**Alignment to the National Next Generation Science Standards**

**S.T.E.A.M.**

**(Science, Technology, Engineering, Arts and Mathematics Project)**

**Homemade Musical Instrument / Musical Enhancement Device**

**Project / Competition**

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**April 2013**

**Kindergarten**

**K-PS2 Motion and Stability: Forces and Interactions**

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| **K-PS2 Motion and Stability: Forces and interactions** | | |
| Students who demonstrate understanding can:  **K-PS2-1. Plan and conduct an investigation to compare the effects of different strengths or different directions**  **of pushes and pulls on the motion of an object.**  [Clarification Statement: Examples of pushes or pulls could include a string attached to an object  being pulled, a person pushing an object, a person stopping a rolling ball, and two objects colliding and pushing on each other.]  [Assessment Boundary: Assessment is limited to different relative strengths or different directions, but not both at the same time.  Assessment does not include non-contact pushes or pulls such as those produced by magnets.]  **K-PS2-2. Analyze data to determine if a design solution works as intended to change the speed or**  **direction of an object with a push or a pull.\*** [Clarification Statement: Examples of problems requiring a solution could include having a  marble or other object move a certain distance, follow a particular path, and knock down other objects. Examples of solutions could include tools such as a  ramp to increase the speed of the object and a structure that would cause an object such as a marble or ball to turn.] [Assessment Boundary:  Assessment does not include friction as a mechanism for change in speed.] | | |
| The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education: | | |
| **Science and Engineering Practices**  **Planning and Carrying Out Investigations**  Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.  With guidance, plan and conduct an investigation in collaboration with peers. (K-PS2-1)  **Analyzing and Interpreting Data**  Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations.  Analyze data from tests of an object or tool to determine if it works as intended. (K-PS2-2)  **-----------------------------------------------------Connections to Nature of Science**  **Scientific Investigations Use a Variety of Methods**  Science uses different ways to study the world. (K-PS2-1) | **Disciplinary Core Ideas**  **PS2.A: Forces and Motion**  Pushes and pulls can have different strengths and directions. (K-PS2-1),(K-PS2-2)  Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it.  (K-PS2-1),(K-PS2-2)  **PS2.B: Types of Interactions**  When objects touch or collide, they push on one another and can change motion. (K-PS2-1)  **PS3.C: Relationship Between Energy and Forces**  A bigger push or pull makes things go faster. (secondary to K-PS2-1)  **ETS1.A: Defining Engineering Problems**  A situation that people want to change or create can be approached as a problem to be solved through engineering. Such problems may have many acceptable solutions. (secondary to K-PS2-2) | **Crosscutting Concepts**  **Cause and Effect**  Simple tests can be designed to  gather evidence to support or refute  student ideas about causes.  (K-PS2-1),(K-PS2-2) |

**K-PS3 Energy**

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| **K-PS3 Energy** | | |
| Students who demonstrate understanding can:  **K-PS3-1. Make observations to determine the effect of sunlight on Earth’s surface.** [Clarification Statement: Examples  of Earth’s surface could include sand, soil, rocks, and water] [Assessment Boundary: Assessment of temperature is limited to relative measures such as  warmer/cooler.]  **K-PS3-2. Use tools and materials to design and build a structure that will reduce the warming effect of**  **sunlight on an area.\*** [Clarification Statement: Examples of structures could include umbrellas, canopies, and tents that minimize the warming  effect of the sun.] | | |
| The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education: | | |
| **Science and Engineering Practices**  **Planning and Carrying Out Investigations**  Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.  Make observations (firsthand or from media) to collect data that can be used to make comparisons. (K-PS3-1)  **Constructing Explanations and Designing Solutions**  Constructing explanations and designing solutions in K–2 builds on prior experiences and progresses to the use of evidence and ideas in constructing evidence-based accounts of natural phenomena and designing solutions.  Use tools and materials provided to design and build a device that solves a specific problem or a solution to a specific problem. (K-PS3-2)  **-----------------------------------------------------------**  **Connections to Nature of Science**  **Scientific Investigations Use a Variety of Methods**  Scientists use different ways to study the world.  (K-PS3-1) | **Disciplinary Core Ideas**  **PS3.B: Conservation of Energy and Energy Transfer**  Sunlight warms Earth’s surface. (K-PS3-1),(K-PS3-2) | **Crosscutting Concepts**  **Cause and Effect**  Events have causes that generate  observable patterns. (K-PS3-1),(K-PS3-2) |

**1st Grade**

**1-PS4 Waves and their Applications in Technologies for Information Transfer**

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| **1-PS4 Waves and their Applications in Technologies for Information Transfer** | | |
| Students who demonstrate understanding can:  **1-PS4-1. Plan and conduct investigations to provide evidence that vibrating materials can make sound**  **and that sound can make materials vibrate.**  [Clarification Statement: Examples of vibrating materials that make sound could include tuning forks and plucking a stretched string. Examples of  how sound can make matter vibrate could include holding a piece of paper near a speaker making sound and holding an object near a vibrating tuning fork.]  **1-PS4-2. Make observations to construct an evidence-based account that objects can be seen**  **only when illuminated.**  [Clarification Statement: Examples of observations could include those made in a completely dark room, a pinhole box, and a video of a cave explorer  with a flashlight. Illumination could be from an external light source or by an object giving off its own light.]  **1-PS4-3. Plan and conduct an investigation to determine the effect of placing objects made with different**  **materials in the path of a beam of light.** [Clarification Statement: Examples of materials could include those that are transparent  (such as clear plastic), translucent (such as wax paper), opaque (such as cardboard), and reflective (such as a mirror).] [Assessment Boundary:  Assessment does not include the speed of light.]  **1-PS4-4. Use tools and materials to design and build a device that uses light or sound to solve the**  **problem of communicating over a distance.\*** [Clarification Statement: Examples of devices could include a light source to send  signals, paper cup and string “telephones,” and a pattern of drum beats.] [Assessment Boundary: Assessment does not include technological details  for how communication devices work.] | | |
| The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education: | | |
| **Science and Engineering Practices**  **Planning and Carrying Out Investigations**  Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.  Plan and conduct investigations collaboratively to produce data to serve as the basis for evidence to answer a question. (1-PS4-1),(1-PS4-3)  **Constructing Explanations and Designing Solutions**  Constructing explanations and designing solutions in K–2 builds on prior experiences and progresses to the use of evidence and ideas in constructing evidence-based accounts of natural phenomena and designing solutions.  Make observations (firsthand or from media) to construct an evidence-based account for natural phenomena. (1-PS4-2)  Use tools and materials provided to design a device that solves a specific problem. (1-PS4-4)  **-------------------------------------------------**  **Connections to Nature of Science**  **Scientific Investigations Use a Variety of Methods**  Science investigations begin with a question. (1-PS4-1)  Science uses different ways to study the world.  (1-PS4-1) | **Disciplinary Core Ideas**  **PS4.A: Wave Properties**  Sound can make matter vibrate, and vibrating matter can make sound. (1-PS4-1)  **PS4.B: Electromagnetic Radiation**  Objects can be seen only when light is available to illuminate them. Some objects give off their own light.  (1-PS4-2)  Some materials allow light to pass through them, others allow only some light through and others block all the light and create a dark shadow on any surface beyond them, where the light cannot reach. Mirrors can be used to redirect a light beam. (Boundary: The idea that light travels from place to place is developed through experiences with light sources, mirrors, and shadows, but no attempt is made to discuss the speed of light.)  (1-PS4-3)  **PS4.C: Information Technologies and Instrumentation**  People also use a variety of devices to communicate (send and receive information) over long distances.  (1-PS4-4) | **Crosscutting Concepts**  **Cause and Effect**  Simple tests can be designed to  gather evidence to support or refute  student ideas about causes.  (1-PS4-1),(1-PS4-2),(1-PS4-3)  **---------------------------------------------------**  **Connections to Engineering, Technology,**  **and Applications of Science**  **Influence of Engineering, Technology,**  **and Science, on Society and the**  **Natural World**  People depend on various technologies in  their lives; human life would be very different  without technology. (1-PS4-4) |

