring, and a $^1/_{16}$ in. hole is drilled in the plexiglass to hold the bulb. Then, a 5 in. threaded rod (#8 -32) is inserted into the hole, so that one end sticks out by 0.25 in., and the other end sticks out by 1.75 in. On the threaded rod in the middle of the ring are 4 #8-32 nuts, and a 0.5 in. piece of 3/8 PVC. Nuts are tightened on either side of the PVC pipe to hold it in place. The two remaining nuts are glued in place with super glue, leaving just enough room for the rod to spin. A knob is then put on the long end of the threaded rod to make it easier to spin. Two disk neodymium magnets 1 in. x 0.25 in. are put on either side of the PVC pipe (Educational Innovation Part Number: M-165).



15. Clipboard (OfficeMax Part Number: 21678980)

    All printed materials used by SciTrek (notebooks, materials page, picture packet, poster parts, instructions, and nametags) can be made available for use and/or editing by emailing scitrekelementary@chem.ucsb.edu.

Types of Documents:

Notebook:
: One given to every student and is filled out by the student. The lead will use a notebook to write in as an example for students. The notebook the lead uses is referred to as the class notebook in these instructions.

Notepad:
: One given to every group and is filled out by the volunteer. In these instructions, the examples are narrower and taller than the notebook pages.

Picture Packet:
: One per class that, if needed, the lead fills out. In these instructions, the examples are the same size as the notebook pages, but they are labeled.

In these instructions, all other example documents are labeled.

Day 1: Technique/Observations/Variables

Note: We **highly recommend** teachers give the procedure assessment prior to Day 1 of the module. The suggested times in the lesson plan below are assuming students completed the procedure assessment prior to SciTrek's arrival.

Schedule:

Times if teacher gave assessment prior to SciTrek:
Introduction (SciTrek Lead) – 2 minutes
Module Introduction (SciTrek Lead) – 5 minutes
Technique (SciTrek Lead) – 15 minutes
Observation Discussion (SciTrek Lead) – 2 minutes
Observations (SciTrek Volunteers) – 18 minutes
Variable Discussion (SciTrek Lead) – 5 minutes
Variables (SciTrek Volunteers) – 10 minutes
Wrap-Up (SciTrek Lead) – 3 minutes

Times if SciTrek must give assessment:
Introduction (SciTrek Lead) – 2 minutes
Procedure Assessment (SciTrek Lead) – 10 minutes
Module Introduction (SciTrek Lead) – 5 minutes
Technique (SciTrek Lead) – 12 minutes
Observation Discussion (SciTrek Lead) – 1 minute
Observations (SciTrek Volunteers) – 17 minutes
Variable Discussion (SciTrek Lead) – 5 minutes
Variables (SciTrek Volunteers) – 5 minutes
Wrap-Up (SciTrek Lead) – 3 minutes

Materials:

(3) Volunteer Boxes:

- ☐ Student nametags
- ☐ (NS+1) Notebooks
- ☐ Volunteer instructions
- ☐ Picture of experimental set-up
- ☐ Volunteer lab coat
- ☐ (2) Pencils
- ☐ (2) Dry erase markers
- ☐ 152 cm measuring tape
- ☐ (2) Rulers
- ☐ Masking tape
- ☐ Wind turbine protractor
- ☐ Multimeter
- ☐ Ziploc bag with example cardstock blade, cardboard blade, and stack of 3 weights

Other Supplies:

- ☐ (3) Notepads
- ☐ Bag with 3 fans and 2 extension cords
- ☐ Bag with 4 wind turbine bases
- ☐ Bag with 8 wind turbine hubs with 3 blades each, 4 hubs with cardstock blades, and 4 hubs cardboard bladed, all with 3 weights.

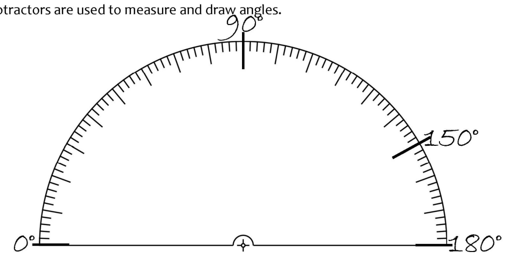
Lead Box:

- ☐ (3) Blank nametags
- ☐ (3) Extra notebooks
- ☐ Lead instructions
- ☐ Wind Turbines picture packet
- ☐ Picture of experimental set-up
- ☐ Lead lab coat
- ☐ Procedure assessment (if teacher did not take assessments, then (35) assessments)
- ☐ Time card
- ☐ (2) Pencils
- ☐ (2) Wet erase markers
- ☐ Black pen
- ☐ (3) Markers (orange, blue, green)
- ☐ 152 cm measuring tape
- ☐ (2) Rulers
- ☐ Masking tape
- ☐ Wind turbine protractor
- ☐ Multimeter
- ☐ Ziploc bag with example cardstock blade, cardboard blade, and stack of 3 weights
- ☐ Hub with one dowel
- ☐ Cardstock blade

Notebook Pages and Notepad Pages:

TECHNIQUE
Protractors

Protractors are used to measure and draw angles.

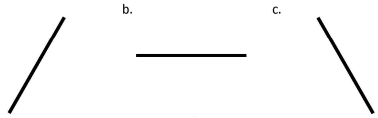


1. Label the following angles on the protractor above:

   a. 0° b. 90° c. 180° d. 150°

2. The following lines have an angle of 0°/180°, 60°, or 120°. Label each line with the corresponding angle value.

a. b. c.



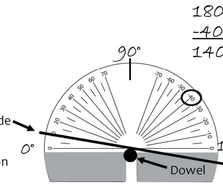
120° 0° / 180° 60°

3. What do you notice about the 120° and 60° angles? They are the same distance from 90°.

2

TECHNIQUE
Protractors

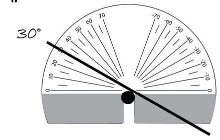
Label 0°, 90°, and 180° on the protractor to the right.



How to find angles between 90° and 180°:
For angles greater than 90°, take the number shown on the wind turbine protractor and subtract that number from 180°.

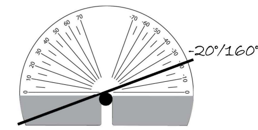
Draw the wind turbine blade at the specified angle.

1.



Angle: 30°

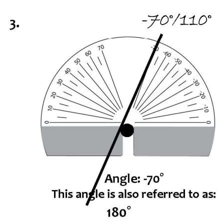
2.



Angle: -20°
This angle is also referred to as:

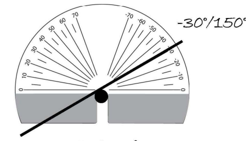
180°
\- 20°
160°

3.



Angle: -70°
This angle is also referred to as:
180°
-70°
110°

4.



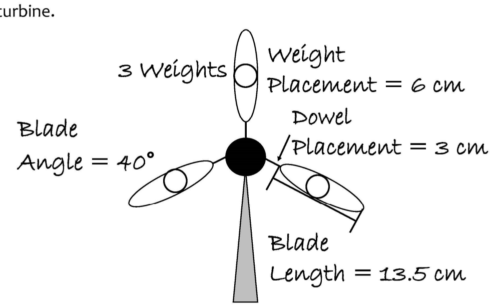
Angle: 150°
This angle is shown as:
180°
-30°
150°

3

OBSERVATIONS

Experimental Set-Up:

On the picture below, indicate relevant dimensions of the wind turbine.



Other aspects of the experimental set-up:

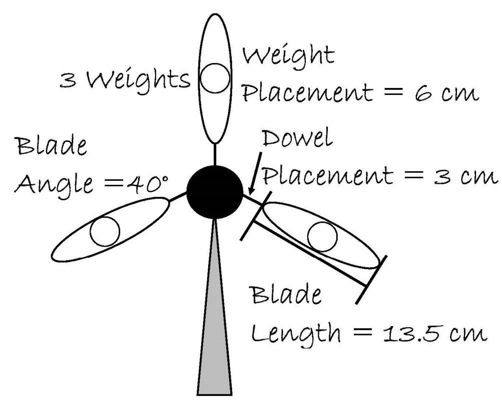
3 Blades
Fan Distance = 60 cm
Cardstock and cardboard blades

2

OBSERVATIONS

Experimental Set-Up:

On the picture below, indicate relevant dimensions of the wind turbine.



Other aspects of the experimental set-up:

3 Blades
Fan Distance =60 cm
Cardstock and Cardboard Blades

4

OBSERVATIONS

	Cardstock Blades	Cardboard Blades
Current (mA):	2.0 mA	2.3 mA
Similarities:	Size, shape, both have plastic around them	
Differences:	Thickness, color, cardboard is less bendy	

Other Observations:

3 Blades evenly spaced on hub

3

OBSERVATIONS

	Cardstock Blades	Cardboard Blades
Current (mA):	2.0 mA	2.3 mA
Similarities:	size, shape, both have plastic around them	
Differences:	thickness, color, cardboard is less bendy	

Other Observations:

3 Blades evenly spaced on hub

5

VARIABLES

Variable	How will changing this variable affect the current?
Blade Angle	The larger the blade angle, the more/less current.
Dowel Placement	The closer the blade is to the hub, the more/less current.
Weight Number	The more weights on the blade, the more/less current.
Fan Distance	The larger the fan distance, the more/less current.
Choose your own!!!	

4

VARIABLES

Variable	How will changing this variable affect the current?
Blade Angle	The larger the blade angle, the more current.
Dowel Placement	The closer the blade is to the hub, the more current.
Weights Number	The more weights on the blade, the less current.
Fan Distance	The larger the fan distance, the more current.
Blade Length	The longer the blades, the more current.

6

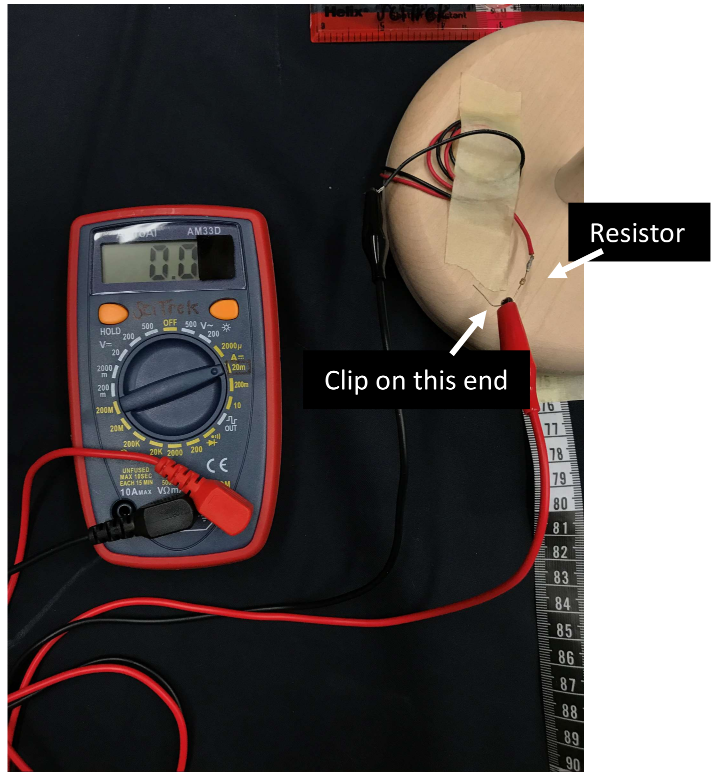
Preparation:

SciTrek Lead:

1. Get the procedure assessments and put them in the lead box.
2. Make sure volunteers are writing their name, and group color, on the whiteboard.
3. Make sure volunteers are passing out nametags.
4. Make sure volunteers are setting up for the initial observation.
5. Set up the document camera for the wind farm picture (picture packet, page 1), class question (notebook, front cover), and technique activity (notebook, pages 2-3).
6. Have a multimeter ready to show students during the Introduction.
7. Have the hub with one dowel, cardstock blade, and wind turbine protractor available to show students during the technique activity.

SciTrek Volunteers:

1. On the front whiteboard in the classroom, write your name and the color of the group (orange, blue, or green) you will be working with.
2. Pass out nametags.
    a. You may need to do this during the Introduction. Quietly set each student's nametag on their desk without talking to them. If names are not written on their desk ask the classroom teacher or lead to help you when they are not talking with the class.
3. Have notebooks available to pass out.
4. Assemble the experimental set-up (shown in picture below as well as in color in the experimental set-up picture in your group box) on a spot on the floor where approximately ten students can sit.
    a. Plug the fan in. Make sure the back of the fan is not put up against a wall or another fan.
    b. Roll out the tape measure, then set the fan and wind turbine stand, **60 cm** from one another, so they are facing each other.
    c. Connect the multimeter to the wind turbine by clipping the alligator clips to the wires on the wind turbine base. The red wire connects to the red wire, and the black wire connects to the black wire. The red wire of the multimeter must be clipped to the red wire of the turbine base **after** the resistor (at the loose end of the wire). <u>Make sure that the red and black wires do not touch</u>. Refer to the picture below to see how this is done.
    d. Make sure each blade has **3 weights** attached at **6 cm**, and the blades are attached to the dowels on the hub at **3 cm**. If the weights have come off, there is masking tape in your box.
    e. Use the wind turbine protractor to ensure that the blade angles are all **40°**. This is done by inserting the wind turbine protractor onto the side of the hub, with the knob, so the dowel is inside the notch of the wind turbine protractor, and the protractor is sitting on top of the hub. If needed, place your forefinger on the back of the binder clip, with your thumb on the front of the blade, and adjust the blade to **40°**.
    f. Connect the wind turbine hub with cardstock blades (white) to the wind turbine stand.
    g. Place the wind turbine hub with the cardboard blades (brown), wind turbine protractor, extra cardstock blade, extra cardboard blade, stack of three weights, and rulers, next to the set-up.
    h. Leave multimeter, and fan, off.
    i. When removing the hub from the wind turbine, always have one hand on the wind turbine, with your thumb on the front washer, and pull the hub off with your other hand.



Introduction:
(2 minutes – Full Class – SciTrek Lead)

For UCSB Lead:
"Hi, we are scientists from UCSB and we want to show you what we do as scientists. We will show you an experiment and then you can make observations, come up with a class question, and design your own experiment to help answer the class question. We want to show you that you can do science and have fun."

For Teacher Lead:
"I have asked some scientists from UCSB to come and help us with a long-term science investigation. We will make observations, come up with a class question, and you will design your own experiment to help answer the class question."

Allow the UCSB volunteers to introduce themselves and share their majors.

Procedure Assessment:
(10 minutes – Full Class – Given By Classroom Teacher Prior to SciTrek)

Tell students, "Before we start with the module, we will determine how your ideas on procedures are developing." Have students write their name, teacher's name, and date at the top of the assessment. Tell students, "When doing this assessment, you should work individually, so there should be no talking." As you are giving the assessment, walk around the room and verify students have written their names at the top of their assessments.

For question *1*, have students write in their own words what they think is the definition of a procedure.

For question *2-8*, read *step 1* of the directions (*Look over the experimental information*); then read the question, changing variable (*nutrient amount*), and controls (*plant type, liquid type, plant mass …*) under the experimental information. You do not need to read the values for the changing variable or controls.

Read *step 2* to the students (*Read each statement (2-8) and underline controls, circle changing variables and box information about data collection*); then read the statement in question *2* and have students annotate it. Once they are done, read *step 3* (*Circle yes if the statement could be a correct step for a procedure about the experimental information below. If not, circle no.*) Have students circle either *Yes* or *No* depending on if they think it is a correct procedural step. For question *3*, read the statement and tell students, “Annotate this statement by underling controls, circling changing variables, and boxing information about data collection.” Once students are done tell them, “Now circle if this could be a correct procedural step or not.” Repeat this process for questions *4-8*. When students are finished, collect the assessments and verify students’ names are written on top.

Module Introduction:
(5 minutes –Full Class – SciTrek Lead)

Have volunteers pass out a notebook to each student.

Have students fill out their name, teacher’s name, group color (color of their name on their nametag: orange, blue, or green), and their volunteer’s name (volunteers’ names should be written on the board next to the group color they will be working with) on the front cover of their notebooks. Students will leave the subgroup number, and class question, blank. If a student does not have a nametag, only have them fill out their name and teacher’s name on the cover of their notebook. They will be placed in a group when the class divides into groups for observations and can fill out their group color and volunteer at that point.

Show students the picture of the wind farm (picture packet, page 1). Ask students, “What is shown in the picture?” By the end of the conversation, make sure students know the picture is of **wind turbines**. If students use the word “windmill,” tell them, “Scientists and engineers call these wind turbines.” Ask students, “What are wind turbines used for?” Possible student response: wind turbines are used to generate electricity. Probe students further by asking them, “What is electricity used for?” Students should be able to list several devices, such as cell phones, TVs, and refrigerators, that use electricity. Tell students, “Scientists use a device called a **multimeter** to measure the amount of electricity a wind turbine produces.” Then, show them the multimeter. Introduce the word **current**, and tell them, “The more current that is measured, the more electricity being produced. Therefore, in this module, we will measure the current the wind turbine produces. The multimeter will read out the current in milliamps.” Have the class say the words “current,” “multimeter,” and “milliamps,” with you, a couple of times, to help them get used to these words.

Note: The term **windmill** is used for wind structures that are used to pump water, grind grain, or perform other tasks, in which the wind energy goes directly into completing a task, without being converted to electricity. The term **wind turbine** is used for wind structures that generate electricity.

Tell students, “For this module, we will be exploring how changing variables associated with the wind turbines affect the amount of electricity/current the wind turbine produces. Or more simply stated, we will explore the question ‘What variables affect the current produced by a wind turbine?’” Write this question on the front page of the class notebook under the document camera, and have students copy the question onto the cover of their notebooks.

Technique:
(15 minutes – Full Class – SciTrek Lead)

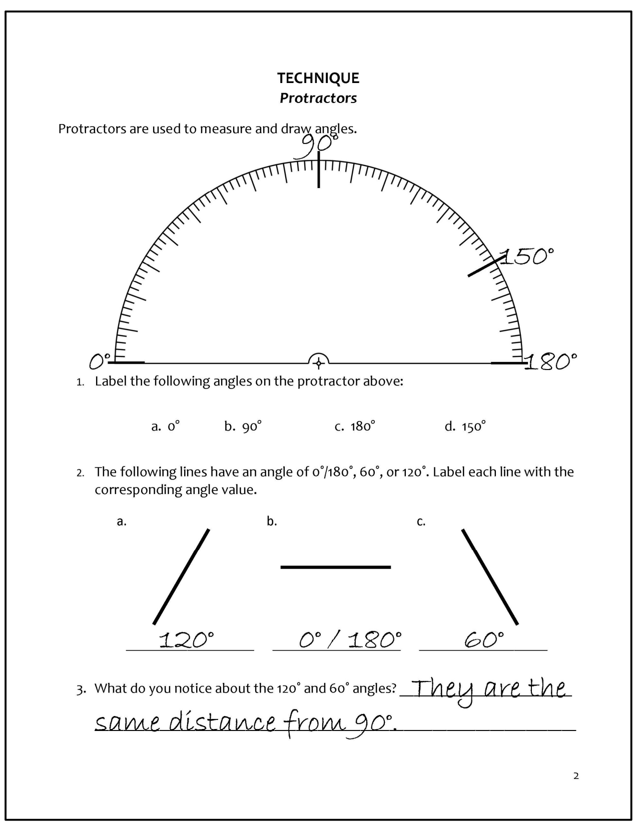
Tell the class, “During our experiments, we will need to be able to describe how the blades are attached to the hub.” Show students the hub, with one dowel, as well as how the cardstock blade can be rotated.

Introduce the terms **hub**, **dowel**, and **blade**. Tell students, “To do this, we will use protractors to measure angles. We will first review what we know about protractors and angles.”

Have students open their notebooks to page 2, while you do the same in the class notebook under the document camera. Point to the protractor on the top of page 2 and tell students, “We need to add some important angels to this protractor.” Place your finger on the left end of the protractor and tell students, “I am going to move my finger around the protractor and when I reach 0˚, you should tell me to stop.” Once there label the angle, then, do the same for 90˚ and 180˚. Ask students, “What does each of the large lines represent?” Students should reply, “10˚.” Ask students, “How much do each of the small lines represent?” Students should reply, “2˚.” Have students to complete *1d* (Label 150˚) on their own. Have volunteers walk around and help struggling students. Once most students have labeled their protractors, ask them, “Which side (before or after 90°) of the protractor is 150˚ on?” Then, have the class count by 10’s with you, starting at 90˚, until you reach 150˚. Label it in the class notebook, and have students adjust their angles, if needed.

Show students the hub, and blade, again, and tell them, “When measuring blade angles, you will look down at the top of the blade to find the angles.” Place the blade under the document camera, and show students, from a top down view, the blade just appears as a line. Read question *2* to students and point to each of the lines in the class notebook (*2a*, *2b*, *2c*). Have students raise their hands, and identify the angle value which corresponds to each picture. These can be done in any order, but students must explain their thinking to you for each answer. For example, if a student tells you that *2a* corresponds with 120˚, ask them, “How do you know this?” Possible student response: 120˚ is larger than 90˚, therefore, the line must be pointed past 90˚.

After the 3 lines are labeled, ask students, “Do you notice anything interesting about the 120˚, and 60˚, lines?” Possible student response: the lines are symmetrical or mirror images of each other. Lead them to understand that 120˚ and 60˚ are both the same distance from 90˚, and therefore, the angles are symmetrical.


TECHNIQUE
Protractors

Protractors are used to measure and draw angles.

1. Label the following angles on the protractor above:

   a. 0° b. 90° c. 180° d. 150°

2. The following lines have an angle of 0°/180°, 60°, or 120°. Label each line with the corresponding angle value.

   a. 120° b. 0° / 180° c. 60°

3. What do you notice about the 120° and 60° angles? They are the same distance from 90°.

2

Tell students, “For this experiment, you will be using a protractor that is specially made for wind turbines.” Show students the wind turbine protractor. Next show students (under the document camera) how the protractor fits over the dowel and sits on the hub.

Wind Turbine Protractor

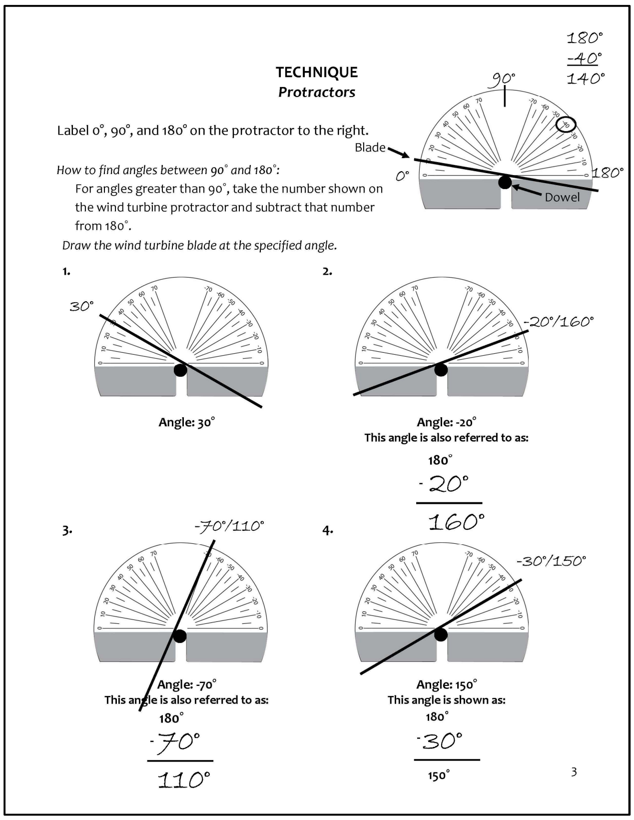
Have students turn to page 3 while you turn to the same page in the class notebook. Tell students, “We are now going to learn how to read the wind turbine protractor, to determine the blade angle.” Point to the picture of the wind turbine protractor in the upper right-hand corner of page 3, and show students where the dowel is in the picture. Ask students, “What is different about this protractor from most protractors you’ve seen?” Possible student response: the right side of the protractor has numbers with minus signs in front of them. Have students label where 0°, 90°, and 180° would be on the protractor. Tell students, “Sometimes protractors show the number that needs to be subtracted from 180˚, instead of the real angle value.” To help students understand, circle *-40°* on the wind turbine protractor picture labeled with 0°, 90°, and 180°. Ask students, “What should we do if we want to find the ‘real’ angle?” Possible student response: we would need to take 180˚, and subtract 40˚. Show the appropriate form of subtraction, as dictated by the classroom teacher, in the margins of the notebook, to determine the angle would be 140˚. Tell students, “When we talk about blade angles larger than 90° during this module, we will refer to them by both their ‘real’ angle as well as the value you would need subtract from 180°. Therefore, we need to be comfortable with determining these values.”

