Science and Innovation

A Boeing/Teaching Channel Partnership

ALTERNATIVE ENERGY

Teacher Handbook

Teaching Channel

Alternative Energy

Days 5 and 6: How Wind Energy Converts to Electrical Energy

Grade Level	Grade 4
Lesson Length	Two 50-minute sessions

Lesson Overview

During Days 5 and 6, students continue to work with the idea that mechanical energy from the wind can be converted into electrical energy. Students build on this understanding by examining motors and generators. Students examine the parts of a simple motor with a specific focus on using the motor to generate electromagnetism; generators in wind turbines utilize a similar process.

Students have ample time to explore with simple motors, and afterwards, they participate in a mini-design competition to see whose design (battery, nail, and a connected wire coil) can generate the most electromagnetic energy and pick up the most metal paper clips. At the end of the lesson, students revise their models for how a wind turbine works to incorporate the science idea of energy transformations.

Connecting to the Next Generation Science Standards

On Days 5 and 6, students make progress toward developing understanding across the following three dimensions:

- Science and Engineering Practices: Constructing Explanations and Designing Solutions
- Disciplinary Core Ideas: PS3.B Conservation of Energy and Energy Transfer
- Crosscutting Concepts: Energy and Matter

In the following table, the specific components addressed in this lesson are underlined and italicized. The specific connections to classroom activity are stated.

Performance Expectations
This lesson contributes toward building understanding of the following *physical science* performance expectation: 4-PS3-4. *Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.*
Specific Connections to Classroom Activity On Days 5 and 6, students begin to make sense of the ways by which mechanical energy from the wind can be converted into electrical energy. Students deconstruct a motor, which is similar to the generator in a wind turbine, to build an understanding of the motor components and characteristics. Students use their understanding to build their own motor. At the end of Day 6, students use their understanding of motors and generators to revise their wind turbine models. Students incorporate the idea that mechanical energy can be converted to electrical energy through a motor to their models.

Dimension	NGSS Element	Connections to Classroom Activity
Science and Engineering Practices	Constructing Explanations and Designing Solutions • *Use evidence (e.g., measurements, observations, patterns) to construct an explanation.* • *Apply scientific ideas to solve design problems.*	Through their investigations with motors and generators, students develop the science idea that mechanical energy can be converted into electrical energy. Students use these ideas to refine their model for how a wind turbine works. In subsequent lessons, students use their revised models to inform design decisions.
Disciplinary Core Ideas	PS3.B: Conservation of Energy and Energy Transfer • *Energy can also be transferred from place to place* by electrical currents, which can then be used locally to produce motion, sound, heat, or light. *The currents may have been produced to begin with by transforming the energy of motion into electrical energy.*	On Days 1 through 4, students began to work with the idea that energy from the wind could be converted into electrical energy. On Days 5 and 6, students examine motors and generators to develop a deeper understanding of how generators can transform mechanical energy into electrical energy.
Crosscutting Concepts	Energy and Matter • *Energy can be transferred in various ways and between objects.*	Students investigate the ways by which motors and generators can transform energy. Specifically, students consider the idea that generators transform energy from the wind into electrical energy.

Basic Teacher Preparation

These two days give students a deeper understanding of how energy is converted from one form to another—an essential concept also linked to how wind turbines work. Day 5 provides an opportunity for students to explore the components of a simple motor. This helps students understand the function of the part of a wind turbine that is not visible—the generator. A wind turbine's generator is essential to convert the mechanical energy generated by a turbine to electrical energy. In this sense, generators and motors have some similarities.

Because actual motors and motor parts are used for many of the explorations, all necessary materials should be gathered ahead of time. The Materials List includes the necessary components and preparation guidelines.

