

DCI: Matter and Its Interactions

HS.PS1.A: Structure and Properties of Matter

The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (HS-PS2-6)

DCI: Motion and Stability: Forces and Interactions

HS.PS2.A: Forces and Motion

Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1)

DCI: Motion and Stability: Forces and Interactions

HS.PS2.A: Forces and Motion

Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. In any system, total momentum is always conserved. (HS-PS2-2)

DCI: Motion and Stability: Forces and Interactions

HS.PS2.A: Forces and Motion

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)

DCI: Motion and Stability: Forces and Interactions

HS.PS2.B: Types of Interactions

Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (HS-PS2-4)

DCI: Motion and Stability: Forces and Interactions

HS.PS2.B: Types of Interactions

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)

DCI: Motion and Stability: Forces and Interactions

HS.PS2.B: Types of Interactions

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)

DCI: Energy

HS.PS3.A: Definitions of Energy

“Electrical energy” may mean energy stored in a battery or energy transmitted by electric currents. (HS-PS2-5)

DCI: Engineering Design

HS.ETS1.A: Defining and Delimiting Engineering Problems

Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (HS-PS2-3)

DCI: Engineering Design

HS.ETS1.C: Optimizing the Design Solution

Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (HS-PS2-3)

DCI: Energy

HS.PS3.A: Definitions of Energy

Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (HS-PS3-1)

DCI: Energy

HS.PS3.B: Conservation of Energy and Energy Transfer

Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. (HS-PS3-1)

DCI: Energy

HS.PS3.B: Conservation of Energy and Energy Transfer

Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-1)

DCI: Energy

HS.PS3.B: Conservation of Energy and Energy Transfer

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)

DCI: Energy

HS.PS3.B: Conservation of Energy and Energy Transfer

The availability of energy limits what can occur in any system. (HS-PS3-1)

DCI: Energy

HS.PS3.A: Definitions of Energy

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DCI: Energy

HS.PS3.A: Definitions of Energy

At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HS-PS3-2)

DCI: Energy

HS.PS3.A: Definitions of Energy

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)

DCI: Energy

HS.PS3.A: Definitions of Energy

At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HS-PS3-3)

DCI: Energy

HS.PS3.D: Energy in Chemical Processes and Everyday Life

Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. (HS-PS3-3)

DCI: Engineering Design

HS.ETS1.A: Defining and Delimiting Engineering Problems

Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (HS-PS3-3)

DCI: Energy

HS.PS3.C: Relationship Between Energy and Forces

When two objects interacting through a field change relative position, the energy stored in the field is changed. (HS-PS3-5)

DCI: Energy

HS.PS3.D: Energy in Chemical Processes and Everyday Life

Nuclear Fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. (HS-ESS1-1)

DCI: Earth's Place in the Universe

HS.ESS1.A: The Universe and Its Stars

The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. (HS-ESS1-1)

DCI: Waves and Their Applications in Technologies for Information Transfer

HS.PS4.B: Electromagnetic Radiation

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. (HS-ESS1-2)

DCI: Earth's Place in the Universe

HS.ESS1.A: The Universe and Its Stars

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)

DCI: Earth's Place in the Universe

HS.ESS1.A: The Universe and Its Stars

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)

DCI: Earth's Place in the Universe

HS.ESS1.A: The Universe and Its Stars

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)

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DCI: Earth's Place in the Universe

HS.ESS1.B: Earth and the Solar System

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)

DCI: Matter and Its Interactions

HS.PS1.C: Nuclear Processes

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. (HS-ESS1-5)

DCI: Earth's Place in the Universe

HS.ESS1.C: The History of Planet Earth

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)

DCI: Earth's Systems

HS.ESS2.B: Plate Tectonics and Large-Scale System Interactions

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. (HS-ESS1-5)

DCI: Matter and Its Interactions

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DCI: Earth's Place in the Universe

HS.ESS1.C: The History of Planet Earth

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)

DCI: Earth's Systems

HS.ESS2.A: Earth Materials and Systems

Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. (HS-ESS2-1)

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DCI: Earth's Systems

HS.ESS2.D: Weather and Climate

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)

DCI: Earth's Systems

HS.ESS2.A: Earth Materials and Systems

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)

DCI: Earth's Systems

HS.ESS2.B: Plate Tectonics and Large-Scale System Interactions

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)