**2nd Grade**

**2-PS1 Matter and its Interactions**

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| **2-PS1 Matter and its Interactions** | | |
| Students who demonstrate understanding can:  **2-PS1-1. Plan and conduct an investigation to describe and classify different kinds of materials by their**  **observable properties.**  [Clarification Statement: Observations could include color, texture, hardness, and flexibility. Patterns could include the similar properties that different materials share.]  **2-PS1-2. Analyze data obtained from testing different materials to determine which materials have the**  **properties that are best suited for an intended purpose.\***  [Clarification Statement: Examples of properties could include, strength, flexibility, hardness, texture, and absorbency.] [Assessment Boundary:  Assessment of quantitative measurements is limited to length.]  **2-PS1-3. Make observations to construct an evidence-based account of how an object made of a small**  **set of pieces can be disassembled and made into a new object.**  [Clarification Statement: Examples of pieces could include blocks, building bricks, or other assorted small objects.]  **2-PS1-4. Construct an argument with evidence that some changes caused by heating or cooling can be**  **reversed and some cannot.** [Clarification Statement: Examples of reversible changes could include materials such as water and butter at  different temperatures. Examples of irreversible changes could include cooking an egg, freezing a plant leaf, and heating paper.] | | |
| The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education: | | |
| **Science and Engineering Practices**  **Planning and Carrying Out Investigations**  Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.  Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence to answer a question. (2-PS1-1)  **Analyzing and Interpreting Data**  Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations.  Analyze data from tests of an object or tool to determine if it works as intended. (2-PS1-2)  **Constructing Explanations and Designing Solutions**  Constructing explanations and designing solutions in K–2 builds on prior experiences and progresses to the use of evidence and ideas in constructing evidence-based accounts of natural phenomena and designing solutions.  Make observations (firsthand or from media) to construct an evidence-based account for natural phenomena. (2-PS1-3)  **Engaging in Argument from Evidence**  Engaging in argument from evidence in K–2 builds on prior experiences and progresses to comparing ideas and representations about the natural and designed world(s).  Construct an argument with evidence to support a claim. (2-PS1-4)  -------------------------------------------------------  **Connections to Nature of Science**  **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena**  Science searches for cause and effect relationships to explain natural events. (2-PS1-4) | **Disciplinary Core Ideas**  **PS1.A: Structure and Properties of Matter**  Different kinds of matter exist and many of them can be either solid or liquid, depending on temperature. Matter can be described and classified by its observable properties. (2-PS1-1)  Different properties are suited to different purposes. (2-PS1-2),(2-PS1-3)  A great variety of objects can be built up from a small set of pieces. (2-PS1-3)  **PS1.B: Chemical Reactions**  Heating or cooling a substance may cause changes that can be observed. Sometimes these changes are reversible, and sometimes they are not. (2-PS1-4) | **Crosscutting Concepts**  **Patterns**  Patterns in the natural and human  designed world can be observed.  (2-PS1-1)  **Cause and Effect**  Events have causes that generate  observable patterns. (2-PS1-4)  Simple tests can be designed to gather  evidence to support or refute student ideas  about causes. (2-PS1-2)  **Energy and Matter**  Objects may break into smaller pieces  and be put together into larger pieces, or  change shapes. (2-PS1-3)  **-----------------------------------------------**  **Connections to Engineering, Technology,**  **and Applications of Science**  **Influence of Engineering, Technology,**  **and Science, on Society and the Natural**  **World**  Every human-made product is designed by  applying some knowledge of the natural world  and is built by using natural materials. (2-PS1-2) |

**K-2-ETS1 Engineering Design**

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| **K-2-ETS1 Engineering Design** | | |
| Students who demonstrate understanding can:  **K-2-ETS1-1. Ask questions, make observations, and gather information about a situation people want to**  **change to define a simple problem that can be solved through the development of a new or improved**  **object or tool.**  **K-2-ETS1-2. Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object**  **helps it function as needed to solve a given problem.**  **K-2-ETS1-3. Analyze data from tests of two objects designed to solve the same problem to compare the**  **strengths and weaknesses of how each performs.** | | |
| The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education: | | |
| **Science and Engineering Practices**  **Asking Questions and Defining Problems**  Asking questions and defining problems in K–2 builds on prior experiences and progresses to simple descriptive questions.  Ask questions based on observations to find more information about the natural and/or designed world. (K-2-ETS1-1)  Define a simple problem that can be solved through the development of a new or improved object or tool. (K-2-ETS1-1)  **Developing and Using Models**  Modeling in K–2 builds on prior experiences and progresses to include using and developing models (i.e., diagram, drawing, physical replica, diorama, dramatization, or storyboard) that represent concrete events or design solutions.  Develop a simple model based on evidence to represent a proposed object or tool. (K-2-ETS1-2)  **Analyzing and Interpreting Data**  Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations.  Analyze data from tests of an object or tool to determine if it works as intended. (K-2-ETS1-3) | **Disciplinary Core Ideas**  **ETS1.A: Defining and Delimiting Engineering Problems**  A situation that people want to change or create can be approached as a problem to be solved through engineering. (K-2-ETS1-1)  Asking questions, making observations, and gathering information are helpful in thinking about problems.  (K-2-ETS1-1)  Before beginning to design a solution, it is important to clearly understand the problem. (K-2-ETS1-1)  **ETS1.B: Developing Possible Solutions**  Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem’s solutions to other people. (K-2-ETS1-2)  **ETS1.C: Optimizing the Design Solution**  Because there is always more than one possible solution to a problem, it is useful to compare and test designs. (K-2-ETS1-3) | **Crosscutting Concepts**  **Structure and Function**  The shape and stability of structures of  natural and designed objects are related to  their function(s). (K-2-ETS1-2) |
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**3rd Grade**

