

High School Physical Sciences

Students in high school continue to develop their understanding of the four core ideas in the physical sciences. These ideas include the most fundamental concepts from chemistry and physics, but are intended to leave room for expanded study in upper-level high school courses. The high school performance expectations in Physical Science build on the middle school ideas and skills and allow high school students to explain more in-depth phenomena central not only to the physical sciences, but to life and earth and space sciences as well. These performance expectations blend the core ideas with scientific and engineering practices and crosscutting concepts to support students in developing useable knowledge to explain ideas across the science disciplines. In the physical science performance expectations at the high school level, there is a focus on several scientific practices. These include developing and using models, planning and conducting investigations, analyzing and interpreting data, using mathematical and computational thinking, and constructing explanations; and to use these practices to demonstrate understanding of the core ideas. Students are also expected to demonstrate understanding of several engineering practices including design and evaluation.

The performance expectations in **PS1: Matter and its interactions** help students formulate an answer to the question, "How can one explain the structure, properties, and interactions of matter?" The PS1 Disciplinary Core Idea from the *NRC Framework* is broken down into three sub-ideas: the structure and properties of matter, chemical reactions, and nuclear processes. Students are expected to develop understanding of the substructure of atoms and to provide more mechanistic explanations of the properties of substances. Chemical reactions, including rates of reactions and energy changes, can be understood by students at this level in terms of the collisions of molecules and the rearrangements of atoms. Students are able to use the periodic table as a tool to explain and predict the properties of elements. Using this expanded knowledge of chemical reactions, students are able to explain important biological and geophysical phenomena. Phenomena involving nuclei are also important to understand, as they explain the formation and abundance of the elements, radioactivity, the release of energy from the sun and other stars, and the generation of nuclear power. Students are also able to apply an understanding of the process of optimization in engineering design to chemical reaction systems. The crosscutting concepts of patterns, energy and matter, and stability and change are called out as organizing concepts for these disciplinary core ideas. In the PS1 performance expectations, students are expected to demonstrate proficiency in developing and using models, planning and conducting investigations, using mathematical thinking, and constructing explanations and designing solutions; and to use these practices to demonstrate understanding of the core ideas.

The Performance Expectations associated with **PS2: Motion and Stability: Forces and Interactions** support students' understanding of ideas related to why some objects will keep moving, why objects fall to the ground and why some materials are attracted to each other while others are not. Students should be able to answer the question, "How can one explain and predict interactions between objects and within systems of objects?" The disciplinary core idea expressed in the *Framework* for PS2 is broken down into the sub ideas of Forces and Motion and Types of Interactions. The performance expectations in PS2 focus on students building understanding of forces and interactions and Newton's Second Law. Students also develop understanding that the total momentum of a system of objects is conserved when there is no net force on the system. Students are able to use Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects. Students are able to apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a



macroscopic object during a collision. The crosscutting concepts of patterns, cause and effect, systems and system models, and structure and function are called out as organizing concepts for these disciplinary core ideas. In the PS2 performance expectations, students are expected to demonstrate proficiency in planning and conducting investigations, analyzing data and using math to support claims, applying scientific ideas to solve design problems, and communicating scientific and technical information; and to use these practices to demonstrate understanding of the core ideas.

The Performance Expectations associated with **PS3: Energy** help students formulate an answer to the question, "How is energy transferred and conserved?" The Core Idea expressed in the *Framework* for PS3 is broken down into four sub-core ideas: Definitions of Energy, Conservation of Energy and Energy Transfer, the Relationship between Energy and Forces, and Energy in Chemical Process and Everyday Life. Energy is understood as quantitative property of a system that depends on the motion and interactions of matter and radiation within that system, and the total change of energy in any system is always equal to the total energy transferred into or out of the system. Students develop an understanding that energy at both the macroscopic and the atomic scale can be accounted for as either motions of particles or energy associated with the configuration (relative positions) of particles. In some cases, the energy associated with the configuration of particles can be thought of as stored in fields. Students also demonstrate their understanding of engineering principles when they design, build, and refine devices associated with the conversion of energy. The crosscutting concepts of cause and effect; systems and system models; energy and matter; and the influence of science, engineering, and technology on society and the natural world are further developed in the performance expectations associated with PS3. In these performance expectations, students are expected to demonstrate proficiency in developing and using models, planning and carry out investigations, using computational thinking and designing solutions; and to use these practices to demonstrate understanding of the core ideas.

The Performance Expectations associated with **PS4: Waves and Their Applications in Technologies for Information Transfer** are critical to understand how many new technologies work. As such, this core idea helps students answer the question, "How are waves used to transfer energy and send and store information?" The disciplinary core idea in PS4 is broken down into Wave Properties, Electromagnetic Radiation, and Information Technologies and Instrumentation. Students are able to apply understanding of how wave properties and the interactions of electromagnetic radiation with matter can transfer information across long distances, store information, and investigate nature on many scales. Models of electromagnetic radiation as either a wave of changing electric and magnetic fields or as particles are developed and used. Students understand that combining waves of different frequencies can make a wide variety of patterns and thereby encode and transmit information. Students also demonstrate their understanding of engineering ideas by presenting information about how technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy. The crosscutting concepts of cause and effect; systems and system models; stability and change; interdependence of science, engineering, and technology; and the influence of engineering, technology, and science on society and the natural world are highlighted as organizing concepts for these disciplinary core ideas. In the PS3 performance expectations, students are expected to demonstrate proficiency in asking questions, using mathematical thinking, engaging in argument from evidence and obtaining, evaluating and communicating information; and to use these practices to demonstrate understanding of the core ideas.

HS-PS1 Matter and Its Interactions

HS-PS1 Matter and Its Interactions

Students who demonstrate understanding can:

- HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.** [Clarification Statement: Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen.] [Assessment Boundary: Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.]
- HS-PS1-2. Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.** [Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.] [Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.]
- HS-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.** [Clarification Statement: Emphasis is on understanding the strengths of forces between particles, not on naming specific intermolecular forces (such as dipole-dipole). Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite). Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.] [Assessment Boundary: Assessment does not include Raoult's law calculations of vapor pressure.]
- HS-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.** [Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.] [Assessment Boundary: Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.]
- HS-PS1-5. Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.** [Clarification Statement: Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules.] [Assessment Boundary: Assessment is limited to simple reactions in which there are only two reactants; evidence from temperature, concentration, and rate data; and qualitative relationships between rate and temperature.]
- HS-PS1-6. Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.*** [Clarification Statement: Emphasis is on the application of Le Chatelier's Principle and on refining designs of chemical reaction systems, including descriptions of the connection between changes made at the macroscopic level and what happens at the molecular level. Examples of designs could include different ways to increase product formation including adding reactants or removing products.] [Assessment Boundary: Assessment is limited to specifying the change in only one variable at a time. Assessment does not include calculating equilibrium constants and concentrations.]
- HS-PS1-7. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.** [Clarification Statement: Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem-solving techniques.] [Assessment Boundary: Assessment does not include complex chemical reactions.]
- HS-PS1-8. Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.** [Clarification Statement: Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations.] [Assessment Boundary: Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.]

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	Disciplinary Core Ideas	Crosscutting Concepts
<p>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.</p> <ul style="list-style-type: none"> Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS1-4), (HS-PS1-8) Use a model to predict the relationships between systems or between components of a system. (HS-PS1-1) <p>Planning and Carrying Out Investigations Planning and carrying out investigations 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.</p> <ul style="list-style-type: none"> 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-PS1-3) <p>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</p>	<p>PS1.A: Structure and Properties of Matter</p> <ul style="list-style-type: none"> Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. (HS-PS1-1) The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. (HS-PS1-1) The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (HS-PS1-3), (secondary to HS-PS2-6) A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. (HS-PS1-4) <p>PS1.B: Chemical Reactions</p> <ul style="list-style-type: none"> Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. (HS-PS1-4), (HS-PS1-5) In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. (HS-PS1-6) The fact that atoms are conserved, together with knowledge of the chemical properties of the elements 	<p>Patterns</p> <ul style="list-style-type: none"> 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-PS1-1), (HS-PS1-2), (HS-PS1-3), (HS-PS1-5) <p>Energy and Matter</p> <ul style="list-style-type: none"> In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HS-PS1-8) The total amount of energy and matter in closed systems is conserved. (HS-PS1-7) 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-PS1-4) <p>Stability and Change</p> <ul style="list-style-type: none"> Much of science deals with constructing explanations of how things change and how they remain stable. (HS-PS1-6) <p style="text-align: center;">-----</p> <p style="text-align: center;"><i>Connections to Nature of Science</i></p> <p>Scientific Knowledge Assumes an Order and Consistency in Natural Systems</p> <ul style="list-style-type: none"> Science assumes the universe is a vast single system in which basic laws are

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HS-PS1 Matter and Its Interactions

<p>mathematical models of basic assumptions.</p> <ul style="list-style-type: none"> Use mathematical representations of phenomena to support claims. (HS-PS1-7) <p>Constructing Explanations and Designing Solutions</p> <p>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.</p> <ul style="list-style-type: none"> Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. (HS-PS1-5) 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-PS1-2) Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-PS1-6) 	<p>involved, can be used to describe and predict chemical reactions. (HS-PS1-2),(HS-PS1-7)</p> <p>PS1.C: Nuclear Processes</p> <ul style="list-style-type: none"> Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process. (HS-PS1-8) <p>PS2.B: Types of Interactions</p> <ul style="list-style-type: none"> 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. (<i>secondary to HS-PS1-1</i>),(<i>secondary to HS-PS1-3</i>) <p>ETS1.C: Optimizing the Design Solution</p> <ul style="list-style-type: none"> 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. (<i>secondary to HS-PS1-6</i>) 	<p>consistent. (HS-PS1-7)</p>
<p><i>Connections to other DCIs in this grade-band:</i> HS.PS3.A (HS-PS1-4),(HS-PS1-5),(HS-PS1-8); HS.PS3.B (HS-PS1-4),(HS-PS1-6),(HS-PS1-7),(HS-PS1-8); HS.PS3.C (HS-PS1-8); HS.PS3.D (HS-PS1-4),(HS-PS1-8); HS.LS1.C (HS-PS1-1),(HS-PS1-2),(HS-PS1-4),(HS-PS1-7); HS.LS2.B (HS-PS1-7); HS.ESS1.A (HS-PS1-8); HS.ESS1.C (HS-PS1-8); HS.ESS2.C (HS-PS1-2),(HS-PS1-3)</p>		
<p><i>Articulation to DCIs across grade-bands:</i> MS.PS1.A (HS-PS1-1),(HS-PS1-2),(HS-PS1-3),(HS-PS1-4),(HS-PS1-5),(HS-PS1-7),(HS-PS1-8); MS.PS1.B (HS-PS1-1),(HS-PS1-2),(HS-PS1-4),(HS-PS1-5),(HS-PS1-6),(HS-PS1-7),(HS-PS1-8); MS.PS1.C (HS-PS1-8); MS.PS2.B (HS-PS1-3),(HS-PS1-4),(HS-PS1-5); MS.PS3.A (HS-PS1-5); MS.PS3.B (HS-PS1-5); MS.PS3.D (HS-PS1-4); MS.LS1.C (HS-PS1-4),(HS-PS1-7); MS.LS2.B (HS-PS1-7); MS.ESS2.A (HS-PS1-7),(HS-PS1-8)</p>		
<p><i>Common Core State Standards Connections:</i></p> <p><i>ELA/Literacy –</i></p> <p>RST.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. (<i>HS-PS1-7</i>)</p> <p>RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS1-3),(HS-PS1-5)</p> <p>WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS1-2),(HS-PS1-5)</p> <p>WHST.9-12.5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-PS1-2)</p> <p>WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS1-3),(HS-PS1-6)</p> <p>WHST.11-12.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS1-3)</p> <p>WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research. (<i>HS-PS1-3</i>)</p> <p>SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (<i>HS-PS1-4</i>)</p> <p><i>Mathematics –</i></p> <p>MP.2 Reason abstractly and quantitatively. (HS-PS1-5),(HS-PS1-7)</p> <p>MP.4 Model with mathematics. (<i>HS-PS1-4</i>),(<i>HS-PS1-8</i>)</p> <p>HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS1-2),(HS-PS1-3),(HS-PS1-4),(HS-PS1-5),(HS-PS1-7),(HS-PS1-8)</p> <p>HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-PS1-4),(HS-PS1-7),(HS-PS1-8)</p> <p>HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (<i>HS-PS1-2</i>),(<i>HS-PS1-3</i>),(<i>HS-PS1-4</i>),(<i>HS-PS1-5</i>),(<i>HS-PS1-7</i>),(<i>HS-PS1-8</i>)</p>		

