Power & Propulsion

Let's Generate

Grade Level(s): 8th and 9th

Academic Content Area(s): Physical Science and Math

Topic(s): Physical Science; Science and Technology; Scientific Inquiry; Measurement

Recommended area of co-teaching for an AFRL Engineer or Scientist.

Main Problem/Essential Question

How can a generator be created from a motor? How can a generator be made to be more efficient?

Summary

This lesson compliments the Dayton Regional STEM Center lesson titled Electric Motors (designed for grade 11).

Students will dissemble a toy motor in order to understand the transformation of kinetic energy to mechanical energy. Through experimentation and research students will discover how to turn their motor into a wind generator. Students will then study the wing/ blade variables of pitch, camber, and surface area in an attempt to improve their generator design. By applying what they have learned through research and scientific inquiry as well as math concepts and the engineering design process, students will collaborate to create a "best" design. The objective of the design is to engineer a generator that can produce enough voltage to light a LED bulb.

Big Idea(s) / Focus

Students will explore how a generator transforms mechanical energy into electrical energy and determine properties that affect propeller efficiency in the quest to generate electricity from a turbine.

Prerequisite Knowledge

Students should have general knowledge of: Magnets, Electricity including simple circuits, Energy Transformations, and Geometry-angle measurements. This general knowledge will be built upon throughout the activity as students explore the function of and create a working generator.

Standards Connections

Science Content Standards:

Physical Science

Students demonstrate an understanding of the composition of physical systems and the concepts and principles that describe and predict physical interactions and events in the natural world. This includes demonstrating an understanding of the structure and properties of matter, the properties of materials and objects, chemical reactions and the conservation of matter. In addition, it includes understanding the nature, transfer and conservation of energy; motion and the forces affecting motion; and the nature of waves and interactions of matter and energy. Students demonstrate an understanding of the historical perspectives, scientific approaches and emerging scientific issues associated with the physical sciences.

Grade 8 - Benchmark B: In simple cases, describe the motion of objects and conceptually describe the effects of forces on an object.	3. Explain that an unbalanced force acting on an object changes that object's speed and/or direction.
Grade 9- Benchmark D: Explain the movement of objects by applying Newton's three laws of motion.	22. Demonstrate that any object does not accelerate (remains at rest or maintains a constant speed and direction of motion) unless an unbalanced (net) force acts on it. 24. Demonstrate that whenever one object exerts a force on another, an equal amount of force is exerted back on the first object. 25. Demonstrate the ways in which frictional forces constrain the motion of objects (e.g., a car traveling around a curve, a block on an inclined plane, a person running, an airplane in flight).
Grade 9 - Benchmark E: Explain how energy may change form or be redistributed but the total quantity of energy is conserved.	15. Trace the transformations of energy within a system (e.g., chemical to electrical to mechanical) and recognize that energy is conserved. Show that these transformations involve the release of some thermal energy.
Grade 9 - Benchmark H: Trace the historical development of scientific theories and ideas, and describe emerging issues in the study of physical sciences.	27. Describe advances and issues in physical science that have important, long-lasting effects on science and society (e.g., atomic theory, quantum theory, Newtonian mechanics, nuclear energy, nanotechnology, plastics, ceramics and communication technology).

Science and Technology

Students recognize that science and technology are interconnected and that using technology involves assessment of the benefits, risks and costs. Students should build scientific and technological knowledge, as well as the skill required to design and construct devices. In addition, they should develop the processes to solve problems and understand that problems may be solved in several ways.

Grade 8 - Benchmark B: Design a solution or product taking into account needs and constraints (e.g., cost, time, trade-offs, properties of materials, safety and aesthetics).	3. Design and build a product or create a solution to a problem given more than two constraints (e.g., limits of cost and time for design and production, supply of materials and environmental effects). 4. Evaluate the overall effectiveness of a product design or solution.
Grade 9 - Benchmark A: Explain the ways in which the processes of technological design respond to the needs of society.	2. Identify a problem or need, propose designs and choose among alternative solutions for the problem. 3. Explain why a design should be continually assessed and the ideas of the design should be tested, adapted and refined.

Scientific Inquiry
Students develop scientific habits of mind as they use the processes of scientific inquiry to ask valid questions and to gather and analyze information. They understand how to develop hypotheses and make predictions. They are able to reflect on scientific practices as they develop plans of action to create and evaluate a variety of conclusions. Students are also able to demonstrate the ability to communicate their findings to others.

Grade 8 - Benchmark B: Analyze and interpret data from scientific investigations using appropriate mathematical skills in order to draw valid conclusions.	3. Read, construct and interpret data in various forms produced by self and others in both written and oral form (e.g., tables, charts, maps, graphs, diagrams and symbols).
Grade 9 - Benchmark A: Participate and apply the processes of scientific investigation to create models and design, conduct, evaluate, and communicate the results of these investigations.	6. Draw logical conclusions based on scientific knowledge and evidence from investigations.

Math Content Standards:

Measurement Standard
Students estimate and measure to a required degree of accuracy and precision by selecting and using appropriate units, tools and technologies.

Grade 8- Benchmark A: Solve increasingly complex non-routine measurement problems and check for reasonableness of results.	3. Use appropriate levels of precision when calculating with measurements.

