|  |  |
| --- | --- |
| **PS2.A: Forces and Motion** PS2.A.1 - Pushes and pulls can have different strengths and directions. (K-PS2-1),(K-PS2-2)  | **PS2.A: Forces and Motion** PS2A.2 - Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. (K-PS2-1),(K-PS2-2) |
| **PS2.B: Types of Interactions** PS2.B.1 - When objects touch or collide, they push on one another and can change motion. (K-PS2-1) | **PS3.B: Conservation of Energy and Energy Transfer**PS3.B.1 - Sunlight warms Earth’s surface. (K-PS3-1),(K-PS3-2) |
| **PS3.C: Relationship Between Energy and Forces** PS3.C.1 - A bigger push or pull makes things speed up or slow down more quickly. (secondary to K-PS2-1) | **LS1.C: Organization for Matter and Energy Flow in Organisms**LS1.C.1 - All animals need food in order to live and grow. They obtain their food from plants or from other animals. Plants need water and light to live and grow. (K-LS1-1) |
| **ESS2.D: Weather and Climate**ESS2.D.1 - Weather is the combination of sunlight, wind, snow or rain, and temperature in a particular region at a particular time. People measure these conditions to describe and record the weather and to notice patterns over time. (K-ESS2-1) | **ESS2.E: Biogeology**ESS2.E.1 - Plants and animals can change their environment. (K-ESS2-2)  |
| **ESS3.A: Natural Resources**ESS3.A.1 - Living things need water, air, and resources from the land, and they live in places that have the things they need. Humans use natural resources for everything they do. (K-ESS3-1) | **ESS3.B: Natural Hazards**ESS3.B.1 - Some kinds of severe weather are more likely than others in a given region. Weather scientists forecast severe weather so that the communities can prepare for and respond to these events. (K-ESS3-2) |
| **ESS3.C: Human Impacts on Earth Systems**ESS3.C.1 - Things that people do to live comfortably can affect the world around them. But they can make choices that reduce their impacts on the land, water, air, and other living things. (secondary to K-ESS2-2) | **ETS1.A: Defining & Delimiting an Engineering Problems**ETS1.A.1 - A situation that people want to change or create can be approached as a problem to be solved through engineering. Such problems may have many acceptable solutions. (secondary to K-PS2-2) |
| **ETS1.A: Defining & Delimiting an Engineering Problems**ETS1.A.2 - Asking questions, making observations, and gathering information are helpful in thinking about problems. (secondary to K-ESS3-2) | **ETS1.B: Developing Possible Solutions**ETS1.B.1 - Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem’s solutions to other people. (secondary to K-ESS3-3) |
|  |  |
| **PS4.A: Wave Properties** PS4.A.1 - Sound can make matter vibrate, and vibrating matter can make sound. (1-PS4-1) | **PS4.B: Electromagnetic Radiation** PS4.B.1 - Objects can be seen if light is available to illuminate them or if they give off their own light. (1-PS4-2)  |
| **PS4.B: Electromagnetic Radiation** PS4.B.2 - Some materials allow light to pass through them, others allow only some light through and others block all the light and create a dark shadow on any surface beyond them, where the light cannot reach. Mirrors can be used to redirect a light beam. (Boundary: The idea that light travels from place to place is developed through experiences with light sources, mirrors, and shadows, but no attempt is made to discuss the speed of light.) (1-PS4-3) | **PS4.C: Information Technologies and Instrumentation** PS4.C.1 - People also use a variety of devices to communicate (send and receive information) over long distances. (1-PS4-4)  |
| **LS1.A: Structure and Function** LS1.A.1 - All organisms have external parts. Different animals use their body parts in different ways to see, hear, grasp objects, protect themselves, move from place to place, and seek, find, and take in food, water and air. Plants also have different parts (roots, stems, leaves, flowers, fruits) that help them survive and grow. (1-LS1-1) | **LS1.B: Growth and Development of Organisms** LS1.B.1 - Adult plants and animals can have young. In many kinds of animals, parents and the offspring themselves engage in behaviors that help the offspring to survive. (1-LS1-2)  |