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HS-PS2 Motion and Stability: Forces and Interactions

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 sliding 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	Disciplinary Core Ideas	Crosscutting Concepts
<p>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.</p> <ul style="list-style-type: none"> 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) <p>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.</p> <ul style="list-style-type: none"> 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) <p>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.</p> <ul style="list-style-type: none"> Use mathematical representations of phenomena to describe explanations. (HS-PS2-2), (HS-PS2-4) <p>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.</p> <ul style="list-style-type: none"> Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects. (HS-PS2-3) <p>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.</p> <ul style="list-style-type: none"> 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 	<p>PS1.A: Structure and Properties of Matter</p> <ul style="list-style-type: none"> The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (secondary to HS-PS2-6) <p>PS2.A: Forces and Motion</p> <ul style="list-style-type: none"> 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. (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) <p>PS2.B: Types of Interactions</p> <ul style="list-style-type: none"> 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) <p>PS3.A: Definitions of Energy</p> <ul style="list-style-type: none"> “Electrical energy” may mean energy stored in a battery or energy transmitted by electric currents. (secondary to HS-PS2-5) <p>ETS1.A: Defining and Delimiting Engineering Problems</p> <ul style="list-style-type: none"> 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) <p>ETS1.C: Optimizing the Design Solution</p> <ul style="list-style-type: none"> 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) 	<p>Patterns</p> <ul style="list-style-type: none"> 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) <p>Cause and Effect</p> <ul style="list-style-type: none"> 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) <p>Systems and System Models</p> <ul style="list-style-type: none"> When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (HS-PS2-2) <p>Structure and Function</p> <ul style="list-style-type: none"> 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)

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HS-PS2 Motion and Stability: Forces and Interactions

<p>(including orally, graphically, textually, and mathematically). (HS-PS2-6)</p> <p style="text-align: center;">-----</p> <p style="text-align: center;">Connections to Nature of Science</p> <p>Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena</p> <ul style="list-style-type: none"> ▪ Theories and laws provide explanations in science. (HS-PS2-1),(HS-PS2-4) ▪ Laws are statements or descriptions of the relationships among observable phenomena. (HS-PS2-1),(HS-PS2-4) 		
<p><i>Connections to other DCIs in this grade-band:</i> HS.PS3.A (HS-PS2-4),(HS-PS2-5); HS.PS3.C (HS-PS2-1); HS.PS4.B (HS-PS2-5); HS.ESS1.A (HS-PS2-1),(HS-PS2-2),(HS-PS2-4); HS.ESS1.B (HS-PS2-4); HS.ESS1.C (HS-PS2-1),(HS-PS2-2),(HS-PS2-4); HS.ESS2.A (HS-PS2-5); HS.ESS2.C (HS-PS2-1),(HS-PS2-4); HS.ESS3.A (HS-PS2-4),(HS-PS2-5)</p>		
<p><i>Articulation to DCIs across grade-bands:</i> MS.PS1.A (HS-PS2-6); MS.PS2.A (HS-PS2-1),(HS-PS2-2),(HS-PS2-3); MS.PS2.B (HS-PS2-4),(HS-PS2-5),(HS-PS2-6); MS.PS3.C (HS-PS2-1),(HS-PS2-2),(HS-PS2-3); MS.ESS1.B (HS-PS2-4),(HS-PS2-5)</p>		
<p><i>Common Core State Standards Connections:</i></p> <p><i>ELA/Literacy –</i></p> <p>RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. <i>(HS-PS2-1),(HS-PS2-6)</i></p> <p>RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-PS2-1)</p> <p>WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. <i>(HS-PS2-6)</i></p> <p>WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS2-3),(HS-PS2-5)</p> <p>WHST.11-12.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. <i>(HS-PS2-5)</i></p> <p>WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research. <i>(HS-PS2-1),(HS-PS2-5)</i></p> <p><i>Mathematics –</i></p> <p>MP.2 Reason abstractly and quantitatively. (HS-PS2-1),(HS-PS2-2),(HS-PS2-4)</p> <p>MP.4 Model with mathematics. (HS-PS2-1),(HS-PS2-2),(HS-PS2-4)</p> <p>HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS2-1),(HS-PS2-2),(HS-PS2-4), <i>(HS-PS2-5),(HS-PS2-6)</i></p> <p>HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. <i>(HS-PS2-1),(HS-PS2-2),(HS-PS2-4),(HS-PS2-5),(HS-PS2-6)</i></p> <p>HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS2-1),(HS-PS2-2),(HS-PS2-4), <i>(HS-PS2-5),(HS-PS2-6)</i></p> <p>HSA-SSE.A.1 Interpret expressions that represent a quantity in terms of its context. (HS-PS2-1),(HS-PS2-4)</p> <p>HSA-SSE.B.3 Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS2-1),(HS-PS2-4)</p> <p>HSA-CED.A.1 Create equations and inequalities in one variable and use them to solve problems. (HS-PS2-1),(HS-PS2-2)</p> <p>HSA-CED.A.2 Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. <i>(HS-PS2-1),(HS-PS2-2)</i></p> <p>HSA-CED.A.4 Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. <i>(HS-PS2-1),(HS-PS2-2)</i></p> <p>HSF-IF.C.7 Graph functions expressed symbolically and show key features of the graph, by in hand in simple cases and using technology for more complicated cases. <i>(HS-PS2-1)</i></p> <p>HSS-ID.A.1 Represent data with plots on the real number line (dot plots, histograms, and box plots). <i>(HS-PS2-1)</i></p>		

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HS-PS3 Energy

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 a combination of energy associated with the motion of particles (objects) and energy associated with the relative position of particles (objects). [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.] [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	Disciplinary Core Ideas	Crosscutting Concepts
<p>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.</p> <ul style="list-style-type: none"> 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) <p>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.</p> <ul style="list-style-type: none"> 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) <p>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.</p> <ul style="list-style-type: none"> Create a computational model or simulation of a phenomenon, designed device, process, or system. (HS-PS3-1) <p>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.</p> <ul style="list-style-type: none"> Design, evaluate, and/or refine a solution to a 	<p>PS3.A: Definitions of Energy</p> <ul style="list-style-type: none"> 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 a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as 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) <p>PS3.B: Conservation of Energy and Energy Transfer</p> <ul style="list-style-type: none"> 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) <p>PS3.C: Relationship Between Energy and Forces</p> <ul style="list-style-type: none"> When two objects interacting through a field change relative position, the energy stored in the field is changed. (HS-PS3-5) <p>PS3.D: Energy in Chemical Processes</p> <ul style="list-style-type: none"> Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the 	<p>Cause and Effect</p> <ul style="list-style-type: none"> 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) <p>Systems and System Models</p> <ul style="list-style-type: none"> 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) <p>Energy and Matter</p> <ul style="list-style-type: none"> 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) <p>-----</p> <p>Connections to Engineering, Technology, and Applications of Science</p> <p>Influence of Science, Engineering, and Technology on Society and the Natural World</p> <ul style="list-style-type: none"> Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HS-PS3-3) <p>-----</p> <p>Connections to Nature of Science</p> <p>Scientific Knowledge Assumes an Order and Consistency in Natural Systems</p>

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HS-PS3 Energy

<p>complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-PS3-3)</p>	<p>surrounding environment. (HS-PS3-3),(HS-PS3-4)</p> <p>ETS1.A: Defining and Delimiting Engineering Problems</p> <ul style="list-style-type: none"> ▪ 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. <i>(secondary to HS-PS3-3)</i> 	<ul style="list-style-type: none"> ▪ Science assumes the universe is a vast single system in which basic laws are consistent. (HS-PS3-1)
<p><i>Connections to other DCIs in this grade-band:</i> HS.PS1.A (HS-PS3-2); HS.PS1.B (HS-PS3-1),(HS-PS3-2); HS.PS2.B (HS-PS3-2),(HS-PS3-5); HS.LS2.B (HS-PS3-1); HS.ESS1.A (HS-PS3-1),(HS-PS3-4); HS.ESS2.A (HS-PS3-1),(HS-PS3-2),(HS-PS3-4); HS.ESS2.D (HS-PS3-4); HS.ESS3.A (HS-PS3-3)</p>		
<p><i>Articulation to DCIs across grade-bands:</i> MS.PS1.A (HS-PS3-2); MS.PS2.B (HS-PS3-2),(HS-PS3-5); MS.PS3.A (HS-PS3-1),(HS-PS3-2),(HS-PS3-3); MS.PS3.B (HS-PS3-1),(HS-PS3-3),(HS-PS3-4); MS.PS3.C (HS-PS3-2),(HS-PS3-5); MS.ESS2.A (HS-PS3-1),(HS-PS3-3)</p>		
<p><i>Common Core State Standards Connections:</i></p> <p><i>ELA/Literacy –</i></p> <p>RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. <i>(HS-PS3-4)</i></p> <p>WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. <i>(HS-PS3-3),(HS-PS3-4),(HS-PS3-5)</i></p> <p>WHST.11-12.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. <i>(HS-PS3-4),(HS-PS3-5)</i></p> <p>WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research. <i>(HS-PS3-4),(HS-PS3-5)</i></p> <p>SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. <i>(HS-PS3-1),(HS-PS3-2),(HS-PS3-5)</i></p> <p><i>Mathematics –</i></p> <p>MP.2 Reason abstractly and quantitatively. (HS-PS3-1),(HS-PS3-2),(HS-PS3-3),(HS-PS3-4),(HS-PS3-5)</p> <p>MP.4 Model with mathematics. (HS-PS3-1),(HS-PS3-2),(HS-PS3-3), <i>(HS-PS3-4)</i>,(HS-PS3-5)</p> <p>HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS3-1),(HS-PS3-3)</p> <p>HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-PS3-1),(HS-PS3-3)</p> <p>HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS3-1),(HS-PS3-3)</p>		

