Science and Engineering

Wind Turbine

link™
CPO Science

Real Investigations in
Science and Engineering

Overview Chart for Investigations–Wind Turbine

	Investigation	Key Question	Summary	Learning Goals	Vocabulary
A1	**Wind Power** Pages 1-6 50 minutes	How does a wind turbine work?	Students will construct a wind turbine that generates power.	• Measure the energy produced by a wind turbine. • Assemble a model of a wind turbine and explain how it works. • Define *criteria* as it relates to an engineering task.	cost-effective criteria efficiency electricity energy resource natural resource nonrenewable resource oil power voltage wind power wind turbine
A2	**Designing a Wind Turbine** Pages 7-12 150 minutes	How can we increase the energy output of a wind turbine?	Students will use the engineering cycle to design a wind turbine that will produce enough voltage to light a bulb.	• Use the engineering cycle to design a wind turbine so that it produces enough energy to light a bulb. • Identify criteria, constraints, and tradeoffs when designing a product. • Use data to refine a design.	constraints criteria engineer engineering cycle prototype trade-off
A3	**Criteria and Constraints** Pages 13-18 50 minutes	How can you construct a cost-effective wind turbine?	Students will construct a wind turbine that has the lowest possible blade mass and the highest possible voltage output.	• Design a wind turbine using mass as a constraint in order to more closely examine criteria and constraints. • Describe criteria and constraints in the context of a wind turbine. • Give examples of trade-offs.	constraints cost-effective criteria efficiency efficient engineering cycle trade-off volt voltage
A4	**Humans and the Environment** Pages 19-26 50 minutes	Where should you construct a wind turbine?	Students learn about an effect of the wind turbine called shadow flicker and think about how engineers choose the sites of wind farms.	• Explore the effects of shadow flicker. • Conduct research to identify ways that wind turbines can impact people through shadow flicker effects. • Recommend ways to address shadow flicker effects in a local community.	Earth's axial tilt perpendicular line plane shadow flicker solar elevation

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A5	**Blade Shape** Pages 27-32 200 minutes	What is the best blade shape for the wind turbine?	Students test different wind turbine blade shapes to determine the best shape for transferring energy from the wind to the wind turbine.	• Investigate the effects of blade shape on the capture of kinetic energy from wind. • Describe the function of blade shapes in the context of kinetic energy transfer to blades and transformation to electrical energy. • Investigate the effects of angle of attack.	angle of attack force kinetic energy oblique angle perpendicular
A6	**Magnetic Braking** Pages 33-38 50 minutes	How can magnets stop the wind turbine from rotating?	Students determine the extent of magnetic fields and how these fields affect the rotation of the wind turbine. The distance between magnetic fields and objects affected by those fields is very important to the design of a wind turbine.	• Investigate the effects of magnets. • Explore the braking effects of an electromagnet on the wind turbine. • Research elevator brakes and wind turbine brakes.	electromagnet magnetic magnetic field magnetism permanent magnet
A7	**Blade Mass** Pages 39-44 50 minutes	How do changes in mass affect the motion of the wind turbine?	In this investigation, students explore how mass affects the motion of the wind turbine's blades.	• Investigate how increasing the mass of the blades lowers the acceleration. • Describe the motion of the turbine blades using Newton's second law of motion. • Explore the construction of commercial wind turbine blades.	acceleration force inertia mass Newton's first law Newton's second law unbalanced forces
A8	**Magnetism and Electricity** Pages 45-52 150 minutes	How are electricity and magnetism related?	In this investigation, students explore how changing magnetic fields generate electric current in the coil of the wind turbine.	• Investigate and diagram magnetic fields. • Explore electromagnetic induction. • Apply understandings of electromagnetic induction to wind turbine designs.	electromagnetic induction electric current
B1	**Blade Mass and Acceleration** Pages 53-58 150 minutes	How does blade mass affect the acceleration of the wind turbine?	Students gather data using the DataCollector to describe the angular speed of the wind turbine. Next, they use graphing techniques to examine their data. Finally, students compare the angular acceleration of four turbine configurations in order to develop an understanding of how blade mass affects turbine function.	• Investigate how increasing the mass of the blades changes angular acceleration. • Describe the motion of turbine blades using Newton's second law of motion. • Analyze graph data.	acceleration angular acceleration angular speed force hertz mass