**3-PS2 Motion and Stability: Forces and Interactions**

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| **3-PS2 Motion and Stability: Forces and Interactions** | | |
| Students who demonstrate understanding can:  **3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced**  **forces on the motion of an object.** [Clarification Statement: Examples could include an unbalanced force on one side of a ball can make it start  moving; and, balanced forces pushing on a box from both sides will not produce any motion at all.] [Assessment Boundary: Assessment is limited to one variable  at a time: number, size, or direction of forces. Assessment does not include quantitative force size, only qualitative and relative. Assessment is limited to gravity  being addressed as a force that pulls objects down.]  **3-PS2-2. Make observations and/or measurements of an object’s motion to provide evidence that a pattern**  **can be used to predict future motion.** [Clarification Statement: Examples of motion with a predictable pattern could include a child swinging  in a swing, a ball rolling back and forth in a bowl, and two children on a see-saw.] [Assessment Boundary: Assessment does not include technical terms such  as period and frequency.]  **3-PS2-3. Ask questions to determine cause and effect relationships of electric or magnetic interactions**  **between two objects not in contact with each other.**  [Clarification Statement: Examples of an electric force could include the force on hair from an electrically charged balloon and the electrical forces between a  charged rod and pieces of paper; examples of a magnetic force could include the force between two permanent magnets, the force between an electromagnet  and steel paperclips, and the force exerted by one magnet versus the force exerted by two magnets. Examples of cause and effect relationships could include  how the distance between objects affects strength of the force and how the orientation of magnets affects the direction of the magnetic force.]  [Assessment Boundary: Assessment is limited to forces produced by objects that can be manipulated by students, and electrical interactions are limited to  static electricity.]  **3-PS2-4. Define a simple design problem that can be solved by applying scientific ideas about magnets. \***  [Clarification Statement: Examples of problems could include constructing a latch to keep a door shut and creating a device to keep two moving objects from  touching each other.] | | |
| The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education: | | |
| **Science and Engineering Practices**  **Asking Questions and Defining Problems**  Asking questions and defining problems in grades 3–5 builds on grades K–2 experiences and progresses to specifying qualitative relationships.  Ask questions that can be investigated based on patterns such as cause and effect relationships. (3-PS2-3)  Define a simple problem that can be solved through the development of a new or improved object or tool.  (3-PS2-4)  **Planning and Carrying Out Investigations**  Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.  Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered (3-PS2-1).  Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution. (3-PS2-2)  **Constructing Explanations and Designing Solutions**  Constructing explanations and designing solutions in 3–5 builds on prior experiences in K–2 and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems.  Apply scientific ideas to solve design problems.  (3-PS2-4)  **------------------------------------------------**  **Connections to Nature of Science**  **Science Knowledge is Based on Empirical Evidence**  Science findings are based on recognizing patterns. (3-PS2-2)  **Scientific Investigations Use a Variety of Methods**  Science investigations use a variety of methods, tools, and techniques. (3-PS2-1) | **Disciplinary Core Ideas**  **PS2.A: Forces and Motion**  Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object’s speed or direction of motion. (Boundary: Qualitative and conceptual, but not quantitative addition of forces are used at this level.)  (3-PS2-1)  The patterns of an object’s motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it. (Boundary: Technical terms, such as magnitude, velocity, momentum, and vector quantity, are not introduced at this level, but the concept that some quantities need both size and direction to be described is developed.) (3-PS2-2)  **PS2.B: Types of Interactions**  Objects in contact exert forces on each other.  (3-PS2-1)  Electric, and magnetic forces between a pair of objects do not require that the objects be in contact.  The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other. (3-PS2-3),(3-PS2-4) | **Crosscutting Concepts**  **Patterns**  Patterns of change can be used to  make predictions. (3-PS2-2)  **Cause and Effect**  Cause and effect relationships are  routinely identified. (3-PS2-1)  Cause and effect relationships  are routinely identified, tested, and  used to explain change. (3-PS2-3)  **------------------------------------------------**  **Connections to Engineering,**  **Technology, and Applications of**  **Science Interdependence of Science,**  **Engineering,** **and Technology**  Scientific discoveries about the natural  world can often lead to new and improved  technologies, which are developed through  the engineering design process. (3-PS2-4) |

**4th Grade**

**4-PS3 Energy**

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| **4-PS3 Energy** | | |
| Students who demonstrate understanding can:  **4-PS3-1. Use evidence to construct an explanation relating the speed of an object to the energy of that object.**  [Assessment Boundary: Assessment does not include quantitative measures of changes in the speed of an object or on any precise or quantitative definition of energy.]  **4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound,**  **light, heat, and electric currents.** [Assessment Boundary: Assessment does not include quantitative measurements of energy.]  **4-PS3-3. Ask questions and predict outcomes about the changes in energy that occur when objects collide.**  [Clarification Statement: Emphasis is on the change in the energy due to the change in speed, not on the forces, as objects interact.] [Assessment Boundary:  Assessment does not include quantitative measurements of energy.]  **4-PS3-4. Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.\***  [Clarification Statement: Examples of devices could include electric circuits that convert electrical energy into motion energy of a vehicle, light, or sound; and,  a passive solar heater that converts light into heat. Examples of constraints could include the materials, cost, or time to design the device.]  [Assessment Boundary:  Devices should be limited to those that convert motion energy to electric energy or use stored energy to cause motion or produce light or sound.] | | |
| **Science and Engineering Practices**  **Asking Questions and Defining Problems**  Asking questions and defining problems in grades 3–5 builds on grades K–2 experiences and progresses to specifying qualitative relationships.  Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships. (4-PS3-3)  **Planning and Carrying Out Investigations**  Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on  K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.  Make observations to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution. (4-PS3-2)  **Constructing Explanations and Designing Solutions**  Constructing explanations and designing solutions in 3–5 builds on K–2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems.  Use evidence (e.g., measurements, observations, patterns) to construct an explanation. (4-PS3-1)  Apply scientific ideas to solve design problems.  (4-PS3-4) | **Disciplinary Core Ideas**  **PS3.A: Definitions of Energy**  The faster a given object is moving, the more energy it possesses. (4-PS3-1)  Energy can be moved from place to place by moving objects or through sound, light, or electric currents.  (4-PS3-2),(4-PS3-3)  **PS3.B: Conservation of Energy and Energy Transfer**  Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced. (4-PS3-2),(4-PS3-3)  Light also transfers energy from place to place.  (4-PS3-2)  Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy. (4-PS3-2),(4-PS3-4)  **PS3.C: Relationship Between Energy and Forces**  When objects collide, the contact forces transfer energy so as to change the objects’ motions. (4-PS3-3)  **PS3.D: Energy in Chemical Processes and Everyday Life**  The expression “produce energy” typically refers to the conversion of stored energy into a desired form for practical use. (4-PS3-4)  **ETS1.A: Defining Engineering Problems**  Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account.  (secondary to 4-PS3-4) | **Crosscutting Concepts**  **Energy and Matter**  Energy can be transferred in various  ways and between  objects. (4-PS3-1), (4-PS3-2),(4-PS3-3),  (4-PS3-4)  **---------------------------------------------**  **Connections to Engineering, Technology,**  **and Applications of Science**  **Influence of Science, Engineering and**  **Technology on Society and the Natural**  **World**  Engineers improve existing technologies  or develop new ones.  (4-PS3-4)  **----------------------------------------------**  **Connections to Nature of Science**  **Science is a Human Endeavor**  Most scientists and engineers work in  teams. (4-PS3-4)  Science affects everyday life. (4-PS3-4) |