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

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 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 photons associated with 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)
- Photoelectric 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)

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

Connections to other DCIs in this grade-band: **HS.PS1.C** (HS-PS4-4); **HS.LS1.C** (HS-PS4-4); **HS.PS3.A** (HS-PS4-4),(HS-PS4-5); **HS.PS3.D** (HS-PS4-3),(HS-PS4-4); **HS.ESS1.A** (HS-PS4-3); **HS.ESS2.A** (HS-PS4-1); **HS.ESS2.D** (HS-PS4-3)

Articulation to DCIs across grade-bands: **MS.PS3.D** (HS-PS4-4); **MS.PS4.A** (HS-PS4-1),(HS-PS4-2),(HS-PS4-5); **MS.PS4.B** (HS-PS4-1),(HS-PS4-2),(HS-PS4-3),(HS-PS4-4),(HS-PS4-5); **MS.PS4.C** (HS-PS4-2),(HS-PS4-5); **MS.LS1.C** (HS-PS4-4); **MS.ESS2.D** (HS-PS4-4)

Common Core State Standards Connections:

ELA/Literacy –

- RST.9-10.8** Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4)
- RST.11-12.1** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. *(HS-PS4-2),(HS-PS4-3),(HS-PS4-4)*
- RST.11-12.7** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. *(HS-PS4-1),(HS-PS4-4)*
- RST.11-12.8** Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4)
- WHST.9-12.2** Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. *(HS-PS4-5)*
- WHST.11-12.8** Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS4-4)

Mathematics –

- MP.2** Reason abstractly and quantitatively. (HS-PS4-1),(HS-PS4-3)
- MP.4** Model with mathematics. (HS-PS4-1)
- HSA-SSE.A.1** Interpret expressions that represent a quantity in terms of its context. (HS-PS4-1), *(HS-PS4-3)*
- HSA-SSE.B.3** Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. *(HS-PS4-1),(HS-PS4-3)*
- HSA.CED.A.4** Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. *(HS-PS4-1),(HS-PS4-3)*

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High School Life Sciences

Students in high school develop understanding of key concepts that will help them make sense of life science. The ideas are built upon students' science understanding of disciplinary core ideas, science and engineering practices, and crosscutting concepts from earlier grades. There are four life science disciplinary core ideas in high school: 1) *From Molecules to Organisms: Structures and Processes*, 2) *Ecosystems: Interactions, Energy, and Dynamics*, 3) *Heredity: Inheritance and Variation of Traits*, 4) *Biological Evolution: Unity and Diversity*. The performance expectations for high school life science blend core ideas with scientific and engineering practices and crosscutting concepts to support students in developing useable knowledge that can be applied across the science disciplines. While the performance expectations in high school life science couple particular practices with specific disciplinary core ideas, instructional decisions should include use of many practices underlying the performance expectations.

The performance expectations in **LS1: *From Molecules to Organisms: Structures and Processes*** help students formulate an answer to the question, "How do organisms live and grow?" The LS1 Disciplinary Core Idea from the *NRC Framework* is presented as three sub-ideas: Structure and Function, Growth and Development of Organisms, and Organization for Matter and Energy Flow in Organisms. In these performance expectations, students demonstrate that they can use investigations and gather evidence to support explanations of cell function and reproduction. They understand the role of proteins as essential to the work of the cell and living systems. Students can use models to explain photosynthesis, respiration, and the cycling of matter and flow of energy in living organisms. The cellular processes can be used as a model for understanding of the hierarchical organization of organism. Crosscutting concepts of matter and energy, structure and function, and systems and system models provide students with insights to the structures and processes of organisms.

The performance expectations in **LS2: *Ecosystems: Interactions, Energy, and Dynamics*** help students formulate an answer to the question, "How and why do organisms interact with their environment, and what are the effects of these interactions?" The LS2 Disciplinary Core Idea includes four sub-ideas: Interdependent Relationships in Ecosystems, Cycles of Matter and Energy Transfer in Ecosystems, Ecosystem Dynamics, Functioning, and Resilience, and Social Interactions and Group Behavior. High school students can use mathematical reasoning to demonstrate understanding of fundamental concepts of carrying capacity, factors affecting biodiversity and populations, and the cycling of matter and flow of energy among organisms in an ecosystem. These mathematical models provide support of students' conceptual understanding of systems and their ability to develop design solutions for reducing the impact of human activities on the environment and maintaining biodiversity. Crosscutting concepts of systems and system models play a central role in students' understanding of science and engineering practices and core ideas of ecosystems.

The performance expectations in **LS3: *Heredity: Inheritance and Variation of Traits*** help students formulate answers to the questions: "How are characteristics of one generation passed to the next? How can individuals of the same species and even siblings have different characteristics?" The LS3 Disciplinary Core Idea from the *NRC Framework* includes two sub-ideas: Inheritance of Traits, and Variation of Traits. Students are able to ask questions, make and defend a claim, and use concepts of probability to explain the genetic variation in a



population. Students demonstrate understanding of why individuals of the same species vary in how they look, function, and behave. Students can explain the mechanisms of genetic inheritance and describe the environmental and genetic causes of gene mutation and the alteration of gene expression. Crosscutting concepts of patterns and cause and effect are called out as organizing concepts for these core ideas.

The performance expectations in **LS4: Biological Evolution: Unity and Diversity** help students formulate an answer to the question, “What evidence shows that different species are related? The LS4 Disciplinary Core Idea involves four sub-ideas: Evidence of Common Ancestry and Diversity, Natural Selection, Adaptation, and Biodiversity and Humans. Students can construct explanations for the processes of natural selection and evolution and communicate how multiple lines of evidence support these explanations. Students can evaluate evidence of the conditions that may result in new species and understand the role of genetic variation in natural selection. Additionally, students can apply concepts of probability to explain trends in populations as those trends relate to advantageous heritable traits in a specific environment. The crosscutting concepts of cause and effect and systems and system models play an important role in students’ understanding of the evolution of life on Earth.

HS-LS1 From Molecules to Organisms: Structures and Processes

HS-LS1 From Molecules to Organisms: Structures and Processes

Students who demonstrate understanding can:

- HS-LS1-1. Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.** [Assessment Boundary: Assessment does not include identification of specific cell or tissue types, whole body systems, specific protein structures and functions, or the biochemistry of protein synthesis.]
- HS-LS1-2. Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.** [Clarification Statement: Emphasis is on functions at the organism system level such as nutrient uptake, water delivery, and organism movement in response to neural stimuli. An example of an interacting system could be an artery depending on the proper function of elastic tissue and smooth muscle to regulate and deliver the proper amount of blood within the circulatory system.] [Assessment Boundary: Assessment does not include interactions and functions at the molecular or chemical reaction level.]
- HS-LS1-3. Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.** [Clarification Statement: Examples of investigations could include heart rate response to exercise, stomate response to moisture and temperature, and root development in response to water levels.] [Assessment Boundary: Assessment does not include the cellular processes involved in the feedback mechanism.]
- HS-LS1-4. Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.** [Assessment Boundary: Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.]
- HS-LS1-5. Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.** [Clarification Statement: Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models.] [Assessment Boundary: Assessment does not include specific biochemical steps.]
- HS-LS1-6. Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.** [Clarification Statement: Emphasis is on using evidence from models and simulations to support explanations.] [Assessment Boundary: Assessment does not include the details of the specific chemical reactions or identification of macromolecules.]
- HS-LS1-7. Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed, resulting in a net transfer of energy.** [Clarification Statement: Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.] [Assessment Boundary: Assessment should not include identification of the steps or specific processes involved in cellular respiration.]

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 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-LS1-2)
- Use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-LS1-4), (HS-LS1-5), (HS-LS1-7)

Planning and Carrying Out Investigations

Planning and carrying out 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-LS1-3)

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 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-LS1-1)
- 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-LS1-6)

Disciplinary Core Ideas

LS1.A: Structure and Function

- Systems of specialized cells within organisms help them perform the essential functions of life. (HS-LS1-1)
- All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells. (HS-LS1-1) (*Note: This Disciplinary Core Idea is also addressed by HS-LS3-1.*)
- Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. (HS-LS1-2)
- Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system. (HS-LS1-3)

LS1.B: Growth and Development of Organisms

- In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism. (HS-LS1-4)

LS1.C: Organization for Matter and Energy Flow in Organisms

- The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. (HS-LS1-5)
- The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. (HS-LS1-6)
- As matter and energy flow through different

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-LS1-2), (HS-LS1-4)

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-LS1-5), (HS-LS1-6)
- Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. (HS-LS1-7)

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-LS1-1)

Stability and Change

- Feedback (negative or positive) can stabilize or destabilize a system. (HS-LS1-3)

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HS-LS1 From Molecules to Organisms: Structures and Processes

<p style="text-align: center;"><i>Connections to Nature of Science</i></p> <p>Scientific Investigations Use a Variety of Methods</p> <ul style="list-style-type: none"> Scientific inquiry is characterized by a common set of values that include: logical thinking, precision, open-mindedness, objectivity, skepticism, replicability of results, and honest and ethical reporting of findings. (HS-LS1-3) 	<p>organizational levels of living systems, chemical elements are recombined in different ways to form different products. (HS-LS1-6),(HS-LS1-7)</p> <ul style="list-style-type: none"> As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment. (HS-LS1-7) 	
<p><i>Connections to other DCIs in this grade-band:</i> HS.PS1.B (HS-LS1-5),(HS-LS1-6),(HS-LS1-7); HS.PS2.B (HS-LS1-7); HS.LS3.A (HS-LS1-1); HS.PS3.B (HS-LS1-5),(HS-LS1-7)</p> <p><i>Articulation to DCIs across grade-bands:</i> MS.PS1.A (HS-LS1-6); MS.PS1.B (HS-LS1-5),(HS-LS1-6),(HS-LS1-7); MS.PS3.D (HS-LS1-5),(HS-LS1-6),(HS-LS1-7); MS.LS1.A (HS-LS1-1),(HS-LS1-2),(HS-LS1-3),(HS-LS1-4); MS.LS1.B (HS-LS1-4); MS.LS1.C (HS-LS1-5),(HS-LS1-6),(HS-LS1-7); MS.LS2.B (HS-LS1-5),(HS-LS1-7); MS.ESS2.E (HS-LS1-6); MS.LS3.A (HS-LS1-1),(HS-LS1-4); MS.LS3.B (HS-LS1-1)</p>		
<p><i>Common Core State Standards Connections:</i></p> <p><i>ELA/Literacy –</i></p> <p>RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-LS1-1),(HS-LS1-6)</p> <p>WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-LS1-1),(HS-LS1-6)</p> <p>WHST.9-12.5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-LS1-6)</p> <p>WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-LS1-3)</p> <p>WHST.11-12.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-LS1-3)</p> <p>WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research. (HS-LS1-1),(HS-LS1-6)</p> <p>SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-LS1-2),(HS-LS1-4),(HS-LS1-5),(HS-LS1-7)</p> <p><i>Mathematics –</i></p> <p>MP.4 Model with mathematics. (HS-LS1-4)</p> <p>HSF-IF.C.7 Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases. (HS-LS1-4)</p> <p>HSF-BF.A.1 Write a function that describes a relationship between two quantities. (HS-LS1-4)</p>		

