NGSS OVERVIEW

ENERGY

Performance Expectation MS-PS3-3: Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.

Performance Expectation MS-PS3-4: Plan an investigation to determine the relationship among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.

Performance Expectation 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.

Performance Expectation MS-ETS1-4: Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs.

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
1. **Investigation: Home Energy Use** Students begin exploring concepts about energy transfer by analyzing qualitative data on energy use in two hypothetical homes in different environments. They consider how certain features of a home may cause the homeowner to use more or less energy. This introduces them to the idea of energy-efficiency. They begin tracking their understanding about energy transfer and developing a plan to increase home energy-efficiency. They will finalize and present that plan in the final activity in this unit.	MS-PS3.A MS-PS3.B	Analyzing and Interpreting Data Asking Questions and Defining Problems	Cause and Effect Energy and Matter	ELA/Literacy: WHST.6-8.9
2. **Laboratory: Drive a Nail** Students plan and carry out an investigation to examine the relationship between gravitational potential energy and kinetic energy of motion. They analyze and interpret the data to quantify the transfer of energy from a falling object (metal rod) to a stationary object (nail). They expand on their understanding of energy-efficiency by considering whether all of the gravitational potential energy has been transferred to the nail.	MS-PS3.B MS-PS3.A MS-PS3.C	Planning and Carrying Out Investigations Analyzing and Interpreting Data	Patterns Cause and Effect Energy and Matter	Mathematics: MP.2 6.EE.C.9 ELA/Literacy: RST. 6-8.3
3. **Role Play: Roller Coaster Energy** Students expand on their understanding of energy transfer and transformations by exploring what is happening to energy during a roller coaster ride. Students use a model to help them explain the repeated transformations of gravitational potential and kinetic energy along the ride, and the transfer of kinetic energy from the roller coaster cars to thermal energy and sound in the tracks.	MS-PS3.B MS-PS3.A	Constructing Explanations and Designing Solutions Developing and Using Models	Energy and Matter	Mathematics: MP.2 ELA/Literacy: WHST.6-8.9

ENERGY (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
4. **Investigation: Shake the Shot** Students continue their exploration of energy transformation and transfer by analyzing and interpreting data from an investigation. This investigation involves transferring kinetic energy from a moving arm to moving metal pellets and then transforming that energy into thermal energy in the metal pellets inside the container. Students measure the rise in temperature of the metal pellets as evidence of the amount of thermal energy transferred.	MS-PS3.B MS-PS3.A MS-PS3.C	Analyzing and Interpreting Data Planning and Carrying Out Investigations	Energy and Matter Patterns Cause and Effect Systems and System Models Scale, Proportion, and Quantity	Mathematics: MP.2 6.EE.C.9 ELA/Literacy: RST. 6-8.3
5. **Reading: Conservation of Energy** Students obtain information from a reading on the behavior of energy. In particular, they develop an initial understanding of the conservation of energy during energy transformations. Students develop arguments to explain that energy cannot be "lost" during energy transformations, arguments that are informed by their growing understanding of systems and system models. They apply this understanding to the topic of energy-efficiency, and use the information to inform their home energy-efficiency plans.	MS-PS3.B MS-PS3.A	Engaging in Argument from Evidence Obtaining, Evaluating, and Communicating Information Connections to Nature of Science: Scientific Knowledge Is Based on Empirical Evidence	Energy and Matter Systems and System Models	ELA/Literacy: WHST.6-8.1 WHST.6-8.9
6. **Investigation: Follow the Energy** Students explore many types of energy transformations and transfers that people encounter regularly in their everyday lives. The ubiquity of energy transfers and transformations reinforces the crosscutting nature of energy. Students present arguments that a change in the kinetic energy of an object results in an energy transfer either to or from that object. This activity provides an opportunity to assess student work related to Performance Expectation MS-PS3-5.	MS-PS3.B MS-PS3.A	Engaging in Argument from Evidence Connections to Nature of Science: Scientific Knowledge Is Based on Empirical Evidence	Energy and Matter	ELA/Literacy: WHST.6-8.1 WHST.6-8.9