Point to the protractor in the upper right-hand corner again, and ask students, “What else is pictured?” Students should reply, “The blade.” Ask them, “Which angle is the blade placed at?” Students should reply, “10˚.” Tell students, “You will be measuring the blade angle from a top-down view, so the blade will look like a line to you, just like in the picture.” Demonstrate how they will adjust blade angles by attaching the example blade to the hub (you do not need to put on the binder clip), and place it under the document camera. Place the wind turbine protractor around the dowel, and rotate the blade to 10˚ to match the picture in the upper right-hand corner of page 3.

Tell students, “We are now going to draw in where a blade would be at a given angle on a wind turbine protractor.” As a class, complete question *1*. Tell students, “I will put my finger on the 0° mark and trace it around the protractor, tell me when to stop when I get to the correct angle.” If students do not tell you to stop, and you pass the correct angle, go back to the 0° mark and start again. Once students have found the correct angle, draw a line representing the blade. Make sure your line touches the dowel to show that the blade and dowel are connected. Label the angle next to the blade. Next, complete question *2* together. Repeat the process of having students tell you when your finger is at the appropriate angle, and when an agreement is reached, draw a line at that angle representing the blade. Then, solve for the ‘real’ angle by writing “20°” next to the minus sign under *180°* and performing the subtraction. Students should determine this angle to be 160˚. Label both the angles next to the blade, “-20°/160°.”

Have students complete question *3* on their own. As students are working, volunteers should walk around and help students that are struggling. Once the majority of students are finished, go over the answer. Repeat the process of having students tell you when your finger is at the appropriate angle and when an agreement is reached, draw a line at that angle representing the blade. Then solve for the real angle for -70˚ by writing "70°" next to the minus sign under *180°* and performing the subtraction. Students should determine the angle is 110˚. Label both angles next to the blade, "-70°/110°."

As a group, complete question *4*. Ask students, "What number would you look for on the wind turbine protractor if you wanted the blade angle at 150˚?" Remind students that for angles over 90˚, the number shown on the wind turbine protractor is the number that would need to subtract from 180˚ to get the 'real' angle. Ask students, "If the angle was 150˚, what would you need to subtract from 180˚ to find the angle on this protractor?" Make sure by the end of the conversation students know they would need to subtract 30˚ from 180˚, therefore, they should look for -30˚ on the wind turbine protractor. Write "30°" next to the minus sign under *180°* in the class notebook. Once they have determined the angle, have them draw the blade at the appropriate position on the protractor on their own. Remind them to write both values of the angle, "-30°/150°," next to the blade. Once the majority of students have completed this, repeat the process of having students tell you when your finger is at the appropriate angle. When an agreement is reached, draw the blade and label the angle.



Tell students, "Now that you know how to use a protractor to measure blade angles, you will be able to use this skill to help you make observations."

Observation Discussion:
(2 minutes – Full Class – SciTrek Lead)

Tell students, "Scientists make many observations." Ask the class, "What is an observation? What are the types of things you can record for an observation?" If they have trouble, show them an object and let them make observations. Turn these specific observations into general features of an observation. Examples of possible general observations are: color, texture, size, weight, temperature, etc. Lead students to understand an observation is a description using your five senses.

Tell students, “In this experiment we are going to make observations of wind turbine that has two different blade materials. You will measure the current the wind turbines produces in milliamps. The more current a wind turbine produces, the more electricity the wind turbine produces.” Put a multimeter under the document camera (shown below), and tell students, “In order to read the current, you will turn the dial to the setting that is boxed.”

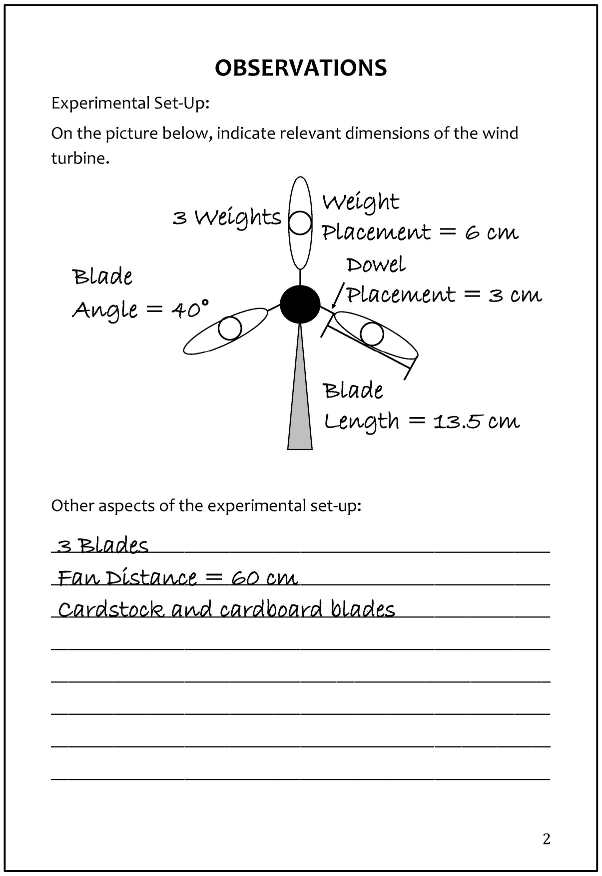
Tell the class, “You will now get in your groups and make observations. To determine your group, you will need to look at the color of your nametag (orange, blue, or green).” Tell each colored group where to go, as well as to bring a pencil and their notebook.

If a student does not have a nametag, identify the group color with the least number of students in it, and write the student’s name on one of the extra nametags in the lead box, using that color of marker.

Observations:
(18 minutes – Groups – SciTrek Volunteers)

Once students come over to your group, have them sit in boy/girl fashion, making sure that no students are sitting behind the fan. Verify the floor is set up as described in the Set-Up section. Have each student turn to page 4 of their notebook.

As a group, have students generate approximately ten observations (approximately one observation per student) about the experimental set-up before you turn on the fan. Observations should be recorded in the notepad by drawing on the picture of the wind turbine, or by writing them under the *Other Aspects of the Experimental Set-Up* section, then, copied by students into their notebooks. Observations about the experimental set-up should be recorded in bullet points to save time. The two extra blades (one cardstock and one cardboard) and extra weights are for students to observe, and measure. Make sure to record the following observations about the experimental set-up: dowel placement (3 cm), blade angle (40°), number of weights (3), weight placement (6 cm), and fan distance (60 cm). This should take you no longer than 15 minutes. An example filled out experimental set-up for the initial observation is shown below.



OBSERVATIONS

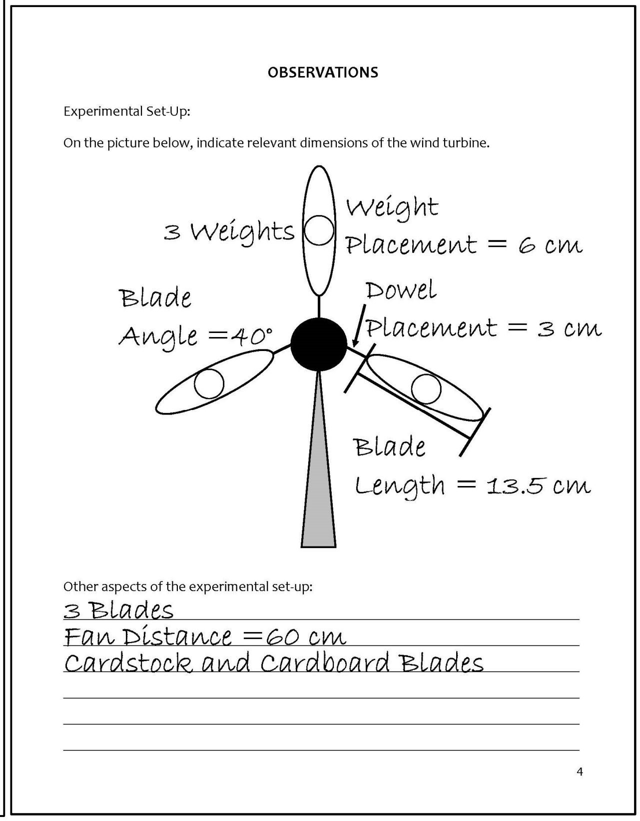
Experimental Set-Up:

On the picture below, indicate relevant dimensions of the wind turbine.

Other aspects of the experimental set-up:

3 Blades
Fan Distance = 60 cm
Cardstock and cardboard blades

2



OBSERVATIONS

Experimental Set-Up:

On the picture below, indicate relevant dimensions of the wind turbine.

Other aspects of the experimental set-up:

3 Blades
Fan Distance =60 cm
Cardstock and Cardboard Blades

4

Have students turn to page 5 of their notebooks, while you turn to page 2 on the notepad. Make sure no students are sitting behind the fan, and nothing is touching the fan. First turn on the multimeter to the boxed setting (20 m), then, turn the fan on level 3 (high). Once the wind turbine has gotten up to speed, have students watch the current reading for about 15 seconds, and then record the current (in mA) that showed up most often. Once students have recorded observations for the cardstock blades, remove that hub from the wind turbine base and replace it with the hub with cardboard blades. When removing the hub from the wind turbine, always have one hand on the wind turbine, with your thumb on the front washer, and pull the hub off with your other hand. Have students measure, and record, the current produced when using the cardboard blades.

Once students have recorded the current measurements for both blade materials, have them generate a list of similarities, and differences, between the two blade materials. It is important they note size and shape as similarities, and flexibility as a difference. Record these in the notepad as students copy them into their notebooks.

If there is additional time, have students generate a list of other observations about the wind turbine system, and record these under *Other Observations* in their notebook. If there is not additional time, leave this section blank.

An example filled out initial observations is shown below.

OBSERVATIONS

	Cardstock Blades	Cardboard Blades
Current (mA):	2.0 mA	2.3 mA
Similarities:	Size, shape, both have plastic around them	
Differences:	Thickness, color, cardboard is less bendy	

Other Observations:

3 Blades evenly spaced on hub

3

OBSERVATIONS

	Cardstock Blades	Cardboard Blades
Current (mA):	2.0 mA	2.3 mA
Similarities:	size, shape, both have plastic around them	
Differences:	thickness, color, cardboard is less bendy	

Other Observations:

3 Blades evenly spaced on hub

5

Variables Discussion:
(5 minutes – Full Class – SciTrek Lead)

Ask the class questions to review the experiment they carried out, as well as what they learned. Make sure by the end of the discussion, students have identified, they worked with two different blade materials (cardstock and cardboard), and they measured the current produced by both. They should have seen the two different blade materials produced similar currents. Most likely, some groups will have the cardstock blades producing more current, and some will have the cardboard blades producing more current. Therefore, they should conclude that blade material does not have a large effect on the current a wind turbine produces.

Note: The blade materials used in this experiment were similar in many ways, causing the currents produced to be close to each other. Students will be given the opportunity to explore other blade materials in the class experiment. This will also allow students to discuss what happens when we collect more data.

Remind the students of the class question they will investigate: What variables affect the current produced by a wind turbine?

Lead students through the following questions and explanations.

What does the word ‘variable’ mean to a scientist?

variables are the parts of the experiment you can change

What was the changing variable in the experiment we just did?

blade material

Do you think there are multiple variables that will affect the current produced by the wind turbine?

multiple variables might affect the current produced by the wind turbine
Explain, this is why we will need to work as a class to answer the class question: "What variables the current a wind turbine produces?"

Tell the class, "You are going to think about variables, in the experiment, you could change, in order to help us answer the class question. In addition to generating variables, you should think about how and/or why these variables might affect the outcome of the experiment." Ask the class, "What do you think is a variable that might affect the current produced by the wind turbine?" Then, have them tell you how and why they think that variable would affect the current produced by a wind turbine. Probe them on how they would design an experiment to test whether this variable affected the current a wind turbine produces. Finally, have the students make a prediction of the results for the experiment they proposed. Remind students, "Predictions can be wrong, and we will not know the true answers until we carry out the experiment."

Ex: *Variable:* blade number

Why might this variable affect the current that the wind turbine produces? A different number of blades will cause the wind turbine to spin at different speeds, and will change the amount of current produced.
How would you test this variable? Do several trials, in which different numbers of blades are attached to the hub, and measure the current produced by each trial.
Prediction: More blades will generate more current.

Tell students, "You will now generate more variables and analyze them in your groups."

Note: If you are running behind and there are less than 5 minutes remaining, generate variables as an entire class instead of in groups.

Variables:
(10 minutes – Groups – SciTrek Volunteers)

As a group, generate a variable and make a prediction about how it could affect the current that the wind turbine produces. Encourage and challenge students to explain why they think their prediction is correct, and how this variable could affect the current produced by the wind turbine. If needed, you can write down a sentence frame for students to use. Repeat this process three more times, record these ideas on the notepad, and have students copy them into their notebooks. If students have different predictions, they can write their own predictions in their notebooks. Next, students will individually generate at least one additional variable, make a prediction about how different values of this variable will affect the current produced by wind turbines, and record their ideas in their notebooks. Have students share these ideas with the group.

Prepare one student to share a variable and why they think it will affect the current produced by wind turbines, during the class discussion.

VARIABLES

Variable	How will changing this variable affect the current?
Blade Angle	The larger the blade angle, the __more/less__ current.
Dowel Placement	The closer the blade is to the hub, the __more/less__ current.
Weight Number	The more weights on the blade, the __more/less__ current.
Fan Distance	The larger the fan distance, the more/less current.
Choose your own!!!	

4

VARIABLES

Variable	How will changing this variable affect the current?
Blade Angle	The larger the blade angle, the more current.
Dowel Placement	The closer the blade is to the hub, the more current.
Weights Number	The more weights on the blade, the less current.
Fan Distance	The larger the fan distance, the more current.
Blade Length	The longer the blades, the more current.

6

Wrap-Up:
(3 minutes – Full Class – SciTrek Lead)

Have one student from each group share a variable they generated, as well as how and why they think it will affect the current the wind turbine produces. Make sure students tell you their predictions about how different values of that variable will affect the current.

Tell students, “Next session, you will design an experiment to answer the class question: What variables affect the current produced by a wind turbine?”

Clean-Up:

1. Collect notebooks with attached nametags.
2. Turn off multimeter.
3. Place wind turbine base, hubs with blades, and fan, back into the bags they came in.
4. Place all other materials into your group box and bring them back to UCSB.

Day 2: Question/Materials Page/Experimental Set-Up/Procedure Activity

Schedule:

Introduction (SciTrek Lead) – 15 minutes
Question (SciTrek Volunteers) – 5 minutes
Materials Page (SciTrek Volunteers) – 5 minutes
Experimental Set-Up (SciTrek Volunteers) – 10 minutes
Procedure Activity (SciTrek Lead) – 23 minutes
Wrap-Up (SciTrek Lead) – 2 minutes

Materials:

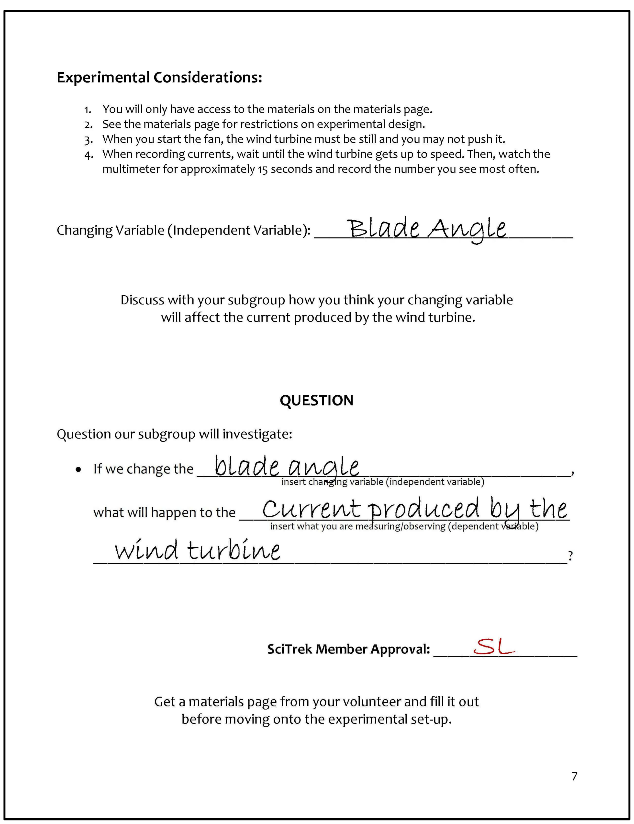
(3) Volunteer Boxes:

- ☐ Nametags
- ☐ Notebooks
- ☐ Volunteer instructions
- ☐ Volunteer lab coat
- ☐ (2) Materials pages (subgroup color & number indicated)
- ☐ (2) Pencils
- ☐ (2) Red pens
- ☐ Paper notepad

Lead Box:

- ☐ (3) Blank nametags
- ☐ (3) Extra notebooks
- ☐ Lead instructions
- ☐ Wind Turbines picture packet
- ☐ Lead lab coat
- ☐ (3) Materials pages
- ☐ Time card
- ☐ (2) Pencils
- ☐ (2) Red pens
- ☐ (2) Wet erase
- ☐ Black pens
- ☐ (3) Markers (orange, blue, green)
- ☐ Paper notepad

Notebook Pages:



Experimental Considerations:

1. You will only have access to the materials on the materials page.
2. See the materials page for restrictions on experimental design.
3. When you start the fan, the wind turbine must be still and you may not push it.
4. When recording currents, wait until the wind turbine gets up to speed. Then, watch the multimeter for approximately 15 seconds and record the number you see most often.

Changing Variable (Independent Variable): Blade Angle

Discuss with your subgroup how you think your changing variable will affect the current produced by the wind turbine.

QUESTION

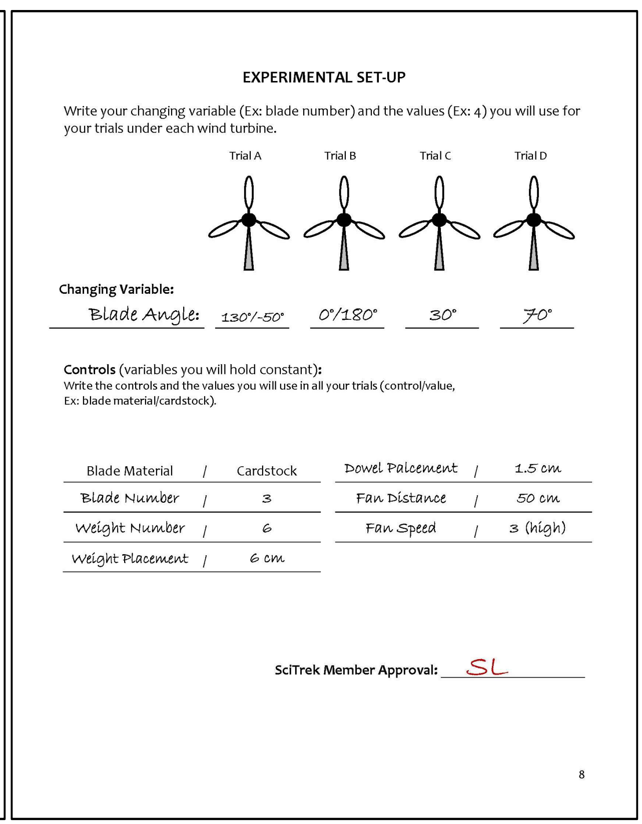
Question our subgroup will investigate:

- If we change the blade angle (insert changing variable (independent variable)), what will happen to the Current produced by the wind turbine (insert what you are measuring/observing (dependent variable))?

SciTrek Member Approval: SL

Get a materials page from your volunteer and fill it out before moving onto the experimental set-up.

7



EXPERIMENTAL SET-UP

Write your changing variable (Ex: blade number) and the values (Ex: 4) you will use for your trials under each wind turbine.

Changing Variable:

	Trial A	Trial B	Trial C	Trial D
Blade Angle:	130°/-50°	0°/180°	30°	70°

Controls (variables you will hold constant)**:**
Write the controls and the values you will use in all your trials (control/value, Ex: blade material/cardstock).

Control	Value	Control	Value
Blade Material	Cardstock	Dowel Palcement	1.5 cm
Blade Number	3	Fan Distance	50 cm
Weight Number	6	Fan Speed	3 (high)
Weight Placement	6 cm		

SciTrek Member Approval: SL

8

SCIENTIFIC PRACTICES
Procedures

Directions: Fill in the missing definition.

- **Procedure:** A set of steps to conduct an experiment.

A complete procedure MUST have:

- All values of the controls and the changing variable.
- The data that will be collected (measurements/observations).
- The steps listed in the order they will be completed.

A complete procedure MUST NEVER have:

- Extra or irrelevant information.
- Opinions about the experiment.
- Incorrect values of controls or the changing variable.

10

SCIENTIFIC PRACTICES
Procedures

QUESTION
If we change the popcorn brand, what will happen to the number of kernels that pop?

EXPERIMENTAL SET-UP

Changing Variable:	Trial A	Trial B	Trial C	Trial D
Popcorn Brand:	Pop Secret	Orville	Smart Balance	Act II

Controls (variables you will hold constant)**:**

Microwave Level / High	Popcorn Color / Yellow
Time / 3 Minutes	Salt Amount / 220 mg
Container Type / Bag	Initial Number of Kernels / 200

Directions:
Step 1: Read each statement and underline controls, circle changing variables, and box information about data collection.
Step 2: Circle yes if the statement could be a correct step for a procedure about the question and experimental set-up above. If not, circle no.

	Statement	*Could this be a procedure step?*
1.	Put the bag in the microwave on high for 3 minutes.	Yes No
2.	Get 200 kernels of yellow A) Pop Secret, B) Orville, C) Smart Balance, D) Act II popcorn.	Yes No
3.	Observe what happens.	Yes No
4.	Put 200 kernels of yellow Pop Secret popcorn and 220 mg of salt in bag A.	Yes No
5.	Get 200 kernels of different yellow popcorn brands.	Yes No
6.	Count the number of kernels that have popped in each bag.	Yes No
7.	Put the tasty popcorn in the microwave on high for 3 minutes.	Yes No

Underline controls, circle changing variables, and box data collection.

11

Preparation:

SciTrek Lead:

1. Make sure volunteers are setting out notebooks in such a way that allows students within the same subgroup to work together.
2. Set up the document camera for the Day 1 experimental set-up picture (picture packet, page 2), question (notebook, page 7), lead materials page (picture packet, page 3), experimental set-up (picture packet, page 4), and procedure activity (notebook, pages 10-11).