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HS-LS2 Ecosystems: Interactions, Energy, and Dynamics

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 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 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

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)

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)

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HS-LS2 Ecosystems: Interactions, Energy, and Dynamics

<p>and will continue to do so in the future. (HS-LS2-3)</p> <ul style="list-style-type: none"> 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) <p>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.</p> <ul style="list-style-type: none"> 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) <hr style="border-top: 1px dashed black;"/> <p style="text-align: center;">Connections to Nature of Science</p> <p>Scientific Knowledge is Open to Revision in Light of New Evidence</p> <ul style="list-style-type: none"> 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) 	<ul style="list-style-type: none"> 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) <p>LS2.D: Social Interactions and Group Behavior</p> <ul style="list-style-type: none"> Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives. (HS-LS2-8) <p>LS4.D: Biodiversity and Humans</p> <ul style="list-style-type: none"> Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). (<i>secondary to HS-LS2-7</i>) 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. (<i>secondary to HS-LS2-7</i>) (<i>Note: This Disciplinary Core Idea is also addressed by HS-LS4-6.</i>) <p>PS3.D: Energy in Chemical Processes</p> <ul style="list-style-type: none"> The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. (<i>secondary to HS-LS2-5</i>) <p>ETS1.B: Developing Possible Solutions</p> <ul style="list-style-type: none"> 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. (<i>secondary to HS-LS2-7</i>) 	
<p><i>Connections to other DCIs in this grade-band:</i> HS.PS1.B (HS-LS2-3),(HS-LS2-5); HS.PS3.B (HS-LS2-3),(HS-LS2-4); HS.PS3.D (HS-LS2-3),(HS-LS2-4); HS.ESS2.A (HS-LS2-3); HS.ESS2.D (HS-LS2-5),(HS-LS2-7); HS.ESS2.E (HS-LS2-2),(HS-LS2-6),(HS-LS2-7); HS.ESS3.A (HS-LS2-2),(HS-LS2-7); HS.ESS3.C (HS-LS2-2),(HS-LS2-7); HS.ESS3.D (HS-LS2-2)</p> <p><i>Articulation across grade-bands:</i> MS.PS1.B (HS-LS2-3); MS.PS3.D (HS-LS2-3),(HS-LS2-4),(HS-LS2-5); MS.LS1.B (HS-LS2-8); MS.LS1.C (HS-LS2-3),(HS-LS2-4),(HS-LS2-5); MS.LS2.A (HS-LS2-1),(HS-LS2-2),(HS-LS2-6); MS.LS2.B (HS-LS2-3),(HS-LS2-4),(HS-LS2-5); MS.LS2.C (HS-LS2-1),(HS-LS2-2),(HS-LS2-6),(HS-LS2-7); MS.ESS2.A (HS-LS2-5); MS.ESS2.E (HS-LS2-6); MS.ESS3.A (HS-LS2-1); MS.ESS3.C (HS-LS2-1),(HS-LS2-2),(HS-LS2-6),(HS-LS2-7); MS.ESS3.D (HS-LS2-7)</p>		
<p><i>Common Core State Standards Connections:</i></p> <p><i>ELA/Literacy –</i></p> <p>RST.9-10.8 Assess the extent to which the reasoning and evidence in a text support the author’s claim or a recommendation for solving a scientific or technical problem. (HS-LS2-6),(HS-LS2-7),(HS-LS2-8)</p> <p>RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-LS2-1),(HS-LS2-2),(HS-LS2-3),(HS-LS2-6),(HS-LS2-8)</p> <p>RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-LS2-6),(HS-LS2-7),(HS-LS2-8)</p> <p>RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-LS2-6),(HS-LS2-7),(HS-LS2-8)</p> <p>WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-LS2-1),(HS-LS2-2),(HS-LS2-3)</p> <p>WHST.9-12.5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-LS2-3)</p> <p>WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-LS2-7)</p> <p><i>Mathematics –</i></p> <p>MP.2 Reason abstractly and quantitatively. (HS-LS2-1),(HS-LS2-2),(HS-LS2-4),(HS-LS2-6),(HS-LS2-7)</p> <p>MP.4 Model with mathematics. (HS-LS2-1),(HS-LS2-2),(HS-LS2-4)</p> <p>HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-LS2-1),(HS-LS2-2),(HS-LS2-4),(HS-LS2-7)</p> <p>HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-LS2-1),(HS-LS2-2),(HS-LS2-4),(HS-LS2-7)</p> <p>HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-LS2-1),(HS-LS2-2),(HS-LS2-4),(HS-LS2-7)</p> <p>HSS-ID.A.1 Represent data with plots on the real number line. (HS-LS2-6)</p> <p>HSS-IC.A.1 Understand statistics as a process for making inferences about population parameters based on a random sample from that population. (HS-LS2-6)</p> <p>HSS-IC.B.6 Evaluate reports based on data. (HS-LS2-6)</p>		

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HS-LS3 Heredity: Inheritance and Variation of Traits

HS-LS3 Heredity: Inheritance and Variation of Traits	
Students who demonstrate understanding can:	
<p>HS-LS3-1. Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. [Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.]</p> <p>HS-LS3-2. Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors. [Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs.] [Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.]</p> <p>HS-LS3-3. Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population. [Clarification Statement: Emphasis is on the use of mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits.] [Assessment Boundary: Assessment does not include Hardy-Weinberg calculations.]</p>	<p>The performance expectations above were developed using the following elements from the NRC document <i>A Framework for K-12 Science Education</i>:</p>
Science and Engineering Practices	Disciplinary Core Ideas
<p>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.</p> <ul style="list-style-type: none"> ▪ Ask questions that arise from examining models or a theory to clarify relationships. (HS-LS3-1) <p>Analyzing and Interpreting Data Analyzing data in 9-12 builds on K-8 experiences 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.</p> <ul style="list-style-type: none"> ▪ Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. (HS-LS3-3) <p>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.</p> <ul style="list-style-type: none"> ▪ Make and defend a claim based on evidence about the natural world that reflects scientific knowledge, and student-generated evidence. (HS-LS3-2) 	<p>LS1.A: Structure and Function</p> <ul style="list-style-type: none"> ▪ All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins. (<i>secondary to HS-LS3-1</i>) (Note: <i>This Disciplinary Core Idea is also addressed by HS-LS1-1.</i>) <p>LS3.A: Inheritance of Traits</p> <ul style="list-style-type: none"> ▪ Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function. (HS-LS3-1) <p>LS3.B: Variation of Traits</p> <ul style="list-style-type: none"> ▪ In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited. (HS-LS3-2) ▪ Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors. (HS-LS3-2),(HS-LS3-3)
<p style="text-align: center;">Crosscutting Concepts</p> <p>Cause and Effect</p> <ul style="list-style-type: none"> ▪ Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS3-1),(HS-LS3-2) <p>Scale, Proportion, and Quantity</p> <ul style="list-style-type: none"> ▪ Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). (HS-LS3-3) <p style="text-align: center;">-----</p> <p style="text-align: center;"><i>Connections to Nature of Science</i></p> <p>Science is a Human Endeavor</p> <ul style="list-style-type: none"> ▪ Technological advances have influenced the progress of science and science has influenced advances in technology. (HS-LS3-3) ▪ Science and engineering are influenced by society and society is influenced by science and engineering. (HS-LS3-3) 	
<p><i>Connections to other DCIs in this grade-band:</i> HS.LS2.A (HS-LS3-3); HS.LS2.C (HS-LS3-3); HS.LS4.B (HS-LS3-3); HS.LS4.C (HS-LS3-3)</p> <p><i>Articulation across grade-bands:</i> MS.LS2.A (HS-LS3-3); MS.LS3.A (HS-LS3-1),(HS-LS3-2); MS.LS3.B (HS-LS3-1),(HS-LS3-2),(HS-LS3-3); MS.LS4.C (HS-LS3-3)</p>	
<p><i>Common Core State Standards Connections:</i></p>	
<p><i>ELA/Literacy –</i></p> <p>RST.11-12.1</p> <p>RST.11-12.9</p> <p>WHST.9-12.1</p> <p><i>Mathematics –</i></p> <p>MP.2</p>	<p>Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (<i>HS-LS3-1</i>),(<i>HS-LS3-2</i>)</p> <p>Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (<i>HS-LS3-1</i>)</p> <p>Write arguments focused on <i>discipline-specific content</i>. (HS-LS3-2)</p> <p>Reason abstractly and quantitatively. (HS-LS3-2),(HS-LS3-3)</p>

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HS-LS4 Biological Evolution: Unity and Diversity

HS-LS4 Biological Evolution: Unity and Diversity
Students who demonstrate understanding can:
<p>HS-LS4-1. Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence. [Clarification Statement: Emphasis is on a conceptual understanding of the role each line of evidence has relating to common ancestry and biological evolution. Examples of evidence could include similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development.]</p>
<p>HS-LS4-2. Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment. [Clarification Statement: Emphasis is on using evidence to explain the influence each of the four factors has on number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning.] [Assessment Boundary: Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.]</p>
<p>HS-LS4-3. Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait. [Clarification Statement: Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.] [Assessment Boundary: Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.]</p>
<p>HS-LS4-4. Construct an explanation based on evidence for how natural selection leads to adaptation of populations. [Clarification Statement: Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.]</p>
<p>HS-LS4-5. Evaluate the evidence supporting claims that changes in environmental conditions may result in (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species. [Clarification Statement: Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species.]</p>
<p>HS-LS4-6. Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.* [Clarification Statement: Emphasis is on testing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.]</p>