ENERGY (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
7. **Laboratory: Mixing Hot and Cold Water** Students conduct an investigation on thermal energy transfer in water, documenting this transfer by measuring temperature changes. They observe the effects of thermal energy being spontaneously transferred from a hot region into a cold one until thermal equilibrium is reached. Students analyze and interpret the data that they collect as they explain the relationship between changes in temperature and thermal energy transfer.	MS-PS3.A MS-PS3.B	Constructing Explanations and Designing Solutions Analyzing and Interpreting Data Planning and Carrying Out Investigations Connections to Nature of Science: Scientific Knowledge Is Based on Empirical Evidence	Energy and Matter Scale, Proportion, and Quantity	Mathematics: MP.2 6.EE.C.9 ELA/Literacy: RST.6-8.3
8. **Laboratory: Thermal Energy Storage** Students apply their understanding of energy transfer to plan and carry out an investigation to determine the factors that influence the change in temperature of cold water when a hot object is immersed in it. This activity provides an opportunity to assess Performance Expectation MS-PS3-4.	MS-PS3.A MS-PS3.B	Planning and Carrying Out Investigations Analyzing and Interpreting Data	Energy and Matter Scale, Proportion, and Quantity Connections to Nature of Science: Science Is a Human Endeavor	Mathematics: MP.2
9. **Reading: Energy Across the Sciences** Students obtain information from text about how scientists in several different disciplines use their understanding of energy to explain scientific phenomena. They read about energy transfers and transformations in examples from the life sciences, earth sciences, and physical sciences. In doing so, students develop an understanding of the crosscutting nature of energy. Students communicate their understanding about the universal nature of energy to others.	MS-PS3.B MS-PS3.A	Obtaining, Evaluating, and Communicating Information	Energy and Matter Systems and System Models	ELA/Literacy: RST.6-8.1 WHST.6-8.9
10. **Design: Energy Transfer Challenge** Students are introduced to the idea that thermal energy transfer can be maximized and minimized by engineering systems that are either good thermal conductors or insulators. They use an engineering design process to design, construct, and test their systems.	MS-PS3.A MS-PS3.B MS-ETS1.A MS-ETS1.B	Constructing Explanations and Designing Solutions Analyzing and Interpreting Data	Energy and Matter Structure and Function	ELA/Literacy: RST.6-8.3

ENERGY (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
11. **Laboratory: Energy in Light** Students investigate the behavior of electromagnetic energy when it hits a surface. They see that the energy can be transmitted, reflected, and absorbed. By conducting an investigation they find that shiny surfaces reflect much of the energy while dark surfaces absorb, transforming some of the light energy into thermal energy.	MS-PS3.B MS-PS3.A	Analyzing and Interpreting Data Constructing Explanations and Designing Solutions	Energy and Matter Patterns	Mathematics: MP.2 6.EE.A.2 ELA/Literacy: RST.6-8.3
12. **Reading: Conduction, Convection, and Radiation** Students are formally introduced to the three types of thermal energy transfer: conduction, convection, and radiation. This knowledge enables students to be able to look at a system and understand how thermal energy enters or exits that system through these different methods of energy transfer, thus reinforcing the idea that when energy is transferred, it can be transferred out of the observed system into a larger system.	MS-PS3.A MS-PS3.B	Constructing Explanations and Designing Solutions	Energy and Matter	ELA/Literacy: WHST.6-8.9
13. **Design: Maximizing Solar Energy Transfer** From the previous two activities, students should now have a better understanding of how solar energy is transferred from the sun to Earth and that different materials absorb, reflect, or transmit this energy in different proportions. In this activity, students design, build, test, and optimize a device to maximize thermal energy transfer: a solar heater. The success of their devices is determined by how well students apply what they have learned about thermal energy transfer and how well students are able to redesign the devices based on performance evaluations in early tests. Students present their final designs to the class and use their results to explain their design process. This activity provides an opportunity to assess Performance Expectations MS-PS3-3 and MS-ETS1-4.	MS-PS3.A MS-PS3.B MS-ETS1.A MS-ETS1.B MS-ETS1.C	Constructing Explanations and Designing Solutions Engaging in Argument from Evidence Developing and Using Models	Energy and Matter	ELA/Literacy: SL.8.4