SciTrek Volunteers:

1. Set out notebooks/nametags to allow students in the same subgroup (same number on the front of their notebook) to work together.
2. Make sure you have two materials pages, each filled out with a subgroup number (1 or 2) and your group's color, to give to subgroups after they complete their question.
3. Have a red pen available, to approve students' questions and experimental set-ups (notebook, pages 7-8).

Note: Set notebooks where students will sit during the module, even if another student is currently at that desk. If needed, students will move to these spots after the Introduction.

Introduction:
(15 minutes – Full Class – SciTrek Lead)

If students are not in their subgroups, tell them, "A notebook will be put on your desk, which is not your notebook and you should not move it. You will move to your notebook after the Introduction."

Show students the picture of the Day 1 experimental set-up (picture packet, page 2) and ask them, "What did we do and learn during our last session?" Possible student response: we did an experiment in which we changed the blade material (cardstock and cardboard), and measured the current a wind turbine produced. We learned the difference in current between the two blade materials is small, and therefore, the blade material does not affect the current significantly. Review the terms: wind turbine, multimeter, current, and milliamp. Ask the class, “What is the class question we will be investigating?” Students should reply, “What variables affect the current produced by a wind turbine?”

Tell students, “One way scientists answer questions is by performing experiments. Today, you will design an experiment to help answer the class question.” Ask the class, “Do you think there are multiple variables that could affect the current a wind turbine produces?” Possible student response: there are probably multiple variables.

Explain to students, “Many times when there is a broad question, like our class question, scientists break it down into smaller, more specific questions which small groups of scientists can investigate. The scientists then compile their work to answer the broader question. Therefore, each subgroup is going to generate a smaller question about one changing variable to investigate. Once we put all the subgroups’ research together, we should be able to answer the class question.”

Subgroups will first generate a question based on the changing variable they plan to explore. They will then fill out their materials page, which will allow them to determine their experimental set-up. Tell students, “You will need to keep a few things in mind, while you are going through this process.”

Experimental Considerations:

1. *You will only have access to the materials on the materials page.*
2. *See the materials page for restrictions on experimental design.*
3. *When you start the fan, the wind turbine must be still, and you may not push it.*
4. *When recording currents, wait until the wind turbine gets up to speed. Then, watch the multimeter for approximately 15 seconds, and record the number you see most often.*

Tell students, “We are now going to generate a class research question/experimental set-up together. I will write it in the class notebook, so you will be able to refer back to it when you are completing the process yourselves.” Make sure students **do not** fill out the class research question/experimental set-up in their notebooks, as they will be completing these pages for their own experiments in subgroups.

Tell students, “For the class experiment, we will do an expanded version of the initial observation, and therefore, we will explore how changing blade material will affect the current the wind turbine produces.” Record “blade material” for the changing variable (notebook, page 7), under the document camera.

Show students how to insert the changing variable and what they plan to measure/observe into the question frame to generate the question that will be investigated, “If we change the <u>blade material,</u> what will happen to the <u>current produced by the wind turbine</u>?”

Experimental Considerations:

1. You will only have access to the materials on the materials page.
2. See the materials page for restrictions on experimental design.
3. When you start the fan, the wind turbine must be still and you may not push it.
4. When recording currents, wait until the wind turbine gets up to speed. Then, watch the multimeter for approximately 15 seconds and record the number you see most often.

Changing Variable (Independent Variable): Blade Material

Discuss with your subgroup how you think your changing variable will affect the current produced by the wind turbine.

QUESTION

Question our subgroup will investigate:

- If we change the blade material (insert changing variable (independent variable)),
  what will happen to the Current produced by the wind turbine (insert what you are measuring/observing (dependent variable))?

SciTrek Member Approval: ____________

Get a materials page from your volunteer and fill it out before moving onto the experimental set-up.

7

Tell students, "Once you have determined your question, and have approval, your volunteer will give you a materials page for determining the values of your controls and changing variable." Ask students, "What is a control?" Make sure by the end of the conversation, students understand controls are variables that are held constant during an experiment. For example, if the blade angle was 30° for all of the trials, then one of their controls would be blade angle. These controls, and control values, can be different from the original experiment they conducted on Day 1, but must remain constant throughout all the trials they do for this experiment.

Show students the lead materials page (picture packet, page 3) and read the first step (*For each bolded word, underline if it is a control and circle if it is a changing variable*). Then, have students tell you what to do for each bolded word. Read steps 2 and 3 on the materials page (*For variables that are controls, choose 1 underlined value. For the variable that is the changing variable, choose 4 values and write the trial letter next to each value.*). Read the general materials to students, ask them if they need each one, and check the box when they say yes. Go through the remaining items on the materials page. If a variable is a control, then choose (do not let students choose) a single underlined value, such as the original value (Ex: 3 for weight number). Assign each control value to a student, and tell them, "You are in charge of remembering this control, and its value, to help when filling out the experimental set-up." For blade material (the changing variable), allow students to select the values. Write the trial letter next to each selected value. Ask students, "Do we want a narrow, or wide, range of values for blade material, and why?" Guide students through selecting a wide range of values for blade material. If they choose a value contrary to their proposed experimental design, question them on their reasoning. For example, if they said they wanted to use a wide range of blade materials, and they only chose materials that did not bend, ask them, "Would the selected values allow us to best answer the question?" Allow them to change their values if needed. Assign the changing variable values to the students who chose them.

MATERIALS PAGE

You will only have access to the following materials.

1) For each bolded word, underline if it is a control, and circle if it is a changing variable. Example control: Blade Material, Example changing variable: Blade Number
2) For variables that are controls, choose one underlined value. When a variable is a control you will only have access to the underlined values.
3) For the variable that is the changing variable, choose four values and write the trial letter (A, B, C, D) next to each value. Example: ☒ Cardstock (original) A

General Materials:
☒ Wind turbine base ☒ Measuring tape ☒ Wind turbine protractor
☒ Multimeter ☒ Binder Clips

Blade Material:
☒ Kleenex B ☒ Paper A ☐ Paper towel
☒ Styrofoam D ☒ Metal C ☐ Cardstock (original)

Blade Number:
☐ 1 ☐ 2 ☒ 3 (original) ☐ 4 ☐ 5 ☐ 6

Weight Number:
☐ 0 ☒ 3 (original) ☐ 6 ☐ 9 ☐ 12 ☐ 15
☐ 18 ☐ 21 ☐ 24

Weight Placement:
☒ 0 cm ☐ 1 cm ☐ 2 cm ☐ 3 cm ☐ 4 cm ☐ 5 cm
☐ 6 cm (original) ☐ 7 cm ☐ 8 cm ☐ 9 cm ☐ 10 cm ☐ 11 cm

****Note:** if you are changing Number of Weights, you may only place your weights at **6 cm**.

Dowel Placement:
☐ 0.5 cm ☐ 1 cm ☐ 1.5 cm ☐ 2 cm ☐ 2.5 cm ☒ 3 cm (original)
☐ 3.5 cm ☐ 4 cm ☐ 4.5 cm ☐ 5 cm ☐ 5.5 cm ☐ 6 cm

Blade Angle:
☐ 0°/180° ☐ 10° ☐ 20° ☒ 30° ☐ 40° (original) ☐ 50°
☐ 60° ☐ 70° ☐ 110°/-70° ☐ 120°/-60° ☐ 130°/-50° ☐ 140°/-40°
☐ 150°/-30° ☐ 160°/-20° ☐ 170°/-10°

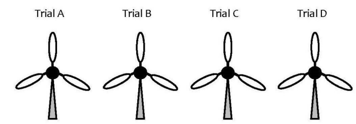
Fan Distance: 50 cm
Any distance between 20 cm – 100 cm (original fan distance = 60 cm)

3

Picture Packet, Page 3

EXPERIMENTAL SET-UP

Write your changing variable (Ex: blade number) and the values (Ex: 4) you will use for your trials under each wind turbine.



Changing Variable:

Blade Materials: Paper Kleenex Metal Stryofoam

Controls (variables you will hold constant):
Write the controls and the values you will use in all your trials (control/value, Ex: blade material/cardstock).

Blade Number / 3 Blade Angle / 30°
Weight Number / 3 Fan Distance / 50 cm
Weight Placement / 6 cm Fan Speed / 3 (high)
Dowel Placement / 1.5 cm

SciTrek Member Approval: ______________

4

Picture Packet, Page 4

Tell students, “Once you have completed your materials page, you will fill out your experimental set-up. First, you will fill out the information on the changing variable.” Ask students, “What is the changing variable for our class experiment, and what values did we select?” Then, fill in the values, for all of the trials (picture packet, page 4). Tell students, “Second, you will fill in information about your controls.” Ask students, “What is one of our controls, and its value, for the class experiment?” Show students how to record the control on the left side of the slash (Ex: blade number), and the value of that control on the right side of the slash (Ex: 3) by doing so in the class notebook. There are seven possible variables to choose from on the materials page. Subgroups will be left with one control blank empty after inserting in the information from the materials page. Since all control blanks must be filled out, tell students, “You need to generate an additional control that does not come from the materials page.” Lead students to realize this should be “fan speed/3 (high).”

Ask students, “Should everyone choose the same changing variable and why or why not?” Possible student response: no, because we will not learn as much about the class question. Tell students, “This means you should try to explore a changing variable you think few other subgroups are exploring. Remember, because we are exploring blade material as a class, you will not be able to change this variable, and the only blade material you will have access to is cardstock. Therefore, you will get a slightly modified materials page. Once your subgroup has completed your experimental set-up, you should raise your hands and get it approved by your volunteer.” Above is an example of what should be filled out for the experimental set-up in the class notebook.

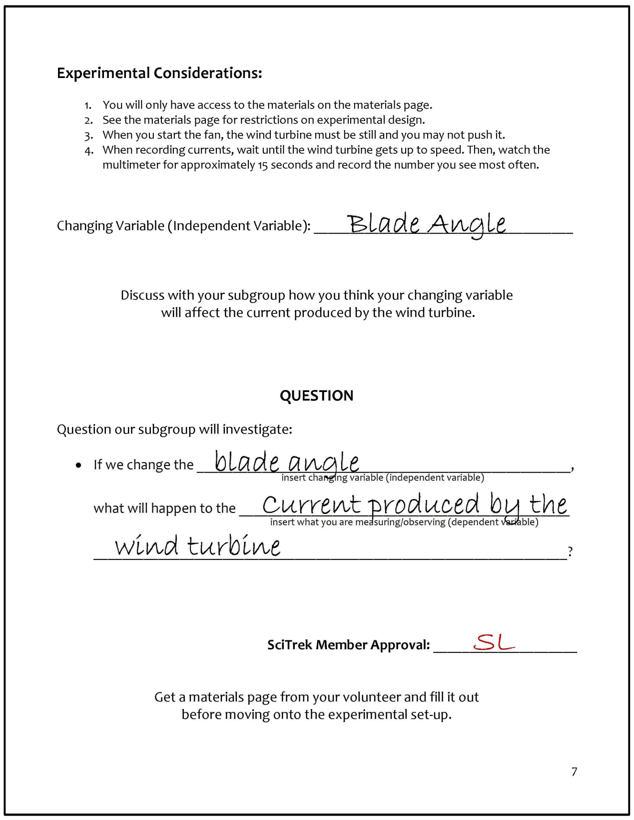
Have students start the design process. Place the class example question (notebook, page 7) under the document camera so students may refer back to it as they design their experiments. As subgroups move onto their experimental set-up, put the class example experimental set-up (picture packet, page 4) under the document camera.

Question:
(5 minutes – Subgroups – SciTrek Volunteers)

Have subgroups decide what changing variable they want to explore for their experiment. Encourage your subgroups to have different changing variables. The lead will help coordinate between groups to ensure there is a variety of changing variables.

Each subgroup should briefly discuss how and why they think their changing variable will affect the current the wind turbine produces.

After subgroups have decided on their changing variable, have them fill out their question. When you sign off on their question, give them a materials page with their subgroup color and number designated in the upper right-hand corner. An example filled-out question is shown below.


Experimental Considerations:

1. You will only have access to the materials on the materials page.
2. See the materials page for restrictions on experimental design.
3. When you start the fan, the wind turbine must be still and you may not push it.
4. When recording currents, wait until the wind turbine gets up to speed. Then, watch the multimeter for approximately 15 seconds and record the number you see most often.

Changing Variable (Independent Variable): Blade Angle

Discuss with your subgroup how you think your changing variable will affect the current produced by the wind turbine.

QUESTION

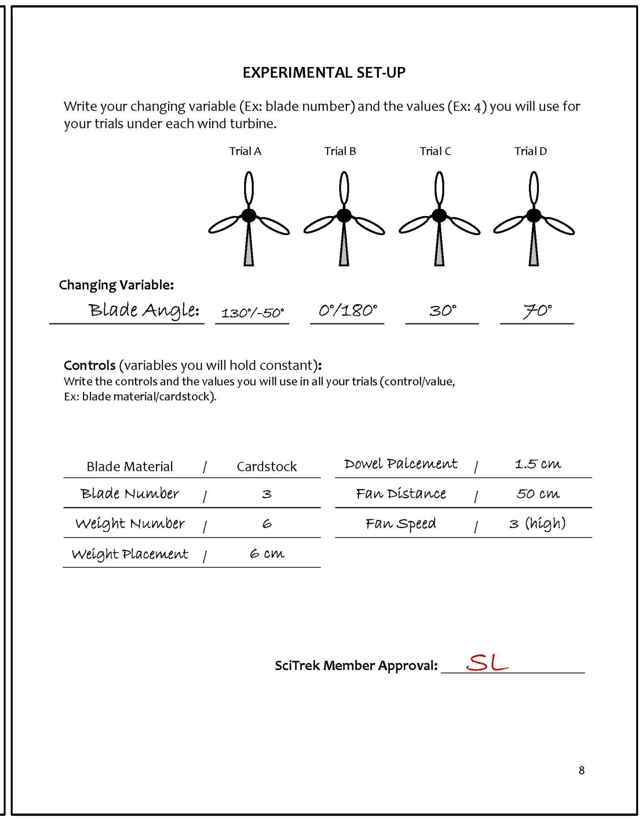
Question our subgroup will investigate:

- If we change the blade angle (insert changing variable (independent variable)), what will happen to the Current produced by the (insert what you are measuring/observing (dependent variable)) wind turbine?

SciTrek Member Approval: SL

Get a materials page from your volunteer and fill it out before moving onto the experimental set-up.

7


EXPERIMENTAL SET-UP

Write your changing variable (Ex: blade number) and the values (Ex: 4) you will use for your trials under each wind turbine.

Changing Variable:

Blade Angle:	130°/-50°	0°/180°	30°	70°

Controls (variables you will hold constant)**:**
Write the controls and the values you will use in all your trials (control/value, Ex: blade material/cardstock).

Blade Material	/	Cardstock	Dowel Palcement	/	1.5 cm
Blade Number	/	3	Fan Distance	/	50 cm
Weight Number	/	6	Fan Speed	/	3 (high)
Weight Placement	/	6 cm			

SciTrek Member Approval: SL

8

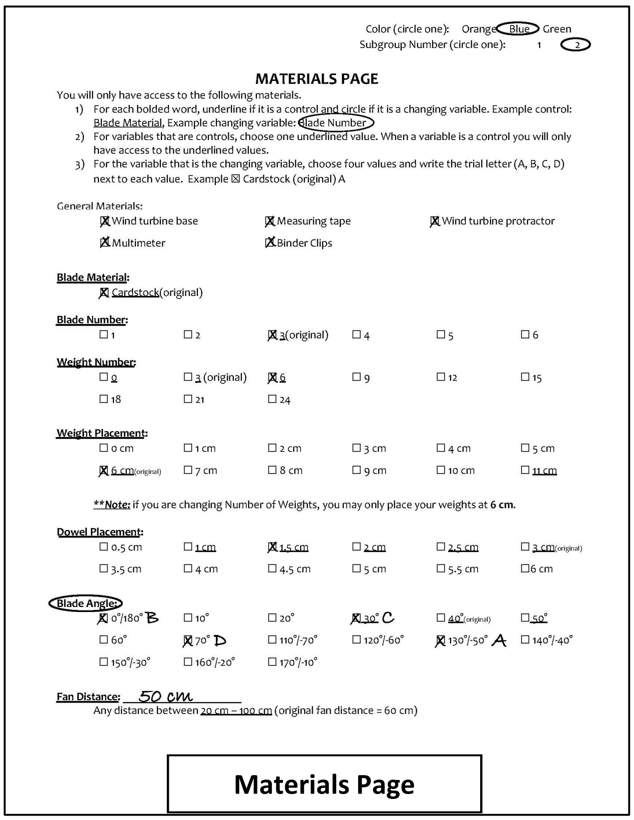
Materials Page:
(5 minutes – Subgroups – SciTrek Volunteers)

Have subgroups underline their controls and circle their changing variable on the materials page. Then, have them use the materials page to choose the values for their controls and changing variable. For the changing variable values, have students write the trial letter (A, B, C, D) next to the value they select. Ask students, “Why did you choose the values you did for your controls and changing variable? Will these values make it easier or harder to answer your question?”

Make sure students have only chosen from the underlined values for their controls on the materials page. An example filled-out materials page is shown below (left).

Experimental Set-Up:
(10 minutes – Subgroups – SciTrek Volunteers)

Have subgroups use their materials page to fill in their experimental set-ups (notebook, page 8). There will be one control blank that will not come from the materials page. For this control students should write "fan speed/3 (high)." When you sign off on their experimental set-ups, ensure that all students within a subgroup have the same trial letters corresponding to the same changing variable values; then, collect the materials page and verify that it is filled out correctly and completely. Filling out the materials page is essential for students to obtain the correct materials for their experiments on Day 4. An example filled out experimental set-up is shown below (right).



Color (circle one): Orange Blue Green
Subgroup Number (circle one): 1 2

MATERIALS PAGE

You will only have access to the following materials.

1) For each bolded word, underline if it is a control and circle if it is a changing variable. Example control: Blade Material, Example changing variable: Blade Number
2) For variables that are controls, choose one underlined value. When a variable is a control you will only have access to the underlined values.
3) For the variable that is the changing variable, choose four values and write the trial letter (A, B, C, D) next to each value. Example ☒ Cardstock (original) A

General Materials:
☒ Wind turbine base ☒ Measuring tape ☒ Wind turbine protractor
☒ Multimeter ☒ Binder Clips

Blade Material:
☒ Cardstock(original)

Blade Number:
☐ 1 ☐ 2 ☒ 3(original) ☐ 4 ☐ 5 ☐ 6

Weight Number:
☐ 0 ☐ 3 (original) ☒ 6 ☐ 9 ☐ 12 ☐ 15
☐ 18 ☐ 21 ☐ 24

Weight Placement:
☐ 0 cm ☐ 1 cm ☐ 2 cm ☐ 3 cm ☐ 4 cm ☐ 5 cm
☒ 6 cm(original) ☐ 7 cm ☐ 8 cm ☐ 9 cm ☐ 10 cm ☐ 11 cm

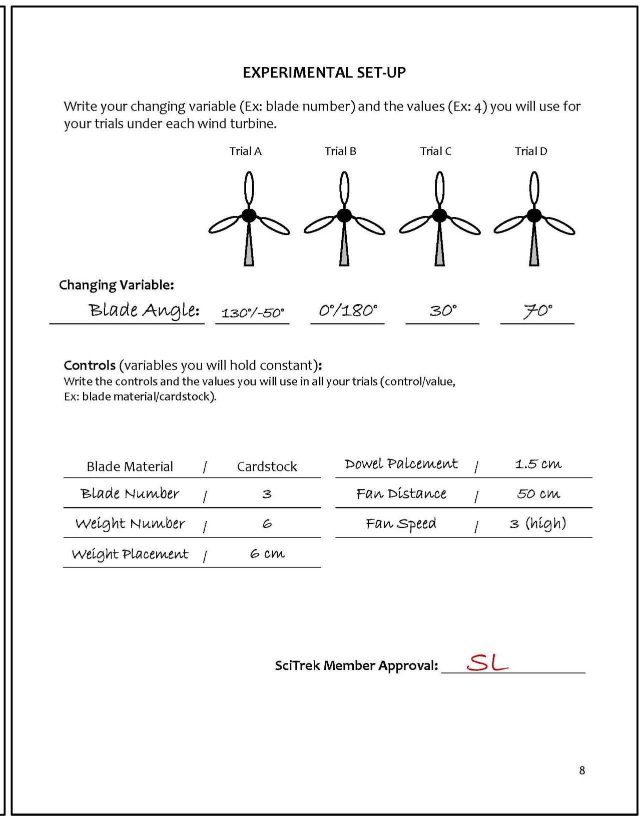
***Note:** if you are changing Number of Weights, you may only place your weights at **6 cm**.

Dowel Placement:
☐ 0.5 cm ☐ 1 cm ☒ 1.5 cm ☐ 2 cm ☐ 2.5 cm ☐ 3 cm(original)
☐ 3.5 cm ☐ 4 cm ☐ 4.5 cm ☐ 5 cm ☐ 5.5 cm ☐ 6 cm

Blade Angle:
☒ 0°/180° B ☐ 10° ☐ 20° ☒ 30° C ☐ 40°(original) ☐ 50°
☐ 60° ☒ 70° D ☐ 110°/-70° ☐ 120°/-60° ☒ 130°/-50° A ☐ 140°/-40°
☐ 150°/-30° ☐ 160°/-20° ☐ 170°/-10°

Fan Distance: 50 cm
Any distance between 20 cm – 100 cm (original fan distance = 60 cm)

Materials Page



EXPERIMENTAL SET-UP

Write your changing variable (Ex: blade number) and the values (Ex: 4) you will use for your trials under each wind turbine.

Changing Variable:

	Trial A	Trial B	Trial C	Trial D
Blade Angle:	130°/-50°	0°/180°	30°	70°

Controls (variables you will hold constant)**:**
Write the controls and the values you will use in all your trials (control/value, Ex: blade material/cardstock).

Blade Material	/	Cardstock	Dowel Palcement	/	1.5 cm
Blade Number	/	3	Fan Distance	/	50 cm
Weight Number	/	6	Fan Speed	/	3 (high)
Weight Placement	/	6 cm			

SciTrek Member Approval: SL

8

Procedure Activity:
(23 minutes – Full Class – SciTrek Lead)

Tell students, "I have heard some great experiments being designed and I am excited to see the outcomes of your experiments. Now that you have determined your experimental set-ups, you are going to write procedures." Ask the class, "What is a procedure?" After listening to the students' answers make sure students understand that a procedure is **a set of steps to conduct an experiment**. Write this definition on page 10 of the class notebook for the students to copy.

Tell students, "In order to write a procedure, we need to make sure that we understand what information MUST be included in a procedure." Ask students, "What information do you think a complete procedure should have?" Make sure that students generate the following three items: *1) all values of the <u>controls</u> and the <u>changing variable</u>, 2) what <u>data</u> will be collected (measurements and observations), and 3) the steps listed in the order that they will be completed*. If students are having trouble generating these ideas, have them think back to the information they put into their questions, and experimental set-ups. Once students have generated these ideas, have them fill in the blanks in their notebooks with the underlined words above, while you fill in the values in the class notebook. Tell students, "To help us recognize control values, changing variable values, and data collection information in procedural steps, we will underline information about controls, circle information about changing variables, and box information about data collection." On the class notebook, underline the word controls, circle the words changing variable, and box the word data.