**4-PS4 Waves and their Applications in Technologies for Information Transfer**

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| **4-PS4 Waves and their Applications in Technologies for Information Transfer** | | |
| Students who demonstrate understanding can:  **4-PS4-1. Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves**  **can cause objects to move.** [Clarification Statement: Examples of models could include diagrams, analogies, and physical models using wire to illustrate  wavelength and amplitude of waves.] [Assessment Boundary: Assessment does not include interference effects, electromagnetic waves, non-periodic waves,  or quantitative models of amplitude and wavelength.]  **4-PS4-2. Develop a model to describe that light reflecting from objects and entering the eye allows objects**  **to be seen.** [Assessment Boundary: Assessment does not include knowledge of specific colors reflected and seen, the cellular mechanisms of vision, or  how the retina works.]  **4-PS4-3. Generate and compare multiple solutions that use patterns to transfer information.\***  [Clarification Statement: Examples of solutions could include drums sending coded information through sound waves, using a grid of 1’s and 0’s representing  black and white to send information about a picture, and using Morse code to send text.] | | |
| **Science and Engineering Practices**  **Developing and Using Models**  Modeling in 3–5 builds on K–2 experiences and progresses to building and revising simple models and using models to represent events and design solutions.  Develop a model using an analogy, example, or abstract representation to describe a scientific principle. (4-PS4-1)  Develop a model to describe phenomena. (4-PS4-2)  **Constructing Explanations and Designing Solutions**  Constructing explanations and designing solutions in 3–5 builds on K–2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems.  Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution. (4-PS4-3)  **-------------------------------------------------**  **Connections to Nature of Science**  **Scientific Knowledge is Based on Empirical Evidence**  Science findings are based on recognizing patterns. (4-PS4-1) | **Disciplinary Core Ideas**  **PS4.A: Wave Properties**  Waves, which are regular patterns of motion, can be made in water by disturbing the surface. When waves move across the surface of deep water, the water goes up and down in place; it does not move in the direction of the wave except when the water meets the beach. (Note: This grade band endpoint was moved from K–2). (4-PS4-1)  Waves of the same type can differ in amplitude (height of the wave) and wavelength (spacing between wave peaks). (4-PS4-1)  **PS4.B: Electromagnetic Radiation**  An object can be seen when light reflected from its surface enters the eyes. (4-PS4-2)  **PS4.C: Information Technologies and Instrumentation**  Digitized information transmitted over long distances without significant degradation. High-tech devices, such as computers or cell phones, can receive and decode information—convert it from digitized form to voice—and vice versa. (4-PS4-3)  **ETS1.C: Optimizing The Design Solution**  Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. (secondary to 4-PS4-3) | **Crosscutting Concepts**  **Patterns**  Similarities and differences in patterns can  be used to sort and classify natural. (4-PS4-1)  Similarities and differences in patterns can  Be used to sort and classify designed products.  (4-PS4-3)  **Cause and Effect**  Cause and effect relationships are routinely  identified. (4-PS4-2)  **---------------------------------------------------**  **Connections to Engineering, Technology,**  **and Applications of Science**  **Interdependence of Science, Engineering,**  **and Technology**  Knowledge of relevant scientific concepts and research findings is important in engineering.  (4-PS4-3) |

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**Middle School**

**MS-PS1 Matter and Its Interactions**

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| **Science and Engineering Practices**  Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS1-2)  **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena**  Laws are regularities or mathematical descriptions of natural phenomena. (MS-PS1-5) | **Disciplinary Core Ideas**  **ETS1.C: Optimizing the Design Solution**  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. (secondary to MS-PS1-6)  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. (secondary to MS-PS1-6) | **Crosscutting Concepts**  Findings of scientific research; and by  differences in such factors as climate,  natural resources, and economic conditions.  Thus technology use varies from region to  region and over time. (MS-PS1-3) |

**MS-PS2 Motion and Stability: Forces and Interactions**

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| **MS-PS2 Motion and Stability: Forces and Interactions** | | |
| Students who demonstrate understanding can:  **MS-PS2-1. Apply Newton’s Third Law to design a solution to a problem involving the motion of two colliding objects.\***  [Clarification Statement: Examples of practical problems could include the impact of collisions between two cars, between a car and stationary objects, and  between a meteor and a space vehicle.] [Assessment Boundary: Assessment is limited to vertical or horizontal interactions in one dimension.]  **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.** [Clarification Statement: Emphasis is on balanced (Newton’s First Law) and  unbalanced forces in a system, qualitative comparisons of forces, mass and changes in motion (Newton’s Second Law), frame of reference, and specification of units.]  [Assessment Boundary: Assessment is limited to forces and changes in motion in one-dimension in an inertial reference frame and to change in one variable at a time.  Assessment does not include the use of trigonometry.]  **MS-PS2-3. Ask questions about data to determine the factors that affect the strength of electric and magnetic**  **forces.**  [Clarification Statement: Examples of devices that use electric and magnetic forces could include electromagnets, electric motors, or generators. Examples of data  could include the effect of the number of turns of wire on the strength of an electromagnet, or the effect of increasing the number or strength of magnets on the  speed of an electric motor.] [Assessment Boundary: Assessment about questions that require quantitative answers is limited to proportional reasoning and algebraic  thinking.]  **MS-PS2-4. Construct and present arguments using evidence to support the claim that gravitational interactions**  **are attractive and depend on the masses of interacting objects.** [Clarification Statement: Examples of evidence for arguments could  include data generated from simulations or digital tools; and charts displaying mass, strength of interaction, distance from the Sun, and orbital periods of objects  within the solar system.] [Assessment Boundary: Assessment does not include Newton’s Law of Gravitation or Kepler’s Laws.]  **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.** [Clarification Statement:  Examples of this phenomenon could include the interactions of magnets, electrically-charged strips of tape, and electrically-charged pith balls. Examples of  investigations could include first-hand experiences or simulations.] [Assessment Boundary: Assessment is limited to electric and magnetic fields, and limited to  qualitative evidence for the existence of fields.] | | |
| The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education: | | |
| **Science and Engineering Practices**  **Asking Questions and Defining Problems**  Asking questions and defining problems in grades 6–8 builds from grades K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models.  Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles.  (MS-PS2-3)  **Planning and Carrying Out Investigations**  Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.  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. (MS-PS2-2)  Conduct an investigation and evaluate the experimental design to produce data to serve as the basis for evidence that can meet the goals of the investigation. (MS-PS2-5)  **Constructing Explanations and Designing Solutions**  Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.  Apply scientific ideas or principles to design an object, tool, process or system. (MS-PS2-1)  **Engaging in Argument from Evidence**  Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.  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. (MS-PS2-4)  **------------------------------------------------------**  **Connections to Nature of Science**  **Scientific Knowledge is Based on Empirical Evidence**  Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS2-2),(MS-PS2-4) | **Disciplinary Core Ideas**  **PS2.A: Forces and Motion**  For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton’s third law). (MS-PS2-1)  The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. (MS-PS2-2)  All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared. (MS-PS2-2)  **PS2.B: Types of Interactions**  Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. (MS-PS2-3)  Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun. (MS-PS2-4)  Forces that act at a distance (electric and magnetic) can be explained by fields that extend through space and can be mapped by their effect on a test object (a ball, a charged object, or a magnet, respectively). (MS-PS2-5) | **Crosscutting Concepts**  **Cause and Effect**  Cause and effect relationships may be used  to predict phenomena in natural or designed  systems. (MS-PS2-3),(MS-PS2-5)  **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. (MS-PS2-1),(MS-PS2-4),  **Stability and Change**  Explanations of stability and change in  natural or designed systems can be constructed  by examining the changes over time and forces  at different scales. (MS-PS2-2)  **----------------------------------------------**  **Connections to Engineering, Technology,**  **and Applications of Science**  **Influence of Science, Engineering, and**  **Technology on Society and the Natural**  **World**  The uses of technologies and any limitations  on their use are driven by individual or societal  needs, desires, and values; by the findings of  scientific research; and by differences in such  factors as climate, natural resources, and  economic conditions. (MS-PS2-1) |