Required Preparation	Links/Additional Information
❑ Gather or purchase the required materials for the lesson	Refer to the Materials List for this lesson
❑ Watch recommended videos	Refer to the Suggested Teacher Resources at the end of this lesson
❑ Review recommend web pages	Refer to the Suggested Teacher Resources at the end of this lesson

Materials List

Item	Description/Additional Information	Quantity	Where to Locate/Buy
Inexpensive electric motors	Comes in a package of 5—may need 2 or 3 packs For exploration and to harvest magnet wire	1 per team, with more for parts harvesting	Electric Motor [Web Link]
Nails	Anything 2+inches long will work For electromagnet	Several nails for each team	Local hardware store, box of several nails [Web Link]
AA or AAA batteries		As needed for motors	Local grocery store
Very fine sandpaper		1 package	Fine sandpaper [Web Link]
Paper clips		1 box	Office supply store
Jumper wires with alligator clips		1 per team	[Web Link]
Small flat head screw drivers		1 per team	Local hardware store
Masking tape		1 roll per team	Local hardware store
Lighter	For the teacher's or adult volunteer's use only	1 per class	Local hardware store

Day 5: How Wind Energy Converts to Electrical Energy

Introduction (10 minutes)

Instruct students to organize all drafts of their Wind Turbine Models—Chart Paper. At this point, students should have at least four models showing revisions over time:

- Initial model
- Initial model including LED light
- Revised model after test #1
- Revised model after test #2

Allow students several minutes to incorporate any new ideas or revisions into their most recent model. Next, instruct students to think about what they are still missing from their model. Have students record their ideas on the back of the chart paper.

As students examine their models, they might find that they have questions about how the mechanical energy from wind is converted into electrical energy. Although they considered this idea on Day 2, they did not have a chance to fully develop the idea.

Have students share their questions with the group. Many teams might touch on the idea of *energy transformation*. Tell students that to answer their questions about energy transformation, they are going to investigate motors and generators.

NGSS Key Moment

Student questions regarding *energy transformations* should drive the investigation of motors and generators.

Mini-Lesson: Motors and Generators (10 minutes)

To introduce helpful background information, show and discuss one or both of the short videos:

- The How Wind Turbines Generate Electricity video shows how the wind's kinetic energy is converted into mechanical energy as the blades turn the rotor inside the generator housing. This spins a magnetic rotor inside loops of copper wire and produces electrical energy.
- The Energy 101: Wind Turbines video is also helpful, but not as detailed as the first video.

Video Links

- How Wind Turbines Generate Electricity [YouTube Link]
- Energy 101: Wind Turbines? [YouTube Link]

Let students know that they are going to explore some basic functions of a motor. While a motor produces mechanical energy and a generator (like that found in a wind turbine) produces electrical energy, they share some similar characteristics, including:

- Both motors and generators produce alternating electric current.
- Many of the parts are similar and both use electromagnetic fields to operate.
- Both motors and generators use direct current and switches to turn.
- Many of the parts are similar and both use turbines to make them spin.

For that reason, today's exploration provides insight into some of basic components and functions of both.

Investigation: How a Motor Works (10 minutes)

Conduct a demonstration for students. Use two jumper wires, the demonstration motor, and a battery. Connect the two jumper wires to the terminals on the motor. These are the little metal tabs that stick out from the back, and touch on the battery, causing the motor to spin. Complete directions are shown in this video. In particular, view the portion at the 1:15 mark.

Swap where the wires touch on the battery and ask students what they think will happen. (The motor will spin in the opposite direction.) See 1:30–1:50 of the video. Ask students to defend their claims with reasoning.

Give each group of students a battery, a simple motor, and two jumper wires with alligator clips at each end.

- Each student in the group should take a turn with the motor, touching wires to the battery, and then reversing it.
- Students can put a small piece of tape on the motor shaft to better see it spin.

Video Links

- Motor Disassembly [YouTube Link]

NGSS Key Moment

This activity allows students to observe the conversion of electrical energy from the battery into the mechanical energy of the motor spinning. The conversion of energy from one form to another is a key learning objective for this unit. Students also observe that changing the direction of voltage (flipping the battery) causes the motor to spin in the opposite direction.

Investigation: Parts of a Motor (15 minutes)

Prior to the lesson, take one motor apart for demonstration purposes. This preliminary work must be completed before class, because it can be challenging. Eventually, each team will be able to disassemble their own motor for exploration purposes.

Show students how to pull out the rotor (the spinning part) of their motors. The rotor has copper wire wound around notches.

Helpful Tip

Watch the **Motor Disassembly** video [YouTube Link] in advance so you can demonstrate the process in a step-by-step manner.

If desired, and if enough motors are available:

- Students can pull out the rotor (spinning part) in their own motors.
- Motor parts (together, but opened) can be passed around the room, so students can put the rotor in and out of the demo motor, or have students do this with their own motors.