Tell students, "We also need to discuss items that MUST NEVER be included in a procedure." Ask students, "What information do you think a complete procedure should not have?" Make sure students generate the following three items: *1) extra or irrelevant information, 2) opinions about the experiment, and 3) incorrect values of controls or the changing variable*. Have students fill in the blanks in their notebooks with the underlined words above, while you fill in the values in the class notebook.

Note: If students need help understanding what it means to have opinions or irrelevant information in a procedure, you can give them the following example: a scientist was designing an experiment to test which laundry detergent will have the largest reduction in the size of grass stains on cotton. Below are examples of steps containing an opinion and irrelevant information:

> Step with an Opinion: Get three brands of good smelling laundry detergent A) Tide, B) Gain, C) All.
> Step with Irrelevant Information: Put on cotton pants and play soccer in them until you get a grass stain.

Experimental Considerations:

1. You will only have access to the materials on the materials page.
2. See the materials page for restrictions on experimental design.
3. When you start the fan, the wind turbine must be still and you may not push it.
4. When recording currents, wait until the wind turbine gets up to speed. Then, watch the multimeter for approximately 15 seconds and record the number you see most often.

Changing Variable (Independent Variable): Blade Angle

Discuss with your subgroup how you think your changing variable will affect the current produced by the wind turbine.

QUESTION

Question our subgroup will investigate:

- If we change the blade angle (insert changing variable (independent variable)), what will happen to the Current produced by the wind turbine (insert what you are measuring/observing (dependent variable))?

SciTrek Member Approval: SL

Get a materials page from your volunteer and fill it out before moving onto the experimental set-up.

7

SCIENTIFIC PRACTICES
Procedures

QUESTION

If we change the popcorn brand, what will happen to the number of kernels that pop?

EXPERIMENTAL SET-UP

Changing Variable:	Trial A	Trial B	Trial C	Trial D
Popcorn Brand:	Pop Secret	Orville	Smart Balance	Act II

Controls (variables you will hold constant)**:**

Microwave Level / High	Popcorn Color / Yellow
Time / 3 Minutes	Salt Amount / 220 mg
Container Type / Bag	Initial Number of Kernels / 200

Directions:
Step 1: Read each statement and underline controls, circle changing variables, and box information about data collection.
Step 2: Circle yes if the statement could be a correct step for a procedure about the question and experimental set-up above. If not, circle no.

		Could this be a procedure step?	
1.	Put the bag in the microwave on high for 3 minutes.	Yes	No
2.	Get 200 kernels of yellow A) Pop Secret, B) Orville, C) Smart Balance, D) Act II popcorn.	Yes	No
3.	Observe what happens.	Yes	No
4.	Put 200 kernels of yellow Pop Secret popcorn and 220 mg of salt in bag A.	Yes	No
5.	Get 200 kernels of different yellow popcorn brands.	Yes	No
6.	Count the number of kernels that have popped in each bag.	Yes	No
7.	Put the tasty popcorn in the microwave on high for 3 minutes.	Yes	No

Underline controls, circle changing variables, and box data collection.

11

Have students turn to page 11 in their notebooks while you put page 11 of the class notebook under the document camera. Tell students, "We are now going to look at a group of scientists' question and experimental set-up, then we will decide if the following seven statements would be appropriate procedural steps for those scientists' experiment. These steps are not meant to be a full procedure and are therefore not in any order. We are just trying to determine whether they could be correct steps in a procedure for this experiment." Go over the question, changing variable, changing variable values, controls, and control values, with the students.

Tell students, "The first thing you should do when looking at a possible procedural step is identify the information within that statement. You will do this by underlining any information about controls, circling information about the changing variable, and boxing information about data collection." To practice, have students look at the question on page 11, and tell you what should be underlined, circled, or boxed. Within the question, students should circle *popcorn brand* and box *number of kernels*. Once they have determined what information is in the step, they will have to check whether the statement could be a possible procedural step by looking at the information in the question and experimental set-up. If the statement could be a possible procedural step, they will circle *Yes*, if not, they will circle *No*. Tell students, "We will now go over all of the statements together."

Below are the explanations and answers to numbers 1-7 on page 11.

1. Put the bag in the microwave on high for 3 minutes.

What should be underlined, circled, and/or boxed?

Bag, *high*, and *3 minutes*, should be underlined.

Are there any opinions, incorrect, or extra/irrelevant information, in this statement?

No.

What is this step about?

This step is about the bag of popcorn that will be microwaved.

Is there any other information which should have been included in this step?

No.

Could this be a correct procedural step?

Yes (have students circle *Yes*).

2. Get 200 kernels of yellow A) Pop Secret, B) Orville, C) Smart Balance, D) Act II popcorn.

What should be underlined, circled, and/or boxed?

200, and *yellow*, should be underlined and *A) Pop Secret, B) Orville, C) Smart Balance, D) Act II* should be circled.

Are there any opinions, incorrect, or extra/irrelevant information, in this statement?

No.

What is this step about?

This step is about gathering the different popcorn needed to complete the experiment.

Is there any other information which should have been included in this step?

No.

Could this be a correct procedural step?

Yes (have students circle *Yes*).

3. Observe what happens.

What should be underlined, circled, and/or boxed?

Observe should be boxed.

Are there any opinions, incorrect, or extra/irrelevant information, in this statement?

No.

What is this step about?

This step is about data collection.

Is there any other information which should have been included in this step?

Yes, this step does not include what data will be collected. Ask students, "What data should be collected to answer the scientists' question?" Students should reply, "The number of kernels that pop for each type of popcorn."

Could this be a correct procedural step?

No (have students circle *No*).

4. Put 200 kernels of yellow Pop Secret popcorn and 220 mg of salt in bag A.

What should be underlined, circled, and/or boxed?

200, *yellow*, and *220 mg*, should be underlined and *Pop Secret* should be circled.

Note: Sometimes the students will tell you to underline *bag*. This is fine, but is not necessary if they don't bring it up.

Are there any opinions, incorrect, or extra/irrelevant information, in this statement?

No.

What is this step about?

Putting the needed materials into the bag to complete the experiment.

Is there any other information which should have been included in this step?

No. Students may bring up that only one changing variable value is listed. Ask students, "Could the rest of the values have been listed in other steps?" They should answer yes, therefore, this information does not need to be included.

Could this be a correct procedural step?

Yes (have students circle *Yes*).

5. Get 200 kernels of different yellow popcorn brands.

What should be underlined, circled, and/or boxed?

200, and *yellow*, should be underlined and *popcorn brands* should be circled.

Are there any opinions, incorrect, or extra/irrelevant information, in this statement?

No.

What is this step about?

Gathering the popcorn that will be used in the experiment.

Is there any other information which should have been included in this step?

Yes, this step does not include the brands of popcorn that will be used. Since this information is missing, scientists who attempt to perform this experiment may use different brands from one another.

Could this be a correct procedural step?

No (have students circle *No*).

6. Count the number of kernels that have popped in each bag.

What should be underlined, circled, and/or boxed?

Bag should be underlined and *number of kernels* should be boxed.

Note: It is also acceptable to box the entire statement since the whole step is about data collection.

Are there any opinions, incorrect, or extra/irrelevant information, in this statement?

No.

What is this step about?

This step is about data collection.

Is there any other information which should have been included in this step?

No. The step is about data collection and includes what data will be collected.

Could this be a correct procedural step?

Yes (have students circle *Yes*).

7. Put the tasty popcorn in the microwave on high for 3 minutes.

What should be underlined, circled, and/or boxed?

High, and *3 minutes* should be underlined.

Are there any opinions, incorrect, or extra/irrelevant information, in this statement?

Yes, the word tasty is an opinion and should not be included in a procedure.

Could this be a correct procedural step?

No (have the students circle *No*).

Wrap-Up:
(2 minutes – Full Class – SciTrek Lead)

Tell students, "Next session, you will write a procedure for your experiment. All of your experiments will help us answer the class question: What variables affect the current produced by a wind turbine?"

Clean-Up:

1. Collect notebooks with attached nametags.
2. Place materials into your group box and bring them back to UCSB.

Day 3: Procedure Activity/Procedure

Schedule:

Introduction (SciTrek Lead) – 3 minutes
Procedure Activity (SciTrek Lead) – 25 minutes
Procedure Discussion/Procedure (SciTrek Lead/SciTrek Volunteers) – 30 minutes
Wrap-Up (SciTrek Lead) – 2 minutes

Materials:

(3) Volunteer Boxes:

- ☐ Nametags
- ☐ Volunteer lab coat
- ☐ (2) Red pens
- ☐ Notebooks
- ☐ (2) Pencils
- ☐ Paper notepad
- ☐ Volunteer instructions

Lead Box:

- ☐ (3) Extra notebooks
- ☐ (2) Pencils
- ☐ Wind turbine protractor
- ☐ Lead instructions
- ☐ (2) Red pens
- ☐ Hub with one dowel
- ☐ Wind turbines picture packet
- ☐ (2) Wet erase markers
- ☐ Cardstock blade
- ☐ Lead lab coat
- ☐ (2) Black pen
- ☐ Binder clip
- ☐ Time card
- ☐ Paper notepad
- ☐ Weight (6 washers)

Notebook Pages:

SCIENTIFIC PRACTICES
Procedures

Directions: Read the following procedure that is based on the question and experimental set-up on page 11 and underline controls, circle changing variables, and box data collection. If any controls are missing or incorrect, add the correct values to the procedure. Remove any extra or irrelevant information from the procedure by crossing it out. If any steps are out of order, draw an arrow (↔) to indicate the correct order.

PROCEDURE

1. Get 200 kernels of yellow A) Pop Secret, B) Orville, C) Smart Balance, D) Act II popcorn.
2. Put each bag in the microwave on high for 3 minutes.
3. Put the popcorn and ~~250 mg~~ 220 mg of salt into four separate bags.
4. Count the $\boxed{\text{number of kernels}}$ that popped in each bag.
5. ~~Eat the popcorn.~~
6. ~~Have fun.~~

12

SCIENTIFIC PRACTICES
Procedures

Directions: Read the following procedure and underline controls, circle changing variables, and box information about data collection.

PROCEDURE

1. Hang a 50 cm string.
2. Attach a metal ball with a mass of A) 20 g, B) 30 g, C) 40 g and circumference of 20 cm to the string.
3. Pull ball back 30 cm from resting point and drop.
4. Measure the $\boxed{\text{time}}$ it takes the balls to complete one swing.

13

PROCEDURE

Procedure Note:
Make sure to include all values of your changing variable in the procedure. Ex: For a subgroup that decided to change blade type one step would be: Get 3 A) metal, B) styrofoam, C) cardstock, and D) tissue paper blades.).

1. Get 3 cardstock blades.
2. Attach 6 weights at 6 cm on the blade.
3. Attach the blades to hub at 1.5 cm and rotate the blades to A) 130°/-50°, B) 0°/180° C) 30°, and D) 70° then, attach hub to base.
4. Set wind turbine 50 cm from fan.
5. Turn fan on speed 3 (high).
6. Measure the $\boxed{\text{current}}$ in mA, produced by the wind turbine.

In your procedure underline controls, circle changing variables, and box data collection. 9

Preparation:

SciTrek Lead:

1. Make sure volunteers are passing out notebooks.
2. Set up the document camera for the procedure activity (notebook, pages 12-13) and procedure (notebook, page 9).
3. Have a hub with one dowel, cardstock blade, and weight, available to show students during the procedure discussion/procedure.

SciTrek Volunteers:

1. Pass out notebooks/nametags.

Note: Pass out notebooks to students. If needed, students will move to their subgroups spots after the procedure activity.

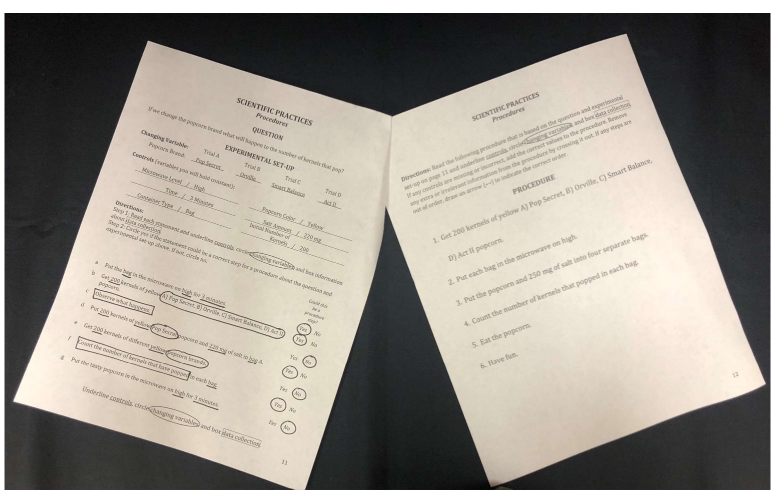
Introduction:
(3 minutes – Full Class – SciTrek Lead)

If students are not in their subgroups, tell them, “You will move to your subgroups after the procedure activty.”

Ask the class, “What is the class question we are investigating?” Students should reply, “What variables affect the current produced by a wind turbine?” Tell them, “Today, you are going to get to write procedures for your experiments.” Ask students, “What is a procedure?” Students should reply, “A set of steps to conduct an experiment.”

Procedure Activity:
(25 minutes – Full Class – SciTrek Lead)

Tell students, “We are now going to look at a complete procedure for the experimental set-up that we were working with last session.” Show students the experimental set-up and review the question, changing variable, and controls (notebook, page 11). Tell students, “Last session, we looked at individual steps to see if they could be correct for the given question and experimental set-up, today we are going to correct a possible complete procedure for the same experiment.” Have students open their notebook, so they can see both pages 11 and 12, as seen in the picture below. Turn the class notebook to page 12.



Read each step of the procedure, and have students tell you what you should underline/circle/box (controls/changing variable/data collection) for each step (shown below). Ask students, “What should you include in a procedure?" Students may answer with any of the following listed in bold below. Cover each of them in the order they are brought up, not the listed order, but make sure to cover all of them by the end of the conversation.

A complete procedure must have all values of the controls and the changing variable.

Ask students, "Are all control values listed in the procedure?" Go through the list of controls and put a check by them on the experimental set-up as students identify them in the procedure. Students should notice that one of the controls, *time*, is not included. Ask students, "What step should the time be included in?" They should reply, "Step 2." Have students use a caret to write in 3 minutes after *on high* in step 2 so that it reads: *Put each bag in the microwave on high for 3 minutes*.

A complete procedure must have the data that will be collected (measurements/observations).

Ask students, "Is the data that will be collected listed in the procedure and if so, in what step?" Students should reply, "Yes, the data that will be collected is listed in step 4." Students should notice that all of the information needed in step 4 is present, and that this aspect of the procedure is complete.

A complete procedure must have the steps listed in the order that they will be completed.

Ask students, "Are the steps listed in the correct order?" Go through the procedural steps once more and the students should notice that steps 2 and 3 are listed in an incorrect order. Draw a double-headed arrow to indicate that steps 2 and 3 should be switched with one another.

A complete procedure must never have extra or irrelevant information.

Ask students, "Is there any extra or irrelevant information about the experiment in this procedure?" Students should notice that *eating the popcorn* (step 5) does not help the scientist answer their original question, so this step is irrelevant. Have students cross out this step.

A complete procedure must never have opinions about the experiment.

Ask students, "Are there any opinions in the procedure?" Students should notice that step 6, *Have fun,* is an opinion. Students should say that not every scientist who performs this experiment will think that popping different brands of popcorn is fun, therefore, this is an opinion. Because opinions cannot be tested, this step is incorrect. Have students cross out this step.

A complete procedure must never have incorrect values of the controls or the changing variable.

Ask students, "Are all control and changing variable values correct in the procedure?" Go through the list of controls and confirm that all but one of the controls is correct. Students should identify that the salt amount listed in step 3 is incorrect. Have students cross out *250 mg,* and write "220 mg."

SCIENTIFIC PRACTICES
Procedures

Directions: Read the following procedure that is based on the question and experimental set-up on page 11 and underline controls, circle changing variables and box data collection. If any controls are missing or incorrect, add the correct values to the procedure. Remove any extra or irrelevant information from the procedure by crossing it out. If any steps are out of order, draw an arrow (↔) to indicate the correct order.

PROCEDURE

1. Get 200 kernels of yellow A) Pop Secret, B) Orville, C) Smart Balance, D) Act II popcorn.
2. Put each bag in the microwave on high. for 3 minutes.
3. Put the popcorn and ~~250 mg~~ 220 mg of salt into four separate bags.
4. Count the number of kernels that popped in each bag.
5. ~~Eat the popcorn.~~
6. ~~Have fun.~~

12

SCIENTIFIC PRACTICES
Procedures

Directions: Read the following procedure and underline controls, circle changing variables and box information about data collection.

PROCEDURE

1. Hang a 50 cm string.
2. Attach a metal ball with a mass of A) 20 g, B) 30 g, C) 40 g and circumference of 20 cm to the string.
3. Pull ball back 30 cm from resting point and drop.
4. Measure the time it takes the balls to complete one swing.

13

Have students turn to page 13 in their notebooks. Turn the class notebook to page 13.

Tell students, “Now you will look at a procedure and try to find the control values, changing variable values, and what data was collected, when you do not have a question or experimental set-up to refer to.”

Read the procedure to the students. After each step, have students tell you what they think should be underlined, circled, or boxed (controls, changing variable, or data collection). The following should be underlined: *50 cm*, *metal*, *20 cm*, *30 cm*, *drop*, and *one swing*. The following should be circled: *A) 20 g, B) 30 g, C) 40 g*. The following should be boxed: *time*. Tell students, “Annotating the procedure has helped me determine the question the scientists were investigating is: If we change the ball mass, what will happen to the time it takes the ball to complete one swing?”

Procedure Discussion/Procedure:
(30 minutes – Full Class/Subgroups – SciTrek Lead/SciTrek Volunteers)

Tell students, “In order to give you an example of how to write a procedure for your experiments, we will write a procedure together for the class experiment. Have students open their notebooks to page 9. Place the class notebook under the document camera open to page 9. Have the picture packet open to page 4 so you are able to quickly flip back and forth between the two. Ask students, “What is the class research question?” Students should reply, “If we change the blade material, what will happen to the current produced by the wind turbine?” Ask students, “What must a complete procedure have?” Make sure students come up with the following three items: 1) all values of the controls and changing variable, 2) the data that will be collected, and 3) the steps listed in the order they will be completed.

Go over the experimental set-up (picture packet, page 4) from Day 2 for the class experiment. Tell students, “I will write down a step of the procedure for the class experiment, then you will write a step for your experiments. Remember, you should **not** copy the class procedure into your notebooks.”

Inform students, "Your hubs will come with the correct number of dowels in them." Show them the example hub with one dowel from the lead box. Ask them, "Knowing this, what should the first step of the procedure be about?" Lead them to understand that it should be about getting the blades. Then, turn to the experimental set-up (picture packet, page 4) and ask them, "Which controls or changing variable should be included in the first step?" Put a small horizontal line next to each one they suggest (*blade material* and *blade number*). Ask students, "Can someone put these variable values into a complete sentence for me?" Possible student response: get 3 A) paper, B) Kleenex, C) metal, and D) Styrofoam blades. Write the step in the class notebook, then ask students, "What should we underline, circle, or box in this step?" Then underline/circle/box the correct information. (Get 3 A) paper, B) Kleenex, C) metal, and D) Styrofoam blades.) Tell students, "In your subgroups you will now write the first steps of your procedures, focusing only on blade material and blade number as well as underline, circle, and box the correct information." Give students a few minutes to work in their subgroups to finish step one. While subgroups are working, their volunteers should help them. If needed, subgroups can dictate the step to volunteers, and they can write it on the paper notepad found in their box and give it to them to copy into their notebooks. If a volunteer is working with multiple subgroups, they should help the subgroup with a changing variable, in the current step, first.

Once students have written their first step, ask them, "What should the second step in the procedure be about?" Lead them to understand that it should be about attaching the weights to the blades. Then, turn to the experimental set-up (picture packet, page 4). Turn the horizontal lines, next to the variables used in step 1, into plus signs by drawing a vertical line through them. Tell students, "This indicates these variables have already been used in the procedure." Ask students, "Which controls or changing variable should be included in the second step?" Put a small horizontal line next to each one they suggest (weight number and weight placement). Ask students, "Can someone put these variable values into a complete sentence for me?" Possible student response: attach 3 weights at 6 cm on the blade. Write the step in the class notebook, then ask students, "What should we underline, circle, or box in this step?" Then underline/circle/box the correct information. (Attach 3 weights at 6 cm on each blade.) Tell students, "In your subgroups you will now write the second steps for your procedures, focusing only on weight number and weight placement as well as underline, circle, and box the correct information."

Once students have written their second step, ask them, "What should the third step in the procedure be about?" Lead them to understand that it should be about attaching the blades to the hub. Then, turn to the experimental set-up (picture packet, page 4). Turn the horizontal lines next to the variables used in step 2 into plus signs. Ask students, "Which controls or changing variable should be included in the third step?" Put a small horizontal line next to each one they suggest (blade angle and dowel placement). Ask students, "Can someone put these variable values into a complete sentence for me?" Possible student response: attach the blades to the hub at 1.5 cm and rotate the blades to 30°, then attach the hub to the base. Write the step in the class notebook, then ask students, "What should we underline, circle, or box in this step?" Then underline/circle/box the correct information. (Attach the blades to the hub at 1.5 cm and rotate the blades to 30°, then attach the hub to the base.) Tell students, "In your subgroups you will now write the third steps for your procedures focusing only on blade angle and dowel placement as well as underline, circle, and box the correct information."

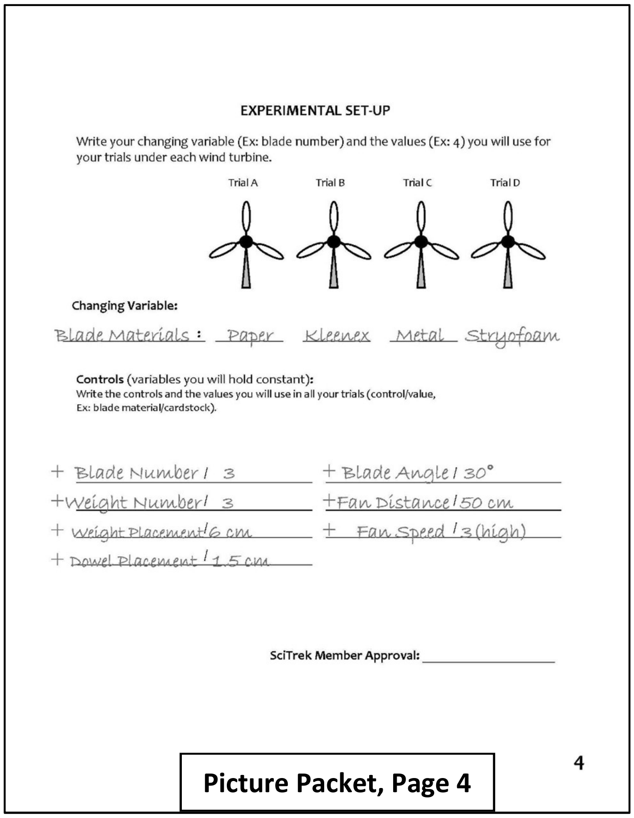
Once students have written their third step, ask them, "What should the fourth step in the procedure be about?" Lead them to understand that it should be about placing the wind turbine and the fan at the right position. Then, turn to the experimental set-up (picture packet, page 4). Turn the horizontal lines next to the variables used in step 3 into plus signs. Ask students, "Which controls or changing variable should be included in the fourth step?" Put a small horizontal line next to each one they suggest (fan distance). Ask students, "Can someone put this variable value into a complete sentence for me?" Possible student response: set the wind turbine 50 cm from the fan. Write the step in the class notebook, then ask students, "What should we underline, circle, or box in this step?" Then underline/circle/box the correct information. (Set the wind turbine 50 cm from the fan.) Tell students, "In your subgroups, you will now write the fourth steps of your procedures, focusing only on fan distance as well as underline, circle, and box the correct information."