| **LS1.D: Information Processing** LS1.D.1 - Animals have body parts that capture and convey different kinds of information needed for growth and survival. Animals respond to these inputs with behaviors that help them survive. Plants also respond to some external inputs. (1-LS1-1)  | **LS3.A: Inheritance of Traits** LS3.A.1 - Young animals are very much, but not exactly like, their parents. Plants also are very much, but not exactly, like their parents. (1-LS3-1)  |
| **LS3.B: Variation of Traits** LS3.B.1 - Individuals of the same kind of plant or animal are recognizable as similar but can also vary in many ways. (1-LS3-1)  | **ESS1.A: The Universe and its Stars** ESS1.A.1 - Patterns of the motion of the sun, moon, and stars in the sky can be observed, described, and predicted. (1-ESS1-1)  |
| **ESS1.B: Earth and the Solar System** ESS1.B.1 - Seasonal patterns of sunrise and sunset can be observed, described, and predicted. (1-ESS1-2)  |  |
|  |  |
|  |  |
| **PS1.A: Structure and Properties of Matter** PS1.A.1 - Different kinds of matter exist and many of them can be either solid or liquid, depending on temperature. Matter can be described and classified by its observable properties. (2-PS1-1)  | **PS1.A: Structure and Properties of Matter** PS1.A.2 - Different properties are suited to different purposes. (2-PS1-2),(2-PS1-3)  |
| **PS1.A: Structure and Properties of Matter** PS1.A.3 - A great variety of objects can be built up from a small set of pieces. (2-PS1-3) | **PS1.B: Chemical Reactions** PS1.B.1 - Heating or cooling a substance may cause changes that can be observed. Sometimes these changes are reversible, and sometimes they are not. (2-PS1-4)  |
| **LS2.A: Interdependent Relationships in Ecosystems** LS2.A.1 - Plants depend on water and light to grow. (2-LS2-1)  | **LS2.A: Interdependent Relationships in Ecosystems** LS2.A.2 - Plants depend on animals for pollination or to move their seeds around. (2-LS2-2)  |
| LS4.D: Biodiversity and Humans LS4.D.1 - There are many different kinds of living things in any area, and they exist in different places on land and in water. (2-LS4-1)  | **ESS1.C: The History of Planet Earth** ESS1.C.1 - Some events happen very quickly; others occur very slowly, over a time period much longer than one can observe. (2-ESS1-1)  |
| **ESS2.A: Earth Materials and Systems** ESS2.A.1 - Wind and water can change the shape of the land. (2-ESS2-1)  | **ESS2.B: Plate Tectonics and Large-Scale System Interactions** ESS.2.B - Maps show where things are located. One can map the shapes and kinds of land and water in any area. (2-ESS2-2)  |
| **ESS2.C: The Roles of Water in Earth’s Surface Processes** ESS2.C.1 - Water is found in the ocean, rivers, lakes, and ponds. Water exists as solid ice and in liquid form. (2-ESS2-3)  | **ETS1.B: Developing Possible Solutions** ETS1.B.1 Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem’s solutions to other people. (secondary to 2-LS2-2)  |
| **ETS1.C: Optimizing the Design Solution** ETS1.C.1 - Because there is always more than one possible solution to a problem, it is useful to compare and test designs. (secondary to 2-ESS2-1) |  |
|  |  |
| **PS2.A: Forces and Motion** PS2.A.1 - Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object’s speed or direction of motion. (Boundary: Qualitative and conceptual, but not quantitative addition of forces are used at this level.) (3-PS2-1)  | **PS2.A: Forces and Motion** PS2.A.2 - The patterns of an object’s motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it. (Boundary: Technical terms, such as magnitude, velocity, momentum, and vector quantity, are not introduced at this level, but the concept that some quantities need both size and direction to be described is developed.) (3-PS2-2)  |