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	Investigation	Key Question	Summary	Learning Goals	Vocabulary
B2	**Magnetism and Electromagnetic Induction** Pages 59-66 150 minutes	How are electromagnetic induction and magnetism related?	Students explore how changing magnetic fields generate an electric current in the coil of the wind turbine.	• Investigate and diagram magnetic fields. • Explore electromagnetic induction. • Apply understandings of electromagnetic induction to wind turbine designs.	electric current electromagnetic induction magnetic magnetic field magnetic flux permanent magnet voltage
B3	**Optimal Wind Turbine Design** Pages 67-72 150 minutes	How can we increase the energy output of a wind turbine?	Students design a wind turbine so that it produces enough energy to light a bulb. Students are introduced to the engineering cycle and practice design skills.	• Use the engineering cycle to design a wind turbine that lights a bulb. • Identify the criteria and constraints in a design problem. • Test a prototype, collect data, and refine the prototype to improve results.	constraints criteria engineer engineering cycle prototype trade-off
B4	**Magnetic Forces** Pages 73-80 50 minutes	How do magnetic forces change the rotation of the wind turbine?	Students explore how magnetic fields change the rotation of the wind turbine.	• Test the strength of a magnetic field. • Use a magnet to test and identify magnetic and non-magnetic materials. • Explain how magnetic forces are involved in the operation of a wind turbine.	electromagnet magnetic field magnetism permanent magnet
B5	**Wind Farm Simulation** Pages 81-88 50 minutes	How do utility companies run a wind farm?	Students create a model wind farm and explore the function and impacts of wind turbines on nature and society.	• Measure electric power generated by a wind farm. • Describe the function of an energy grid. • Observe the effects of an unsynchronized power source on an AC electric grid.	electrical power energy grid power-line frequency synchronization wind farm
B6	**Selecting a Wind Turbine Site** Pages 89-94 50 minutes	Should a wind turbine be built in your town?	Students will explore the costs of installing a wind turbine and decide if a turbine should be built at a given site.	• Measure the wind at a potential wind turbine site using climate data. • Compute the energy output needed to meet a turbine's operating costs. • Make an argument for or against building a wind turbine.	kilowatt-hour operating costs rated operating speed rated power output

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	Investigation	Key Question	Summary	Learning Goals	Vocabulary
B7	**Designing a Cost-Effective Wind Turbine** Pages 95-100 50 minutes	How can you construct a cost-effective wind turbine?	Students will use the engineering cycle to design a wind turbine that produces enough energy to light a bulb at the lowest possible cost.	• Design a wind turbine using simulated costs for each component as constraints. • Describe criteria, constraint, and trade-offs. • Infer examples of criteria, constraints, and trade-offs in real-world engineering activities.	constraints cost-effective design criteria engineer engineering cycle trade-off
C1	**Wind Turbine Site Analysis** Pages 101-110 200 minutes	How do you determine the best site for building a wind turbine?	Students will explore the costs of installing a wind turbine and decide if a turbine should be built at a given site.	• Measure the wind at a potential wind turbine site using climate data. • Analyze the geography and shadow flicker of a given turbine site using spatial data and geometry. • Research and select a suitable wind turbine model for a given site. • Compute the energy output needed to meet a turbine's operating costs.	azimuth constraints criteria engineering cycle horizontal coordinate system kilowatt-hour rated operating speed rated power output shadow flicker solar elevation trade-off
C2	**Kinetic Energy and Electrical Energy** Pages 111-118 200 minutes	How much kinetic energy becomes electrical energy?	You will measure the kinetic energy of the turbine blades and compare this with the electrical energy generated in the coil.	• Define *kinetic energy*. • Describe the kinetic energy in the wind turbine's rotation. • Compare kinetic energy with electrical energy.	angular velocity efficiency electrical energy electrical output electrical power input work kinetic energy moment of inertia output work power rotational frequency rotational inertia work

Next Generation Science Standards Correlation

CPO Science *Link* investigations are designed for successful implementation of the Next Generation Science Standards. The following chart shows the NGSS Performance Expectations and dimensions that align to the investigations in this title.