Once students have written their fourth step, ask them, "What should the fifth step in the procedure be about?" Lead them to understand that it should be about turning the fan on. Then, turn to the experimental set-up (picture packet, page 4). Turn the horizontal lines next to the variable used in step 4 into a plus sign. Ask students, "Which controls or changing variable should be included in this step?" Put a small horizontal line next to the one they suggest (fan speed). Ask students, "Can someone put this variable value into a complete sentence for me?" Possible student response: turn the fan on speed 3 (high). Write the step in the class notebook, then ask students, "What should we underline, circle, or box in this step. Then underline/circle/box the correct information. (Turn the fan on speed 3 (high).) Ask students, "Are we all turning the fan on speed 3?" Student will reply, "Yes." Tell them, "Since we are all doing the same thing for this step, we can all copy this exactly as it is into our notebooks." Give students a couple minutes to write this in their notebooks, and then underline/circle/box the correct information.

Once students have written their fifth steps, ask them, "What should the sixth step in the procedure be about?" Lead them to understand that it should be about data collection. Ask students, "Can someone tell me, in a complete sentence, what we will record at the end of the experiment?" Possible student response: measure the current in mA produced by the wind turbine. Write the step in the class notebook, then ask students, "What should we underline, circle, or box in this step?" (Measure the current in mA produced by the wind turbine). Ask students, "Will all subgroups measure the current the wind turbine produces?" Students will reply, "Yes." Tell them, "Since we are all doing the same thing for this step, we can all copy this exactly as it is into our notebooks." Give students a couple minutes to write this in their notebook, and then underline/circle/box the correct information.

Flip back to page 4 of the picture packet. Turn the horizontal line next to the variable used in step 5 into a plus sign and ask students, "Do we have all the variable values in our procedure?" Students should reply, "Yes." This indicates that the procedure is completed.

Below is what the class experimental set-up should look like with plus signs next to all controls and changing variable values, to indicate they have been included in the procedure. In addition, there is an example of a subgroup's procedure.



EXPERIMENTAL SET-UP

Write your changing variable (Ex: blade number) and the values (Ex: 4) you will use for your trials under each wind turbine.

Trial A | Trial B | Trial C | Trial D

Changing Variable:

Blade Materials : Paper | Kleenex | Metal | Stryofoam

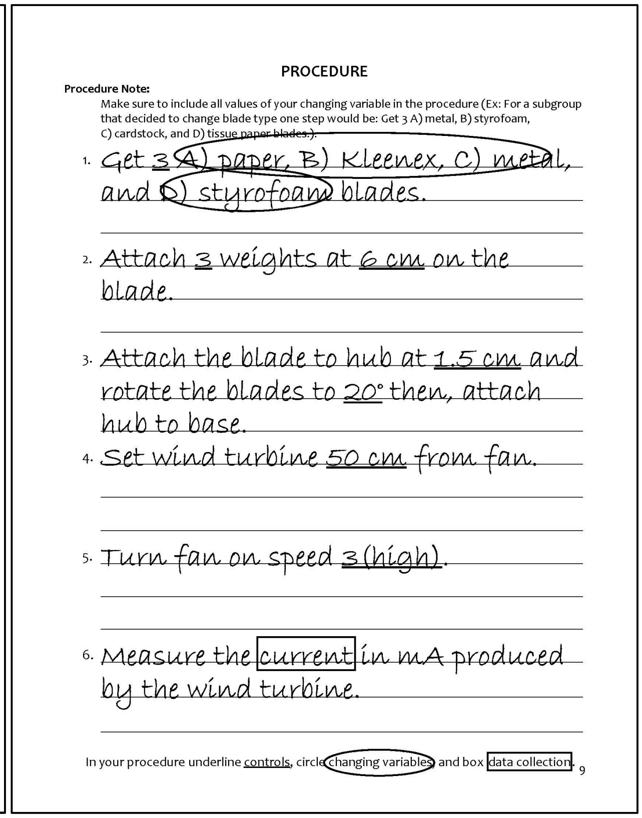
Controls (variables you will hold constant):
Write the controls and the values you will use in all your trials (control/value, Ex: blade material/cardstock).

+ Blade Number / 3
+ Blade Angle / 30°
+ Weight Number / 3
+ Fan Distance / 50 cm
+ Weight Placement / 6 cm
+ Fan Speed / 3 (high)
+ Dowel Placement / 1.5 cm

SciTrek Member Approval: ________________

4

Picture Packet, Page 4

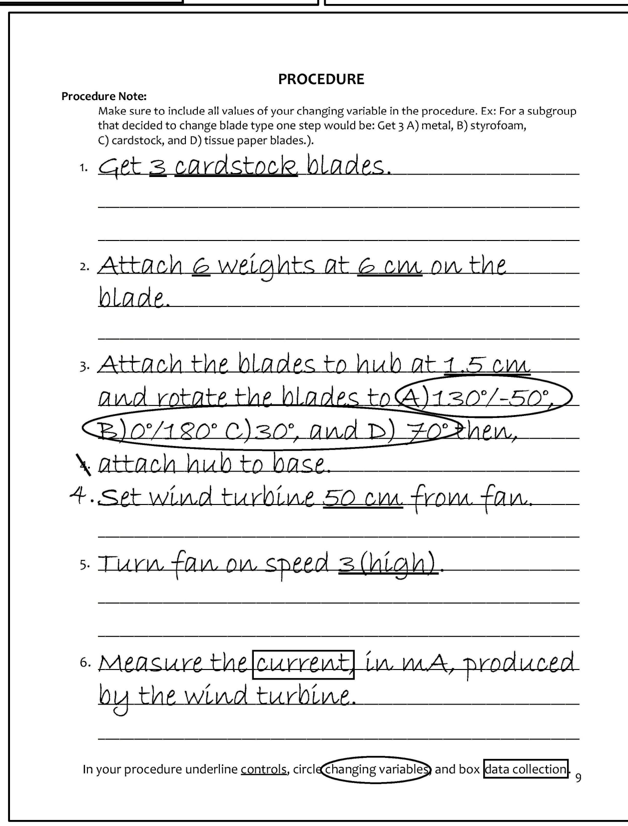


PROCEDURE

Procedure Note:
Make sure to include all values of your changing variable in the procedure (Ex: For a subgroup that decided to change blade type one step would be: Get 3 A) metal, B) styrofoam, C) cardstock, and D) tissue paper blades.).

1. Get 3 A) paper, B) Kleenex, C) metal, and D) styrofoam blades.
2. Attach 3 weights at 6 cm on the blade.
3. Attach the blade to hub at 1.5 cm and rotate the blades to 20° then, attach hub to base.
4. Set wind turbine 50 cm from fan.
5. Turn fan on speed 3 (high).
6. Measure the $\boxed{\text{current}}$ in mA produced by the wind turbine.

In your procedure underline controls, circle changing variables, and box data collection. 9



PROCEDURE

Procedure Note:
Make sure to include all values of your changing variable in the procedure. Ex: For a subgroup that decided to change blade type one step would be: Get 3 A) metal, B) styrofoam, C) cardstock, and D) tissue paper blades.).

1. Get 3 cardstock blades.
2. Attach 6 weights at 6 cm on the blade.
3. Attach the blades to hub at 1.5 cm and rotate the blades to A) 130°/-50°, B) 0°/180° C) 30°, and D) 70° then, ~~4.~~ attach hub to base.
4. Set wind turbine 50 cm from fan.
5. Turn fan on speed 3 (high).
6. Measure the $\boxed{\text{current}}$ in mA, produced by the wind turbine.

In your procedure underline controls, circle changing variables, and box data collection. 9

If there is additional time, have the groups complete the results table. For details on how to do this, see Day 4.

Wrap-Up:
(2 minutes – Full Class – SciTrek Lead)

Tell students, "Next session, you will perform your experiments, and graph your results."

Clean-Up:

1. Collect notebooks with attached nametags.
2. Place materials into your group box and bring them back to UCSB.

Day 4: Results Table/Experiment/Graph

Schedule:

Introduction (SciTrek Lead) – 15 minutes
Results Table (SciTrek Volunteers) – 5 minutes
Experiment (SciTrek Volunteers) – 28 minutes
Graph (SciTrek Volunteers) – 10 minutes
Wrap-Up (SciTrek Lead) – 2 minutes

Materials:

(3) Volunteer Boxes:

☐ Nametags
☐ Notebooks
☐ Volunteer instructions
☐ Picture of experimental set-up
☐ Volunteer lab coat
☐ (2) Pencils

(2) Ziploc bags (two gallon size), labeled (with subgroup number), with the following:

☐ Masking tape page with needed pieces of tape
☐ (Number of blades + 4) Binder clips
☐ Cardstock blades
☐ Weights
☐ Wind turbine protractor
☐ Hub(s)
☐ Multimeter
☐ 152 cm measuring tape

Materials needed based on changing variable selected.

Changing Variable	Hubs	Blades	Weights
Number of Blades	4	6	6
Blade Angle Dowel Placement	2	6	6
Turbine Angle Fan Distance	1	3	3
Number of Weights Weight Placement	2	12	12

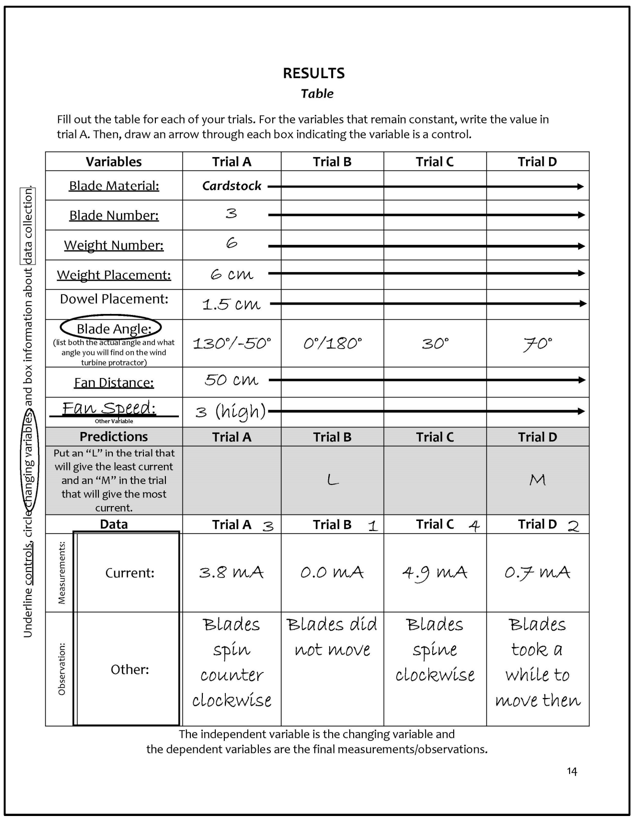
Other Supplies:

☐ (2) Bags with 3 fans and 2 extension cords each
☐ Bag with 7 wind turbine bases

Lead Box:

- ☐ (3) Extra notebooks
- ☐ Lead instructions
- ☐ Wind turbines picture packet
- ☐ Picture of experimental set-up
- ☐ Lead lab coat
- ☐ Time card
- ☐ (2) Pencils
- ☐ (2) Wet erase markers
- ☐ (2) Black pen
- ☐ Hub with 1 dowel and attached blade
- ☐ Masking tape
- ☐ (2) Masking tape pages with needed pieces of tape
- ☐ (4) Wind turbine protractors
- ☐ (2) Multimeters
- ☐ Ziploc bag with (16) stacks of 3 weights, (9) stacks of 6 weights and (10) cardstock blades, (2) 152 cm measuring tapes, (10) binder clips, (2) hubs with 3 attached dowels

Notebook Pages:


RESULTS

Table

Fill out the table for each of your trials. For the variables that remain constant, write the value in trial A. Then, draw an arrow through each box indicating the variable is a control.

Underline controls, circle changing variables, and box information about data collection.

Variables	Trial A	Trial B	Trial C	Trial D
Blade Material:	Cardstock →			
Blade Number:	3 →			
Weight Number:	6 →			
Weight Placement:	6 cm →			
Dowel Placement:	1.5 cm →			
Blade Angle: (list both the actual angle and what angle you will find on the wind turbine protractor)	130°/-50°	0°/180°	30°	70°
Fan Distance:	50 cm →			
Fan Speed: (Other Variable)	3 (high) →			
Predictions	**Trial A**	**Trial B**	**Trial C**	**Trial D**
Put an "L" in the trial that will give the least current and an "M" in the trial that will give the most current.		L		M
Data	**Trial A** 3	**Trial B** 1	**Trial C** 4	**Trial D** 2
Measurements: Current:	3.8 mA	0.0 mA	4.9 mA	0.7 mA
Observation: Other:	Blades spin counter clockwise	Blades did not move	Blades spine clockwise	Blades took a while to move then

The independent variable is the changing variable and the dependent variables are the final measurements/observations.

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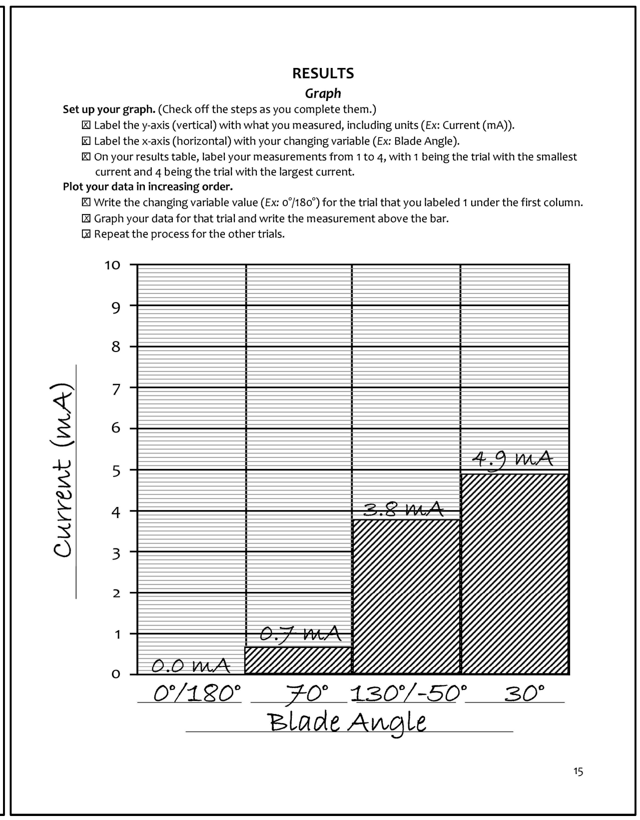
RESULTS

Graph

Set up your graph. (Check off the steps as you complete them.)

- ☒ Label the y-axis (vertical) with what you measured, including units (*Ex:* Current (mA)).
- ☒ Label the x-axis (horizontal) with your changing variable (*Ex:* Blade Angle).
- ☒ On your results table, label your measurements from 1 to 4, with 1 being the trial with the smallest current and 4 being the trial with the largest current.

Plot your data in increasing order.

- ☒ Write the changing variable value (*Ex:* 0°/180°) for the trial that you labeled 1 under the first column.
- ☒ Graph your data for that trial and write the measurement above the bar.
- ☒ Repeat the process for the other trials.

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Preparation:

SciTrek Lead:

1. Make sure volunteers are setting out notebooks.
2. Make sure volunteers are setting up for the experiment.
3. Set up the document camera for the filled-out results table (picture packet, page 5) and graph (notebook, page 15).
4. Have hub with one dowel, cardstock blade, binder clip, and wind turbine protractor, available to show students during the Introduction.

SciTrek Volunteers:

1. Set out notebooks/nametags.
2. Set-up experiments in separate areas on the floor.
   a. Plug the fans in, and set the wind turbine bases next to the fans. Make sure the backs of the fans are not put up against a wall or another fan.
   b. Connect the multimeter to the wind turbine by clipping the alligator clips to the wires on the wind turbine base. The red wire connects to the red wire, and the black wire connects to the black wire. The red wire of the multimeter must be clipped to the red wire of the turbine base **after** the resistor (on the loose end of the wire). Make sure the red and black wires do not touch. For a picture of how this is done, refer to the Day 1 set-up.
   c. Set out the bag of materials next to the wind turbine base, and fan.
   d. Leave multimeter, and fan, off.

Note: Set notebooks where students will sit during the module, even if another student is currently at that desk. If needed, students will move to these spots after the Introduction.

Introduction:
(15 minutes – Full Class – SciTrek Lead)

If students are not in their subgroups, tell them, "A notebook will be put on your desk, which is not your notebook and you should not move it. You will move to your notebook after the Introduction."

Ask the class, "What is the class question we have been investigating?" Students should reply, "What variables affect the current produced by a wind turbine?"

Tell students, "Today, you will conduct your experiments to answer this question. However, before you start your experiments, you need to fill out the results table (some students might have completed this in the previous session)." Put the filled-out results table (picture packet, page 5, shown below) under the document camera. Tell students, "You should first underline controls, circle changing variables, and box information about data collection. For controls, you will write the control value in the *Trial A* box. Then, draw an arrow through the remaining trials' boxes. For the changing variable, you will write the changing variable value in each box." Show students both of these on the filled-out results table. Tell students, "Once you have filled out your results table, you will make predictions about which trial will produce the least/most current. You will write an 'L' in the box of the trial you think will produce the least current, and an "M" in the box of the trial you think will produce the most current. If you think all trials will produce the same current, you will write 'same' over all boxes. Once finished, you can raise your hands and you will be told where your materials are on the floor."

Ask students, "What was your first procedural step about?" Possible student response: getting the correct hub, and number of blades. Show students the hub with 1 blade as an example. Ask students, "What was the second procedural step about?" Possible student response: attaching the weights to the blades. Show students the premade weight stacks and tell them, "Weight stacks will be found in your bag of materials." Then, show students how to attach the appropriate number of weights to the blade in the correct place. You will do this by placing the bottom of the weight on the line of the blade which corresponds to the weight placement. Tell students, "Once the weight is in the correct position, you will tape the weight to the blade, with the tape found on a card in your bag of materials. The tape card also has instructions on how to tape the weights." Show students the tape card. One side is marked *first* with a diagram of a vertically taped weight, and the other side is marked *second* with a diagram of a horizontally taped weight. Ask students, "Which piece of tape should you use first?" Students should reply, "The tape on the side marked 'first.'" Use one of the 7 cm pieces of masking tape (from the *first* side) to vertically tape the example weight to the blade. Be sure to wrap the tape snuggly around the edges of the weight. Then, use a 10 cm piece of masking tape (from the *second* side) to horizontally tape the weight to the blade, making sure that the tape is wrapped snuggly around the weight, and the tape goes around the back of the blade.

Ask students, "What was your third procedural step about?" Possible student response: attaching the blades to the hub, and the correct placement and angle. Show them how to insert the straw (on the back of the blade) onto the dowel, and adjust the blade so that it is at the correct dowel placement using the markings on the dowel with the blade facing the front of the hub (the side with the knob). Place the example blade on the hub, and show students how to fix it to the dowel with a binder clip. The binder clip should be placed on the silver rectangle on the back of the straw. After placing the blade on the hub, remind students they will adjust the blade angle by using the wind turbine protractor. Show them how to use the protractor by inserting it onto the front side of the hub (the side with the knob). Tell students, "If the blade angle is less than 90°, you turn the blade so the blades pass 0°, 10°, etc. until the desired blade angle is reached. If the blade angle is greater than 90°, you turn the blade so that the blades pass 0°, -10°, etc. until the desired blade angle is reached. This will result in the number side of the blade always facing the fan. When adjusting the blade, you must keep your index finger on the binder clip and your thumb on the front of the blade so it doesn't come off." Tell students, "You will repeat this process for each blade on the hub, and then attach the hub to the wind turbine base."

Then, ask students, "What was your fourth procedural step about?" Possible student response: setting the wind turbine at the correct distance. Tell students, "Lay out the measuring tape so that it starts at the fan, and goes outwards. Then, position the turbine at the correct distance."

Ask students, "What was your fourth procedural step about?" Possible student response: turning the fan on. They should tell you the fan should be set to 3 (high). Tell students, "You cannot stand behind the fan while running the experiment." Then, ask them, "What was your last procedural step about?" Possible student response: recording the current the wind turbine produces. Ask students, "What units will we use to measure current?" Students should reply, "Milliamps." Remind students to include units when recording data. Tell students, "You will turn on the fan, and wait for the wind turbine to get up to speed. You should not push the blades to get them to spin. Then, you will watch the current values for approximately 15 seconds, and record the current (in milliamps) you see most often. In addition, you will record any other interesting observations. As soon as the first hub is assembled, you should attach it to the turbine, and record the current. The hub can then be disassembled so the parts can be used to construct other hubs."

Tell students, "When you remove a hub from the wind turbine, you should always have one hand on the wind turbine, with your thumb on the front washer, and pull the hub off with your other hand." Demonstrate how to do this. Tell them, "If you are having trouble removing or installing a hub, you should ask a volunteer for help."

Note: Students will have to reuse parts to make all the measurements. Below is a chart of the materials that will be given to students.

Changing Variable	Hubs	Blades
Number of Blades	4	6
Blade Angle Dowel Placement	2	6
Turbine Angle Fan Distance	1	3
Number of Weights Weight Placement	2	12

Tell students, "I have already run the class experiment, and collected the data." Ask students, "What is the class experimental question?" Students should reply, "If we change the blade material, what will happen to the current produced by a wind turbine?" Show students where you recorded the class experimental data.

Tell students, "Once you have collected your data, you will display your measurements on a graph." Show them how to make a graph using the class data, but make sure they **do not** copy this data into their notebooks; they will graph their own data. Take out the class results table (picture packet, page 5; below left), and put it under the document camera. Also, have the class notebook open to page 15. Point to the checklist at the top of page 15 of the class notebook and tell students, "In order to make a graph, you will need to follow the checklist at the top of this page."

Go through the checklist, and use the results table in the picture packet, to show students how to set up the graph and plat the data points.

Set up your graph. (Check off the steps as you complete them.)

Tell students, "First, we need to set up the graph, before we can plot the data."

☐ *Label the y-axis (vertical) with what you measured, including units (Ex: Current (mA)).*

Tell students, "Since the question is about the current produced by the wind turbine, I will graph current." Write "Current (mA)" on the y-axis of the graph. Have students look at the graph, and identify that each line on the graph represents 0.1 mA.

☐ *Label the x-axis (horizontal) with your changing variable (Ex: Blade Angle).*

Ask students, "What is the changing variable in this experiment?" Students should reply, "Blade material." Record "Blade Material" on the x-axis title.

☐ *On your results table, label your measurements from 1 to 4, with 1 being the trial with the smallest current and 4 being the trial with the largest current.*

Tell students, "Graphs are used to see how changing variables affect a measurement. One way to make it easier to find patterns is to graph the data in increasing order." Put the class results table (picture packet, page 5, shown below, left) under the document camera, and have students help determine the order in which the trials will be graphed (B, A, D, then C). Write the appropriate number by each trial. This is the step that both students and volunteers often forget, so emphasize its importance when completing it with the class.

Plot your data in increasing order.

Tell students, "Now that you have determined the order in which you will graph your data, you need to plot your data in increasing order. To do this, there are a few steps you need to follow."