Preparation for Activity
Gather necessary materials as outlined in the materials section.

<u>Prepare the Following Copies</u>
Pre-test/Post-test (Appendix A) – 2 per student
Student Generator Research Rubric (Appendix B) – 1 per student
Variable Research Rubric (Appendix C) – 1 per student
Group Work Rubric (Appendix D) – 1 per student

Scientific Process Rubric (Appendix E) – 1 per student
Student Generator Plan Sheet (Appendix F) – 1 per student
Walkabout Student Worksheet (Appendix G) – 2 per student

Critical Vocabulary

Angle-of-Attack - angle difference between the incoming airflow and the chord line of the airfoil.

Aspect ratio - the ratio of the length of the wing to the average chord length often times given as the ratio of the span squared to the wing area.

Camber - the asymmetry of the airfoil about the chord-line

Chord – (on a wing or propeller) the distance from the leading edge to the trailing edge, measured parallel to the flow over the surface.

Drag - a force that opposes motion (or thrust) and is defined in a similar manner to Lift:

$$\text{Drag} = 0.5 \times (\rho) \times (V_\infty)^2 \times (A) \times (CD)$$

where ρ is the density of the fluid, V_∞ is the freestream speed of the fluid, A is the area that the fluid flows across, and the CD is the coefficient of drag that varies by the surface geometry and orientation of the surface to the flow.

Energy Transformations - the process of converting energy from one form to another. The six forms of energy are chemical, electrical, mechanical, radiant (light), thermal, and nuclear.

Generator- a system that converts mechanical energy into electrical energy by electromagnetic induction.

Lift - When a fluid flows over an aerodynamic surface, the force that results from the differential speeds of the flow over and under the surface as described by Bernoulli's Principal is called Lift. Lift which is an opposing force to weight is given by the equation:

$$\text{Lift} = 0.5 \times (\rho) \times (V_\infty)^2 \times (A) \times (CL)$$

where ρ is the density of the fluid, V_∞ is the freestream speed of the fluid, A is the area that the fluid flows across, and the CL is the coefficient of lift that varies by the surface geometry and orientation of the surface to the flow. From a comparison of the Lift equation to the Drag equation, it can be observed that the same parameters that increase Lift also increase Drag.

Motor- a system that converts any form of energy into mechanical energy, imparting motion

Pitch – (As related to aircraft propellers) the twist angle of the propeller blade as measured from a reference plane that is perpendicular to the longitudinal axis of the aircraft.

Span – (of a wing) the wing tip-to-wing tip distance.

Surface area- area of the exposed surface.

Wing Area –the projected area of the wing, where total surface area is the area of the wing (both top and bottom) located between the leading edge and trailing edge of the wing. The wing area is closely on-half that of the total surface area.

Timeframe

Day	*Approximate Time Allotment*	*Activities*
1	40-50 min.	Administer Pre-Test (Appendix A) Electric Motor Disassembly
2	40-50 min.	Virtual Electric Motors Module.
3	40-50 min.	Motor → Generator Challenge
4	40-50 min.	Generator Research
5	40-50 min.	Generator Roundtable Discussion Mini-Lesson: Blades
6	40-50 min.	NASA sim software/Introduce Engineering Design Challenge
7	40-50 min.	Engineering Design Challenge: Angle of Attack, Surface Area & Camber subgroups
8-9	90-100 min.	New group assignment forming Optimal design teams Optimal Design Team: Redesign
10	40-50 min.	Walkabout Class discussion Administer post-test (Appendix A)

Materials & Equipment

Prior to the activity secure the following materials:

Enough 1.5 Volt Motors for all students to work in teams of two.
LED light bulbs—1 per team (Christmas lights cut in pieces)
C Battery to run motors—1 per team
Wires with alligator clips-4 per team
Voltmeter/Multimeter—1 per team
Small Screwdriver Set—1 per team
Hot Glue & Hot Glue Guns- 1 per team
Popsicle Sticks-Box of 500 per class
Styrofoam to serve as hub to hold blades (2x2 block)
Optional: science journal- 1 per student

Material Breakup by day:

Day 1: Introduction

Copies of Pre-Test (Appendix A)
1.5V DC motors-1 per group of two students
C Battery – 1 per group
Small screwdriver set-1 per team
Generator Plan Sheet (Appendix F)

Day 2: Electric Motors Inquiry
Computer and Internet access for each group

Day 3: Motor →Generator challenge

One 1.5V DC motor- per group of 2 students
1 LED light per group
Wires with alligator clips to connect lights to motor casing
Access to a variety of materials to capture/transform energy for the generator design: String, Styrofoam, cardboard, paper, popsicle sticks
Access to fans, water, hairdryers or other materials to power their designs
Access to scissors, glue, hot glue guns, rulers and exacto-knives

Day 4: Class designs and research discussion

Poster-paper or other media form for brainstorming
Access to internet to begin research as time is available
Generator Research Guidelines (Appendix B)

Day 5: Round Table Discussions and Mini-Lesson

Optional: Computer connected to LCD projector with PowerPoint capabilities

Day 6: NASA simulator

Computers with internet access for free NASA simulator
Copies of Student Design Plan (Appendix F)