NGSS Performance Expectations	Wind Turbine Investigations
MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.	A2, A3, A4
MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.	A1
MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.	A7
MS-PS2-5. Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.	A8
MS-PS3-2. Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.	A6
MS-PS3-5. Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.	A5
HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.	B5
HS-ETS1-4. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.	B6, B7, C1
HS-PS2-1. Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.	B1
HS-PS2-5. Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.	B2
HS-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.	C2
HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.	B3
HS-PS3-5. Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.	B4

Next Generation Science Standards Correlation (cont'd)

NGSS Science and Engineering Practices	Wind Turbine Investigations
Analyzing and Interpreting Data	B1
Asking Questions and Defining Problems	A2, A3, A4
Constructing Explanations and Designing Solutions	B3, B5
Developing and Using Models	A6, B4
Engaging in Argument from Evidence	A1, A5
Planning and Carrying Out Investigations	A7, A8, B2
Using Mathematics and Computational Thinking	B6, B7, C1, C2

NGSS Disciplinary Core Ideas	Wind Turbine Investigations
ETS1.B: Developing Possible Solutions	A1, B6, B7, C1
ETS1.A: Defining and Delimiting Engineering Problems	A2, A3, A4
PS2.A: Forces and Motion	A7, B1
PS2.B: Types of Interactions	A8, B2
PS3.A: Definitions of Energy	A6, B3, C2
PS3.B: Conservation of Energy and Energy Transfer	A5
PS3.C: Relationship Between Energy and Forces	A6, B4

NGSS Crosscutting Concepts	Wind Turbine Investigations
Cause and Effect	A8, B1, B2, B4
Energy and Matter	A5, B3
Influence of Science, Engineering, and Technology on Society and the Natural World	A2, A3, A4, B5
Stability and Change	A7
Systems and System Models	A6, B6, B7, C1, C2

Common Core State Standards Correlation

CCSS-Mathematics		Wind Turbine Investigations
6.RP.A.1	Understand the concept of ratio and use ratio language to describe a ratio relationship between two quantities.	A5, A8
7.EE.3	Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies.	A1, A2, A3, A4
7.EE.B.3	Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form, using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies.	A7
7.EE.B.4	Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities.	A7
7.RP.A.2	Recognize and represent proportional relationships between quantities.	A5, A8
8.F.A.3	Interpret the equation $y = mx + b$ as defining a linear function, whose graph is a straight line; give examples of functions that are not linear.	A5
HSA-CED.A.1	Create equations and inequalities in one variable and use them to solve problems.	B1
HSA-CED.A.2	Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.	B1
HSA-CED.A.4	Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations.	B1
HSA-SSE.A.1	Interpret expressions that represent a quantity in terms of its context.	B1
HSF-IF.C.7	Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases.	B2, B4, C1
HSN-Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.	B1, B2, B3, C1, C2
HSN-Q.A.2	Define appropriate quantities for the purpose of descriptive modeling.	B1, B2, B3, C1, C2
HSN-Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.	B1, B2, B3, C1, C2
HSS-ID.A.1	Represent data with plots on the real number line.	B1, C1
MP.2	Reason abstractly and quantitatively.	A1, A2, A3, A4, A5, A6, A7, A8, B1, B3, B4, B5, B6, B7, C1, C2
MP.4	Model with mathematics.	B1, B3, B4, B5, B6, B7, C1, C2

Common Core State Standards Correlation (cont'd)

CCSS-English Language Arts & Literacy		Wind Turbine Investigations
RST.6-8.1	Cite specific textual evidence to support analysis of science and technical texts.	A1, A2, A3, A4, A5
RST.6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.	A7, A8
RST.6-8.9	Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.	A1
RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.	B1
RST.11-12.7	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.	B1, B5, B6, B7, C1
RST.11-12.8	Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.	B5, B6, B7, C1
RST.11-12.9	Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.	B5, B6, C1
SL.8.5	Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest.	A2
SL.11-12.5	Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.	B4, C2
WHST.6-8.7	Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.	A1, A7, A8
WHST.6-8.8	Gather relevant information from multiple print and digital sources; assess the credibility of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and providing basic bibliographic information for sources.	A4
WHST.6-8.9	Draw evidence from informational texts to support analysis, reflection, and research.	A1
WHST.9-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.	B3, B4, B5
WHST.11-12.8	Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.	B2, B4
WHST.9-12.9	Draw evidence from informational texts to support analysis, reflection, and research.	B1, B2, B4