☐ *Write the changing variable values (Ex: 0°/180°) for the trial that you labeled 1 under the first column.*

Ask students, "Which trial was labeled 1?" Students should reply, "Trial B." Then, ask them, "What should I write for the first column?" Students should reply, "Kleenex." Write "Kleenex" for the first trial in the class notebook.

☐ *Graph your data for that trial and write the measurement above the bar.*

Ask students, "What current should we graph for the first column?" Students should reply, "0 mA." Put your finger at zero, and tell students, "Tell me when to stop once I reach the appropriate level." Once you have reached the level, draw the line, write the numerical value over the line, and quickly shade below the line. Tell students, "Look how quickly I filled in the column. I challenge you to fill your graph in faster than I did, when you graph your own data."

☐ *Repeat the process for the other trials.*

Ask students, “What is the value for the changing variable for the trial we will graph next?” Students should reply, “Paper.” Write this in the next column. Ask students, “What is the current for this trial?” Students should reply, “0.3 mA.” Have students help you identify where 0.3 mA is, then, draw a line, and write the numerical value over the line. Repeat this process for the final two columns.

RESULTS

Table

Fill out the table for each of your trials. For the variables that remain constant, write the value in *Trial A*. Then, draw an arrow through each box indicating the variable is a control.

Underline controls, circle changing variables, and box information about data collection.

Variables	Trial A	Trial B	Trial C	Trial D
Blade Material:	Paper	Kleenex	Metal	Styrofoam
Blade Number:	3			
Weight Number:	3			
Weight Placement:	6 cm			
Dowel Placement:	1.5 cm			
Blade Angle: (list both the actual angle and what angle you will find on the wind turbine protractor)	30°			
Fan Distance:	50 cm			
Fan Speed: (Other Variable)	3 (high)			
Predictions	**Trial A**	**Trial B**	**Trial C**	**Trial D**
Put an “L” in the trial that will give the least current and an “M” in the trial that will give the most current.				
Data	**Trial A** 2	**Trial B** 1	**Trial C** 4	**Trial D** 3
Measurements: Current:	0.3 mA	0.0 mA	2.0 mA	1.9 mA
Observation: Other:	Blades bent	Blades ripped	Blades did not bend	Blades did not bend

The independent variable is the changing variable and the dependent variables are the final measurements/observations.

Picture Packet, Page 5

5

RESULTS

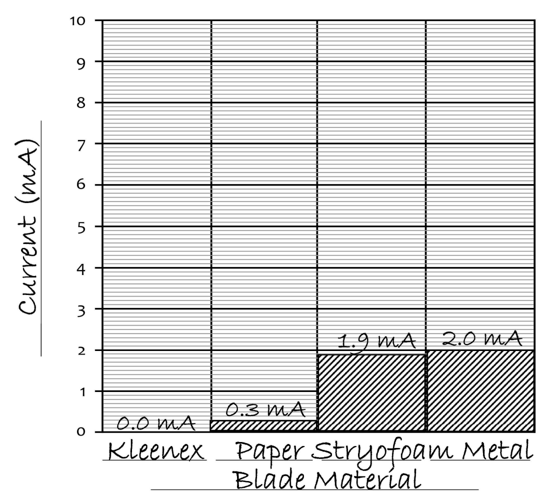
Graph

Set up your graph. (Check off the steps as you complete them.)

☒ Label the y-axis (vertical) with what you measured including units (*Ex:* Current (mA)).
☒ Label the x-axis (horizontal) with your changing variable (*Ex:* Blade Angle).
☒ On your results table, label your measurements from 1 to 4, with 1 being the trial with the smallest current and 4 being the trial with the largest current.

Plot your data in increasing order.

☒ Write the changing variable value (*Ex:* 0°/180°) for the trial that you labeled 1 under the first column.
☒ Graph your data for that trial and write the measurement above the bar.
☒ Repeat the process for the other trials.



15

Tell students, “You will now fill out your results tables and start your experiments. When you are done with your experiments, you can graph your results.”

Results Table:

(5 minutes – Subgroups – SciTrek Volunteers)

Have students underline the variables that are controls, circle the variable that is their changing variable, and box information about data collection. When writing the values make sure for controls, they only write the value of the control in the *Trial A* box, then, draw an arrow through the remaining trials’ boxes. For the changing variable, they should write the values in each trial’s corresponding box.

If a group is changing blade angle, and have selected any angles over 90°, have them record both the real angle, as well as the angle seen on the wind turbine protractor. For example, 110° would be recorded as 110°/-70°.

When students have finished, have them make predictions about how much current each wind turbine will produce in comparison to one another. Have them write “L” in the box of the trial they think will produce the least current and “M” in the box of the trial they think will produce the most current. They will leave two of the boxes empty. If they think all trials will produce the same current, have them write “same” over all of the boxes. It is okay if the students in a subgroup have different predictions. An example filled-out results table is shown in the Experiment section below (left).

Experiment:
(28 minutes – Subgroups – SciTrek Volunteers)

Once subgroups have completed the variables and predictions section of the results table, have them move to their supplies on the floor. If students are missing any of their experimental materials, the lead box has extra materials. The lead box also has extra wind turbine protractors you can give groups, if it will help them finish making their hubs faster.

Subgroups will only be given limited materials. The chart below shows the materials subgroups will be given. Therefore, as soon as subgroups have a hub constructed, they should use it to determine the current it will produce and then, disassemble it so they can use the parts to make additional hubs. For subgroups changing blade number, have them make and test the hub with the largest blade number first, then reuse the blades to construct hubs that have less blades.

Changing Variable	Hubs	Blades
Blade Number	4	6
Blade Angle Dowel Placement	2	6
Blade Angle Fan Distance	1	3
Weight Number Weight Placement	2	12

When subgroups are ready to measure the current, have students find a place around the set-up; ensure no students are sitting behind the fan and the wind turbine is stationary. Subgroups should then turn the multimeter to the boxed setting, followed by turning the fan on. Subgroups will wait for the wind turbine to get up to speed, then, record the current that appears most often over the course of approximately 15 seconds. Students should not push the blades to start them, even if they don't turn on their own. To remove the hub, students should put one hand on the wind turbine head with their thumb on the front washer, then use the other hand to pull on the hub. If students are struggling with this, remove the hub for them.

Subgroups changing the weight number, or weight placement, will take the most time. Help these groups first.

As soon as students finish all of their trials, collect the materials, and return them to your group box. If your subgroups have things under control, help other subgroups. Once a subgroup has finished, they can move onto graphing their results. An example filled-out results table is shown below (right).

RESULTS

Table

Fill out the table for each of your trials. For the variables that remain constant, write the value in trial A. Then, draw an arrow through each box indicating the variable is a control.

Underline controls, circle changing variables, and box information about data collection.

Variables	Trial A	Trial B	Trial C	Trial D
Blade Material:	Cardstock			
Blade Number:	3			
Weight Number:	6			
Weight Placement:	6 cm			
Dowel Placement:	1.5 cm			
Blade Angle: (list both the actual angle and what angle you will find on the wind turbine protractor)	130°/-50°	0°/180°	30°	70°
Fan Distance:	50 cm			
Fan Speed: Other Variable	3 (high)			
Predictions	**Trial A**	**Trial B**	**Trial C**	**Trial D**
Put an "L" in the trial that will give the least current and an "M" in the trial that will give the most current.		L		M
Data	**Trial A** 3	**Trial B** 1	**Trial C** 4	**Trial D** 2
Measurements: Current:	3.8 mA	0.0 mA	4.9 mA	0.7 mA
Observation: Other:	Blades spin counter clockwise	Blades did not move	Blades spine clockwise	Blades took a while to move then

The independent variable is the changing variable and the dependent variables are the final measurements/observations.

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RESULTS

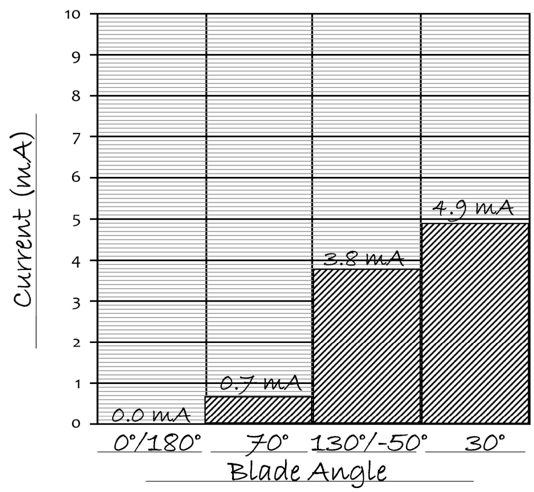
Graph

Set up your graph. (Check off the steps as you complete them.)

- ☒ Label the y-axis (vertical) with what you measured, including units (*Ex:* Current (mA)).
- ☒ Label the x-axis (horizontal) with your changing variable (*Ex:* Blade Angle).
- ☒ On your results table, label your measurements from 1 to 4, with 1 being the trial with the smallest current and 4 being the trial with the largest current.

Plot your data in increasing order.

- ☒ Write the changing variable value (*Ex:* 0°/180°) for the trial that you labeled 1 under the first column.
- ☒ Graph your data for that trial and write the measurement above the bar.
- ☒ Repeat the process for the other trials.



15

Graph:

(10 minutes – Subgroups – SciTrek Volunteers)

Help subgroups fill out their graphs by having them complete the checklist on the top of page 15. Be sure students label the y-axis with "Current (mA)" and the x-axis with their changing variable. Step 3 of the graphing checklist has students label their measurements in increasing order (1-4) on their results table to ensure that they are graphed in increasing order, as seen in the example above. This makes it easier for the students to see trends in their data. In the example above, the trials were graphed in the following order: B, D, A, C. Once students have graphed their values, make sure they write the numerical value of the current on top of each column, so it is easy to quickly read the graph. An example filled out graph is shown above (right).

Wrap-Up:

(2 minutes – Full Class – SciTrek Lead)

Tell students, "Next session, you will have time to analyze your data, and create a poster to share your results with the class."

Clean-Up:

1. Collect notebooks with attached nametags.
2. Turn off multimeter.
3. Place wind turbine bases and fans back in bags they came in.
4. Place all other materials into your group box and bring them back to UCSB.

Day 5: Results Summary/Poster Making

Schedule:

Introduction (SciTrek Lead) – 10 minutes
Results Summary (SciTrek Volunteers) – 15 minutes
Poster Making (SciTrek Volunteers) – 30 minutes
Wrap-Up (SciTrek Lead) – 5 minutes

Notebook Page:

RESULTS
Summary

My experiment shows that as the blade angle moves away from 0°/180° and 90° more current is produced, because when the blade angle was 0°/180°, the current was 0.0 mA (least), and when the blade angle was 70° (close to 90°), the current was 0.7 mA, but when the blade angle was 30° the current was 4.9 mA (most).

I acted like a scientist when I wrote a procedure for my experiment.

NOTES ON PRESENTATIONS
What variables affect the current a wind turbine produces?

Changing Variable:				
Current Produced (mA):				

Changing Variable:				
Current Produced (mA):				

16

Preparation:

SciTrek Lead:
1. Make sure volunteers are setting out notebooks.
2. Find a place to leave student posters.
3. Set up the document camera for the results graph (notebook, page 15) and results summary (notebook, page 16).

SciTrek Volunteers:
1. Set out notebooks/nametags.

Note: Set notebooks where students will sit during the module, even if another student is currently at that desk. If needed, students will move to these spots after the Introduction.

Materials:

(3) Volunteer Boxes:

- ☐ Nametags
- ☐ Notebooks
- ☐ Volunteer instructions
- ☐ Volunteer lab coat
- ☐ Poster diagram
- ☐ (2) Stickers on how to present results
- ☐ (2) Pencils
- ☐ Paper notepad
- ☐ (Bag) Paperclips
- ☐ Highlighter
- ☐ Scissors
- ☐ (2) Glues
- ☐ (2) Poster parts packs (scientists' names, question, experimental set-up, procedure, results table, results graph, results summary, (6) *I acted like a scientist when*, (6) picture spaces)

Other Supplies:

- ☐ Poster paper tube

Lead Box:

- ☐ (3) Extra notebooks
- ☐ Lead instructions
- ☐ Wind turbines picture packet
- ☐ Poster diagram
- ☐ Lead lab coat
- ☐ Time card
- ☐ (2) Stickers on how to present results
- ☐ (2) Pencils
- ☐ (2) Wet erase markers
- ☐ (2) Black pens
- ☐ Paper notepad
- ☐ (Bag) Paperclips
- ☐ (2) Highlighters
- ☐ (2) Scissors
- ☐ (2) Glues
- ☐ Scotch tape
- ☐ (2 each color) Poster part packs

Introduction:
(10 minutes – Full Class – SciTrek Lead)

If students are not in their subgroups tell them, "A notebook will be put on your desk, which is not your notebook and you should not move it. You will move to your notebooks after the Introduction."

Ask the class, "What is the class question we have been investigating?" Students should reply, "What variables affect the current produced by a wind turbine?" Tell students, "Today, you are going to analyze your results from your experiments which will allow you to start answering the class question. We will start by analyzing the class data together." Put the filled-out results graph from the class experiment under the document camera (notebook, page 15). Tell students, "We will now work together to try to determine which value(s) of our changing variable allow us to get the greatest current and why."

Ask students, "What patterns do you see in the results?" To help students see the patterns, have them look at the two materials that gave the smallest currents (Kleenex and paper), and ask them, "What do these materials have in common?" If needed, show students the results table (picture packet, page 5) and have them look at the *other* section under data. By the end of the conversation, students should realize materials that give the smallest current are materials that either ripped, or bent, when the fan was turned on. Have students look at the two materials that gave the largest currents (Styrofoam and metal) and ask them, "What do these materials have in common?" By the end of the conversation, they should realize these materials did not rip or bend. Ask students, "What do you notice about the materials that did not bend or rip, from the data." Possible student response: the currents are all close to 1.9 mA.

Tell students, "Now, we need to summarize the data to tell people what values of the changing variable give the largest currents or the trend/pattern we see in the data regarding current production." Start students out by saying "My experiment shows the blade materials that produce the largest current are…" Have students tell you what should go next and ask the class whether they agree. By the end of the conversation, make sure students agree the blade materials that give the largest currents are materials which do not bend, and these materials all give approximately the same current. Ask students, “Can we test whether the flexibility of a material affects the current produced by a wind turbine?” Students should reply, “Yes.” Tell students, “If a statement is testable, then it is a claim, and claims are the first part of results summaries.” Write “stiffer blade materials produce more current” in the class notebook.

Tell students, “Now we need to use data to support the claim. There are two forms of data: observations, and measurements.” Ask students, “What type of data will we use to support our claim?” Students should reply, “Measurements.” Ask students, “What measurements would we need to back up our claim?” Write the following data statement after the claim in the class notebook: “because when Kleenex (flexible) was used, the current produced was 0.0 mA (least current), but when metal (stiff) was used, the current produced was 2.0 mA (most current).”

RESULTS

Summary

My experiment shows that stiffer blade materials produce more current, because when Kleenex (flexible) was used, the current produced was 0.0 mA (least current), but when metal (stiff) was used, the current produced was 2.0 mA (most current).

I acted like a scientist when

NOTES ON PRESENTATIONS

What variables affect the current a wind turbine produces?

Changing Variable:				
Current Produced (mA):				

Changing Variable:				
Current Produced (mA):				

16

Tell students, “Think back to the original observations we made as a class. Ask them, “What blade materials did we use for these observations?” They should reply, “Cardstock, and cardboard.” Ask them, “What did we learn from our data?” Possible student response: the current was about the same for the two blade materials. Ask students, “Are these results consistent with what we just saw from our class experiment?” Possible student response: yes, because neither of the blades were that flexible. Remind students, “It is important for scientists to repeat their experiments, to make sure their results are consistent.”

Tell students, “Results summaries are strongest when they allow us to make predictions.” Ask students, “Based on our results summary, can you predict another material that would produce a high current?” Possible student response: wood. Ask students, “Can you predict another material that would produce a small, or no, current?” Possible student response: tissue paper. Ask students, “How much current do you predict would be produced by a stiff material?” Students should reply, “Approximately 1.9 mA.”

Tell students, "After you summarize your experimental findings, you will fill in the sentence frame *I acted like a scientist when*, stating how you acted like a scientist during your SciTrek experience. Try to come up with a unique answer that is something besides 'I did an experiment.'"

Tell students, "When engineers/scientists complete their experiments, they make posters to present their findings to other engineers/scientists. Each subgroup will create a poster to present to the class during the next session. This presentation will be your chance to tell the class what your subgroup has discovered about the class question. You should write as neatly as possible on the poster parts, so the other class members can read your posters. You will now start working with your subgroup to analyze your experimental results, and make a poster."

Results Summary:
(15 minutes – Subgroups – SciTrek Volunteers)

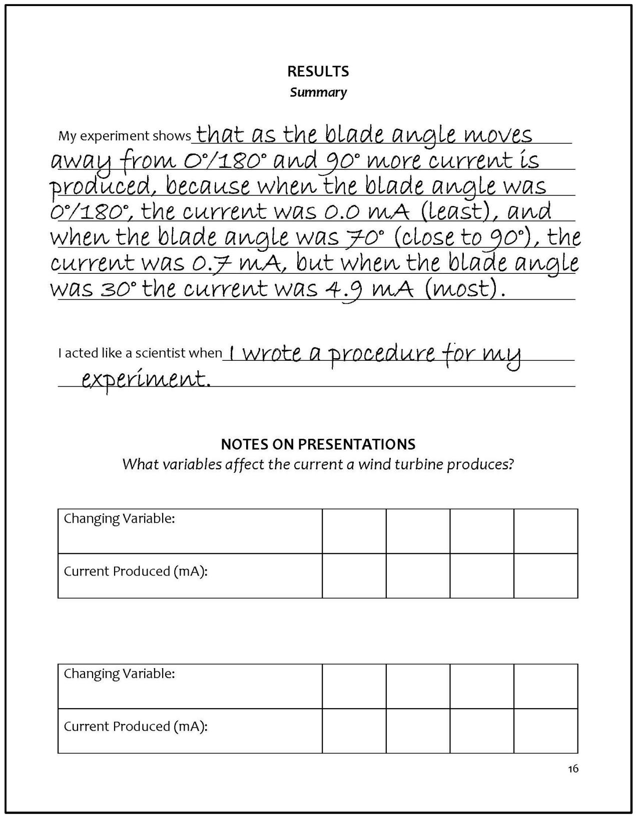
Have subgroups use their graphs to look for patterns in their data. Challenge subgroups to think about how their changing variable did or did not affect the current.

When writing their results summary (notebook, page 16), make sure subgroups' results summaries have both a claim (statement that can be tested), ad supporting data (measurements and/or observations). If the values of their changing variable have an order (Ex: 20 cm → 40 cm → 80 cm), then, that variable does have an effect on the current a wind turbine produces. If, on the other hand, there was no order for their changing variable values (Ex: 9 weights → 3 weights → 24 weights), and/or the difference between the currents is small for each trial, then that variable does not have an effect on the current a wind turbine produces. If possible, try to have subgroups generate a claim that allows them to make predictions about something they have not tested. Because this is an engineering activity, the claim should be focused on the value (or pattern of values) of their changing variable that produced the most current. An appropriate claim could be: as the wind source gets closer to the turbine, more current is produced. This is an appropriate claim because it allows the students to make a prediction about what would happen if new values of their changing variable were introduced.

After generating a claim about their experiment, subgroups will write the word "because," and follow it with supporting data. Their supporting data should include at least two pieces of data, typically the minimum, and maximum, currents. Make sure subgroups are using their changing variable values (not trial letters), and specific measurements, to support their claims. The supporting data for the previously mentioned claim would be: because when the fan distance was 20 cm, the current was 5.4 mA, and when the fan distance was 80 cm, the current was 2.3 mA.

Results summaries are still valid, and important, if they show the changing variable tested does not have an effect on the current produced by the wind turbine. Even if their results summary is contrary to what you think, have subgroups make a claim based solely on their data. An example filled out results summary is shown below.

Once students have filled out their results summary, have them fill in the sentence frame (notebook, page 16), *I acted like a scientist when*. Each student's response should be unique and specific. They should **not** write, "when I did an experiment," because this is general, and applies to all of the students in the class. If students are having trouble with this sentence frame, ask them, "What did you do during SciTrek?"



RESULTS
Summary

My experiment shows that as the blade angle moves away from 0°/180° and 90° more current is produced, because when the blade angle was 0°/180°, the current was 0.0 mA (least), and when the blade angle was 70° (close to 90°), the current was 0.7 mA, but when the blade angle was 30° the current was 4.9 mA (most).

I acted like a scientist when I wrote a procedure for my experiment.

NOTES ON PRESENTATIONS
What variables affect the current a wind turbine produces?

Changing Variable:				
Current Produced (mA):				

Changing Variable:				
Current Produced (mA):				

16

Poster Making:
(30 minutes – Subgroups – SciTrek Volunteers)

Each subgroup (four/five/six students) will make one poster for their experiment.

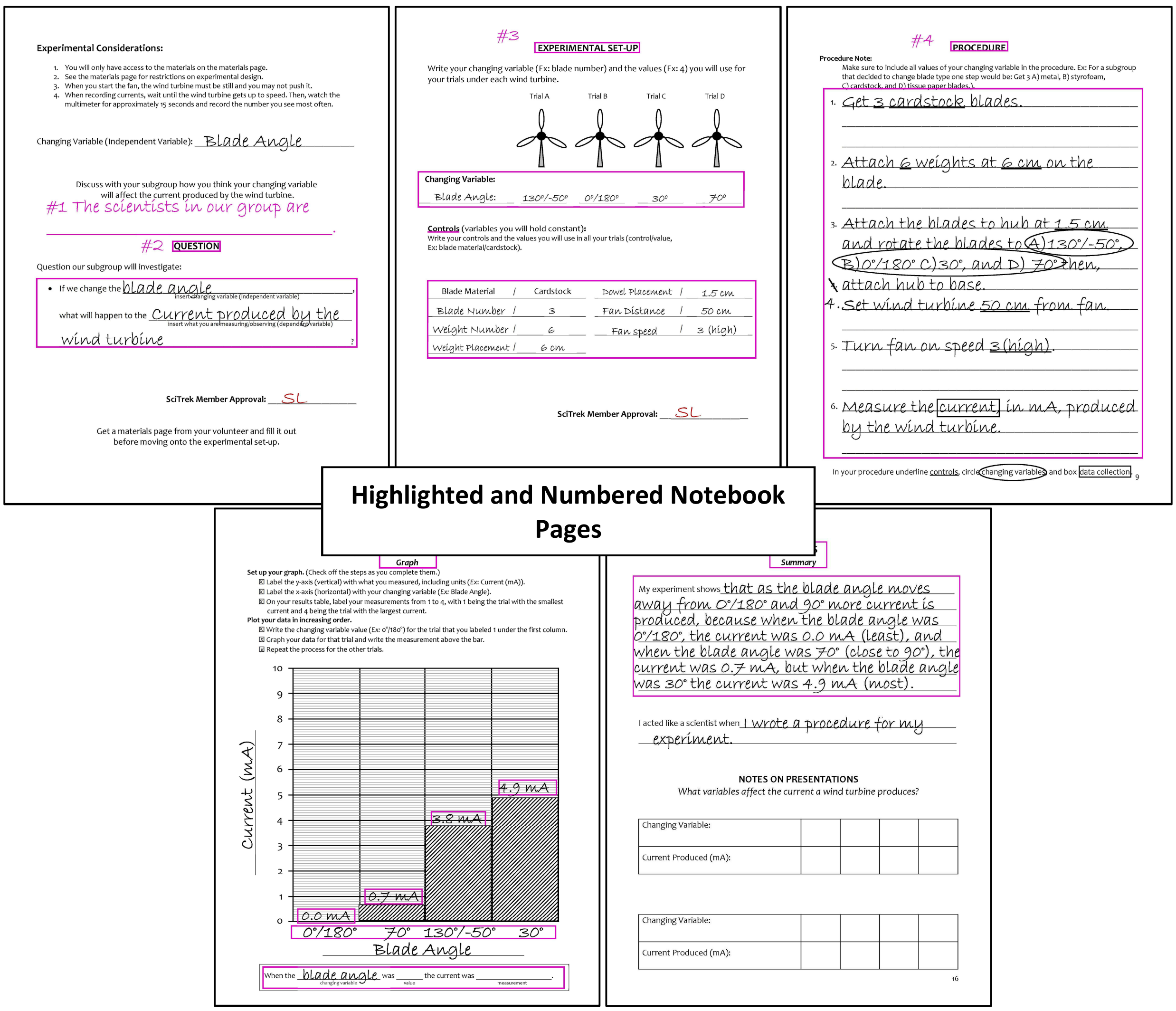
Pass out the writing portions (general poster parts and *I acted like a scientist when*) and have students write their names on them and complete them. In addition, have each student write their name on the scientists' names poster parts. Use the following guidelines when assigning poster parts:

Number of Students in Subgroup	Poster Division Each student gets an *I acted like a scientist when,* and picture space.	
4	1. Question and Experimental Set-Up 2. Procedure 3. Results Graph* 4. Results Summary	Student who finishes 1st, completes the results table (<u>not</u> presented)
5	1. Question 2. Experimental Set-Up 3. Procedure 4. Results Graph* 5. Results Summary	Student who finishes 1st, completes the results table (<u>not</u> presented)
6	1. Question 2. Experimental Set-Up 3. Procedure (Presents 1st half of procedure) 4. Results Table (Presents 2nd half of procedure) 5. Results Graph* 6. Results Summary	

*Give the results graph to the student who is most confident in presenting.