Day 7: Engineering Design Challenge

Popsicle sticks to construct the blades—blade material should be kept constant for this portion of the exercise.
Styrofoam to attach blades into (2x2 block)
Scissors, glue, hot glue guns, rulers and other craft supplies
Fan/Hairdryer to spin the blades—several available to the class
Voltmeter or Multimeter-1 per team
Wires to connect components
LED light
Optional: Students may need to have access to a video-camera, movie software, and stopwatches to determine Rotations per minute

Day 8-9: Redesign and Formation of Optimal Design Team

Popsicle sticks to construct the blades
Styrofoam to attach blades into (2x2 block)
Scissors, glue, hot glue guns, rulers and other craft supplies
Fan to spin the blades
Voltmeter or Multimeter-1 per team
Wires to connect components
LED light
Optional: Students may need to have access to a video-camera, movie software, and stopwatches in order to complete optional Rotations per Minute Calculations

Day 10: Walkabout and Post-Test

Walkabout Student Hand-Out (Appendix G)
Copies of Post Test (Appendix A)

Safety & Disposal

Wear goggles when

- using sharp objects
- working with projectiles

Use of knives and other sharp objects

- cut away from self
- When handing a sharp instrument to another person, lay the instrument down and let the other person pick it up.
- do not hold an object while another person cuts
- follow classroom policy when walking with sharps

Use of glue gun

- point objects being heated away from you and others
- never reach over the heat source
- wait for hot objects to cool before touching or storing

Teacher Instructions

Day 1: Introduction

1. Administer the Pre-Test.
2. Students should be grouped in pairs to complete the disassembly of a small toy DC electric motor.

   (Teacher's Note): Larger groups can be used; however, this makes it more difficult to ensure that everyone has the opportunity to be hands-on with such small equipment.
3. Students should record in their laboratory notebook or sheet of paper every step they take and be careful to identify every component they remove. Students should draw detailed diagrams as they disassemble their motor. Students should try to figure out how the motor

works throughout this activity. Students can be provided with the Generator Plan Sheet (Appendix F)

(Teacher's Note): It is recommended that students use a science journal throughout this lesson to catalog growing concepts and conclusions. Students may use digital cameras to provide further documentation.

4. Students should re-assemble their motor.

Day 2: Electric Motors Inquiry

1. Have students navigate through the software in the Electric Motors module. (http://www.daytonregionalstemcenter.org/uploads/curriculum/avetec.htm)

   (Teacher's Note): Larger groups can be used; however, smaller teams allow students to have more interaction with the software. In this activity students will virtually take apart the motor, learn how a motor works, and learn the significance of each structure in the motor.

   Optional: If teacher has access to an electronic white board, this portion of the activity could be done as a class.

Day 3: Motor →Generator Challenge

1. Challenge students to answer:

   "How can a motor be turned into a generator?"

   Students should demonstrate that they can answer this question by turning their motor into a generator, lighting a LED bulb.

2. Have students document their trials and continue to test and retest designs that they develop.

   Teacher's Note: It is recommended that students record this information within their science journal.

3. Have student pairs share out their designs with the class.

4. Lead a discussion with the class:

   Looking at the designs constructed, how could these designs be improved?

   What worked and what didn't work?

   How do you make a generator more efficient?

   (Teacher's Note): It is recommended that this be done as an informal discussion.

An AFRL Electrical or Mechanical Engineer can be invited into the classroom to help students explore their motors/ generators. This individual can help students brainstorm on how to accomplish the presented challenge as well as encourage students to further explore their equipment capabilities. This individual can also discuss the importance of generators in industry in regards to money and safety.

Day 4: Generator Research

1. Lead students to brainstorm real world applications of generators.

   Discuss how generators convert energy.

From this brainstorm divide students up in teams of 4 to research real-world applications of generators.

Provide the Generator Research Guidelines rubric (Appendix B) to direct the students.

2. Allow student teams of four to research and document their findings of generators and how they work. (Refer to Appendix B).

   (Teacher's Note): It is recommended that student's research be recorded in their science journals.

Day 5: Roundtable Discussion & Mini-Lesson

1. Lead a roundtable discussion on the findings from the generator research. Allow each team to share a portion of their research.

   (Teacher's Note): Evaluate using the Generator Research rubric, Appendix B.

2. As a class, discuss what characteristics all of the generators have in common, for example: conversion of mechanical energy to electrical, uses a motor, has a flow of electrons, etc.
3. Present a background lesson on propeller blade design and how propeller design can be used to improve efficiency of generators looking at these three traits: angle of attack, surface area, and camber.
4. Divide the class into teams of four.

   Assign a variable (2 groups per variable): angle of attack, surface area, and camber to each group.

Day 6: NASA Simulator

1. Introduce students to NASA software simulator (www.grc.nasa.gov/WWW/K-12/airplane/foil3.html) to experiment with their assigned research topic (angle of attack, surface area, or camber).

   Each student should have ample opportunity to manipulate their assigned variable and see impact on a plane wing.

   Have each student record what the level of their assigned variable was at optimum performance and turn in the data as an exit slip.

2. Provide students with the engineering challenge to demonstrate how their topic, angle of attack, surface area, or camber can be tested using propellers.

