Lab Handout

Lab 22. Conservation of Energy and Wind Turbines: How Can We Maximize the Amount of Electrical Energy That Will Be Generated by a Wind Turbine Based on the Design of Its Blades?

Introduction

The United States relies heavily on fossil fuels, such as oil, coal, and natural gas, for energy. Americans burn fossil fuels to power their cars, to heat and light their homes, and to run their consumer electronics and household appliances. Unfortunately, when the supply of fossil fuels declines, it can lead to an energy crisis. In 1973, for example, the Organization of the Petroleum Exporting Companies (OPEC) declared an oil embargo and drastically reduced the amount of oil they sent to the United States. This six-month embargo caused widespread gasoline shortages and significant price increases. A second oil crisis in the United States occurred in 1979 as a result of a decrease in the output of oil from the Middle East along with price increases. This decrease in output resulted in gasoline shortages and long lines at gasoline stations throughout the United States (see Figure L22.1).These events led to a political push for policies that would make America more energy independent. A country that is energy independent does not need to import oil or other forms of energy from other countries to meet the energy demands of its citizens.

FIGURE L22.1

A long line at a gas station in Maryland as a result of the 1979 oil crisis

More recently, evidence that the burning of fossil fuels contributes to climate change has exacerbated the need to develop new energy sources. To combat the effects of climate change, scientists have been working on ways to harness and use renewable energy sources. Renewable energy sources are forms of energy that are continuously replenished. Solar, tidal, and geothermal energy are examples of renewable energy sources. Furthermore, all renewable energy sources are clean, which means they do not contribute to climate change. These sources of energy, however, are often difficult to access without the development of new technologies.

One of the more promising renewable energy sources is wind. Wind is just the movement of a large number of air particles from one area to another. In the United States,

wind energy is a very attractive option because the Great Plains states of Texas, Oklahoma, Kansas, Nebraska, and the Dakotas have vast open spaces where wind blows for extended periods of time. Wind energy takes advantage of the law of conservation of energy to convert the kinetic energy of air particles (gases such nitrogen [N_2], oxygen [O_2], water vapor, and others) into electrical energy. To achieve this conversion, several huge wind turbines are built to create a wind farm (see Figure L22.2). When air particles collide with the blades on the turbine, they transfer some momentum to the blades. This momentum transfer causes the turbine to spin, resulting in an increase in the kinetic energy of the turbine blades. The turbine then turns a generator, producing an electric current from a transfer of kinetic energy to electric energy. Wires carry the current to other locations, for use in homes and businesses.

FIGURE L22.2

A wind farm

When designing a wind turbine, scientists and engineers must account for a variety of factors related to how and where wind blows. As mentioned earlier, wind farms are best placed in the Great Plains, yet only a small percentage of people live in this geographic location, so scientists and engineers must also think about how to move the energy generated to more populous areas. Another factor is the height of the turbine. Wind tends to blow faster at higher altitudes, meaning the height of the turbine affects the amount of energy produced. Other potential factors that may influence the amount of electrical energy produced include the angle of the blades relative to the wind, the number of blades on the turbine, and the shape and mass of the turbine blades.

Your Task

Use what you know about the conservation of energy, systems, models, and structure and function to test the effect of changes to the design of wind turbine blades on the amount of electrical energy produced by the wind turbine. Your goal is to determine how the angle, number, and shape of the blades that are attached to the wind turbine affect the amount of electrical energy that the wind turbine is able to produce.

The guiding question of this investigation is, ***How can we maximize the amount of electrical energy that will be generated by a wind turbine based on the design of its blades?***

Materials

You may use any of the following materials during your investigation:

- Safety glasses or goggles (required)
- Wind turbine kit with adjustable blades
- Fan to generate wind
- Multimeter or galvanometer
- Electric wires
- Lightbulbs
- Ruler
- Protractor

Safety Precautions

Follow all normal lab safety rules. In addition, take the following safety precautions:

1. Wear sanitized safety glasses or goggles during lab setup, hands-on activity, and takedown.
2. Handle blades with care. They can puncture skin.
3. Electric wire may get hot. Use caution when touching exposed parts of wires.
4. Handle lightbulbs with care. They can get hot and burn skin; also, they are fragile and can break easily, causing a sharp hazard that can cut or puncture skin.
5. Keep fingers and toes out of the way of moving objects.
6. Wash hands with soap and water after completing the lab.