**MS-PS3 Energy**

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| **MS-PS3 Energy** | | |
| Students who demonstrate understanding can:  **MS-PS3-1. Construct and interpret graphical displays of data to describe the relationships of kinetic energy**  **to the mass of an object and to the speed of an object.**  [Clarification Statement: Emphasis is on descriptive relationships between kinetic energy and mass separately from kinetic energy and speed. Examples could  include riding a bicycle at different speeds, rolling different sizes of rocks downhill, and getting hit by a wiffle ball versus a tennis ball.]  **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.** [Clarification Statement: Emphasis is on relative amounts of potential  energy, not on calculations of potential energy. Examples of objects within systems interacting at varying distances could include: the Earth and either a roller coaster  cart at varying positions on a hill or objects at varying heights on shelves, changing the direction/orientation of a magnet, and a balloon with static electrical charge  being brought closer to a classmate’s hair. Examples of models could include representations, diagrams, pictures, and written descriptions of systems.]  [Assessment Boundary: Assessment is limited to two objects and electric, magnetic, and gravitational interactions.]  **MS-PS3-3. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes**  **thermal energy transfer.\*** [Clarification Statement: Examples of devices could include an insulated box, a solar cooker, and a Styrofoam cup.]  [Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.]  **MS-PS3-4. 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.**  [Clarification Statement: Examples of experiments could include comparing final water temperatures after different masses of ice melted in the same volume of water  with the same initial temperature, the temperature change of samples of different materials with the same mass as they cool or heat in the environment, or the same  material with different masses when a specific amount of energy is added.] [Assessment Boundary: Assessment does not include calculating the total amount of thermal  energy transferred.]  **MS-PS3-5. 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.** [Clarification Statement: Examples of empirical evidence used in arguments could include  an inventory or other representation of the energy before and after the transfer in the form of temperature changes or motion of object.] [Assessment Boundary:  Assessment does not include calculations of energy.] | | |
| The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education: | | |
| **Science and Engineering Practices**  **Developing and Using Models**  Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to describe, test, and predict more abstract phenomena and design systems.  Develop a model to describe unobservable mechanisms. (MS-PS3-2)  **Planning and Carrying Out Investigations**  Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.  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. (MS-PS3-4)  **Analyzing and Interpreting Data**  Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.  Construct and interpret graphical displays of data to identify linear and nonlinear relationships. (MS-PS3-1)  **Constructing Explanations and Designing Solutions**  Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.  Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process or system. (MS-PS3-3)  **Engaging in Argument from Evidence**  Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed worlds.  Construct, use, 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. (MS-PS3-5)  **-------------------------------------------------**  **Connections to Nature of Science**  **Scientific Knowledge is Based on Empirical Evidence**  Science knowledge is based upon logical and conceptual connections between evidence and explanations (MS-PS3-4),(MS-PS3-5) | **Disciplinary Core Ideas**  **PS3.A: Definitions of Energy**  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. (MS-PS3-1)  A system of objects may also contain stored (potential) energy, depending on their relative positions. (MS-PS3-2)  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. (MS-PS3-3),(MS-PS3-4)  **PS3.B: Conservation of Energy and Energy Transfer**  When the motion energy of an object changes, there is inevitably some other change in energy at the same time. (MS-PS3-5)  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. (MS-PS3-4)  Energy is spontaneously transferred out of hotter regions or objects and into colder ones. (MS-PS3-3)  **PS3.C: Relationship Between Energy and Forces**  When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object. (MS-PS3-2)  **ETS1.A: Defining and Delimiting an Engineering Problem**  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. (secondary to MS-PS3-3)  **ETS1.B: Developing Possible Solutions**  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. (secondary to MS-PS3-3) | **Crosscutting Concepts**  **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.  (MS-PS3-1),(MS-PS3-4)  **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. (MS-PS3-2)  **Energy and Matter**  Energy may take different forms (e.g.  energy in fields, thermal energy, energy of  motion). (MS-PS3-5)  The transfer of energy can be tracked as  energy flows through a designed or natural  system. (MS-PS3-3) |
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| **MS-PS4 Waves and Their Applications in Technologies for Information Transfer**   |  |  |  | | --- | --- | --- | | **MS-PS4 Waves and Their Applications in Technologies for Information Transfer** | | | | Students who demonstrate understanding can:  **MS-PS4-1. Use mathematical representations to describe a simple model for waves that includes how the**  **amplitude of a wave is related to the energy in a wave.** [Clarification Statement: Emphasis is on describing waves with both qualitative  and quantitative thinking.] [Assessment Boundary: Assessment does not include electromagnetic waves and is limited to standard repeating waves.]  **MS-PS4-2. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through**  **various materials.** [Clarification Statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, simulations,  and written descriptions.] [Assessment Boundary: Assessment is limited to qualitative applications pertaining to light and mechanical waves.]  **MS-PS4-3. Integrate qualitative scientific and technical information to support the claim that digitized signals**  **(sent as wave pulses) are a more reliable way to encode and transmit information.** [Clarification Statement: Emphasis is on  a basic understanding that waves can be used for communication purposes. Examples could include using fiber optic cable to transmit light pulses, radio wave pulses  in wifi devices, and conversion of stored binary patterns to make sound or text on a computer screen.] [Assessment Boundary: Assessment does not include binary  counting. Assessment does not include the specific mechanism of any given device.] | | | | The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education: | | | | **Science and Engineering Practices**  **Developing and Using Models**  Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.  Develop and use a model to describe phenomena. (MS-PS4-2)  **Using Mathematics and Computational Thinking**  Mathematical and computational thinking at the 6–8 level builds on K–5 and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments.  Use mathematical representations to describe and/or support scientific conclusions and design solutions.  (MS-PS4-1)  **Obtaining, Evaluating, and Communicating Information**  Obtaining, evaluating, and communicating information in 6-8 builds on K-5 and progresses to evaluating the merit and validity of ideas and methods.  Integrate qualitative scientific and technical information in written text with that contained in media and visual displays to clarify claims and findings.  (MS-PS4-3)  **----------------------------------------------------**  **Connections to Nature of Science**  **Scientific Knowledge is Based on Empirical Evidence**  Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS4-1) | **Disciplinary Core Ideas**  **PS4.A: Wave Properties**  A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. (MS-PS4-1)  A sound wave needs a medium through which it is transmitted. (MS-PS4-2)  **PS4.B: Electromagnetic Radiation**  When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object’s material and the frequency (color) of the light. (MS-PS4-2)  The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends. (MS-PS4-2)  A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media. (MS-PS4-2)  However, because light can travel through space, it cannot be a matter wave, like sound or water waves. (MS-PS4-2)  **PS4.C: Information Technologies and Instrumentation**  Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information.  (MS-PS4-3) | **Crosscutting Concepts**  **Patterns**  Graphs and charts can be used to identify  patterns in data. (MS-PS4-1)  **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. (MS-PS4-2)  Structures can be designed to serve  particular functions. (MS-PS4-3)  **----------------------------------------**  **Connections to Engineering, Technology,**  **and Applications of Science**  **Influence of Science, Engineering, and**  **Technology on Society and the Natural**  **World**  Technologies extend the measurement,  exploration, modeling, and computational  capacity of scientific investigations.  (MS-PS4-3)  **-----------------------------------------**  **Connections to Nature of Science**  **Science is a Human Endeavor**  Advances in technology influence the  progress of science and science has  influenced advances in technology. (MS-PS4-3) | | | |
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**MS-ETS1 Engineering Design**