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	Disciplinary Core Ideas	Crosscutting Concepts
<p>Analyzing and Interpreting Data Analyzing data in 9–12 builds on K–8 experiences 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.</p> <ul style="list-style-type: none"> ▪ Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. (HS-LS4-3) <p>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.</p> <ul style="list-style-type: none"> ▪ Create or revise a simulation of a phenomenon, designed device, process, or system. (HS-LS4-6) <p>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.</p> <ul style="list-style-type: none"> ▪ Construct 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-LS4-2),(HS-LS4-4) <p>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 or historical episodes in science.</p> <ul style="list-style-type: none"> ▪ Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments. (HS-LS4-5) <p>Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 9–12</p>	<p>LS4.A: Evidence of Common Ancestry and Diversity</p> <ul style="list-style-type: none"> ▪ Genetic information provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence. (HS-LS4-1) <p>LS4.B: Natural Selection</p> <ul style="list-style-type: none"> ▪ Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals. (HS-LS4-2),(HS-LS4-3) ▪ The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. (HS-LS4-3) <p>LS4.C: Adaptation</p> <ul style="list-style-type: none"> ▪ Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. (HS-LS4-2) ▪ Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. (HS-LS4-3),(HS-LS4-4) ▪ Adaptation also means that the distribution of traits in a population can change when conditions change. (HS-LS4-3) ▪ Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline—and sometimes the extinction—of some species. (HS-LS4-5),(HS-LS4-6) 	<p>Patterns</p> <ul style="list-style-type: none"> ▪ 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-LS4-1),(HS-LS4-3) <p>Cause and Effect</p> <ul style="list-style-type: none"> ▪ Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS4-2),(HS-LS4-4),(HS-LS4-5),(HS-LS4-6) <hr style="border-top: 1px dashed black;"/> <p style="text-align: center;"><i>Connections to Nature of Science</i></p> <p>Scientific Knowledge Assumes an Order and Consistency in Natural Systems</p> <ul style="list-style-type: none"> ▪ Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. (HS-LS4-1),(HS-LS4-4)

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HS-LS4 Biological Evolution: Unity and Diversity

<p>builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs.</p> <ul style="list-style-type: none"> ▪ Communicate scientific information (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-LS4-1) <p style="text-align: center;">----- <i>Connections to Nature of Science</i></p> <p>Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena</p> <ul style="list-style-type: none"> ▪ 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-LS4-1) 	<ul style="list-style-type: none"> ▪ Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost. (HS-LS4-5) <p>LS4.D: Biodiversity and Humans</p> <ul style="list-style-type: none"> ▪ 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. (HS-LS4-6) <i>(Note: This Disciplinary Core Idea is also addressed by HS-LS2-7.)</i> <p>ETS1.B: Developing Possible Solutions</p> <ul style="list-style-type: none"> ▪ 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. <i>(secondary to HS-LS4-6)</i> ▪ 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. <i>(secondary to HS-LS4-6)</i>
<p><i>Connections to other DCIs in this grade-band:</i> HS.LS2.A (HS-LS4-2), (HS-LS4-3), (HS-LS4-4), (HS-LS4-5); HS.LS2.D (HS-LS4-2), (HS-LS4-3), (HS-LS4-4), (HS-LS4-5); HS.LS3.A (HS-LS4-1); HS.LS3.B (HS-LS4-1), (HS-LS4-2) (HS-LS4-3), (HS-LS4-5); HS.ESS1.C (HS-LS4-1); HS.ESS2.D (HS-LS4-6); HS.ESS2.E (HS-LS4-2), (HS-LS4-5), (HS-LS4-6); HS.ESS3.A (HS-LS4-2), (HS-LS4-5), (HS-LS4-6); HS.ESS3.C (HS-LS4-6); HS.ESS3.D (HS-LS4-6)</p>	
<p><i>Articulation across grade-bands:</i> MS.LS2.A (HS-LS4-2), (HS-LS4-3), (HS-LS4-5); MS.LS2.C (HS-LS4-5), (HS-LS4-6); MS.LS3.A (HS-LS4-1); MS.LS3.B (HS-LS4-1), (HS-LS4-2), (HS-LS4-3); MS.LS4.A (HS-LS4-1); MS.LS4.B (HS-LS4-2), (HS-LS4-3), (HS-LS4-4); MS.LS4.C (HS-LS4-2), (HS-LS4-3), (HS-LS4-4), (HS-LS4-5); MS.ESS1.C (HS-LS4-1); MS.ESS3.C (HS-LS4-5), (HS-LS4-6)</p>	
<p><i>Common Core State Standards Connections:</i></p> <p><i>ELA/Literacy –</i></p> <p>RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. <i>(HS-LS4-1), (HS-LS4-2), (HS-LS4-3), (HS-LS4-4)</i></p> <p>RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-LS4-5)</p> <p>WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. <i>(HS-LS4-1), (HS-LS4-2), (HS-LS4-3), (HS-LS4-4)</i></p> <p>WHST.9-12.5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. <i>(HS-LS4-6)</i></p> <p>WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-LS4-6)</p> <p>WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research. <i>(HS-LS4-1), (HS-LS4-2), (HS-LS4-3), (HS-LS4-4), (HS-LS4-5)</i></p> <p>SL.11-12.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. <i>(HS-LS4-1), (HS-LS4-2)</i></p> <p><i>Mathematics –</i></p> <p>MP.2 Reason abstractly and quantitatively. <i>(HS-LS4-1), (HS-LS4-2), (HS-LS4-3), (HS-LS4-4), (HS-LS4-5)</i></p> <p>MP.4 Model with mathematics. <i>(HS-LS4-2)</i></p>	

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High School Earth and Space Sciences

Students in high school continue to develop their understanding of the three disciplinary core ideas in the Earth and Space Sciences. The high school performance expectations in Earth and Space Science build on the middle school ideas and skills and allow high school students to explain more in-depth phenomena central not only to the earth and space sciences, but to life and physical sciences as well. These performance expectations blend the core ideas with scientific and engineering practices and crosscutting concepts to support students in developing useable knowledge to explain ideas across the science disciplines. While the performance expectations shown in high school earth and space science couple particular practices with specific disciplinary core ideas, instructional decisions should include use of many practices that lead to the performance expectations.

The performance expectations in **ESS1: Earth's Place in the Universe**, help students formulate an answer to the question: "What is the universe, and what is Earth's place in it?" The ESS1 Disciplinary Core Idea from the *NRC Framework* is broken down into three sub-ideas: the universe and its stars, Earth and the solar system and the history of planet Earth. Students examine the processes governing the formation, evolution, and workings of the solar system and universe. Some concepts studied are fundamental to science, such as understanding how the matter of our world formed during the Big Bang and within the cores of stars. Others concepts are practical, such as understanding how short-term changes in the behavior of our sun directly affect humans. Engineering and technology play a large role here in obtaining and analyzing the data that support the theories of the formation of the solar system and universe. The crosscutting concepts of patterns, scale, proportion, and quantity, energy and matter, and stability and change are called out as organizing concepts for these disciplinary core ideas. In the ESS1 performance expectations, students are expected to demonstrate proficiency in developing and using models, using mathematical and computational thinking, constructing explanations and designing solutions, engaging in argument, and obtaining, evaluating and communicating information; and to use these practices to demonstrate understanding of the core ideas.

The performance expectations in **ESS2: Earth's Systems**, help students formulate an answer to the question: "How and why is Earth constantly changing?" The ESS2 Disciplinary Core Idea from the *NRC Framework* is broken down into five sub-ideas: Earth materials and systems, plate tectonics and large-scale system interactions, the roles of water in Earth's surface processes, weather and climate, and biogeology. For the purpose of the NGSS, biogeology has been addressed within the life science standards. Students develop models and explanations for the ways that feedbacks between different Earth systems control the appearance of Earth's surface. Central to this is the tension between internal systems, which are largely responsible for creating land at Earth's surface, and the sun-driven surface systems that tear down the land through weathering and erosion. Students begin to examine the ways that human activities cause feedbacks that create changes to other systems. Students understand the system interactions that control weather and climate, with a major emphasis on the mechanisms and implications of climate change. Students model the flow of energy between different components of the weather system and how this affects chemical cycles such as the carbon cycle. The crosscutting concepts of cause and effect, energy and matter, structure and function and stability and change are called out as organizing concepts for these disciplinary core ideas. In the ESS2 performance expectations, students are expected to demonstrate proficiency in



developing and using models, planning and carrying out investigations, analyzing and interpreting data, and engaging in argument; and to use these practices to demonstrate understanding of the core ideas.

The performance expectations in **ESS3: Earth and Human Activity** help students formulate an answer to the question: "How do Earth's surface processes and human activities affect each other?" The ESS3 Disciplinary Core Idea from the *NRC Framework* is broken down into four sub-ideas: natural resources, natural hazards, human impact on Earth systems, and global climate change. Students understand the complex and significant interdependencies between humans and the rest of Earth's systems through the impacts of natural hazards, our dependencies on natural resources, and the significant environmental impacts of human activities. Engineering and technology figure prominently here, as students use mathematical thinking and the analysis of geoscience data to examine and construct solutions to the many challenges facing long-term human sustainability on Earth. The crosscutting concepts of cause and effect, systems and system models, and stability and change are called out as organizing concepts for these disciplinary core ideas. In the ESS3 performance expectations, students are expected to demonstrate proficiency in developing and using analyzing and interpreting data, mathematical and computational thinking, constructing explanations and designing solutions and engaging in argument; and to use these practices to demonstrate understanding of the core ideas.

HS-ESS1 Earth's Place in the Universe

HS-ESS1 Earth's Place in the Universe

Students who demonstrate understanding can:

- HS-ESS1-1. Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation.** [Clarification Statement: Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun's core to reach Earth. Examples of evidence for the model include observations of the masses and lifetimes of other stars, as well as the ways that the sun's radiation varies due to sudden solar flares ("space weather"), the 11-year sunspot cycle, and non-cyclic variations over centuries.] [Assessment Boundary: Assessment does not include details of the atomic and sub-atomic processes involved with the sun's nuclear fusion.]
- HS-ESS1-2. Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.** [Clarification Statement: Emphasis is on the astronomical evidence of the red shift of light from galaxies as an indication that the universe is currently expanding, the cosmic microwave background as the remnant radiation from the Big Bang, and the observed composition of ordinary matter of the universe, primarily found in stars and interstellar gases (from the spectra of electromagnetic radiation from stars), which matches that predicted by the Big Bang theory (3/4 hydrogen and 1/4 helium).]
- HS-ESS1-3. Communicate scientific ideas about the way stars, over their life cycle, produce elements.** [Clarification Statement: Emphasis is on the way nucleosynthesis, and therefore the different elements created, varies as a function of the mass of a star and the stage of its lifetime.] [Assessment Boundary: Details of the many different nucleosynthesis pathways for stars of differing masses are not assessed.]
- HS-ESS1-4. Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.** [Clarification Statement: Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets and moons.] [Assessment Boundary: Mathematical representations for the gravitational attraction of bodies and Kepler's Laws of orbital motions should not deal with more than two bodies, nor involve calculus.]
- HS-ESS1-5. Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks.** [Clarification Statement: Emphasis is on the ability of plate tectonics to explain the ages of crustal rocks. Examples include evidence of the ages oceanic crust increasing with distance from mid-ocean ridges (a result of plate spreading) and the ages of North American continental crust decreasing with distance away from a central ancient core of the continental plate (a result of past plate interactions).]
- HS-ESS1-6. Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history.** [Clarification Statement: Emphasis is on using available evidence within the solar system to reconstruct the early history of Earth, which formed along with the rest of the solar system 4.6 billion years ago. Examples of evidence include the absolute ages of ancient materials (obtained by radiometric dating of meteorites, moon rocks, and Earth's oldest minerals), the sizes and compositions of solar system objects, and the impact cratering record of planetary surfaces.]