Once students have finished their written section(s), have them draw a picture of their experiment or how they acted like a scientist.

In the students' notebooks, highlight and number the section(s) that they will present. The parts should be numbered as follows: 1) scientists' names, 2) question, 3) experimental set-up, 4) procedure, 5) results graph, and 6) results summary (see example below). Students will **not** present the results table or *I acted like a scientist when* parts from their poster. If a student is presenting multiple sections, use the paperclips in your group box to clip together the sections they are reading, so when presenting, it will be easy for them to flip back and forth between the pages.



Highlighted and Numbered Notebook Pages

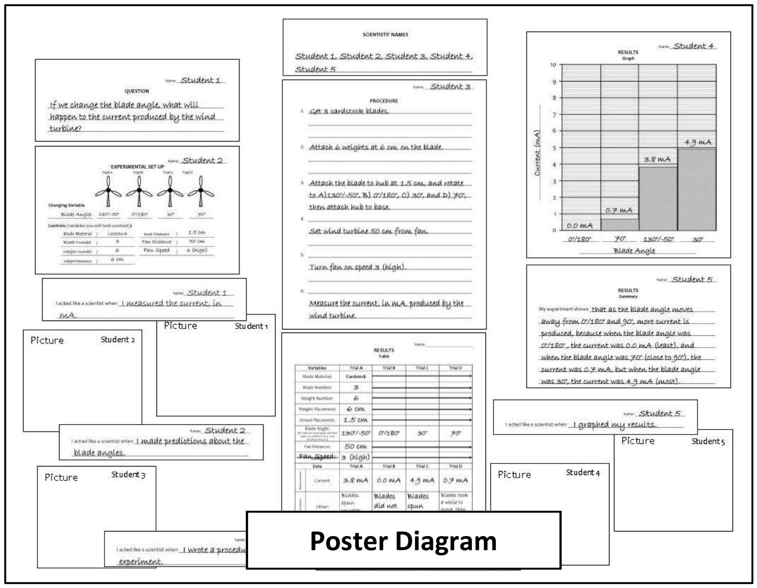
Place the following sentence frame sticker on the notebook page of the student who is presenting the results graph (notebook, page 15).

When the ______(you should fill this blank out for the student)______ was _______ the current was __________________ mA. changing variable / value / measurement

Then, practice reading the four sentences with that student. For the graph above, the first sentence would read: When the **weight number** was **21** the current was **0** mA. Make sure you fill in the first blank in the sentence frame (Ex: weight number) for the student, but leave the *value* and *measurement* blanks empty. The student will fill these in verbally for each data piece.

As soon as students have completed some of their pieces, start gluing them onto the large poster paper, in landscape orientation, exactly as they are arranged in the example below. Do not allow students to glue the poster parts on the posters. Do not wait until students have completed all the pieces to start gluing them onto the posters.

Once the poster is complete, have students start practicing for the presentation. Make sure students read from their notebooks, instead of from the poster.



Poster Diagram

Ask each of your subgroups a few questions about their posters. Have them use their findings to predict what would happen to the current a wind turbine produces for other changing variable values they did not perform tests on. For instance, if the subgroup's results summary was, "My experiment shows that as the blade angle gets farther away from 0° or 90°, the wind turbine produces more current, because 0˚ and 70˚ both produced 0 mA, and 30˚ produced 4.7 mA," ask the subgroup to predict what current a blade angle of 45˚ would produce. They should be able to predict that it would be ~ 2 mA.

If there is additional time, tell each subgroup, "Other students will ask you questions during your poster presentations. You should think about what questions you might be asked, and think of the answers to those questions, so you will be prepared during your presentation."

Wrap-Up:
(5 minutes – Full Class – SciTrek Lead)

Ask students the following questions:

How did you act like a scientist during this project?
What did you do, that scientists do?

After discussing how they acted like scientists, and talking about how everyone does things scientists do in their everyday lives, tell students, "Next session, you will present your findings to the class, and I am looking forward to hearing about all of your experiments."

Clean-Up:

1. Collect notebooks with attached nametags.
2. Leave posters in the classroom.
3. Place all other materials into your group box and bring them back to UCSB.

Day 6: Poster Presentations

Schedule:

Introduction (SciTrek Lead) – 2 minutes
Practice Posters (SciTrek Volunteers) – 10 minutes
Poster Presentations (SciTrek Volunteers/SciTrek Lead) – 46 minutes
Wrap-Up (SciTrek Lead) – 2 minutes

Materials:

(3) Volunteer Boxes:

☐ Nametags
☐ Notebooks
☐ Volunteer instructions
☐ Volunteer lab coat
☐ (2) Pencils
☐ (Bag) Paperclips
☐ Highlighter

Lead Box:

☐ (3) Extra notebooks
☐ Lead instructions
☐ Wind turbines picture packet
☐ Lead lab coat
☐ Time card
☐ (2) Stickers on how to present graph
☐ (2) Pencils
☐ (2) Wet erase markers
☐ (Bag) Paperclips
☐ (2) Highlighters
☐ Scotch tape

*Student posters should already be in the classroom.

Preparation:

SciTrek Lead:

1. Make sure volunteers are passing out notebooks.
2. Set up the document camera for the *Notes on Presentations* (picture packet, pages 6 and 7).
3. Organize posters so experiments featuring the same changing variable will be presented back-to-back and posters are presented from simplest to understand, to most difficult to understand (suggested order: fan speed, fan placement, blade angel, dowel placement, weight placement, weight number, and blade number).

SciTrek Volunteers:

1. Pass out notebooks/nametags.

Note: Today, students will sit in their regular classroom seats during poster presentations.

Notebook and Picture Packet Pages:

RESULTS

Summary

My experiment shows that as the blade angle moves away from 0°/180° and 90° more current is produced, because when the blade angle was 0°/180°, the current was 0.0 mA (least), and when the blade angle was 70° (close to 90°), the current was 0.7 mA, but when the blade angle was 30° the current was 4.9 mA (most).

I acted like a scientist when I wrote a procedure for my experiment.

NOTES ON PRESENTATIONS

What variables affect the current a wind turbine produces?

Changing Variable: Fan Distance (cm)	100	70	45	20
Current Produced (mA):	4.0	4.6	5.0	5.3

Changing Variable: Weight Placement (cm)	0	11	2	7
Current Produced (mA):	3.2	3.3	3.3	3.4

16

Changing Variable: Weight Number	21	6	0	12
Current Produced (mA):	0.0	6.3	6.4	6.5

Changing Variable: Blade Number	1	5	4	2
Current Produced (mA):	0.0	0.8	6.7	7.0

Changing Variable: Blade Number	1	4	2	3
Current Produced (mA):	0.0	5.5	5.8	6.1

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NOTES ON PRESENTATIONS

What variables affect the current a wind turbine produces?

Subgroup 1

Changing Variable: Fan Distance (cm)	100	70	45	20
Current (mA):	4.0	4.6	5.0	5.3

Summary: As the turbine gets closer to the fan, more current is produced.

Subgroup 2

Changing Variable: Weight Placement (cm)	0	11	2	7
Current (mA):	3.2	3.3	3.3	3.4

Summary: Weight placement does not affect the current.

Subgroup 3

Changing Variable: Weight Number	21	6	0	12
Current (mA):	0.0	6.3	6.4	6.5

Summary: The weight number does not affect the current, until the weight number becomes too large.

Subgroup 4

Changing Variable: Blade Number	1	5	4	2
Current (mA):	0.0	0.8	6.7	7.0

Summary: Blades that are evenly spaced on the hub (balanced), will produce more current.

6

Picture Packet, Page 6

Group 5

Cheapest Slightly more current

Changing Variable: Blade Number	1	4	2	3
Current (mA):	0.0	5.5	5.8	6.1

Summary: Agrees with group 4

Group 6

Changing Variable: Blade Angle (°)	0/180	70	130/-50	30
Current (mA):	0.0	0.7	3.8	4.9

Summary: As the blade angle moves away form 0°/180° and 90°, more current is produced. Blade angles on either side of 90°, will spin in different directions.

7

Picture Packet, Page 7

Introduction:
(2 minutes – Full Class – SciTrek Lead)

Tell students, “Today you will present your posters to the class. This is a common practice in engineering and science. Engineers and scientists go to conferences where they present posters about the experiments they conducted. At these presentations, other engineers and scientists give them feedback on their experiments, which allows them to return to the lab with new ideas for future experiments. You will have 10 minutes to practice presenting your poster with your subgroup. When you present, you should read from your notebooks, not your poster. After practicing, you will return to your normal classroom seats.”

Practice Posters:
(10 minutes – Subgroups – SciTrek Volunteers)

Have subgroups practice their poster presentation, making sure they are reading the poster parts in the correct order (scientists’ names, question, experimental set-up, procedure, results graph, and results summary). Make sure each student’s part is highlighted in their notebook. If students are reading from multiple pages, use a paperclip to clip these pages together, to make it easier for them to flip back and forth. Remind students to read from their notebooks rather than from their posters.

If there is additional time, tell subgroups, “Students will ask you question during your poster presentation. You should think about what questions you might be asked and think of the answers to those questions so you will be prepared during your presentation.”

Do not let poster practice go over 10 minutes.

Poster Presentations:
(46 minutes – Full Class – SciTrek Volunteers/SciTrek Lead)

Have students return to their original class seats. Ask the class, “What is the question we have been investigating?” Students should reply, “What variables affect the current produced by a wind turbine?” Tell students, “During the presentations, you are going to take notes.” Have them turn to page 16 in their notebooks while you turn to page 6 of the picture packet. Tell them, “You will need to record each subgroup’s changing variable after the subgroup says their question. In addition, when the group presents their graph, you will need to record the values of the changing variable, as well as the corresponding measurements collected by the subgroup.”

Tell students, “You will get the chance to ask scientific questions after each presentation. These questions are important, because you will have to summarize what you learned from the subgroup so I can record this on the *Notes on Presentations*. Therefore, your questions should focus on helping you be able to summarize the subgroup’s findings.”

Notebooks only have room for notes on five presentations. Therefore, they will not take notes on their own presentation.

Explain to students, “One very important thing to an engineer is being able to build something that works well, and is cost efficient. When comparing different changing variable values, you should keep in mind whether changing the variable value cost more money. If changing the variable does not cost more, then you should go with the value the produces the most current. If changing the variable costs more, you must decide if it is worth spending the money to get more current. If the difference in current is small between variable values, it might not be worth the cost. If the difference in current is large, it most likely is worth the additional cost. Before moving on to the next presentation, as a class, we will decide which value of the changing variable would be the ‘best’ for a wind turbine company to use, and we will circle that changing variable value in our notes.”

Volunteers should make sure students are quiet and respectful when other subgroups are presenting. When one of your subgroups is presenting, go to the front of the room with them; prompt students if they do not know who talks next, and remind them to read from their notebooks.

During the student question time, the lead and/or volunteers should ask at least one question. Examples of possible questions are: “How do you know…?” or “Is there anything else you can do to get more information about your question?” Each subgroup should answer approximately five questions (one question per student). When students are done asking questions, have them summarize what the subgroup found, and circle the value of the changing variable that would be ‘best’ for a wind turbine company.

An example filled out *Notes on Presentations* (lead) are shown below. For an example of student presentation notes, see Notebook and Picture Packet Pages section above.

NOTES ON PRESENTATIONS

What variables affect the current a wind turbine produces?

Subgroup 1

Changing Variable: Fan Distance (cm)	100	70	45	20
Current (mA):	4.0	4.6	5.0	5.3

Summary: As the turbine gets closer to the fan, more current is produced.

Subgroup 2

Changing Variable: Weight Placement (cm)	0	11	2	7
Current (mA):	3.2	3.3	3.3	3.4

Summary: Weight placement does not affect the current.

Subgroup 3

Changing Variable: Weight Number	21	6	0	12
Current (mA):	0.0	6.3	6.4	6.5

Summary: The weight number does not affect the current, until the weight number becomes too large.

Subgroup 4

Changing Variable: Blade Number	1	5	4	2
Current (mA):	0.0	0.8	6.7	7.0

Summary: Blades that are evenly spaced on the hub (balanced), will produce more current.

6

Picture Packet, Page 6

Cheapest Slightly more current

Group 5

Changing Variable: Blade Number	1	4	2	3
Current (mA):	0.0	5.5	5.8	6.1

Summary: Agrees with group 4

Group 6

Changing Variable: Blade Angle (°)	0/180	70	130/-50	30
Current (mA):	0.0	0.7	3.8	4.9

Summary: As the blade angle moves away form 0°/180° and 90°, more current is produced. Blade angles on either side of 90°, will spin in different directions.

7

Picture Packet, Page 7

After all poster presentations have been given, ask the class, “What did we learn about the current produced by wind turbines?” Have them summarize the class findings. The highlights from many experiments are shown below. Do not expect students to know highlights from experiments that were not run.

- The shorter the *fan distance*, the larger the current.
- The closer the *blade angle* is to 90°, the smaller the current, unless the blade angle is 0°/180° which will give no current. When using blade angles above 90°, the wind turbine spins the opposite direction, and a minus sign appears next to the current.
  Note: The minus sign that appears in front of the current indicates that electricity is flowing in the opposite direction.

- The larger the *dowel placement* (the farther out the blade is placed), the smaller the current.
- *Weight placement* on the blade has minimal effect on the current.
  Note: If subgroups assemble their blades perfectly, they might see the closer the weights are to the hub, the higher the current, but most likely they will not be able to see this because the change in current is ~0.2 mA for the weights used.
- The *weight number* should have little effect on the current the wind turbine produces. However, what many subgroups find is, if there are more weights, the wind turbine produces less current. This may be because many subgroups make their wind turbines at slightly different blade angles or weight placements. Subgroups also find this pattern if they do not tape their weights down tightly enough, and the weights move slightly when the turbine is spinning, causing an imbalance, and a decrease in current. These differences are exaggerated when the blade becomes heavier.
- The *blade number* does not affect the current produced as long as the blades are evenly spaced. When the blades are unevenly spaced, the wind turbine will not produce current (as in the case with one blade), or will have a harder time getting started and up to speed (as in the case with 5 blades).

When summarizing experiments, use student-collected data, and not what they should have found from the list above. Ask students, "If you want to produce as much current as possible, for the least amount of money which values of the variables should you use?"

- Blade Material: Non-bendable material
- Fan Distance: Close to fan
- Blade Angle: 10°
- Dowel Placement: 0.5 cm
- Weight Number: 0, Having 0 weights would make it cheaper than having more weights.
- Weight Placement: Because there are no weights, weight placement does not matter.
- Blade Number: 2, Having 2 blades would make it cheaper than having more blades,

If no one in the class did experiments on one of the variables above, they will not know how that variable affects the current produced by the wind turbine, so do not expect them to tell you which value to use. Tell students, "You have taught me a lot about wind turbines, and the current they produce."

Wrap-Up:
(2 minutes – Full Class – SciTrek Lead)

Tell students, "The mentors who have been working with you are undergraduate and graduate students who volunteer their time, so you can do experiments. This is the last day you will see your volunteers, so we should say thank you and goodbye to them. I will come back and work with you one more day."

Have students remove the paper parts of their nametags (which they can keep) from the plastic holders and return the plastic holders to their volunteers.

Clean-Up:

1. Collect plastic nametag holders and allow students to keep the paper part of their nametags.
2. Collect notebooks.
3. Leave posters in the classroom.
4. Place all other materials into your group box and bring them back to UCSB.
5. If you will not be attending the tie to standards day, remove all materials from your lab coat pockets, remove your nametag, unroll your lab coat sleeves, and put your lab coat into the dirty clothes bag at UCSB.

Day 7: Draw a Scientist/Tie to Standards/Content Assessment

Note: We **highly recommend** teachers give the procedure assessment prior to Day 7 of the module. The suggested times in the lesson plan below are assuming students completed the procedure assessment prior to SciTrek's arrival.

Schedule:

Times if teacher gave assessment prior to SciTrek:
Draw a Scientist (SciTrek Lead) – 5 minutes
Tie to Standards (SciTrek Lead) – 45 minutes
Content Assessment (SciTrek Lead) – 10 minutes

Times if SciTrek must give assessment*:*
Procedure Assessment (SciTrek Lead) – 10 minutes
Draw a Scientist (SciTrek Lead) – 5 minutes
Tie to Standards (SciTrek Lead) – 35 minutes
Content Assessment (SciTrek Lead) – 10 minutes

Materials:

Lead Box:

☐ (3) Extra notebooks
☐ Notebooks
☐ Lead instructions
☐ Wind turbines picture packet
☐ Lead lab coat
☐ Procedure assessment (if teacher did not take assessments, then (35))
☐ (35) Draw a scientist
☐ (35) Content assessments
☐ Time card
☐ (2) Pencils
☐ (2) Wet erase markers
☐ (2) Black pens
☐ Teacher final survey QR code
☐ Extension cord

Other Supplies:

☐ Wind turbine base
☐ Fan
☐ Box of tie to standards materials (clipboard, eraser, flashlight, wind turbine protractor, 152 cm measuring tape, multimeter, wind turbine hub with 3 blades attached, Tupperware with (magnet/electricity apparatus, 2 magnets, and 3 paperclips), masking tape, and radiometer)

Notebook Pages:

TIE TO STANDARDS

1. What does the current reading tell us? Electricity is being generated by the wind turbine.
2. Electric currents are a form of energy.
3. Energy cannot be created nor destroyed, but it can be transferred.
4. Energy can also be stored, such as the case of gravitational energy.
5. Forms of energy

electrical currents	sound
gravitational	light
motion	heat

18

6. Identify the energy transfers in the wind turbine.

Wind / motion → blades / motion → electrical current

Energy Source / Energy Form → Energy Source / Energy Form → Energy Form

7. What could the energy in the wind turbine be used for? Video games / light

Energy Source / Energy Form

8. Magnets can generate electricity if the magnet is moving.
9. What are the blades turning inside the wind turbine housing?

magnets

10. What type of area would you recommend that Windy Works purchase land?

In a windy area

19

11. Windy Works has already decided on the manufacturing specifications below, but needs help deciding which values of three variables to use in constructing their wind turbines.
    1. Circle the value of the changing variable you think Windy Works should use.
    2. Look at the data and box the value of the changing variable that is Windy Works' "best" option.

Wind Turbine Manufacturing Specifications:

Blade Material / Cardstock	Wind Angle / 90°
Blade Number / 3	Weight Placement / 7 cm

Blade Angle:	$\boxed{10°}$	30°	70°
Dowel Placement:	$\boxed{0.5 \text{ cm}}$	3.5 cm	6.0 cm
Weight Number:	$\boxed{0}$	6	12

12. Current produced by ideal wind turbine: 8.5 mA

20

Preparation:

SciTrek Lead:

1. Get the procedure assessments and put them in the lead box.
2. If the teacher is not leading the tie to standards activity, do the following:
    a. Ask the teacher if they completed the SciTrek final survey. If not, give them the QR code from the lead box, and ask them to go to the website (at a later time), and fill out the evaluation of the program.
    b. Give the teacher an extra notebook and have them fill it out with their students to follow along during the tie to standards activity.
    c. Collect the teacher's lab coat and put it in the lead box.
3. If you are a teacher and have not completed the SciTrek final survey, take the QR code from the lead box, and fill out the evaluation of the program, at a later time.
4. Pass out notebooks.
5. Set up the document camera for the tie to standards activity (notebook, pages 18-20; picture packet, pages 8-11).
6. Assemble the tie to standards set-up.
    a. Verify the blades on the hub are at a **dowel placement = 0.5 cm**, and a **blade angle = 10˚,** then attach the hub to the wind turbine base.
    b. Roll out the tape measure, set the **fan distance = 60 cm**, and position the wind turbine so the head is pointing at the fan.
    c. Connect the multimeter to the wind turbine base, making sure the red and black wires do not touch. The red clamp should be connected to the red wire **after** the resistor (on the loose end of the wire).
    d. Leave the multimeter, and fan, off.
    e. Set the radiometer on a flat surface, where students will be able to see it. It is important it is not moved once it is set down, because it takes a long time for the blades to come to rest.
7. Put your lab coat in the lead box at the end of the day.

Procedure Assessment:
(10 minutes – Full Class – Given by Classroom Teacher Prior to SciTrek)

Tell students, "Before we start our activity, we will determine how your ideas on procedures are developing." Have students write their name, teacher's name, and date at the top of the assessment. Tell students, "When doing this assessment, you should work individually, so there should be no talking." As you are giving the assessment, walk around the room and verify students have written their name at the top of their assessments.

For page 1, question *1*, have students write in their own words what they think the definition of a procedure is.

For page 1, question *2*, read the statements and have students fill in the blanks with the missing words. When students are finish have them turn to page 2.

For page 2, questions 3-8, read step *1* of the directions (*Look over the experimental information*); then read the question, changing variable (*wheel material*), and controls (*wheel circumference, vehicle mass, vehicle type*…) under the experimental information. You do not need to read the values for the changing variable or controls. Read step *2* to the students (*Read each statement (3-9) and underline controls, circle changing variable, and box information about data collection*); then read the statement in question 3 and have students annotate it. Once they are done, read step 3 (*Circle yes if the statement could be a correct step for a procedure about experimental information below. If not, circle no.*) Have students circle either

Yes or No depending on if they think it is a correct procedural step. For question 4, read the statement and tell students, "Annotate this statement by underlining controls, circling changing variables, and boxing information about data collection." Once students are done tell them, "Now circle if this could be a correct procedural step or not." Repeat this process for question 5-9. When students are finished, have them turn to page 3.

For page 3, question *10*, have students write down two things that scientists do, other than experiments.