Mention that when electricity passes through the copper wires, it creates a magnetic field that pushes against the permanent magnets inside. The permanent magnets are usually a black band along the inside wall of the motor housing. Ask students to identify these.

Get the disassembly started by bending back the little tabs on the small motors that hold on the plastic back. After that, have students continue with their own disassembly. Have each group remove one wire from their motor.

Once the wires are removed from the motors, remove the insulation from the tips of the wires. The wires look like raw copper, but they are actually covered in a clear varnish for insulation. The best removal method is to burn off the insulation. Hold a flame (from a lighter or other source) to the tip for a few seconds.

Important Note

For safety, only the teacher or adult volunteer should use a flame! Otherwise, students can use sandpaper to remove the insulation, but this will add time.

Lesson Close (5 minutes)

Have students clean up and put away all materials. They use the same materials on the next day.

Homework

Ask students to create a sketch of the disassembled motor. Tell students to label the parts and explain what each part does.

Day 6: How Wind Energy Converts to Electrical Energy

Introduction (5 Minutes)

Have students share their homework task:

- *What parts of the motor did they label?*
- *What does each part do?*

Investigation: Design a Motor (20 minutes)

Using one of the wires previously prepared:

1. Demonstrate winding a coil of the copper wire around a nail.
2. Leave ~6-inch wire leads.
3. Connect the battery to wire leads using alligator clips.
4. Use the nail to pick up paperclips.

Hand out wires (after removing the tip insulation). Have students wrap the wire around the nail, connect alligator clips, and hook to the battery.

Note that reversing the battery reverses the magnetic field (north vs. south) but either way, the nail will pick up paperclips. Ask students to speculate about why this works.

Explain that the electromagnet in a wind turbine generator is wrapped in just the right way on the motor's rotor and pushes against the fixed permanent magnets in the walls of the motor. Have students manipulate the number of coils and how closely together the wire coils are wound around the nail. As students work, have them consider the following questions:

- *How does this affect the magnetism and ability to pick up the paper clips?*
- *Which team's nail/coil design can pick up the most clips?*
- *What variables contribute to a better "pick-up"?*
- *Why does this occur and what can be inferred about the increase or decrease in effectiveness?*

Video Link

For a demonstration of this sequence, view this video:

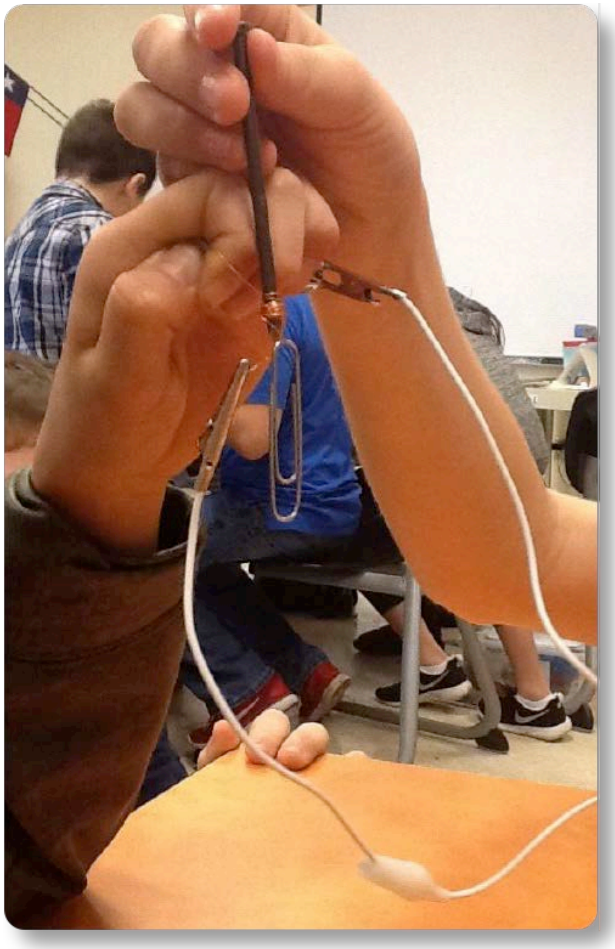
▶ Electromagnetic Build [YouTube]