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	Disciplinary Core Ideas	Crosscutting Concepts
<p>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 relationships among variables between systems and their components in the natural and designed world(s).</p> <ul style="list-style-type: none"> Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-ESS1-1) <p>Using Mathematical 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.</p> <ul style="list-style-type: none"> Use mathematical or computational representations of phenomena to describe explanations. (HS-ESS1-4) <p>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.</p> <ul style="list-style-type: none"> Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, 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-ESS1-2) Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. (HS-ESS1-6) <p>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.</p> <ul style="list-style-type: none"> Evaluate evidence behind currently accepted explanations or solutions to determine the merits of arguments. (HS-ESS1-5) <p>Obtaining, Evaluating, and Communicating Information</p>	<p>ESS1.A: The Universe and Its Stars</p> <ul style="list-style-type: none"> The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. (HS-ESS1-1) The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. (HS-ESS1-2), (HS-ESS1-3) The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. (HS-ESS1-2) Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode. (HS-ESS1-2), (HS-ESS1-3) <p>ESS1.B: Earth and the Solar System</p> <ul style="list-style-type: none"> Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. (HS-ESS1-4) <p>ESS1.C: The History of Planet Earth</p> <ul style="list-style-type: none"> Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old. (HS-ESS1-5) Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history. (HS-ESS1-6) <p>ESS2.B: Plate Tectonics and Large-Scale System Interactions</p> <ul style="list-style-type: none"> Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its 	<p>Patterns</p> <ul style="list-style-type: none"> Empirical evidence is needed to identify patterns. (HS-ESS1-5) <p>Scale, Proportion, and Quantity</p> <ul style="list-style-type: none"> The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. (HS-ESS1-1) Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). (HS-ESS1-4) <p>Energy and Matter</p> <ul style="list-style-type: none"> Energy cannot be created or destroyed—only moved between one place and another place, between objects and/or fields, or between systems. (HS-ESS1-2) In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HS-ESS1-3) <p>Stability and Change</p> <ul style="list-style-type: none"> Much of science deals with constructing explanations of how things change and how they remain stable. (HS-ESS1-6) <hr/> <p style="text-align: center;"><i>Connections to Engineering, Technology, and Applications of Science</i></p> <hr/> <p>Interdependence of Science, Engineering, and Technology</p> <ul style="list-style-type: none"> Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (HS-ESS1-2), (HS-ESS1-4) <hr/> <p style="text-align: center;"><i>Connections to Nature of Science</i></p> <hr/> <p>Scientific Knowledge Assumes an Order and Consistency in Natural Systems</p>

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HS-ESS1 Earth's Place in the Universe

<p>Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs.</p> <ul style="list-style-type: none"> Communicate scientific 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-ESS1-3) <p style="text-align: center;">----- <i>Connections to Nature of Science</i></p> <p>Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena</p> <ul style="list-style-type: none"> 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-ESS1-2),(HS-ESS1-6) Models, mechanisms, and explanations collectively serve as tools in the development of a scientific theory. (HS-ESS1-6) 	<p>geologic history. (<i>ESS2.B Grade 8 GBE</i>) (<i>secondary to HS-ESS1-5</i>)</p> <p>PS1.C: Nuclear Processes</p> <ul style="list-style-type: none"> Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials. (<i>secondary to HS-ESS1-5</i>),(<i>secondary to HS-ESS1-6</i>) <p>PS3.D: Energy in Chemical Processes and Everyday Life</p> <ul style="list-style-type: none"> Nuclear Fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. (<i>secondary to HS-ESS1-1</i>) <p>PS4.B Electromagnetic Radiation</p> <ul style="list-style-type: none"> Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities. (<i>secondary to HS-ESS1-2</i>) 	<ul style="list-style-type: none"> Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. (HS-ESS1-2) Science assumes the universe is a vast single system in which basic laws are consistent. (HS-ESS1-2)
<p><i>Connections to other DCIs in this grade-band:</i> HS.PS1.A (HS-ESS1-2),(HS-ESS1-3); HS.PS1.C (HS-ESS1-1),(HS-ESS1-2),(HS-ESS1-3); HS.PS2.A (HS-ESS1-4),(HS-ESS1-6); HS.PS3.A (HS-ESS1-1),(HS-ESS1-2); HS.PS3.B (HS-ESS1-2),(HS-ESS1-5); HS.PS4.A (HS-ESS1-2); HS.ESS2.A (HS-ESS1-5)</p>		
<p><i>Articulation of DCIs across grade-bands:</i> MS.PS1.A (HS-ESS1-1),(HS-ESS1-2),(HS-ESS1-3); MS.PS2.A (HS-ESS1-4); MS.PS2.B (HS-ESS1-4),(HS-ESS1-6); MS.PS4.B (HS-ESS1-1),(HS-ESS1-2); MS.ESS1.A (HS-ESS1-1),(HS-ESS1-2),(HS-ESS1-3),(HS-ESS1-4); MS.ESS1.B (HS-ESS1-4),(HS-ESS1-6); MS.ESS1.C (HS-ESS1-5),(HS-ESS1-6); MS.ESS2.A (HS-ESS1-1),(HS-ESS1-5),(HS-ESS1-6); MS.ESS2.B (HS-ESS1-5),(HS-ESS1-6); MS.ESS2.D (HS-ESS1-1)</p>		
<p><i>Common Core State Standards Connections:</i></p> <p><i>ELA/Literacy –</i></p> <p>RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (<i>HS-ESS1-1</i>),(<i>HS-ESS1-2</i>),(<i>HS-ESS1-5</i>),(<i>HS-ESS1-6</i>)</p> <p>RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-ESS1-5),(HS-ESS1-6)</p> <p>WHST.9-12.1 Write arguments focused on <i>discipline-specific content</i>. (HS-ESS1-6)</p> <p>WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-ESS1-2),(<i>HS-ESS1-3</i>),(<i>HS-ESS1-5</i>)</p> <p>SL.11-12.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. (<i>HS-ESS1-3</i>)</p> <p><i>Mathematics –</i></p> <p>MP.2 Reason abstractly and quantitatively. (HS-ESS1-1),(HS-ESS1-2),(HS-ESS1-3),(HS-ESS1-4),(HS-ESS1-5),(HS-ESS1-6)</p> <p>MP.4 Model with mathematics. (HS-ESS1-1),(HS-ESS1-4)</p> <p>HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-ESS1-1),(HS-ESS1-2),(HS-ESS1-4),(HS-ESS1-5),(HS-ESS1-6)</p> <p>HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-ESS1-1),(<i>HS-ESS1-2</i>),(HS-ESS1-4),(<i>HS-ESS1-5</i>),(<i>HS-ESS1-6</i>)</p> <p>HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS1-1),(HS-ESS1-2),(HS-ESS1-4),(HS-ESS1-5),(HS-ESS1-6)</p> <p>HSA-SSE.A.1 Interpret expressions that represent a quantity in terms of its context. (<i>HS-ESS1-1</i>),(<i>HS-ESS1-2</i>),(HS-ESS1-4)</p> <p>HSA-CED.A.2 Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. (<i>HS-ESS1-1</i>),(<i>HS-ESS1-2</i>),(<i>HS-ESS1-4</i>)</p> <p>HSA-CED.A.4 Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (<i>HS-ESS1-1</i>),(<i>HS-ESS1-2</i>),(<i>HS-ESS1-4</i>)</p> <p>HSF-IF.B.5 Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes. (<i>HS-ESS1-6</i>)</p> <p>HSS-ID.B.6 Represent data on two quantitative variables on a scatter plot, and describe how those variables are related. (<i>HS-ESS1-6</i>)</p>		

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HS-ESS2 Earth's Systems

HS-ESS2 Earth's Systems	
Students who demonstrate understanding can:	
HS-ESS2-1.	Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features. [Clarification Statement: Emphasis is on how the appearance of land features (such as mountains, valleys, and plateaus) and sea-floor features (such as trenches, ridges, and seamounts) are a result of both constructive forces (such as volcanism, tectonic uplift, and orogeny) and destructive mechanisms (such as weathering, mass wasting, and coastal erosion).] [Assessment Boundary: Assessment does not include memorization of the details of the formation of specific geographic features of Earth's surface.]
HS-ESS2-2.	Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems. [Clarification Statement: Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.]
HS-ESS2-3.	Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection. [Clarification Statement: Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Examples of evidence include maps of Earth's three-dimensional structure obtained from seismic waves, records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth's layers from high-pressure laboratory experiments.]
HS-ESS2-4.	Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate. [Clarification Statement: Examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years: long-term changes in atmospheric composition.] [Assessment Boundary: Assessment of the results of changes in climate is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.]
HS-ESS2-5.	Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes. [Clarification Statement: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).]
HS-ESS2-6.	Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere. [Clarification Statement: Emphasis is on modeling biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere (including humans), providing the foundation for living organisms.]
HS-ESS2-7.	Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth. [Clarification Statement: Emphasis is on the dynamic causes, effects, and feedbacks between the biosphere and Earth's other systems, whereby geoscience factors control the evolution of life, which in turn continuously alters Earth's surface. Examples include how photosynthetic life altered the atmosphere through the production of oxygen, which in turn increased weathering rates and allowed for the evolution of animal life; how microbial life on land increased the formation of soil, which in turn allowed for the evolution of land plants; or how the evolution of corals created reefs that altered patterns of erosion and deposition along coastlines and provided habitats for the evolution of new life forms.] [Assessment Boundary: Assessment does not include a comprehensive understanding of the mechanisms of how the biosphere interacts with all of Earth's other systems.]