   Angle of Attack—At what angle should the blades be set to have in order to achieve the best results?

   Surface Area—What is the optimum surface area of the propeller blades to achieve the best results?

   Camber—What is the optimum camber to have with the propeller blade constructed to achieve the best results?

   (Teacher's Note): The Engineering Design Challenge can be introduced by distributing challenge cards, rather than formally introducing the assignment as a large group.

3. Set constants for teams to follow. For example—3 blades would be the constant surface area for the angle of attack group and the camber group. Groups should always test the same distance from the fan/hairdryer.

Day 7: Engineering Design Challenge

1. Allow students to design, construct, and test their propellers.

   Teacher should monitor student work and assist teams as needed. Pose questions about form and function.

2. Monitor the processes in which students are collecting data and provide necessary feedback.
3. Students should be instructed to connect their generator to a voltmeter and a light and record the obtained voltage.
4. Once teams complete their design, instruct them to summarize the data and recommendations in science journals, or other documentation plan.
5. Provide students a copy of Appendix C (Variable Research Guideline rubric).

An AFRL Electrical or Mechanical Engineer can be invited into the classroom to help students explore the engineering challenge and optimize their design.

Day 8-9: Redesign and Formation of Optimal Design Team

1. Have each team share their expert opinions on what is the optimum camber, angle of attack or surface area for the propeller.
2. Once the informal discussion is complete, divide the class into teams of six. Each team should consist of two students from each variable group. The resulting group will have two members of the camber team, the surface area team and the attack angle team.
3. Have the optimal design teams discuss and use their expertise on each design aspect to create the most efficient design, through redesign and synthesis of all three aspects into one optimal propeller design.

   (Teacher's Note): Reformed design teams should record their brainstorming and optimal design in their science notebooks. This entry should also include any collected data from the day's efforts.

An AFRL Electrical or Mechanical Engineer can be invited into the classroom to help students explore the engineering challenge, optimize their designs, and discuss real world applications for generators.

Day 10: Walkabout and Post-Test

1. Have Reformed design teams set up their design and display their collected data for a Walkabout.
2. Have students use Appendix G for Walkabout.

   (Teacher's Note): Here students and teacher walk around the room and examine every team's design, looking at what design produced the highest voltage and what design aspects were used to create the propeller. It is recommended that students are responsible for filling out a form for two or three peer designs.

3. Lead a question and answer session where teams can ask other teams questions and discuss how they were able to manipulate variables.

4. Administer post-test.

An AFRL Electrical or Mechanical Engineer can be invited into the classroom to participate in the Walkabout and post activity discussion.

Background Information

About Generators:

Batteries cannot provide us with high voltage electricity. Their use is limited to small devices that need electricity of a few volts because the power of chemical reactions are limited. In order to supply enough electricity for homes and industry, large scale electric dynamos or generators are necessary.

In 1831, Michael Faraday in England discovered that some electric currents were produced when he moved a magnet in and out of a coil of wire. This is called electromagnetic induction and can be used for transforming mechanical energy into electrical energy. The electric current in the coil, in turn, produces magnetic field and the coil behaves like a magnet. An electromotive force (EMF) acts between the coil and the magnet.

In a simple electric motor, current flows through a coil of wire between the poles of permanent magnets. When a current flows through the wire in the magnetic field, there is a force on it. The forces on the coil push one side of it down and the other side up (For more information about motors, refer to the information provided in the Dayton Regional STEM Center's Electric Motor lesson). When you turn the coil by force, on the other hand, it can generate electricity because the coil cuts the magnetic field.

About Propellers:

In this lesson, students will make their own generator/wind turbine using wood blades and a motor. The propeller design created using various blade arrangements and positions determines the strength of EMF (electromotive force), thereby demonstrating the efficiency of transforming mechanical energy into electrical energy.

Surface area: More blades, more surface area and more force (lift). However, a large number of blades would also create more drag. There must be a tradeoff between lift and drag in terms of the number of blades.

Pitch: is determined by the angle of the blades relative to the plane perpendicular to the axis of the propellers. Shallower angles create more drag. Steeper angles create less lift.

Camber: Just like the curved surface creates lift on an air foil, the camber of each blade creates lift.

Instructional Tips

- If time is a constraint, you may wish to skip the Day 1 activity of dismantling the motor and proceed directly into the Day 2 virtual motor activity. This is also an option if you have already completed the Electric Motors lesson.
- Lights- You can purchase a string of LED Christmas light strands and cut them apart for this activity to save money. Regular Christmas lights will also work for this activity. If

purchasing LED bulbs from a store (RadioShack for example) the longer leg is the positive side and the shorter the negative side. Students could practice wiring the light with just the battery to see the proper arrangement prior to experimenting.