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| **MS-ETS1 Engineering Design** | | |
| Students who demonstrate understanding can:  **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.**  **MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they**  **meet the criteria and constraints of the problem.**  **MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions**  **to identify the best characteristics of each that can be combined into a new solution to better meet the criteria**  **for success.**  **MS-ETS1-4. 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.** | | |
| The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education: | | |
| **Science and Engineering Practices**  **Asking Questions and Defining Problems**  Asking questions and defining problems in grades 6–8 builds on grades K–5 experiences and progresses to specifying relationships between variables, clarify arguments and models.  Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions. (MS-ETS1-1)  **Developing and Using Models**  Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.  Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs. (MS-ETS1-4)  **Analyzing and Interpreting Data**  Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.  Analyze and interpret data to determine similarities and differences in findings. (MS-ETS1-3)  **Engaging in Argument from Evidence**  Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.  Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. (MS-ETS1-2) | **Disciplinary Core Ideas**  **ETS1.A: Defining and Delimiting Engineering Problems**  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 are likely to limit possible solutions. (MS-ETS1-1)  **ETS1.B: Developing Possible Solutions**  A solution needs to be tested, and then modified on the basis of the test results, in order to improve it.  (MS-ETS1-4)  There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (MS-ETS1-2), (MS-ETS1-3)  Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. (MS-ETS1-3)  Models of all kinds are important for testing solutions. (MS-ETS1-4)  **ETS1.C: Optimizing the Design Solution**  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 those characteristics may be incorporated into the new design. (MS-ETS1-3)  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. (MS-ETS1-4) | **Crosscutting Concepts**  **Influence of Science, Engineering, and**  **Technology on Society and the Natural**  **World**  All human activity draws on natural  resources and has both short and long-term consequences, positive as well as negative,  for the health of people and the natural  environment. (MS-ETS1-1)  The uses of technologies and limitations on  their use are driven by individual or societal  needs, desires, and values; by the findings of  scientific research; and by differences in such  factors as climate, natural resources, and  economic conditions. (MS-ETS1-1) |

 **High School**

**HS-PS2 Motion and Stability: Forces and Interactions**

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| **HS-PS2 Motion and Stability: Forces and Interactions** | | |
| Students who demonstrate understanding can:  **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.** [Clarification Statement:  Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object,  an object rolling down a ramp, or a moving object being pulled by a constant force.] [Assessment Boundary: Assessment is limited to one-dimensional motion  and to macroscopic objects moving at non-relativistic speeds.]  **HS-PS2-2. Use mathematical representations to support the claim that the total momentum of a system of**  **objects is conserved when there is no net force on the system.** [Clarification Statement: Emphasis is on the quantitative conservation  of momentum in interactions and the qualitative meaning of this principle.] [Assessment Boundary: Assessment is limited to systems of two macroscopic bodies  moving in one dimension.]  **HS-PS2-3. Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the**  **force on a macroscopic object during a collision.\*** [Clarification Statement: Examples of evaluation and refinement could include determining  the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or  a parachute.] [Assessment Boundary: Assessment is limited to qualitative evaluations and/or algebraic manipulations.]  **HS-PS2-4. Use mathematical representations of Newton’s Law of Gravitation and Coulomb’s Law to describe**  **and predict the gravitational and electrostatic forces between objects.** [Clarification Statement: Emphasis is on both quantitative  and conceptual descriptions of gravitational and electric fields.] [Assessment Boundary: Assessment is limited to systems with two objects.]  **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.** [Assessment Boundary: Assessment is limited to designing  and conducting investigations with provided materials and tools.]  **HS-PS2-6. Communicate scientific and technical information about why the molecular-level structure is important**  **in the functioning of designed materials.\*** [Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning  of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained  molecules, and pharmaceuticals are designed to interact with specific receptors.] [Assessment Boundary: Assessment is limited to provided molecular structures of  specific designed materials.] | | |
| The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education: | | |
| **Science and Engineering Practices**  **Planning and Carrying Out Investigations**  Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical and empirical models.  Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS2-5)  **Analyzing and Interpreting Data**  Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.  Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. (HS-PS2-1)  **Using Mathematics and Computational Thinking**  Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.  Use mathematical representations of phenomena to describe explanations. (HS-PS2-2),(HS-PS2-4)  **Constructing Explanations and Designing Solutions**  Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.  Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects. (HS-PS2-3)  **Obtaining, Evaluating, and Communicating Information**  Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.  Communicate scientific and technical information (e.g. about the process of development and the design and performance of a proposed process or system) in multiple formats | **Disciplinary Core Ideas**  **PS2.A: Forces and Motion**  Newton’s second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1)  Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. In any system, total momentum is always conserved. (HS-PS2-2)  If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. (HS-PS2-2),(HS-PS2-3)  **PS2.B: Types of Interactions**  Newton’s law of universal gravitation and Coulomb’s law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (HS-PS2-4)  Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.  (HS-PS2-4),(HS-PS2-5)  Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. (HS-PS2-6),  (secondary to HS-PS1-1),(secondary to HS-PS1-3)  **PS3.A: Definitions of Energy**  …and “electrical energy” may mean energy stored in a battery or energy transmitted by electric currents.(secondary to HS-PS2-5)  **ETS1.A: Defining and Delimiting Engineering Problems**  Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.  (secondary to HS-PS2-3)  **ETS1.C: Optimizing the Design Solution**  Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (secondary to HS-PS2-3) | **Crosscutting Concepts**  **Patterns**  Different patterns may be observed at each  of the scales at which a system is studied and  can provide evidence for causality in  explanations of phenomena. (HS-PS2-4)  **Cause and Effect**  Empirical evidence is required to differentiate  between cause and correlation and make  claims about specific causes and effects.  (HS-PS2-1),(HS-PS2-5)  Systems can be designed to cause a desired  effect. (HS-PS2-3)  **Systems and System Models**  When investigating or describing a system,  the boundaries and initial conditions of the  system need to be defined. (HS-PS2-2)  **Structure and Function**  Investigating or designing new systems or  structures requires a detailed examination of  the properties of different materials, the  structures of different components, and  connections of components to reveal its function  and/or solve a problem. (HS-PS2-6) |