ENERGY (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
14. **Laboratory: Hot Bulbs** Students apply their understanding of the concepts of energy transfer and transformation to compare the efficiencies of two different types of light bulbs. They do so by measuring the amount of thermal energy produced by the two bulbs, applying the law of conservation of energy, and calculating how much of the electrical energy supplied was converted into light energy.	MS-PS3.A MS-PS3.B	Analyzing and Interpreting Data Planning and Carrying Out Investigations	Energy and Matter Connections to Nature of Science: Science Addresses Questions About the Natural and Material World	Mathematics: MP.2 6.EE.A.2 ELA/Literacy: RST.6-8.3
15. **Problem Solving: Improving Home Energy-Efficiency** Students obtain more information about factors that can affect energy use in the home. They apply their understanding of energy transfer and energy transformation to develop a home energy-efficiency plan to use less energy. Students communicate their plan be preparing a report to present to the hypothetical homeowners.	MS-PS3.B	Obtaining, Evaluating and Communicating Information	Energy and Matter Connections to Nature of Science: Science Addresses Questions About the Natural and Material World	Mathematics: MP.2 ELA/Literacy: WHST.6-8.9

NGSS CORRELATIONS

ENERGY

Crosscutting Concepts		Activity number
Cause and Effect	Cause and effect relationships may be used to predict phenomena in natural or designed systems.	1, 2, 4
Energy and Matter	The transfer of energy can be tracked as energy flows through a designed or natural system.	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15
	Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion).	2, 3, 4, 5, 6, 7, 9, 11, 12, 15
Patterns	Patterns can be used to identify cause and effect relationships.	2, 4
	Graphs, charts, and images can be used to identify patterns in data.	11
	Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems.	11
Structure and Function	Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.	10
Systems and System Models	Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems.	4, 5, 9
Scale, Proportion, and Quantity	Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.	4, 7, 8
	The observed function of natural and designed systems may change with scale.	7
Connections to the Nature of Science	Scientists and engineers are guided by habits of mind, such as intellectual honesty, tolerance of ambiguity, skepticism, and openness to new ideas.	8
	Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes.	14, 15

Science and Engineering Practices		Activity number
Analyzing and Interpreting Data	Analyze and interpret data to determine similarities and differences in findings.	7, 8, 10
	Analyze and interpret data to provide evidence for phenomena.	1, 2, 4, 7, 11, 14
	Apply concepts of statistics and probability (including mean, median, mode, and variability) to analyze and characterize data, using digital tools when feasible.	4
Asking Questions and Defining Problems	Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information.	1
Constructing Explanations and Designing Solutions	Construct an explanation that includes qualitative or quantitative relationships between variables that predict or describe phenomena.	3, 7, 12
	Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.	10
	Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process or system.	10, 13
	Apply scientific ideas to construct an explanation for real world phenomena, examples, or events.	11
Developing and Using Models	Develop a model to describe unobservable mechanisms.	3
	Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs.	13
Engaging in Argument from Evidence	Construct and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.	5, 6, 13
	Respectfully provide and receive critiques about one's explanations, procedures, models, and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail.	13
Obtaining, Evaluating, and Communicating Information	Integrate qualitative scientific and technical information in written text with that contained in media and visual displays to clarify claims and findings.	5, 9, 15

Science and Engineering Practices		Activity number
Planning and Carrying Out Investigations	Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.	2, 7, 8
	Conduct an investigation to produce data to serve as the basis for evidence that meet the goals of an investigation.	4, 7, 14
Connections to the Nature of Science	Scientific knowledge is based on logical and conceptual connections between evidence and explanations.	5, 6, 7
Disciplinary Core Ideas		**Activity number**
Defining and Delimiting Engineering Problems (ETS1.A)	The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions.	10, 13
Developing Possible Solutions (ETS1.B)	A solution needs to be tested, and then modified on the basis of the test results in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem.	10, 13
	Models of all kinds are important for testing solutions.	13
Optimizing the Design Solution (ETS1.C)	Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of the characteristics may be incorporated into the new design.	13
	The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.	13