Tell students, "The remaining questions are opinion questions and have no right answer, therefore you should be totally honest." For page 3, question *11*, have students circle whether they like science more, the same, or less after going through the SciTrek Program.

For page 3, question *12*, tell students, "The next question is about how much your identify with a scientist." Point the circle on the far left that are not overlapping and ask them, "Do you think a person that circles these would identify as a scientist or not?" By the end of the conversation make sure they understand that that person would not identify as a scientist. Repeat the process for the circles on the far right (completing overlapping, therefore the person always identifies as a scientist) and the circles in the middle (half way overlapping, therefore the person sometimes identifies as a scientist). The have the students circle the circles that represents their identity as a scientist. Make sure students have only circled one set of circles for this question.

For page 3, question *13*, have students circle whether they feel more, the same, or less like a scientist after going through the SciTrek Program.

For page 3, question *14*, have students circle whether would like to get a job as a scientist.

For page 3, question *15*, have students circle whether they feel more, the same, or less interested in science after going through the SciTrek Program.

For page 3, question *16*, have students circle whether they feel more, the same, or less confident in doing science after going through the SciTrek Program.

For page 3, questions 17-21, have students circle how interested they are in different subjects. When they are finished, collect the assessments and verify the students' names are on the top.

Draw a Scientist:
(5 minutes – Full Class – SciTrek Lead)

Pass out a *Draw a Scientist* paper to each student and have them write their name, teacher's name, and date at the top of the paper. Tell students, "I am going to give you **exactly** 4 minutes to draw a picture of what you think a scientist looks like." Start the timer and when 3 minutes is up, give students a 1-minute warning. After 4 minutes is over tell students, "If you drew a specific person, on the line at the bottom of the paper write who you drew. If you did not draw a specific person, leave the line blank." When students are finished, collect the papers and verify the students' names are written on top.

Tie to Standards:
(45 minutes – Full Class – SciTrek Lead)

Tell the class, "I enjoyed your poster presentations last session. Today, you are going to learn more about electric currents, and how wind turbines work."

Energy (20 minutes)

Ask students, “What did you measure during your experiments?” Students should reply, “The current produced by the wind turbine.” Ask students, “What does the current reading tell us?” Possible student response: the current tells us that electricity is being generated by the wind turbine. Ask students, “What does the amount of current tell us about the amount of electricity produced?” Possible student response: the larger the current, the more electricity produced. Have students fill in question *1* on page 18. See example below.

TIE TO STANDARDS

1. What does the current reading tell us? Electricity is being generated by the wind turbine.

Ask students, “What is an example of something that uses electricity?” Possible student responses: light bulbs, iPhones, refrigerators, etc. Ask students, “Do these things, such as a light bulb, take energy?” Students should reply, “Yes.” Ask students, “Where did the energy come from?” Students should reply, “The electricity.” Lead students to understand that electricity, or electric currents, are a form of energy, and have them fill in question *2* on page 18.

Tell students, “One scientific law is that energy cannot be created, nor destroyed, but it can be transferred from one form to another.” Then have students fill in question *3* on page 18. See example below.

2. Electric currents are a form of energy.

3. Energy cannot be created nor destroyed, but it can be transferred.

Ask students, “Can you give me an example of energy being transferred but not destroyed?” Allow a few students to share their ideas. Possible student response: when I kick a ball, energy is transferred from me into the ball (picture packet, page 8). Ask students, “What happens when the ball hits a wall?” Make sure, by the end of the conversation, students understand when a ball hits a wall, the ball transfers its energy to the wall. Because the wall is much larger than the ball, the energy from the ball makes the wall move so little that we can’t see it.

Picture Packet, Page 8

8

Tell students, “We are going to explore this idea.” Take out the SciTrek eraser, hold it up in the air, and ask the class “Does this eraser have energy?” Ask a couple of students to explain their reasoning. Pick a student that said the eraser did not have energy to come to the front of the class and have them hold out a clipboard at arm’s length. Hold the SciTrek eraser above the clipboard and drop the eraser onto the clipboard. Ask the student who is holding the clipboard, “What did you observe?” Possible student response: I felt, heard, and saw the eraser hit the clipboard. Ask the class, “What does it mean if the eraser was felt and heard as it hit the clipboard?” Possible student response: the eraser must have had energy, which was transferred to the clipboard when it hit it. Ask students, “How could we transfer more, or less, energy to the clipboard?” Possible student response: we could transfer more energy by moving the eraser up, and less energy by moving the eraser down. Try this by dropping the eraser closer and father from the clipboard, and have the student make observations. Discuss with students, when an object is held at a certain height, it stores a certain amount of gravitational energy. This amount of energy is related to the height it is being held at, as well as the mass of that object. This type of energy is called gravitational energy. Have students fill in question *4* on page 18. See example below.

4. Energy can also be ___stored___, such as the case of gravitational energy.

Tell students, “We have talked about two forms of energy: electrical currents and gravitational.” Show students these on the list on question *5* on page 18. Ask the class, “Do you think there are other types of energy?” Students should reply, “Yes”. Tell the class, “We will try to figure out what some of these other types of energy are, and add them to our list.”

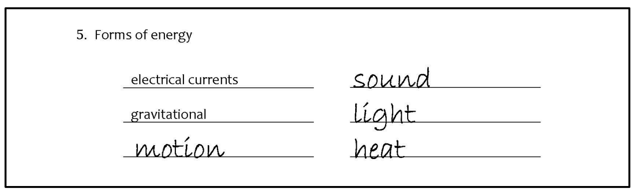
Ask students, “Knowing energy cannot be created or destroyed, where did the eraser’s gravitational energy get transferred to?” Students should be able to generate the following two sources: motion and sound. Tell students, “Roller coasters are another device the takes advantage of the conversion between gravitational and motion energy. All objects that are in motion have energy. Sound is also a form of energy.” Ask students, “Have you ever been somewhere where a loud sound was produced, and felt the sound, or saw the sound, cause something to move?” Some examples might be loud stereos or sonic booms (caused by an aircraft going faster than the speed of sound) causing windows to vibrate. Write these two types of energy on the table in question *5*.

Have students generate other examples of energy. Make sure students generate light and heat. If students are struggling, ask students, “What would happen if a wind turbine was connected to a light bulb?” Students should reply, “The bulb will light up.” Ask students, “Is light is a form of energy?” Have the class vote yes or no. To prove light is a form of energy point out the radiometer, making sure to not move it. Ask students, “Would it take energy to turn the vanes?” Students should reply, “Yes.” Shine a flashlight on the device. The vanes will start turning when they are illuminated with light from the flashlight. Ask students, “Where did the vanes get the energy from?” Since the only thing that changed was the addition of the light, students will say the light. You can also talk about sunlight transferring its energy to people’s skin, and giving them a sunburn. Record light in the table of question 5.

Note: *How the radiometer works (not to be discussed with students):* The radiometer has very few gas molecules inside of it. When light hits the vanes inside the radiometer, the black vanes absorb more energy than the white vanes, which causes the black side to get hotter. This heat energy is transferred to the molecules that are in proximity to the black side of the vanes, causing the molecules to move faster and hit the black side of the vane more often. The molecules eventually hit the side of the glass and transfer the energy to the glass and the process is repeated.

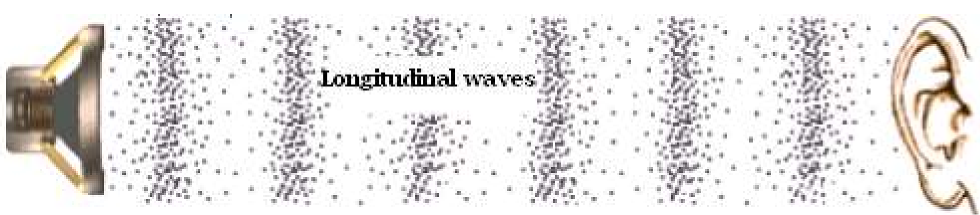
If students still have not gotten heat as an energy source, ask students, “When an electrical current causes a light bulb to shine, is all of the electrical energy transferred into light energy or is some of the energy going into another source?” If students are struggling, ask them, “What would you feel if you touched a light bulb?” Students should reply, “Heat.” Record hear in the table for question *5*.

Make sure all six sources of energy are filled in on question 5 on page 18. See example below.


5. Forms of energy

electrical currents	sound
gravitational	light
motion	heat

Note: There are two overarching types of energy: stored energy (which is called potential energy), and motion energy (which is called kinetic energy). The terms potential and kinetic energy are not used at this grade level in NGSS. It is recommended not to use these terms with students. One reason for this recommendation is that some forms of energy are a combination of both types of energy, for example electrical currents have both kinetic energy (due to the motion of the electrons), and potential energy (due to the charge on the particles). Sound is another example of energy that has both kinetic and potential energy. Sound is made up of longitudinal waves (compression waves) that have kinetic energy when the particles are spread out (areas with small concentration of dots below) and potential energy when the particles are compressed (areas with large concentration of dots below).



Energy Transfer (10 minutes)

Tell students, “We are not going to look at the energy transfers that allow a wind turbine to generate electrical current.” Ask students, “Where did the wind turbine originally get its energy from?” Possible student response: the energy came from the wind. Have students look at the list of types of energy, and tell you what type of energy the wind has. Record “wind/motion” on the first blank of question *6* and have students copy this into their notebooks. Ask students, “Where did the wind transfer some of its energy to?” Possible student response: the blades on the wind turbine. Ask students, “What type of energy do the blades have?” Record “blades/motion” on the second blank of question *6*, and have students copy this into their notebooks. Ask students, “What form of energy is coming out of the wind turbine?” Record “electrical current” on the last blank of question *6* and have students copy this into their notebooks.

6. Identify the energy transfers in the wind turbine.

Wind / motion → blades / motion → electrical current

Energy Source / Energy Form → Energy Source / Energy Form → Energy Form

Ask students, “What could the energy in the wind turbine be used for?” Have a few students share their ideas, making sure that they tell you both the source, and form, of the energy example. For example, if the source of energy is a stereo and the form of energy is sound, “stereo/sound” would be recorded. If they suggest an energy source that can produce multiple forms of energy, write them both down. For example, if the source is a lamp, the forms of energy would be light and heat “lamp/light, heat.” Record one of the student’s ideas for question *7*, and have students copy this into their notebooks.

7. What could the energy in the wind turbine be used for? Video games / light

Energy Source / Energy Form

Tell students, “Now that we know the energy transfers that occur to convert the energy in the wind into electricity, we are now going to focus on how motion energy can be used to create an electrical current.” Show students the magnet/electricity apparatus. Explain to students, “The light bulb is attached to a coil of wire. But the wire is not plugged into anything.” Quickly spin the handle of the apparatus to show the light bulb does not light. Next, take one of the magnets out of the container. These magnets are **extremely strong**, so be careful when handling the magnets. Touch one of the magnets to a couple of the paperclips to show students the metal circles are in fact magnets. Next, attach the magnets to the magnet/electricity apparatus by placing one magnet on either side of the PVC pipe in the center of the apparatus. Do not allow the magnets to touch because it will be extremely hard to separate them. Show students, simply having a magnet in the center of the apparatus does not cause the light bulb to light. Quickly spin the handle of the apparatus to show them the light bulb lights when there is a moving magnet. Ask students, “Can you describe what was needed to get the bulb to light?” Possible student response: when there is a moving magnet near a wire, it can cause a light bulb to shine. Have students fill in question *8* in their notebooks.

8. Magnets can generate electricity if the magnet is moving.

Note: The voltage generated is proportional to the number of coils present. In order to generate enough voltage to light the bulb, we need ~400 loops of wire.

Remind students, “On a wind turbine, the blades are spinning, and electric currents are being produced.” Ask students, “What do you think the blades on the wind turbine are turning inside the wind turbine housing?” Record “magnets” for question *9*. Ask students, “What does the magnet have to be close to?” Students should reply, “A coil of wire.” Tell students, “The most common ways of generating electricity such as burning natural gas, and using uranium, rely on turning large magnets to generate electrical current.” Ask students, “What would we need to do if we want to produce the most amount of current?” Possible student response: we would need to spin the magnets as fast as possible.

9. What are the blades turning inside the wind turbine housing?

magnets

Engineering Extension: Building a Wind Turbine (15 minutes)

Tell students, “Now that you understand energy transfer and wind turbines, you will give advice to a company called Windy Works that is looking to build a wind farm. Windy Works would like you to make recommendations for where to buy land, and how to build the optimal wind turbine.” Ask students, “What do you think the optimal wind turbine will do?” Students should reply, “Produce the most electricity, for the cheapest price.” Make sure students bring up both current, and cost.

Ask students, “What type of area would you recommend that Windy Works purchase land in and why?” Possible student response: Windy Works should purchase land in a windy area because we saw when the fan distance increased, the current produced decreased, showing that less electricity is produced when there is less wind present. Try to have students reference their data from their experiments when justifying their answer. Have students fill in the answer for question *10*.

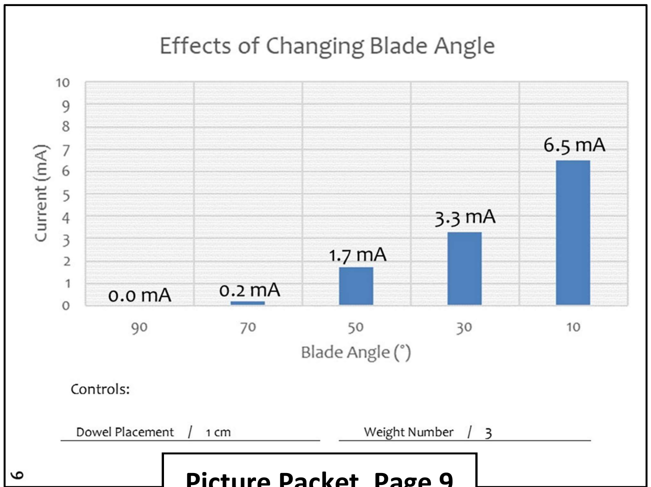
10. What type of area would you recommend that Windy Works purchase land?

In a windy area

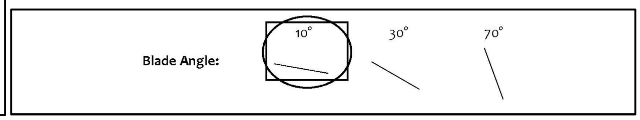
Have the students turn to page 20 in their notebooks.

Tell students, “We will now help Windy Works determine which values they should use for three different variables associated with manufacturing wind turbines: blade angle, dowel placement, and weight number. You will go through each of these variables and circle the value you think the company should use. After you complete this, I will show you data that I gathered, and you will box the value the data suggests would be the ‘best’ value for manufacturing the wind turbines. Remember, ‘best’ for Windy Works means producing the most current, for the cheapest price.” Read the manufacturing specifications that Windy Works has already decided they will use for their wind turbines: “*the blade material is cardstock…*”

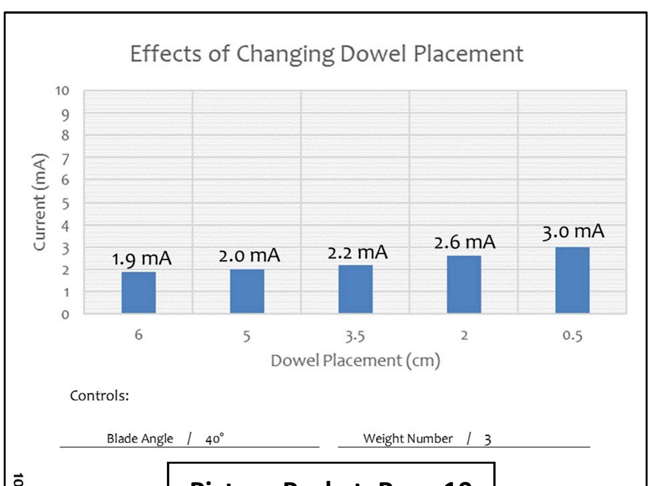
Have students circle which blade angle they think would allow a wind turbine to generate the most current. Then, have students share their ideas, as well as their thinking behind their answer. Try to have students reference data from a subgroup experiment if blade angle was picked as a changing variable. Show students the data that you collected (picture packet, page 9). Have a student tell you what was plotted on the x-axis (blade angle) and what was plotted on the y-axis (current). Ask them, “Which blade angle produced the most current?, and which produced the least current?” Students should reply, “10˚,” and “90˚,” respectively. Ask students, “Do you think the difference in currents is significant, or within the error of the measurements?” Possible student response: the blade angle affects the current significantly, because I can clearly see a pattern that as the blade angle gets closer to 90˚ the current drops. Ask students, “Would having an angle of 10˚ compared to 90˚ change the cost of manufacturing the wind turbine?” Possible student response: it would not change the price because the same wind turbine head would be used for both blade angles. Ask students, “Which blade angle would you recommend for Windy Works to use?” Students should reply, “10˚.” Have students box *10˚*.



Picture Packet, Page 9



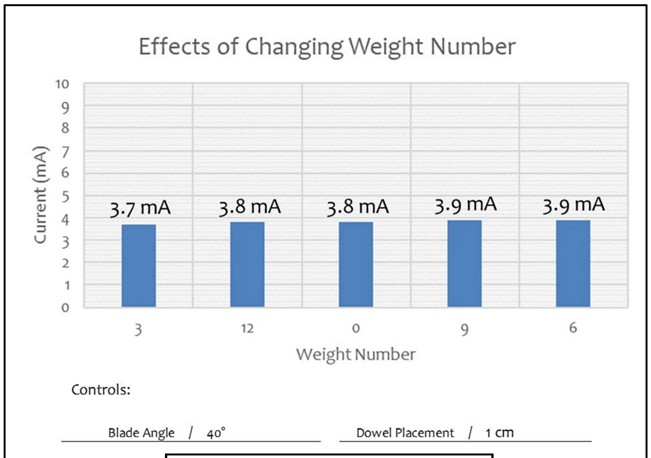
Have students circle which dowel placement they think would allow a wind turbine to generate the most current. Then, have students share their ideas as well as their thinking behind their answer. Try to have students reference data from a subgroup experiment if dowel placement was picked as a changing variable. Show students the data that you took (picture packet, page 10). Have a student tell you what was plotted on the x-axis (dowel placement) and what was plotted on the y-axis (current). Ask students, “Which dowel placement produced the most current?, and which produced the least current?” They should reply, “0.5 cm,” and “6.0 cm,” respectively. Ask students, “Do you think the difference in currents is significant, or is it within the error of the measurements?” Possible student response: the dowel placement affects the current significantly because I can clearly see a trend that as the dowel placement gets farther away from the hub, the current goes down. However, the effects of dowel placement are not as great as blade angle. Ask students, “Would having a dowel placement of 0.5 cm compared to 6.0 cm change the cost of manufacturing the wind turbine?” Possible student response: having a dowel placement of 6.0 cm might cost the company more than having a dowel placement of 0.5 cm because more material is needed for the rod. Therefore, not only does 0.5 cm provide more current, it also might be cheaper to manufacture. Ask students “Which dowel placement would you recommend for Windy Works to uses?” Students should reply, “0.5 cm.” Have students box *0.5 cm*.



Picture Packet, Page 10

Dowel Placement: $\boxed{0.5 \text{ cm}}$ 3.5 cm 6.0 cm

Have students circle which weight number they think would allow a wind turbine to generate the most current. Then, have students share their ideas as well as their thinking behind their answer. Try to have students reference data from a subgroup experiment if weight number was picked as a changing variable. Show students the data that you took (picture packet, page 11). Have a student tell you what was plotted on the x-axis (weight number) and what was plotted on the y-axis (current). Ask students, “Which weight number produced the most current?, and which produced the least current?" Students should reply, "6, and 9," and "3," respectively. Ask students "Do you think the difference in currents is significant, or is it within the error of the measurements?" Possible student response: weight number does not affect the current significantly because there is no pattern in the amount of current as the weight number increases, in addition, the current values are close together. Ask students, "Would having 0 weights compared to 12 weights change the cost of manufacturing the wind turbine?" Possible student response: the more weight the wind turbine has, the more it costs, because more material is needed. Therefore, it is cheaper to use less weight, because having less weight does not decrease the current. Ask students, "Which number of weights would you recommend that Windy Works uses?" Students should reply, "0." Have students box *0*.



Picture Packet, Page 11

Weight Number: $\boxed{0}$ 6 12

Tell students, "Now you have the values of the variables you would suggest that Windy Works uses, we are going to test your recommendations." Ask students, "What is the maximum amount of current that you got in your experiments?" Allow subgroups to share their answers. Ask students, "What amount of current do you think a wind turbine with your specifications will produce?" Students should suggest a value that is greater than the values they saw and greater than 6.5 mA, because this is the largest value seen in the graphs. Tell students, "I have set-up a wind turbine with your suggested values." Turn on the fan and have a student read the current off the multimeter. Record this value for question *12*.

12. Current produced by ideal wind turbine: 8.5 mA

Tell students, "You have taught me a lot about energy and wind turbines. I learned there are many different types of energy, and energy cannot be created, nor destroyed, but it can be transferred. I also learned there are different ways to build a wind turbine to increase the amount of current that it will produce. Before I leave, I would like to see how your science content knowledge has changed."

Content Assessment:
(10 minutes – Full Class – SciTrek Lead)

Have students close their notebooks, and place them in the corners of their desks. Pass out the content assessment to students. Have students write their name, teacher's name, and date at the top of their assessment. Tell students, "When doing this assessment, you should work individually, so there should be no talking." Read each of the content questions to the students and have them select/fill out the correct answer. As you are giving the assessment, walk around the room and verify students have written their names on their assessments. When done, collect the assessments.

Tell students, “You can keep your notebooks, I have enjoyed working, and learning with you.I hope you will continue to see yourselves as scientists and explore the world around you.”

Clean-Up:

1. Leave notebooks with students.
2. Place all other materials into the lead box and bring them back to UCSB.
3. Remove all materials from your lab coat pockets, remove your nametag, unroll your lab coat sleeves, and put your lab coat into the dirty clothes bag at UCSB.

Extra Practice Solutions:

EXTRA PRACTICE

Procedures

QUESTION

If we change the solid type what will happen to $\boxed{\text{the temperature}}$ at which the water boils?

EXPERIMENTAL SET-UP

Changing Variable:	Trial A	Trial B	Trial C	Trial D
Solid Type:	Sugar	Salt	Baking Soda	None

Controls (variables you will hold constant)**:**

Solid Amount / 10 g	Heat Source / Bunsen burner
Liquid Amount / 250 mL	Liquid Type / Water
Container Type / Beaker	Container Size / 500 mL

Directions:

Step 1: Read each statement and underline <u>controls</u>, circle changing variables, and box information about $\boxed{\text{data collection}}$.

Step 2: Circle yes if the statement could be a correct step for a procedure about the question and experimental set-up above. If not, circle no.

		Could this be a procedure step?	
1.	Put <u>10 g</u> of A) sugar, B) salt, C) baking soda, D) none into each <u>beaker</u>.	*Yes*	*No*
2.	Light the awesome <u>Bunsen burner</u>.	*Yes*	*No*
3.	Put <u>250 mL</u> of <u>water</u> into each <u>500 mL</u> beaker.	*Yes*	*No*
4.	$\boxed{\text{Gather results}}$ from the experiment.	*Yes*	*No*
5.	Put <u>10 g</u> of baking soda into beaker C.	*Yes*	*No*
6.	Measure the $\boxed{\text{temperature}}$ the solution boils at.	*Yes*	*No*
7.	Put <u>10 g</u> of different solid types into each <u>beaker</u>.	*Yes*	*No*

Underline <u>controls</u>, circle changing variables, and box $\boxed{\text{data collection}}$.

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