**HS-PS3 Energy**

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| **HS-PS3 Energy** | | |
| Students who demonstrate understanding can:  **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.**  [Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] [Assessment Boundary: Assessment is limited  to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational,  magnetic, or electric fields.]  **HS-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as**  **either motions of particles or energy stored in fields.** [Clarification Statement: Examples of phenomena at the macroscopic scale could  include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two  electrically-charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.]  **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.\*** [Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices  could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms  and efficiency.] [Assessment Boundary: Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices  constructed with materials provided to students.]  **HS-PS3-4. Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two**  **components of different temperature are combined within a closed system results in a more uniform energy**  **distribution among the components in the system (second law of thermodynamics).** [Clarification Statement: Emphasis is on  analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of  investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.] [Assessment Boundary:  Assessment is limited to investigations based on materials and tools provided to students.]  **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.** [Clarification Statement:  Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other,  including an explanation of how the change in energy of the objects is related to the change in energy of the field.] [Assessment Boundary: Assessment is limited  to systems containing two objects.] | | |
| The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education: | | |
| **Science and Engineering Practices**  **Developing and Using Models**  Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.  Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS3-2),(HS-PS3-5)  **Planning and Carrying Out Investigations**  Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.  Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS3-4)  **Using Mathematics and Computational Thinking**  Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.  Create a computational model or simulation of a phenomenon, designed device, process, or system.  (HS-PS3-1)  **Constructing Explanations and Designing Solutions**  Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.  Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.  (HS-PS3-3) | **Disciplinary Core Ideas**  **PS3.A: Definitions of Energy**  Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system’s total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.  (HS-PS3-1),(HS-PS3-2)  At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HS-PS3-2) (HS-PS3-3)  These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as either motions of particles or energy stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. (HS-PS3-2)  **PS3.B: Conservation of Energy and Energy Transfer**  Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. (HS-PS3-1)  Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-1),(HS-PS3-4)  Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (HS-PS3-1)  The availability of energy limits what can occur in any system. (HS-PS3-1)  Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down).  (HS-PS3-4)  **PS3.C: Relationship Between Energy and Forces**  When two objects interacting through a field change relative position, the energy stored in the field is changed. (HS-PS3-5)  **PS3.D: Energy in Chemical Processes**  Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. (HS-PS3-3),  (HS-PS3-4)  **ETS1.A: Defining and Delimiting Engineering Problems**  Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.  (secondary to HS-PS3-3) | **Crosscutting Concepts**  **Cause and Effect**  Cause and effect relationships can be  suggested and predicted for complex natural  and human designed systems by examining  what is known about smaller scale  mechanisms within the system. (HS-PS3-5)  **Systems and System Models**  When investigating or describing a system,  the boundaries and initial conditions of the  system need to be defined and their inputs  and outputs analyzed and described using  models. (HS-PS3-4)  Models can be used to predict the behavior  of a system, but these predictions have limited  precision and reliability due to the assumptions  and approximations inherent in models.  (HS-PS3-1)  **Energy and Matter**  Changes of energy and matter in a system  can be described in terms of energy and  matter flows into, out of, and within that  system. (HS-PS3-3)  Energy cannot be created or destroyed—  only moves between one place and another  place, between objects and/or fields, or  between systems. (HS-PS3-2)  **-------------------------------**  Science assumes the universe is a vast  single system in which basic laws are  consistent. (HS-PS3-1) |

**HS-PS4 Waves and Their Applications in Technologies for Information Transfer**

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| **HS-PS4 Waves and Their Applications in Technologies for Information Transfer** | | |
| Students who demonstrate understanding can:  **HS-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency,**  **wavelength, and speed of waves traveling in various media.** [Clarification Statement: Examples of data could include electromagnetic  radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.] [Assessment Boundary:  Assessment is limited to algebraic relationships and describing those relationships qualitatively.]  **HS-PS4-2. Evaluate questions about the advantages of using a digital transmission and storage of information.**  [Clarification Statement: Examples of advantages could include that digital information is stable because it can be stored reliably in computer memory, transferred  easily, and copied and shared rapidly. Disadvantages could include issues of easy deletion, security, and theft.]  **HS-PS4-3. Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be**  **described either by a wave model or a particle model, and that for some situations one model is more useful**  **than the other.**  [Clarification Statement: Emphasis is on how the experimental evidence supports the claim and how a theory is generally modified in light of new evidence.  Examples of a phenomenon could include resonance, interference, diffraction, and photoelectric effect.] [Assessment Boundary: Assessment does not include  using quantum theory.]  **HS-PS4-4. Evaluate the validity and reliability of claims in published materials of the effects that different**  **frequencies of electromagnetic radiation have when absorbed by matter.** [Clarification Statement: Emphasis is on the idea that  different frequencies of light have different energies, and the damage to living tissue from electromagnetic radiation depends on the energy of the radiation.  Examples of published materials could include trade books, magazines, web resources, videos, and other passages that may reflect bias.] [Assessment Boundary:  Assessment is limited to qualitative descriptions.]  **HS-PS4-5. Communicate technical information about how some technological devices use the principles of**  **wave behavior and wave interactions with matter to transmit and capture information and energy.\***  [Clarification Statement: Examples could include solar cells capturing light and converting it to electricity; medical imaging; and communications technology.]  [Assessment Boundary: Assessments are limited to qualitative information. Assessments do not include band theory.] | | |
| The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education: | | |
| **Science and Engineering Practices**  **Asking Questions and Defining Problems**  Asking questions and defining problems in grades 9–12 builds from grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.  Evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design. (HS-PS4-2)  **Using Mathematics and Computational Thinking**  Mathematical and computational thinking at the 9-12 level builds on K-8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.  Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations. (HS-PS4-1)  **Engaging in Argument from Evidence**  Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about natural and designed worlds. Arguments may also come from current scientific or historical episodes in science.  Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (HS-PS4-3)  **Obtaining, Evaluating, and Communicating Information**  Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.  Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible. (HS-PS4-4)  Communicate technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-PS4-5)  **-----------------------------------------------------**  **Connections to Nature of Science**  **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena**  A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.  (HS-PS4-3) | **Disciplinary Core Ideas**  **PS3.D: Energy in Chemical Processes**  Solar cells are human-made devices that likewise capture the sun’s energy and produce electrical energy. (secondary to HS-PS4-5)  **PS4.A: Wave Properties**  The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing. (HS-PS4-1)  Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. (HS-PS4-2),  (HS-PS4-5)  [From the 3–5 grade band endpoints] Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.) (HS-PS4-3)  **PS4.B: Electromagnetic Radiation**  Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. (HS-PS4-3)  When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells.  (HS-PS4-4)  Photovoltaic materials emit electrons when they absorb light of a high-enough frequency. (HS-PS4-5)  **PS4.C: Information Technologies and Instrumentation**  Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them. (HS-PS4-5) | **Crosscutting Concepts**  **Cause and Effect**  Empirical evidence is required to  differentiate between cause and correlation  and make claims about specific causes and  effects. (HS-PS4-1)  Cause and effect relationships can be  suggested and predicted for complex  natural and human designed systems by  examining what is known about smaller  scale mechanisms within the system.  (HS-PS4-4)  Systems can be designed to cause a  desired effect. (HS-PS4-5)  **Systems and System Models**  Models (e.g., physical, mathematical,  computer models) can be used to simulate  systems and interactions—including energy,  matter, and information flows—within and  between systems at different scales.  (HS-PS4-3)  **Stability and Change**  Systems can be designed for greater or  lesser stability. (HS-PS4-2)  **---------------------------------------------**  **Connections to Engineering,**  **Technology, and Applications of**  **Science Interdependence of Science,**  **Engineering, and Technology**  Science and engineering complement  each other in the cycle known as research  and development (R&D). (HS-PS4-5)  **Influence of Engineering, Technology,**  **and Science on Society and the**  **Natural World**  Modern civilization depends on major  technological systems. (HS-PS4-2),  (HS-PS4-5)  Engineers continuously modify these  technological systems by applying  scientific knowledge and engineering  design practices to increase benefits  while decreasing costs and risks.  (HS-PS4-2) |