DCI: Earth's Place in the Universe

HS.ESS1.B: Earth and the Solar System

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. (HS-ESS2-4)

DCI: Earth's Systems

HS.ESS2.A: Earth Materials and Systems

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)

DCI: Earth's Systems

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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-ESS2-4)

DCI: Earth's Systems

HS.ESS2.D: Weather and Climate

Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (HS-ESS2-4)

DCI: Earth's Systems

HS.ESS2.C: The Roles of Water in Earth's Surface Processes

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)

DCI: Earth and Human Activity

HS.ESS3.A: Natural Resources

Resource availability has guided the development of human society. (HS-ESS3-1)

DCI: Earth and Human Activity

HS.ESS3.B: Natural Hazards

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) (HS-ESS3-1)

DCI: Earth and Human Activity

HS.ESS3.A: Natural Resources

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)

DCI: Engineering Design

HS.ETS1.B: Developing Possible Solutions

When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts. (HS-ESS3-2)

Performance Expectation

HS-PS2-1: Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.

Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.

Performance Expectation

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.

Performance Expectation

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.

** This performance expectation integrates traditional science content with engineering through a practice or disciplinary code idea.*

Performance Expectation

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.

Performance Expectation

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.

Clarification Statement: none

Assessment Boundary: Assessment is limited to designing and conducting investigations with provided materials and tools.

Performance Expectation

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.

** This performance expectation integrates traditional science content with engineering through a practice or disciplinary code idea.*

Performance Expectation

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.

Performance Expectation

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 motions of particles (objects) and energy associated with the relative positions 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.

Assessment Boundary: none

Performance Expectation

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.

** This performance expectation integrates traditional science content with engineering through a practice or disciplinary code idea.*

Performance Expectation

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.

Performance Expectation

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 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.

Performance Expectation

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).

Assessment Boundary: none

Performance Expectation

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.

Performance Expectation

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.

Performance Expectation

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 of oceanic crust increasing with distance from mid-ocean ridges (a result of plate spreading) and the ages of North American continental crust increasing with distance away from a central ancient core (a result of past plate interactions).

Assessment Boundary: none

Performance Expectation

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.

Assessment Boundary: none

Performance Expectation

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.

Performance Expectation

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.

Assessment Boundary: none

Performance Expectation

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.

Assessment Boundary: none

Performance Expectation

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.

Performance Expectation

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).

Assessment Boundary: none

Performance Expectation

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.

Assessment Boundary: none

Performance Expectation

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.

Assessment Boundary: none

** This performance expectation integrates traditional science content with engineering through a practice or disciplinary code idea.*

Science and Engineering Practices

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.

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)

Science and Engineering Practices

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.

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)

Science and Engineering Practices

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 representations of phenomena to describe explanations. (HS-PS2-2), (HS-PS2-4)

Science and Engineering Practices

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects. (HS-PS2-3)

Science and Engineering Practices

Obtaining, Evaluating, and Communicating Information

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.

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 (including orally, graphically, textually, and mathematically). (HS-PS2-6)

Science and Engineering Practices

Using Mathematics and Computational Thinking

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Create a computational model or simulation of a phenomenon, designed device, process, or system. (HS-PS3-1)

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 world(s).

Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.

(HS-PS3-2)

Science and Engineering Practices

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-PS3-3)

Science and Engineering Practices

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(HS-PS3-5)

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(HS-ESS1-1)

Science and Engineering Practices

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-ESS1-2)

Science and Engineering Practices

Obtaining, Evaluating, and Communicating Information

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.

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)

Science and Engineering Practices

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 or computational representations of phenomena to describe explanations. (HS-ESS1-4)

Science and Engineering Practices

Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.

Evaluate evidence behind currently accepted explanations or solutions to determine the merits of arguments. (HS-ESS1-5)

Science and Engineering Practices

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

Apply scientific 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)

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 world(s).

Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-ESS2-1)

Science and Engineering Practices

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.

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)

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 world(s).

Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-ESS2-3)

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 world(s).

Use a model to provide mechanistic accounts of phenomena. (HS-ESS2-4)

Science and Engineering Practices

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.

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)

Science and Engineering Practices

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-ESS3-1)

Science and Engineering Practices

Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.