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	Disciplinary Core Ideas	Crosscutting Concepts
<p>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 relationships among variables between systems and their components in the natural and designed world(s).</p> <ul style="list-style-type: none"> Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-ESS2-1), (HS-ESS2-3), (HS-ESS2-6) Use a model to provide mechanistic accounts of phenomena. (HS-ESS2-4) <p>Planning and Carrying Out Investigations Planning and carrying out investigations 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.</p> <ul style="list-style-type: none"> 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-ESS2-5) <p>Analyzing and Interpreting Data Analyzing data in 9–12 builds on K–8 experiences 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.</p> <ul style="list-style-type: none"> 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-ESS2-2) 	<p>ESS1.B: Earth and the Solar System</p> <ul style="list-style-type: none"> Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes. (<i>secondary to HS-ESS2-4</i>) <p>ESS2.A: Earth Materials and Systems</p> <ul style="list-style-type: none"> Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. (HS-ESS2-1), (HS-ESS2-2) Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior. (HS-ESS2-3) The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles. (HS-ESS2-4) <p>ESS2.B: Plate Tectonics and Large-Scale System Interactions</p> <ul style="list-style-type: none"> The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle, providing the primary source of the heat that drives mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection. (HS-ESS2-3) 	<p>Cause and Effect</p> <ul style="list-style-type: none"> Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-ESS2-4) <p>Energy and Matter</p> <ul style="list-style-type: none"> The total amount of energy and matter in closed systems is conserved. (HS-ESS2-6) Energy drives the cycling of matter within and between systems. (HS-ESS2-3) <p>Structure and Function</p> <ul style="list-style-type: none"> The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. (HS-ESS2-5) <p>Stability and Change</p> <ul style="list-style-type: none"> Much of science deals with constructing explanations of how things change and how they remain stable. (HS-ESS2-7) Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. (HS-ESS2-1) Feedback (negative or positive) can stabilize or destabilize a system. (HS-ESS2-2) <p style="text-align: center;">-----</p> <p style="text-align: center;">Connections to Engineering, Technology, and Applications of Science</p>

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HS-ESS2 Earth's Systems

<p>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.</p> <ul style="list-style-type: none"> ▪ Construct an oral and written argument or counter-arguments based on data and evidence. (HS-ESS2-7) <p style="text-align: center;">-----</p> <p style="text-align: center;"><i>Connections to Nature of Science</i></p> <p>Scientific Knowledge is Based on Empirical Evidence</p> <ul style="list-style-type: none"> ▪ Science knowledge is based on empirical evidence. (HS-ESS2-3) ▪ Science disciplines share common rules of evidence used to evaluate explanations about natural systems. (HS-ESS2-3) ▪ Science includes the process of coordinating patterns of evidence with current theory. (HS-ESS2-3) ▪ Science arguments are strengthened by multiple lines of evidence supporting a single explanation. (HS-ESS2-4) 	<ul style="list-style-type: none"> ▪ Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust. (<i>ESS2.B Grade 8 GBE</i>) (HS-ESS2-1) <p>ESS2.C: The Roles of Water in Earth's Surface Processes</p> <ul style="list-style-type: none"> ▪ The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks. (HS-ESS2-5) <p>ESS2.D: Weather and Climate</p> <ul style="list-style-type: none"> ▪ The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. (HS-ESS2-2),(HS-ESS2-4) ▪ Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. (HS-ESS2-6),(HS-ESS2-7) ▪ Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (HS-ESS2-6),(HS-ESS2-4) <p>ESS2.E: Biogeology</p> <ul style="list-style-type: none"> ▪ The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it. (HS-ESS2-7) <p>PS4.A: Wave Properties</p> <ul style="list-style-type: none"> ▪ Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet. (<i>secondary to HS-ESS2-3</i>) 	<p>Interdependence of Science, Engineering, and Technology</p> <ul style="list-style-type: none"> ▪ Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (HS-ESS2-3) <p>Influence of Engineering, Technology, and Science on Society and the Natural World</p> <ul style="list-style-type: none"> ▪ 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-ESS2-2)
<p><i>Connections to other DCIs in this grade-band:</i> HS.PS1.A (HS-ESS2-5),(HS-ESS2-6); HS.PS1.B (HS-ESS2-5),(HS-ESS2-6); HS.PS2.B (HS-ESS2-1),(HS-ESS2-3); HS.PS3.A (HS-ESS2-4); HS.PS3.B (HS-ESS2-2),(HS-ESS2-3),(HS-ESS2-4),(HS-ESS2-5); HS.PS3.D (HS-ESS2-3),(HS-ESS2-6); HS.PS4.B (HS-ESS2-2); HS.LS1.C (HS-ESS2-6); HS.LS2.A (HS-ESS2-7); HS.LS2.B (HS-ESS2-2),(HS-ESS2-6); HS.LS2.C (HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-7); HS.LS4.A (HS-ESS2-7); HS.LS4.B (HS-ESS2-7); HS.LS4.C (HS-ESS2-7); HS.LS4.D (HS-ESS2-2),(HS-ESS2-7); HS.ESS1.C (HS-ESS2-4); HS.ESS3.C (HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-5),(HS-ESS2-6); HS.ESS3.D (HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-6)</p>		
<p><i>Articulation of DCIs across grade-bands:</i> MS.PS1.A (HS-ESS2-3),(HS-ESS2-5),(HS-ESS2-6); MS.PS1.B (HS-ESS2-3); MS.PS2.B (HS-ESS2-1),(HS-ESS2-3); MS.PS3.A (HS-ESS2-3),(HS-ESS2-4); MS.PS3.B (HS-ESS2-3),(HS-ESS2-4); MS.PS3.D (HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-6); MS.PS4.B (HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-5),(HS-ESS2-6); MS.LS1.C (HS-ESS2-4); MS.LS2.A (HS-ESS2-7); MS.LS2.B (HS-ESS2-1),(HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-6); MS.LS2.C (HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-7); MS.LS4.A (HS-ESS2-7); MS.LS4.B (HS-ESS2-7); MS.LS4.C (HS-ESS2-2),(HS-ESS2-7); MS.ESS1.C (HS-ESS2-1),(HS-ESS2-7); MS.ESS2.A (HS-ESS2-1),(HS-ESS2-2),(HS-ESS2-3),(HS-ESS2-4),(HS-ESS2-5),(HS-ESS2-6),(HS-ESS2-7); MS.ESS2.B (HS-ESS2-1),(HS-ESS2-2),(HS-ESS2-3),(HS-ESS2-4),(HS-ESS2-6); MS.ESS2.C (HS-ESS2-1),(HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-5),(HS-ESS2-6),(HS-ESS2-7); MS.ESS2.D (HS-ESS2-1),(HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-5); MS.ESS3.C (HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-6),(HS-ESS2-7); MS.ESS3.D (HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-6)</p>		
<p><i>Common Core State Standards Connections:</i></p> <p><i>ELA/Literacy –</i></p> <p>RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (<i>HS-ESS2-2</i>),(<i>HS-ESS2-3</i>)</p> <p>RST.11-12.2 Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. (<i>HS-ESS2-2</i>)</p> <p>WHST.9-12.1 Write arguments focused on <i>discipline-specific content</i>. (HS-ESS2-7)</p> <p>WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-ESS2-5)</p> <p>SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (<i>HS-ESS2-1</i>),(<i>HS-ESS2-3</i>),(<i>HS-ESS2-4</i>)</p> <p><i>Mathematics –</i></p> <p>MP.2 Reason abstractly and quantitatively. (HS-ESS2-1),(HS-ESS2-2),(HS-ESS2-3),(HS-ESS2-4),(HS-ESS2-6)</p> <p>MP.4 Model with mathematics. (HS-ESS2-1),(HS-ESS2-3),(HS-ESS2-4),(HS-ESS2-6)</p> <p>HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-ESS2-1),(HS-ESS2-2),(HS-ESS2-3),(HS-ESS2-4),(HS-ESS2-6)</p> <p>HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-ESS2-1),(HS-ESS2-3),(HS-ESS2-4),(HS-ESS2-6)</p> <p>HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS2-1),(HS-ESS2-2),(HS-ESS2-3),(HS-ESS2-4),(HS-ESS2-5),(HS-ESS2-6)</p>		

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HS-ESS3 Earth and Human Activity

HS-ESS3 Earth and Human Activity	
Students who demonstrate understanding can:	
HS-ESS3-1.	Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. [Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.]
HS-ESS3-2.	Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.* [Clarification Statement: Emphasis is on the conservation, recycling, and reuse of resources (such as minerals and metals) where possible, and on minimizing impacts where it is not. Examples include developing best practices for agricultural soil use, mining (for coal, tar sands, and oil shales), and pumping (for petroleum and natural gas). Science knowledge indicates what can happen in natural systems—not what should happen.]
HS-ESS3-3.	Create a computational simulation to illustrate the relationships among the management of natural resources, the sustainability of human populations, and biodiversity. [Clarification Statement: Examples of factors that affect the management of natural resources include costs of resource extraction and waste management, per-capita consumption, and the development of new technologies. Examples of factors that affect human sustainability include agricultural efficiency, levels of conservation, and urban planning.] [Assessment Boundary: Assessment for computational simulations is limited to using provided multi-parameter programs or constructing simplified spreadsheet calculations.]
HS-ESS3-4.	Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.* [Clarification Statement: Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).]
HS-ESS3-5.	Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth’s systems. [Clarification Statement: Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature) and their associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition).] [Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.]
HS-ESS3-6.	Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. [Clarification Statement: Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere. An example of the far-reaching impacts from a human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations.] [Assessment Boundary: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.]

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	Disciplinary Core Ideas	Crosscutting Concepts
<p>Analyzing and Interpreting Data Analyzing data in 9–12 builds on K–8 experiences 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.</p> <ul style="list-style-type: none"> Analyze data using computational models in order to make valid and reliable scientific claims. (HS-ESS3-5) <p>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.</p> <ul style="list-style-type: none"> Create a computational model or simulation of a phenomenon, designed device, process, or system. (HS-ESS3-3) Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations. (HS-ESS3-6) <p>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 knowledge, principles, and theories.</p> <ul style="list-style-type: none"> Construct 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-ESS3-1) Design 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-ESS3-4) <p>Engaging in Argument from Evidence Engaging in argument from evidence in 9–12 builds on K–8</p>	<p>ESS2.D: Weather and Climate</p> <ul style="list-style-type: none"> Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere. (<i>secondary to HS-ESS3-6</i>) <p>ESS3.A: Natural Resources</p> <ul style="list-style-type: none"> Resource availability has guided the development of human society. (HS-ESS3-1) All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors. (HS-ESS3-2) <p>ESS3.B: Natural Hazards</p> <ul style="list-style-type: none"> Natural hazards and other geologic events have shaped the course of human history; [they] have significantly altered the sizes of human populations and have driven human migrations. (HS-ESS3-1) <p>ESS3.C: Human Impacts on Earth Systems</p> <ul style="list-style-type: none"> The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. (HS-ESS3-3) Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (HS-ESS3-4) <p>ESS3.D: Global Climate Change</p> <ul style="list-style-type: none"> Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. (HS-ESS3-5) Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities. (HS-ESS3-6) <p>ETS1.B: Developing Possible Solutions</p> <ul style="list-style-type: none"> When evaluating solutions, it is important to take into 	<p>Cause and Effect</p> <ul style="list-style-type: none"> Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-ESS3-1) <p>Systems and System Models</p> <ul style="list-style-type: none"> 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-ESS3-6) <p>Stability and Change</p> <ul style="list-style-type: none"> Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. (HS-ESS3-3), (HS-ESS3-5) Feedback (negative or positive) can stabilize or destabilize a system. (HS-ESS3-4) <p>-----</p> <p>Connections to Engineering, Technology, and Applications of Science</p> <p>Influence of Engineering, Technology, and Science on Society and the Natural World</p> <ul style="list-style-type: none"> Modern civilization depends on major technological systems. (HS-ESS3-1), (HS-ESS3-3) Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HS-ESS3-2), (HS-ESS3-4) New technologies can have deep impacts