- Voltmeters/Multimeters- be sure that students are able to correctly use these tools prior to the start of the activity. To teach the use of either of the tools, hook the meter up to the battery and have students record the voltage which should be at 1.5 with the C batteries used in this lesson.
- Styrofoam- If you cannot find Styrofoam precut to the correct size, you can take sheets of Styrofoam and cut to the desired size using a metal tube or cookie cutter.
- Encourage students to complete research outside of class for homework to maximize class time for engineering collaboration.
- Have one set of motors that students take apart and put back together throughout Day 1 of the activity. Then provide students new motors to work with for the remainder of the activity. Sometimes it is hard for students to reconstruct the motors correctly and that could impact generator performance during testing.
- Have students test and retest throughout the process. Students may want to borrow or copy designs from other teams—allow this to happen and see how an idea can be improved upon through collaboration. Draw attention to how improvements can always be made through the engineering design process and the advantage to a team working through a design process together versus an individual.
- If you would like to include practice with Metric Conversions within the unit, this can be done using the voltmeter converting from millivolts to volts.

Assignment of Student Roles and Responsibilities:

Grouping for Day 1-Day 7

Member	***Role Name***	***Brief Description***
1	Engineer	Responsible for investigation, documentation, and synthesis of scientific concepts. Responsible for employment of the Engineering Design Process and collaboration with team members.

Grouping for Day 8-Day 10

Member	***Role Name***	***Brief Description***
1	Camber Expert(s)	Responsible for providing the insight into the test results of camber. Share data and graphic information to support choices related to the optimum camber to have propellers set to.

2	Angle of Attack Expert(s)	Responsible for providing the insight into the test results for the Angle of Attack. Share data and graphic information to support choices related to the optimum Angle of Attack to have propellers set to.
3	Surface Area Expert(s)	Responsible for providing the insight into the test results for Surface Area. Share data and graphic information to support choices related to the optimum Surface Area to have the propellers set to.

Student Instructions

Generator Research Guidelines(Appendix B)
Variable (Camber, Surface Area, Angle of Attack) Research Guidelines (Appendix C)

Formative Assessments

Generator Research Rubric (Appendix B) This rubric evaluates the team presentation on a generator in use in society today. Students are challenged to research the generator, explain the mechanics, function, and design as well as the societal impact of the generator.

Variable Presentation Rubric (Appendix C) this rubric is designed to evaluate the design team on the content of their presentation.

Group Work Rubric (Appendix D) This rubric can be used on any day in the activity where students are collaborating in a group setting.

Scientific Process Skills Rubric (Appendix F) This rubric is designed for days 7-9 when students are working in teams testing one of the variables as well as for days 10-11 when students are creating the synthesis product of all three design aspects.

Post-Activity Discussion

Students will complete a Walkabout of all team designs and develop a question list for a number of predetermined designs. The teacher will lead a class question and answer session requiring students to refer to their individual Walkabout sheets on the various designs. Students can then be asked to write a reflection on how they would continue to improve their own design.

Potential Student Questions:

- What is the difference between motors and generators?
- Which are more efficient—motors or generators?
- How can a generator be made to be more efficient or better at converting energy?

- How is camber demonstrated in the design of a propeller blade? What is the optimum camber?
- How does surface area affect the design of a propeller blade? What are the advantages to a high surface area? To a small surface area?
- How does the angle of attack of the propeller blade affect performance?

Technology Connection

Integration Model	***Application Description***
Technology that supports students and teachers in **adjusting, adapting, or augmenting** teaching and learning to meet the needs of individual learners or groups of learners	MS Word
Technology that supports students and teachers in **dealing effectively with data**, including data management, manipulation, and display	Students can utilize Excel to create data spreadsheets and coordinating graphs. Students will use multimeters/voltmeters Electronic white board
Technology that supports students and teachers in conducting **inquiry**, including the effective use of Internet research methods	Students will use the internet and other resources to research a generator, how it functions and its role in society to create a PowerPoint presentation for the class. DC Motors Multimeter/Voltmeter
Technology that supports students and teachers in **simulating** real world phenomena including the modeling of physical, social, economic, and mathematical relationships	Students will utilize NASA simulation software (www.grc.nasa.gov/WWW/K-12/airplane/foil3.html) to manipulate their assigned variable of camber, surface area, or angle of attack. Electric Motors module. (http://www.daytonregionalstemcenter.org/uploads/curriculum/avetec.htm)
Technology that supports students and teachers in **communicating and collaborating** including the effective use of multimedia tools and online collaboration	Optional: Electronic white board

Interdisciplinary Connection

Math—Students will be looking at relationships that exist between assigned experiment topic (camber, surface area, & angle of attack) and generator performance creating data tables and graphs. Students should graph voltage to their assigned topic of camber, surface area, or angle of attack. Students will also utilize geometry skills to correctly use a protractor to set blade angles.

Social Studies—Investigate the history and design modifications of the propeller over time.

Home Connection

Have students explore their homes for both motors and generators. Students can explore when a generator is used versus a motor?

Differentiated Instruction (Process, Product, or Content)

Process: With the variation in groups throughout the activity, teachers can manipulate grouping to have students in the best learning environment. By knowing strengths and weaknesses of students, teachers can always assign the roles within the groups. If groups are evenly skilled, students could decide roles.

Product: For differentiation of product, teachers can challenge through questioning to push teams to higher levels of thinking, experimentation and research. All teams must meet required elements, but the teacher can challenge teams with questions like, "What happens if you try…" "Try to achieve an even higher voltage such as…"

Content: For differentiation of content, the teacher can assign the topic of research to provide a simpler generator to research.