Disciplinary Core Ideas		Activity number
Definitions of Energy (PS3.A)	Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.	2, 3, 4, 6
	A system of objects may also contain stored (potential) energy, depending on their relative positions.	2, 3, 6, 9
	Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.	1, 7, 8, 10, 11, 12, 13, 14
	The term "heat" as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects.	5, 7, 8, 10, 12, 14
Conservation of Energy and Energy Transfer (PS3.B)	When the kinetic energy of an object changes, there is inevitably some other change in energy at the same time.	2, 3, 4, 5, 6, 9, 12, 15
	The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment.	1, 4, 6, 7, 8, 11, 14, 15
	Energy is spontaneously transferred out of hotter regions or objects and into colder ones.	1, 7, 8, 9, 10, 12, 13, 15
Relationship Between Energy and Forces (PS3.C)	When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.	2, 4
Performance Expectations		**Activity number**
Energy (PS3)	Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.* (MS-PS3-3)	13
	Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample. (MS-PS3-4)	8
	Construct, use, and present arguments to support the claim that when the motion energy of an object changes, energy is transferred to or from the object. (MS-PS3-5)	6
Engineering Design (ETS1)	Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.	13

COMMON CORE STATE STANDARDS: CONNECTIONS AND CORRELATIONS

ENERGY

Making Connections in ELA

As with all SEPUP instructional materials, this unit introduces multiple opportunities for students to engage in a range of ELA practices and skills that are important grade-specific goals of the common core state standards and are also essential to the sensemaking students are doing throughout the unit. Specifically, in activity 5, students read informational texts on the conservation of energy and energy transfer. They use this information to construct arguments about why energy cannot be lost (WHST.6-8.9; WHST.6-8.1). Further along, in activity 7, they build on their understanding of energy by investigating thermal energy transfer in water, through careful analysis of water temperature changes (RST.6-8.3). Students then read texts about how scientists across disciplines use energy in their research - they then discuss with fellow students the connections across disciplines (in activity 9) (RST.6-8.1). In activity 13, students design and test thermal ovens that maximize thermal energy transfer, and then present their findings for the optimal oven design to the class (SL.8.4). In addition, Appendix E: Literacy Strategies in the Student Book contains optional resources to support reading, writing and oral communication.

<table>
<tr><th colspan="2">Common Core State Standards – English Language Arts</th><th>Activity number</th></tr>
<tr><td rowspan="2">Reading in Science and Technical Subjects (RST)</td><td>Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. (RST.6-8.1)</td><td>9</td></tr>
<tr><td>Follow precisely a multi-step procedure when carrying out experiments, taking measurements, or performing technical tasks. (RST.6-8.3)</td><td>2, 4, 7, 10, 11, 14</td></tr>
<tr><td>Speaking and Listening (SL)</td><td>Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound and valid reasoning, and well-chosen details: use appropriate eye contact, adequate volume, and clear pronunciation. (SL.8.4)</td><td>13</td></tr>
<tr><td rowspan="2">Writing in History/ Social Studies, Science, and Technological Subjects (WHST)</td><td>Write arguments focused on discipline-specific content. (WHST.6-8.1)</td><td>5, 6</td></tr>
<tr><td>Draw evidence from informational texts to support analysis, reflection, and research. (WHST.6-8.9)</td><td>1, 3, 5, 6, 9, 12, 15</td></tr>
</table>

Making Connections in Mathematics

This unit introduces multiple opportunities for students to engage in math practices and skills that are important grade-specific goals of the common core state standards and are also essential to the sensemaking students are doing throughout the unit. Specifically, in activity 2, students analyze and interpret data related to the transfer of energy from a falling object to a stationary one. In this activity, students explore independent and dependent variables, and calculate class means (MP.2; 6.EE.C.9). In activity four, students engage in another investigation where they measure temperature as evidence of energy transformation from one form to another (MP.2; 6.EE.C.9). Additionally, in an investigation in activity 11, students use an equation to calculate the change in temperature of a variety of materials over time. They use this information to consider how light interacts with these different materials (6.EE.A.2). For the activities where students create graphical representations of data to find relationships (for example, Activity 11), an optional student sheet entitled "Scatterplot and Line Graphing Checklist" is provided in Appendix C: Science Skills in the Student Book for students who need additional support.

Common Core State Standards – Mathematics		Activity number
Mathematical Practice (MP)	Reason abstractly and quantitatively. (MP.2)	2, 3, 4, 7, 8, 11, 14, 15
Expressions and Equations (EE)	Write, read, and evaluate expressions in which letters stand for numbers. (6.EE.A.2)	11, 14
	Use variables to represent two quantities in a real-world problem that change in relationship to one another; write an equation to express one quantity, thought of as the independent variable. Analyze the relationship between the dependent and independent variables using graphs and tables, and relate these to the equation. (6.EE.C.9)	2, 4, 7