**HS-LS2 Ecosystems: Interactions, Energy, and Dynamics**

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| **HS-LS2 Ecosystems: Interactions, Energy, and Dynamics** | | |
| Students who demonstrate understanding can:  **HS-LS2-1. Use mathematical and/or computational representations to support explanations of factors that**  **affect carrying capacity of ecosystems at different scales.** [Clarification Statement: Emphasis is on quantitative analysis and  comparison of the relationships among interdependent factors including boundaries, resources, climate, and competition. Examples of mathematical comparisons  could include graphs, charts, histograms, and population changes gathered from simulations or historical data sets.] [Assessment Boundary: Assessment does  not include deriving mathematical equations to make comparisons.]  **HS-LS2-2. Use mathematical representations to support and revise explanations based on evidence about**  **factors affecting biodiversity and populations in ecosystems of different scales.** [Clarification Statement: Examples of  mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.] [Assessment  Boundary: Assessment is limited to provided data.]  **HS-LS2-3. Construct and revise an explanation based on evidence for the cycling of matter and flow of**  **energy in aerobic and anaerobic conditions.** [Clarification Statement: Emphasis is on conceptual understanding of the role of aerobic  and anaerobic respiration in different environments.] [Assessment Boundary: Assessment does not include the specific chemical processes of either aerobic  or anaerobic respiration.]  **HS-LS2-4. Use mathematical representations to support claims for the cycling of matter and flow of energy**  **among organisms in an ecosystem.** [Clarification Statement: Emphasis is on using a mathematical model of stored energy in biomass to describe  the transfer of energy from one trophic level to another and that matter and energy are conserved as matter cycles and energy flows through ecosystems.  Emphasis is on atoms and molecules such as carbon, oxygen, hydrogen and nitrogen being conserved as they move through an ecosystem.]  [Assessment Boundary: Assessment is limited to proportional reasoning to describe the cycling of matter and flow of energy.]  **HS-LS2-5. Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of**  **carbon among the biosphere, atmosphere, hydrosphere, and geosphere.** [Clarification Statement: Examples of models could  include simulations and mathematical models.] [Assessment Boundary: Assessment does not include the specific chemical steps of photosynthesis and respiration.]  **HS-LS2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain**  **relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result**  **in a new ecosystem.** [Clarification Statement: Examples of changes in ecosystem conditions could include modest biological or physical changes,  such as moderate hunting or a seasonal flood; and, extreme changes, such as volcanic eruption or sea level rise.]  **HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the**  **environment and biodiversity.\*** [Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination  of invasive species.]  **HS-LS2-8. Evaluate the evidence for the role of group behavior on individual and species’ chances to survive**  **and reproduce.** [Clarification Statement: Emphasis is on: (1) distinguishing between group and individual behavior, (2) identifying evidence supporting the  outcomes of group behavior, and (3) developing logical and reasonable arguments based on evidence. Examples of group behaviors could include flocking,  schooling, herding, and cooperative behaviors such as hunting, migrating, and swarming.] | | |
| The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education: | | |
| **Science and Engineering Practices**  **Developing and Using Models**  Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show how relationships among variables between systems and their components in the natural and designed worlds.  Develop a model based on evidence to illustrate the relationships between systems or components of a system. (HS-LS2-5)  **Using Mathematics and Computational Thinking**  Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.  Use mathematical and/or computational representations of phenomena or design solutions to support explanations. (HS-LS2-1)  Use mathematical representations of phenomena or design solutions to support and revise explanations.  (HS-LS2-2)  Use mathematical representations of phenomena or design solutions to support claims. (HS-LS2-4)  **Constructing Explanations and Designing Solutions**  Constructing explanations and designing solutions in  9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.  Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students’ own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-LS2-3)  Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-LS2-7)  **Engaging in Argument from Evidence**  Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.  Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (HS-LS2-6)  Evaluate the evidence behind currently accepted explanations to determine the merits of arguments.  (HS-LS2-8)  **-------------------------------------------------------**  **Connections to Nature of Science**  **Scientific Knowledge is Open to Revision in Light of New Evidence**  Most scientific knowledge is quite durable, but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence.  (HS-LS2-2),(HS-LS2-3)  Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation. (HS-LS2-6),(HS-LS2-8) | **Disciplinary Core Ideas**  **LS2.A: Interdependent Relationships in Ecosystems**  Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. (HS-LS2-1),(HS-LS2-2)  **LS2.B: Cycles of Matter and Energy Transfer in Ecosystems**  Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. (HS-LS2-3)  Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved. (HS-LS2-4)  Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes. (HS-LS2-5)  **LS2.C: Ecosystem Dynamics, Functioning, and Resilience**  A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. (HS-LS2-2),(HS-LS2-6)  Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species. (HS-LS2-7)  **LS2.D: Social Interactions and Group Behavior**  Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives. (HS-LS2-8)  **LS4.D: Biodiversity and Humans**  Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). (secondary to HS-LS2-7)  Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. (secondary to HS-LS2-7) (Note: This Disciplinary Core Idea is also addressed by HS-LS4-6.)  **PS3.D: Energy in Chemical Processes**  The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. (secondary to HS-LS2-5)  **ETS1.B: Developing Possible Solutions**  When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts. (secondary to HS-LS2-7) | **Crosscutting Concepts**  **Cause and Effect**  Empirical evidence is required to  differentiate between cause and correlation  and make claims about specific causes and  effects. (HS-LS2-8)  **Scale, Proportion, and Quantity**  The significance of a phenomenon is  dependent on the scale, proportion, and  quantity at which it occurs. (HS-LS2-1)  Using the concept of orders of magnitude  allows one to understand how a model at one  scale relates to a model at another scale.  (HS-LS2-2)  **Systems and System Models**  Models (e.g., physical, mathematical,  computer models) can be used to simulate  systems and interactions—including energy,  matter, and information flows—within and  between systems at different scales.  (HS-LS2-5)  **Energy and Matter**  Energy cannot be created or destroyed—it  only moves between one place and another  place, between objects and/or fields, or  between systems. (HS-LS2-4)  Energy drives the cycling of matter within  and between systems. (HS-LS2-3)  **Stability and Change**  Much of science deals with constructing  explanations of how things change and how  they remain stable. (HS-LS2-6),(HS-LS2-7) |

**HS-ETS1 Engineering Design**

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| **HS-ETS1 Engineering Design** | | |
| Students who demonstrate understanding can:  **HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints**  **for solutions that account for societal needs and wants.**  **HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more**  **manageable problems that can be solved through engineering.**  **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.**  **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.** | | |
| The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education: | | |
| **Science and Engineering Practices**  **Asking Questions and Defining Problems**  Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.  Analyze complex real-world problems by specifying criteria and constraints for successful solutions.  (HS-ETS1-1)  **Using Mathematics and Computational Thinking**  Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.  Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (HS-ETS1-4)  **Constructing Explanations and Designing Solutions**  Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles and theories.  Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-2)  Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-3) | **Disciplinary Core Ideas**  **ETS1.A: Defining and Delimiting Engineering Problems**  Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (HS-ETS1-1)  Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.  (HS-ETS1-1)  **ETS1.B: Developing Possible Solutions**  When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)  Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (HS-ETS1-4)  **ETS1.C: Optimizing the Design Solution**  Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (HS-ETS1-2) | **Crosscutting Concepts**  **Systems and System Models**  Models (e.g., physical, mathematical,  computer models) can be used to  simulate systems and interactions—  including energy, matter, and information  flows— within and between systems at  different scales. HS-ETS1-4)  **---------------------------------------------**  **Connections to Engineering,**  **Technology,**  **and Applications of Science**  **Influence of Science, Engineering,**  **and Technology on Society and the**  **Natural World**  New technologies can have deep  impacts on society and the environment,  including some that were not anticipated.  Analysis of costs and benefits is a critical  aspect of decisions about technology.  (HS-ETS1-1) (HS-ETS1-3) |