(Teacher's Note): This unit can be used to lead into a unit on Energy Forms. Students could determine which renewable resource is the most practical for their region

Career Connection

Electrical and Aeronautical Engineer

Propellers touch upon many aspects of our lives from generating electricity from wind turbine generators, to being at the heart of turbine engines that power commercial and military aircraft. Many of the same propeller design parameters that are used by engineers working power solutions for aircraft are also employed by engineers developing efficient propellers for marine (boat) applications. The fundamental design philosophy governing propeller performance that was touched upon in this lesson plan is derived from the aerodynamics of lifting surfaces such as wings and hence applicable to a broad spectrum of other engineering problems where mechanical devices are used to extract energy from a flowing fluid.

Reference Materials:

Critical Vocabulary Definitions:

1. Aerodynamics, Aeronautics, and Flight Mechanics, Barnes W. McCormick, John Wiley & Sons Publishing, 1979

2. Introduction to Flight, 4th Edition, John D. Anderson Jr., McGraw-Hill Science/Engineering/Math, 1999

Background Information Section:

1. "Electricity" Eyewitness Books, Dorling Kindersley, New York, 1992.

2. "Faraday's Electromagnetic Lab" online simulation by PhET, University of Colorado at Boulder, http://phet.colorado.edu/en/simulation/faraday

Additional Resources

Resource:	***Purpose and Application:***
Wind turbine concepts defined and explained.	http://www.otherpower.com/otherpower_wind_tips.html
Information on wind turbine technology	http://tfcenergy.com/the-technology.htm
How wind turbines work	www1.eere.energy.gov/windandhydro/wind_how.html
Basic propeller design	www.woodenpropeller.com/Basic_Propeller_Design.html
Efficient propeller design	www.sciencebuddies.org/science-fair-projects/project_ideas/Aero_p018.shtml
History of the development of propeller technology	www.mh-aerotools.de/airfoils/prophist.htm
NASA airfoil simulator software	www.grc.nasa.gov/WWW/K-12/airplane/foil3.htm
Dayton Regional STEM Center electric motor simulator software	http://www.daytonregionalstemcenter.org/uploads/curriculum/avetec.htm

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Teacher Reflections

- Were students focused and on task throughout the lesson? *Insert answer here.*
- If not, what improvements could be made the next time this lesson is used? *Insert answer here.*
- Were the students led too much in the lesson or did they need more guidance? *Insert answer here.*
- Did the students learn what they were supposed to learn? *Insert answer here.*
- How do you know? *Insert answer here.*
- How did students demonstrate that they were actively learning? *Insert answer here.*

- Did you find it necessary to make any adjustments during the lesson? *Insert answer here.*
- What were they? *Insert answer here.*
- Did the materials that the students were using affect classroom behavior or management? *Insert answer here.*
- What were some of the problems students encountered when using the …? *Insert answer her*
- Are there better items that can be used next time? *Insert answer here.*
- Which ones worked particularly well? *Insert answer here.*

Additional Comments

Appendix A: Pre/Post-Test

Name___________________________________

1. What are the 5 main forms of energy? Give an example of an energy transformation.

2. What is a motor? What is a generator? How do they function in terms of energy transformations?

3. What are the resources we use to make generators produce electricity? Name at least three resources and explain how they are used.

4. What force makes wind turbines turn and how does it work? Be sure to reference Newton's Third Law in your answer.

5. What are the 3 main conditions for a wind turbine to be efficient for generating electricity? How does each of the conditions affect the electric output?

Pre-Test / Post-Test

1. What are the 5 main forms of energy? Give an example of an energy transformation.

Energy has different forms, all of which represent an ability of an object to do work. The basic forms of energy are: mechanical energy (kinetic energy and potential energy), electrical energy, thermal or heat energy, chemical energy, light energy, sound energy, and nuclear energy. An example of transformation of energy could be a car moving by burning gas. The chemical energy of the burning gas is transformed into mechanical energy (kinetic energy) of the moving car. The mechanical energy is transformed into heat and sound energy and maybe into light energy if the car has the lights on.

2. What is a motor? What is a generator? How do they function in terms of energy transformations?

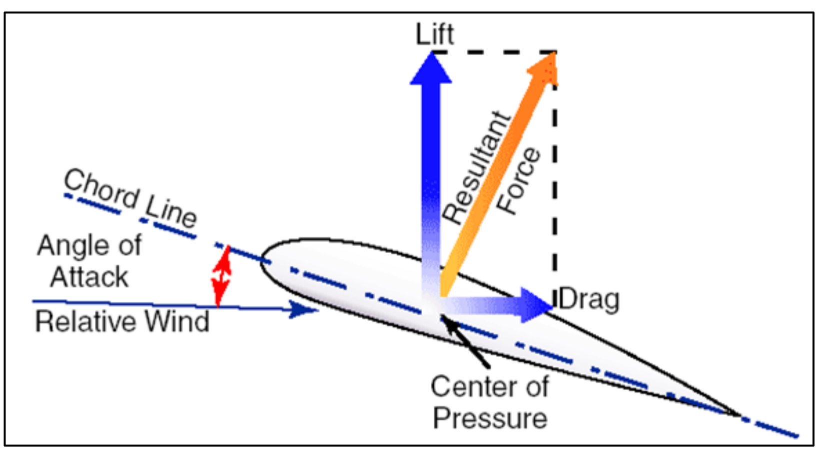
A motor transforms electrical energy into mechanical energy. A generator transforms mechanical energy into electrical energy. When an electric current flows through the wire in the magnetic field, there is a force on it. The forces on the coil push one side of the coil down and the other side up and the coil starts to rotate. When you turn the coil by force, on the other hand, it can generate electricity because the coil cuts the magnetic field.