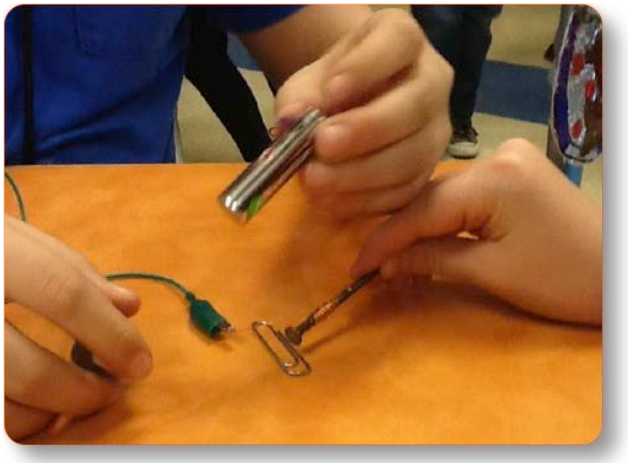
Important Note

The wire may get hot. This can occur due to the wire being connected to the battery without resistance, which can cause a high current.

NGSS Key Moment

Electromagnets create a force on most metals and especially on other magnets. The force is what converts electrical energy (from the battery) to mechanical energy (the spinning motor).





Important Note

The strength of the magnetic field will increase with more wraps of wire because this makes the electrical field stronger. A stronger electrical field correlates with a stronger magnetic field. So, if the coil of wire is closer to the tip of the nail (where the paper clips touch) that will also make the magnetic field stronger there.

Images provided by Jessica Kline.

Investigation: Revising Our Model (15 minutes)

Provide students with a fresh piece of chart paper. Instruct students to develop a final model to demonstrate how a wind turbine spins and converts wind energy into electrical energy. The final model should incorporate ideas addressed on Days 5 and 6, and should build on the draft models. Tell students to use their final model to justify design decisions in the design challenge.

Lesson Close (10 minutes)

During the remaining class time, reintroduce students to the design challenge. Remind students that, earlier in the module, their teams conducted trials to see if they could modify turbine blades to produce more energy. The ultimate design challenge is to:

Create a blade design that generates the most speed and electricity on the prototype turbine.

Prepare students for a final design model competition. Their designs should be based on many design and data collection trials, and science ideas related to how wind turbines work. Students

should adjust as many factors as they want with the turbine blades. All student modifications should be justified and explained by their model for how a wind turbine works.

Here are the key requirements of the final design challenge:

- Students must keep track of their data (collected from various trials) and be prepared to share it.
- Students must keep track of all their models explaining how the wind turbine generates electricity and be prepared to share them during their presentation.
- Students may refine their models during the design process.
- Once a final design is chosen, students must draw a blueprint or model that shows the key elements of their selected blade design and how the blades work on the turbine. Key elements must be labeled.
- Each team gives a 4- to 5-minute oral presentation explaining the rationale behind their design as well as the data collected. Students must use their models to explain their reasoning.
- Each team member must write up his or her own abstract (summary of the research process and findings).
- Each team member must have a role in the presentation (such as design reviewer, data reporter, model explainer, summarizer of what the team learned, and so forth).
- At the end of each oral presentation, the team conducts three trials with the optimized turbine blades.

Important Note

Guidelines for the **Design Challenge** and a final scoring rubric are included in **Appendix C** and **Appendix D**.

Assessment

Several opportunities for formative assessment exist in this lesson:

- Student sketches of the disassembled motor on Day 5.
- Revised models for wind turbines created on Day 6.
- Consider gathering evidence of student progress through small group and whole group discussions.

Use the identified assessment opportunities to monitor student progress on disciplinary core ideas, science and engineering practices, and crosscutting concepts. Provide appropriate supports or extensions when necessary.

Reference Appendix B for suggestions for meeting the needs of all learners.

Community Connections

Students may have parents, guardians, or family members who work as mechanics, electricians, or motorized equipment. Ask the students to bring in anecdotal examples about how these adults use or interact with motors, electricity, or forms of energy in their work.

Suggested Teacher Resources

Meeting the Needs of All Learners	Alternative Energy Teacher Handbook, Appendix B
Design Challenge	Alternative Energy Teacher Handbook, Appendix C
Motor Disassembly	[YouTube Link]
Electromagnetic Build	[YouTube Link]
Department of Energy	[Web Link]
How Wind Turbines Generate Electricity	[YouTube Link]
Energy 101: Wind Turbines	[YouTube Link]