Investigation Proposal Required? ☐ Yes ☐ No

Getting Started

You will need to design and carry out at least three different experiments to determine how to maximize the amount of electrical energy that is generated by a wind turbine based on the design of its blades. You will need to conduct three different experiments because you will need to be able to answer the following questions before you can develop an answer to the guiding question for this lab:

1. How does changing the number of blades affect the energy output of the turbine?
2. How does changing the shape of the blades affect the energy output of the turbine?
3. How does changing the angle of the blades affect the energy output of the turbine?

It will be important for you to determine what type of data you need to collect, how you will collect it, and how you will analyze it for each experiment, because each experiment is slightly different.

To determine *what type of data you need to collect,* think about the following questions:

- What are the boundaries and components of the system you are studying?
- How do the components of the system interact with each other?
- How can you describe the components of the system quantitatively?
- How could you keep track of changes in this system quantitatively?
- How might the structure of a wind turbine blade relate to its function?
- How might changes to the structure of a wind turbine blade affect how it functions?
- Is it useful to track how energy flows into, out of, or within this system?
- What will be the independent variable and the dependent variable for each experiment?

To determine *how you will collect the data,* think about the following questions:

- How will you vary the independent variable during each experiment?
- What will you do to hold the other variables constant during each experiment?
- When will you need to take measurements or observations during each experiment?
- What scale or scales should you use when you take your measurements?

To determine *how you will analyze the data,* think about the following questions:

- What types of calculations will you need to make?
- What types of comparisons will you need to make?
- How could you use mathematics to determine if there is a difference between the groups?
- What type of table or graph could you create to help make sense of your data?

Connections to the Nature of Scientific Knowledge and Scientific Inquiry

As you work through your investigation, you may want to consider

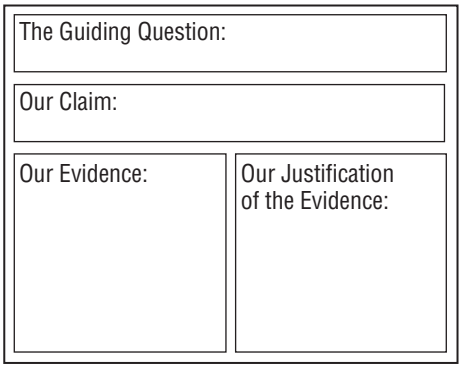
- how scientific knowledge changes over time, and
- how the culture of science, societal needs, and current events influence the work of scientists.

Initial Argument

Once your group has finished collecting and analyzing your data, your group will need to develop an initial argument. Your initial argument needs to include a claim, evidence to support your claim, and a justification of the evidence. The *claim* is your group's answer to the guiding question. The *evidence* is an analysis and interpretation of your data. Finally, the

justification of the evidence is why your group thinks the evidence matters. The justification of the evidence is important because scientists can use different kinds of evidence to support their claims. Your group will create your initial argument on a whiteboard. Your whiteboard should include all the information shown in Figure L22.3.

FIGURE L22.3
Argument presentation on a whiteboard



Argumentation Session

The argumentation session allows all of the groups to share their arguments. One or two members of each group will stay at the lab station to share that group's argument, while the other members of the group go to the other lab stations to listen to and critique the other arguments. This is similar to what scientists do when they propose, support, evaluate, and refine new ideas during a poster session at a conference. If you are presenting your group's argument, your goal is to share your ideas and answer questions. You should also keep a record of the critiques and suggestions made by your classmates so you can use this feedback to make your initial argument stronger. You can keep track of specific critiques and suggestions for improvement that your classmates mention in the space below.

Critiques about our initial argument and suggestions for improvement:

If you are critiquing your classmates' arguments, your goal is to look for mistakes in their arguments and offer suggestions for improvement so these mistakes can be fixed. You should look for ways to make your initial argument stronger by looking for things that the other groups did well. You can keep track of interesting ideas that you see and hear during the argumentation in the space below. You can also use this space to keep track of any questions that you will need to discuss with your team.

Interesting ideas from other groups or questions to take back to my group:

Once the argumentation session is complete, you will have a chance to meet with your group and revise your initial argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the best argument possible.

Report

Once you have completed your research, you will need to prepare an *investigation report* that consists of three sections. Each section should provide an answer to the following questions:

1. What question were you trying to answer and why?
2. What did you do to answer your question and why?
3. What is your argument?

Your report should answer these questions in two pages or less. This report must be typed, and any diagrams, figures, or tables should be embedded into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable or valid!