3. What are the resources we use to make generators produce electricity? Name at least three resources and explain how they are used.

Magnetic fields have to change inside the coil of wire in order to produce an electric current. This means that mechanical work needs to be supplied when a magnet and a coil move relative to the other. Mechanical energy can be provided by rotating turbines. Major resources that we use for making turbines rotate are coal, oil and nuclear materials. Steam jets are produced by burning coal, oil, or by nuclear reactions. Falling water and wind are also used as resources for making turbines rotate.

4. What force makes wind turbines to turn and how does it work? Be sure to reference Newton's Third Law in your answer.

When air flows over a curved surface, a force of lift is produced in the direction perpendicular to the incoming airflow. Lift is the force that makes airplanes fly. Airflows on the wings create lift that can move the aircraft into a higher altitude. In the same way, airflows on each of the blades of a wind turbine can make the turbine rotate. Stronger lift can make a turbine turn faster.



http://www.free-online-private-pilot-ground-school.com/aerodynamics.html

5. What are the 3 main conditions for a wind turbine to be efficient for generating electricity? How does each of the conditions affect the electric output?

An increase of the rotational speed of a wind turbine will bring a higher electricity output. All of the factors tested, surface area, pitch, and camber, affect the speed of rotation by changing the amount of lift that each of the blades produces in the airflow.

Pre-Test / Post-Test Rubric

CATEGORY	3 Points	2 Points	Point
1. 1. **What are the 5 main forms of energy and how do they relate to each other? Give an example of energy transformation.**	Five forms are named and related to each other with an example of energy transformation.	Only two of the forms are named with an example of energy transformation.	Only one form is named.
2. W2. **What is a motor? What is a generator? How do they function?**	Accurate definition for motor and generator are provided this definition includes accurate description of function. (4 components: 2 definitions & 2 function descriptions)	Only accurate definitions are provided for motor and generator. Descriptions of functions are either incorrect or missing (2 components)	Attempt is provided including vocabulary such as mechanical energy, electrical energy, machine, flow of electrons. However, answer is not complete or correct.
3. W3. **What are the resources we use to make generators produce electricity? Name at least three resources and explain how they are used.**	Three resources are accurately named and explained.	Only two resources are accurately named and explained.	Only one resource is named.
4. W4. **What force makes wind turbines to turn and how does it work?**	The force of lift is named. The way in which lift works in a wind turbine is accurately explained.	Response does not name a force of lift. Mention could be made of the relevance to wings but no clear relation is made between wings and blades of a turbine.	Response does not demonstrate how a wind turbine turns. Lack of understanding is apparent.
5. What are the 3 main conditions for a wind turbine to be efficient for generating electricity? How does each of the conditions affect the electric output?	Three conditions are clearly/accurately named. The necessity for tradeoffs for some of the conditions is discussed with an	Only two conditions are accurately named. The necessity for tradeoffs for the conditions is mentioned but	Only one condition is named.

	accurate qualitative argument.	without any qualitative argument.	

Appendix B: Generator Research Guidelines

Task:

- ✓ Each team is to research their assigned generator and create a PowerPoint presentation including the following key components:
- ✓ A clear explanation of how the generator is designed and constructed. The mechanics of the generator should be discussed.
- ✓ Step-by-step explanation of how the generator functions—what are the energy transformations and where do they occur?
- ✓ Information provided on how wind turbines function as generators including definitions, design variations, and benefits/ uses.
- ✓ How does the use of this generator impact society? What are positive and negative aspects of the generator?

Grading Rubric:

Category	4	3	2	1
Generator Construction & Design	Explanations indicate a clear and accurate understanding of scientific principles underlying the construction and design.	Explanations indicate a relatively accurate understanding of scientific principles underlying the construction and design.	Explanations indicate a basic understanding of scientific principles underlying the construction and design.	Explanations do not illustrate any understanding of the scientific principles underlying the construction and design.
Generator Function	Explanations indicate a clear and accurate understanding of how the generator functions and energy transformations involved.	Explanations indicate a relatively accurate understanding of how the generator functions and the energy transformations.	Explanations indicate a basic understanding of how the generator functions or energy transformations.	Explanations do not illustrate any understanding of how the generator functions or energy transformations.
Wind turbine	All 4 components (turbine function, use as a generator, two benefits/uses, two design modifications) are accurately provided.	3 of the 4 components are correctly provided.	2 of the 4 components are correctly provided.	1 of the 4 components is correctly provided.
Societal Impact	Both positive and negative societal impacts are clearly and accurately addressed and explained	Both positive and negative societal impacts are addressed but not fully explained.	Either positive or negative impacts are addressed but not both.	No societal impacts are addressed.