Evaluate 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)

Crosscutting Concepts

Patterns

Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-PS2-4)

Crosscutting Concepts

Cause and Effect

Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS2-1), (HS-PS2-5)

Crosscutting Concepts

Cause and Effect

Systems can be designed to cause a desired effect. (HS-PS2-3)

Crosscutting Concepts

Systems and System Models

When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (HS-PS2-2)

Crosscutting Concepts

Structure and Function

Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. (HS-PS2-6)

Crosscutting Concepts

Systems and System Models

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)

Crosscutting Concepts

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-PS3-2)

Crosscutting Concepts

Energy and Matter

Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS-PS3-3)

Crosscutting Concepts

Cause and Effect

Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. (HS-PS3-5)

Crosscutting Concepts

Scale, Proportion, and Quantity

The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. (HS-ESS1-1)

Crosscutting Concepts

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-ESS1-2)

Crosscutting Concepts

Energy and Matter

In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HS-ESS1-3)

Crosscutting Concepts

Scale, Proportion, and Quantity

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)

Crosscutting Concepts

Patterns

Empirical evidence is needed to identify patterns. (HS-ESS1-5)

Crosscutting Concepts

Stability and Change

Much of science deals with constructing explanations of how things change and how they remain stable. (HS-ESS1-6)

Crosscutting Concepts

Stability and Change

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)

Crosscutting Concepts

Stability and Change

Feedback (negative or positive) can stabilize or destabilize a system. (HS-ESS2-2)

Crosscutting Concepts

Energy and Matter

Energy drives the cycling of matter within and between systems. (HS-ESS2-3)

Crosscutting Concepts

Cause and Effect

Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-ESS2-4)

Crosscutting Concepts

Structure and Function

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)

Crosscutting Concepts

Cause and Effect

Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-ESS3-1)

Connections to Nature of Science

Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

Theories and laws provide explanations in science, but theories do not with time become laws or facts. (HS-PS2-1), (HS-PS2-4)

Connections to Nature of Science

Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

Laws are statements or descriptions of the relationships among observable phenomena. (HS-PS2-1), (HS-PS2-4)

Connections to Engineering, Technology, and Applications 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-ESS1-2)

Connections to Engineering, Technology, and Applications of Science

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Connections to Engineering, Technology, and Applications of Science

Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

Models, mechanisms, and explanations collectively serve as tools in the development of a scientific theory. (HS-ESS1-6)

Connections to Engineering, Technology, and Applications of Science

Science Knowledge Is Based on Empirical Evidence

Science knowledge is based on empirical evidence. (HS-ESS2-3)

Connections to Engineering, Technology, and Applications of Science

Science Knowledge Is Based on Empirical Evidence

Science disciplines share common rules of evidence used to evaluate explanations about natural systems. (HS-ESS2-3)

Connections to Engineering, Technology, and Applications of Science

Science Knowledge Is Based on Empirical Evidence

Science includes the process of coordinating patterns of evidence with current theory. (HS-ESS2-3)

Connections to Engineering, Technology, and Applications of Science

Science Knowledge Is Based on Empirical Evidence

Science arguments are strengthened by multiple lines of evidence supporting a single explanation. (HS-ESS2-4)

Connections to Engineering, Technology, and Applications of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

Science assumes the universe is a vast single system in which basic laws are consistent. (HS-PS3-1)

Connections to Engineering, Technology, and Applications of Science

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Connections to Engineering, Technology, and Applications of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

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)

Connections to Engineering, Technology, and Applications of Science

Science Addresses Questions About the Natural and Material World

Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions. (HS-ESS3-2)

Connections to Engineering, Technology, and Applications of Science

Science Addresses Questions About the Natural and Material World

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)

Connections to Engineering, Technology, and Applications of Science

Science Addresses Questions About the Natural and Material World

Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues. (HS-ESS3-2)

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology on Society and the Natural World

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)

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). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (HS-ESS1-2)

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Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology on Society and the Natural World

New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ESS2-2)

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Common Core State Standards for ELA/Literacy

Reading in Science

RST.11-12.1 - Key Ideas and Details

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-PS2-1), (HS-PS2-6)

Common Core State Standards for ELA/Literacy

Reading in Science

RST.11-12.7 - Integration of Knowledge and Ideas

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)

Common Core State Standards for ELA/Literacy

Writing in Science

WHST.11-12.7 - Research to Build and Present Knowledge

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-PS2-2), (HS-PS2-5)

Common Core State Standards for ELA/Literacy

Writing in Science

WHST.11-12.8 - Research to Build and Present Knowledge

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-PS2-5)

Common Core State Standards for ELA/Literacy

Writing in Science

WHST.11-12.9 - Research to Build and Present Knowledge

Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS2-1), (HS-PS2-5)

Common Core State Standards for ELA/Literacy

Writing in Science

WHST.9-12.2 - Text Types and Purposes

Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS2-6)

Common Core State Standards for Mathematics

Creating Equations

HSA-CED.A.1 - Create equations that describe numbers or relationships.

Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational and exponential functions. (HS-PS2-1), (HS-PS2-2)

Common Core State Standards for Mathematics

Creating Equations

HSA-CED.A.2 - Create equations that describe numbers or relationships.

Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. (HS-PS2-1), (HS-PS2-2)

Common Core State Standards for Mathematics

Creating Equations

HSA-CED.A.4 - Create equations that describe numbers or relationships.

Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-PS2-1), (HS-PS2-2)

Common Core State Standards for Mathematics

Seeing Structure in Expressions

HSA-SSE.A.1 - Interpret the structure of expressions.

Interpret expressions that represent a quantity in terms of its context. (HS-PS2-1), (HS-PS2-4)

Common Core State Standards for Mathematics

Seeing Structure in Expressions

HSA-SSE.B.3 - Write expressions in equivalent forms to solve problems.

Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. ^{...}

Common Core State Standards for Mathematics

Interpreting Functions

HSF-IF.C.7 - Analyze functions using different representations.

Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases. (HS-PS2-1)

Common Core State Standards for Mathematics

Number and Quantity » Quantities

HSN-Q.A.1 - Reason quantitatively and use units to solve problems.

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), (HS-PS2-5), (HS-PS2-6)

Common Core State Standards for Mathematics

Number and Quantity » Quantities

HSN-Q.A.2 - Reason quantitatively and use units to solve problems.

Define appropriate quantities for the purpose of descriptive modeling.

(HS-PS2-1), (HS-PS2-2), (HS-PS2-4), (HS-PS2-5), (HS-PS2-6)

Common Core State Standards for Mathematics

Number and Quantity » Quantities

HSN-Q.A.3 - Reason quantitatively and use units to solve problems.

Choose a level of accuracy appropriate to limitations on measurement

when reporting quantities. (HS-PS2-1), (HS-PS2-2), (HS-PS2-4), (HS-PS2-5), (HS-PS2-6)

Common Core State Standards for Mathematics

Statistics & Probability » Interpreting Categorical & Quantitative Data

HSS-ID.A.1 - Summarize, represent, and interpret data on a single count or measurement variable

Represent data with plots on the real number line (dot plots, histograms, and box plots). (HS-PS2-1)

Common Core State Standards for Mathematics

Mathematical Practices

MP.2 - Reason abstractly and quantitatively

Mathematically proficient students make sense of quantities and their relationships in problem situations. They bring two complementary abilities to bear on problems involving quantitative relationships: the ability to decontextualize—to abstract a given situation and represent it symbolically and manipulate the representing symbols as if they have a life of their own, without necessarily attending to their referents—and the ability to contextualize, to pause as needed during the manipulation process in order to probe into the referents for the symbols involved. Quantitative reasoning entails habits of creating a coherent representation of the problem at hand; considering the units involved; attending to the meaning of quantities, not just how to compute them; and knowing and flexibly using different properties of operations and objects. (HS-PS2-1), (HS-PS2-2), (HS-PS2-4)

Common Core State Standards for Mathematics

Mathematical Practices

MP.4 - Model with mathematics

Mathematically proficient students can apply the mathematics they know to solve problems arising in everyday life, society, and the workplace. A student might use geometry to solve a design problem or use a function to describe how one quantity of interest depends on another. Mathematically proficient students who can apply what they know are comfortable making assumptions and approximations to simplify a complicated situation, realizing that these may need revision later. They are able to identify important quantities in a practical situation and map their relationships using such tools as diagrams, two-way tables, graphs, flowcharts and formulas. They can analyze those relationships mathematically to draw conclusions. They routinely interpret their mathematical results in the context of the situation and reflect on whether the results make sense, possibly improving the model if it has not served its purpose. (HS-PS2-1), (HS-PS2-2), (HS-PS2-4)