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HS-ESS3 Earth and Human Activity

<p>experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.</p> <ul style="list-style-type: none"> ▪ Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations). (HS-ESS3-2) <hr style="border-top: 1px dashed black;"/> <p style="text-align: center;">Connections to Nature of Science</p> <p>Scientific Investigations Use a Variety of Methods</p> <ul style="list-style-type: none"> ▪ Science investigations use diverse methods and do not always use the same set of procedures to obtain data. (HS-ESS3-5) ▪ New technologies advance scientific knowledge. (HS-ESS3-5) <p>Scientific Knowledge is Based on Empirical Evidence</p> <ul style="list-style-type: none"> ▪ Science knowledge is based on empirical evidence. (HS-ESS3-5) ▪ Science arguments are strengthened by multiple lines of evidence supporting a single explanation. (HS-ESS3-5) 	<p>account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (<i>secondary to HS-ESS3-2</i>), (<i>secondary HS-ESS3-4</i>)</p>	<p>on society and the environment, including some that were not anticipated. (HS-ESS3-3)</p> <ul style="list-style-type: none"> ▪ Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ESS3-2) <hr style="border-top: 1px dashed black;"/> <p style="text-align: center;">Connections to Nature of Science</p> <p>Science is a Human Endeavor</p> <ul style="list-style-type: none"> ▪ Science is a result of human endeavors, imagination, and creativity. (HS-ESS3-3) <p>Science Addresses Questions About the Natural and Material World</p> <ul style="list-style-type: none"> ▪ Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions. (HS-ESS3-2) ▪ Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. (HS-ESS3-2) ▪ Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues. (HS-ESS3-2)
<p><i>Connections to other DCIs in this grade-band:</i> HS.PS1.B (HS-ESS3-3); HS.PS3.B (HS-ESS3-2), (HS-ESS3-5); HS.PS3.D (HS-ESS3-2), (HS-ESS3-5); HS.LS1.C (HS-ESS3-5); HS.LS2.A (HS-ESS3-2), (HS-ESS3-3); HS.LS2.B (HS-ESS3-2), (HS-ESS3-3), (HS-ESS3-6); HS.LS2.C (HS-ESS3-3), (HS-ESS3-4), (HS-ESS3-6); HS.LS4.D (HS-ESS3-2), (HS-ESS3-3), (HS-ESS3-4), (HS-ESS3-6); HS.ESS2.A (HS-ESS3-2), (HS-ESS3-3), (HS-ESS3-6); HS.ESS2.D (HS-ESS3-5); HS.ESS2.E (HS-ESS3-3)</p>		
<p><i>Articulation of DCIs across grade-bands:</i> MS.PS1.B (HS-ESS3-3); MS.PS3.B (HS-ESS3-5); MS.PS3.D (HS-ESS3-2), (HS-ESS3-5); MS.LS2.A (HS-ESS3-1), (HS-ESS3-2), (HS-ESS3-3); MS.LS2.B (HS-ESS3-2), (HS-ESS3-3); MS.LS2.C (HS-ESS3-3), (HS-ESS3-4), (HS-ESS3-6); MS.LS4.C (HS-ESS3-3); MS.LS4.D (HS-ESS3-1), (HS-ESS3-2), (HS-ESS3-3); MS.ESS2.A (HS-ESS3-1), (HS-ESS3-3), (HS-ESS3-4), (HS-ESS3-5), (HS-ESS3-6); MS.ESS2.C (HS-ESS3-6); MS.ESS2.D (HS-ESS3-5); MS.ESS3.A (HS-ESS3-1), (HS-ESS3-2), (HS-ESS3-3); MS.ESS3.B (HS-ESS3-1), (HS-ESS3-4), (HS-ESS3-5); MS.ESS3.C (HS-ESS3-2), (HS-ESS3-3), (HS-ESS3-4), (HS-ESS3-5), (HS-ESS3-6); MS.ESS3.D (HS-ESS3-4), (HS-ESS3-5), (HS-ESS3-6)</p>		
<p><i>Common Core State Standards Connections:</i></p> <p>ELA/Literacy –</p> <p>RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (<i>HS-ESS3-1</i>), (HS-ESS3-2), (HS-ESS3-4), (HS-ESS3-5)</p> <p>RST.11-12.2 Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. (<i>HS-ESS3-5</i>)</p> <p>RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-ESS3-5)</p> <p>RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-ESS3-2), (HS-ESS3-4)</p> <p>WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-ESS3-1)</p> <p>Mathematics –</p> <p>MP.2 Reason abstractly and quantitatively. (<i>HS-ESS3-1</i>), (HS-ESS3-2), (HS-ESS3-3), (<i>HS-ESS3-4</i>), (HS-ESS3-5), (HS-ESS3-6)</p> <p>MP.4 Model with mathematics. (HS-ESS3-3), (HS-ESS3-6)</p> <p>HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (<i>HS-ESS3-1</i>), (HS-ESS3-4), (HS-ESS3-5), (HS-ESS3-6)</p> <p>HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (<i>HS-ESS3-1</i>), (<i>HS-ESS3-4</i>), (<i>HS-ESS3-5</i>), (HS-ESS3-6)</p> <p>HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (<i>HS-ESS3-1</i>), (<i>HS-ESS3-4</i>), (HS-ESS3-5), (HS-ESS3-6)</p>		

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High School Engineering Design

At the high school level students are expected to engage with major global issues at the interface of science, technology, society and the environment, and to bring to bear the kinds of analytical and strategic thinking that prior training and increased maturity make possible. As in prior levels, these capabilities can be thought of in three stages—defining the problem, developing possible solutions, and improving designs.

Defining the problem at the high school level requires both qualitative and quantitative analysis. For example, the need to provide food and fresh water for future generations comes into sharp focus when considering the speed at which world population is growing, and conditions in countries that have experienced famine. While high school students are not expected to solve these challenges, they are expected to begin thinking about them as problems that can be addressed, at least in part, through engineering.

Developing possible solutions for major global problems begins by breaking them down into smaller problems that can be tackled with engineering methods. To evaluate potential solutions students are expected to not only consider a wide range of criteria, but to also recognize that criteria need to be prioritized. For example, public safety or environmental protection may be more important than cost or even functionality. Decisions on priorities can then guide tradeoff choices.

Improving designs at the high school level may involve sophisticated methods, such as using computer simulations to model proposed solutions. Students are expected to use such methods to take into account a range of criteria and constraints, to try and anticipate possible societal and environmental impacts, and to test the validity of their simulations by comparison to the real world.

Connections with other science disciplines help high school students develop these capabilities in various contexts. For example, in the life sciences students are expected to design, evaluate, and refine a solution for reducing human impact on the environment (HS-LS2-7) and to create or revise a simulation to test solutions for mitigating adverse impacts of human activity on biodiversity (HS-LS4-6). In the physical sciences students solve problems by applying their engineering capabilities along with their knowledge of conditions for chemical reactions (HS-PS1-6), forces during collisions (HS-PS2-3), and conversion of energy from one form to another (HS-PS3-3). In the Earth and space sciences students apply their engineering capabilities to reduce human impacts on Earth systems, and improve social and environmental cost-benefit ratios (HS-ESS3-2, HS-ESS3-4).

By the end of 12th grade students are expected to achieve all four HS-ETS1 performance expectations (HS-ETS1-1, HS-ETS1-2, HS-ETS1-3, and HS-ETS1-4) related to a single problem in order to understand the interrelated processes of engineering design. These include analyzing major global challenges, quantifying criteria and constraints for solutions; breaking down a complex problem into smaller, more manageable problems, evaluating alternative solutions based on prioritized criteria and trade-offs, and using a computer simulation to model the impact of proposed solutions. While the performance expectations shown in High School Engineering Design couple particular practices with specific disciplinary core ideas, instructional decisions should include use of many practices that lead to the performance expectations.

HS-ETS1 Engineering Design

HS-ETS1 Engineering Design		
<p>Students who demonstrate understanding can:</p> <p>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.</p> <p>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.</p> <p>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.</p> <p>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.</p>		
<p>The performance expectations above were developed using the following elements from the NRC document <i>A Framework for K-12 Science Education</i>:</p>		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>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.</p> <ul style="list-style-type: none"> ▪ Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (HS-ETS1-1) <p>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.</p> <ul style="list-style-type: none"> ▪ 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) <p>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.</p> <ul style="list-style-type: none"> ▪ 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) 	<p>ETS1.A: Defining and Delimiting Engineering Problems</p> <ul style="list-style-type: none"> ▪ 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) <p>ETS1.B: Developing Possible Solutions</p> <ul style="list-style-type: none"> ▪ 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) <p>ETS1.C: Optimizing the Design Solution</p> <ul style="list-style-type: none"> ▪ 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) 	<p>Systems and System Models</p> <ul style="list-style-type: none"> ▪ 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) <p style="text-align: center;">-----</p> <p style="text-align: center;">Connections to Engineering, Technology, and Applications of Science</p> <p>Influence of Science, Engineering, and Technology on Society and the Natural World</p> <ul style="list-style-type: none"> ▪ 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)
<p><i>Connections to HS-ETS1.A: Defining and Delimiting Engineering Problems include:</i></p> <p>Physical Science: HS-PS2-3, HS-PS3-3</p> <p><i>Connections to HS-ETS1.B: Designing Solutions to Engineering Problems include:</i></p> <p>Earth and Space Science: HS-ESS3-2, HS-ESS3-4, Life Science: HS-LS2-7, HS-LS4-6</p> <p><i>Connections to HS-ETS1.C: Optimizing the Design Solution include:</i></p> <p>Physical Science: HS-PS1-6, HS-PS2-3</p>		
<p><i>Articulation of DCIs across grade-bands: MS.ETS1.A (HS-ETS1-1),(HS-ETS1-2),(HS-ETS1-3),(HS-ETS1-4); MS.ETS1.B (HS-ETS1-2),(HS-ETS1-3),(HS-ETS1-4); MS.ETS1.C (HS-ETS1-2),(HS-ETS1-4)</i></p>		
<p><i>Common Core State Standards Connections:</i></p> <p>ELA/Literacy –</p> <p>RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-ETS1-1),(HS-ETS1-3)</p> <p>RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-ETS1-1),(HS-ETS1-3)</p> <p>RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (HS-ETS1-1),(HS-ETS1-3)</p> <p>Mathematics –</p> <p>MP.2 Reason abstractly and quantitatively. (HS-ETS1-1),(HS-ETS1-3),(HS-ETS1-4)</p> <p>MP.4 Model with mathematics. (HS-ETS1-1),(HS-ETS1-2),(HS-ETS1-3),(HS-ETS1-4)</p>		