Appendix C: Variable Research Rubric

Category	4	3	2	1
Variable Explanation	Variable is defined and explained in detail, showing a clear understanding of how the variable affects efficiency.	Variable is defined or explained, showing an understanding of the concept but does not relate variable to efficiency.	Variable is defined or explained at a basic level of understanding.	Variable is not defined nor explained. No relation to efficiency is made.
Testing Methodology	Testing Process was completed in an orderly manner following engineering design process. Excellent Detail—anyone could repeat testing process with no questions.	Testing process was completed and reported lacking minor detail. In order to repeat testing, questions would have to be asked.	Testing process was completed and reported lacking major details. In order to repeat testing, numerous questions would have to be asked.	Testing process was unorganized or not recorded. Retesting would not be able to be completed from the information provided.
Generator Construction & Design	Explanations indicate a clear and accurate understanding of scientific principles underlying the construction and design.	Explanations indicate a relatively accurate understanding of scientific principles underlying the construction and design.	Explanations indicate a basic understanding of scientific principles underlying the construction and design.	Explanations do not illustrate any understanding of the scientific principles underlying the construction and design.
Generator Function	Explanations indicate a clear and accurate understanding of how the generator functions.	Explanations indicate a relatively accurate understanding of how the generator functions.	Explanations indicate a basic understanding of how the generator functions.	Explanations do not illustrate any understanding of how the generator functions.
Data Interpretation	Data Tables and Graphs are included within presentation. Organized and correctly structured with exceptional interpretation of results.	Data Tables and Graphs are included within presentation. Organized and correctly structured but no detailed interpretation of results.	Data Tables and Graphs are included within presentation but not labeled correctly.	Data Tables and Graphs are not included within the presentation.

Appendix D: Group Work Rubric

Category	4	3	2	1
Contributions	Routinely provides useful ideas when participating in the group or classroom discussion. Contributes with full effort.	Usually provides useful ideas when participating in the group or classroom discussion. A strong group member who shows effort.	Sometimes provides useful ideas when participating in the group or classroom discussion. A satisfactory group member who does only what is required.	Rarely or never provides productive ideas when participating in the group or classroom discussion.
Problem-Solving	Actively looks for and suggests solutions to problems.	Refines solutions suggested by others but does not provide any original ideas.	Does not suggest or refine solutions, but is willing to try out solutions suggested by others.	Does not try to solve problems or help others solve problems. Let's others do the work
Focus on the Task	Consistently stays focused on the task and what needs to be done. Very motivated in this challenge.	Focuses on the task and what needs to be done most of the time.	Focuses on the task and what needs to be done some of the time. (Other group members may need to urge this individual to stay on-task.)	Rarely focuses on the task and what needs to be done. Let's others do the work.
Preparedness	Brings needed materials to class and is always ready to work.	Almost always brings needed materials to class and is ready to work.	Almost always brings needed materials but sometimes needs to settle down and get to work.	Often forgets needed materials or is rarely ready to get to work.
Work Ethic	Work reflects best effort from this student.	Work reflects a strong effort from this student.	Work reflects some effort from this student.	Work reflects very little effort on the part of this student.
Collaboration	Almost always listens to, shares with, and supports the efforts of others. Has demonstrated great cooperation.	Usually listens to, shares, with, and supports the efforts of others, generally cooperative.	Often listens to, shares with, and supports the efforts of others, but has been uncooperative at times.	Rarely listens to, shares with, and supports the efforts of other, is generally uncooperative.

Appendix E: Scientific Process Rubric

Category	4	3	2	1
Plan	Plan is neat with clear measurements and labeling for all components.	Plan is neat with clear measurements and labeling for most components.	Plan provides clear measurements and labeling for most components.	Plan does not show measurements clearly or is otherwise inadequately labeled.
Data Collection	Data taken several times in a careful, reliable manner.	Data taken twice in a careful, reliable manner.	Data taken once in a careful, reliable manner.	Data not taken carefully OR not taken in a reliable manner.
Modification/ Testing	Clear evidence of troubleshooting, testing, and refinements based on data or scientific principles.	Clear evidence of troubleshooting, testing and refinements.	Some evidence of troubleshooting, testing and refinements.	Little evidence of troubleshooting, testing or refinement.
Construction: Material usage	Appropriate materials were selected and creatively modified in ways that made them even better.	Appropriate materials were selected and there was an attempt at creative modification to make them better.	Appropriate materials were selected.	Inappropriate materials were selected and contributed to a product that performed poorly.
Scientific Knowledge	Explanations indicate a clear and accurate understanding of scientific principles underlying the construction and modifications.	Explanations indicate a relatively accurate understanding of scientific principles underlying the construction and modifications.	Explanations indicate a basic understanding of scientific principles underlying the construction and modifications.	Explanations do not illustrate any understanding of the scientific principles underlying the construction and modifications.

Appendix F: Generator Plan Sheet

Appendix G: Design Walkabout Student Record Sheet

Positive Design Aspects:

2.

3.

Suggestions for Design Improvements:
Improvements:

1.

2.

3.

Questions for Design Team:

1.

2.

3.

Positive Design Aspects:

1.

2.

3.

Suggestions for Design

1.

2.

3.

Questions for Design Team:

1.

2.

3.