| **PS2.B: Types of Interactions** PS2.B.1 - Objects in contact exert forces on each other. (3-PS2-1)  | **PS2.B: Types of Interactions** PS2.B.2 - Electric, and magnetic forces between a pair of objects do not require that the objects be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other. (3-PS2-3),(3-PS2-4) |
| **LS1.B: Growth and Development of Organisms** LS1.B.1 - Reproduction is essential to the continued existence of every kind of organism. Plants and animals have unique and diverse life cycles. (3-LS1-1)  | **LS2.C: Ecosystem Dynamics, Functioning, and Resilience** LS2.C.1 - When the environment changes in ways that affect a place’s physical characteristics, temperature, or availability of resources, some organisms survive and reproduce, others move to new locations, yet others move into the transformed environment, and some die. (secondary to 3-LS4-4)  |
| **LS2.D: Social Interactions and Group Behavior** LS2.D.1 - Being part of a group helps animals obtain food, defend themselves, and cope with changes. Groups may serve different functions and vary dramatically in size (Note: Moved from K–2). (3-LS2-1)  | **LS3.A: Inheritance of Traits** LS3.A.1 - Many characteristics of organisms are inherited from their parents. (3-LS3-1)  |
| **LS3.A: Inheritance of Traits** LS3.A.2 - Other characteristics result from individuals’ interactions with the environment, which can range from diet to learning. Many characteristics involve both inheritance and environment. (3-LS3-2)  | **LS3.B: Variation of Traits** LS3.B.1 - Different organisms vary in how they look and function because they have different inherited information. (3-LS3-1)  |
| **LS3.B: Variation of Traits** LS3.B.2 - The environment also affects the traits that an organism develops. (3-LS3-2)  | **LS4.A: Evidence of Common Ancestry and Diversity** LS4.A.1- Some kinds of plants and animals that once lived on Earth are no longer found anywhere. (Note: moved from K-2) (3-LS4-1)  |
| **LS4.A: Evidence of Common Ancestry and Diversity** LS4.A.2 - Fossils provide evidence about the types of organisms that lived long ago and also about the nature of their environments. (3-LS4-1)  | **LS4.B: Natural Selection** LS4.B.1 - Sometimes the differences in characteristics between individuals of the same species provide advantages in surviving, finding mates, and reproducing. (3-LS4-2)  |
| **LS4.C: Adaptation** LS4.C.1 - For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all. (3-LS4-3)  | **LS4.D: Biodiversity and Humans** LS4.D.1 - Populations live in a variety of habitats, and change in those habitats affects the organisms living there. (3-LS4-4)  |
| **ESS2.D: Weather and Climate** ESS2.D.1 - Scientists record patterns of the weather across different times and areas so that they can make predictions about what kind of weather might happen next. (3-ESS2-1)  | **ESS2.D: Weather and Climate** ESS2.D.2 - Climate describes a range of an area's typical weather conditions and the extent to which those conditions vary over years. (3-ESS2-2)  |
| **ESS3.B: Natural Hazards** ESS3.B.1 - A variety of natural hazards result from natural processes. Humans cannot eliminate natural hazards but can take steps to reduce their impacts. (3-ESS3-1) (Note: This Disciplinary Core Idea is also addressed by 4-ESS3-2.)  |  |
|  |  |
|  |  |
| **PS3.A: Definitions of Energy** PS3.A.1 - The faster a given object is moving, the more energy it possesses. (4-PS3-1)  | **PS3.A: Definitions of Energy** PS3.A.2 - Energy can be moved from place to place by moving objects or through sound, light, or electric currents. (4-PS3-2),(4-PS3-3)  |
| **PS3.B: Conservation of Energy and Energy Transfer** PS3.B.1 - Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced. (4-PS3-2),(4-PS3-3)  | **PS3.B: Conservation of Energy and Energy Transfer** PS3.B.2 - Light also transfers energy from place to place. (4-PS3-2)  |
| **PS3.B: Conservation of Energy and Energy Transfer** PS3.B.3 - Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy. (4-PS3-2),(4-PS3-4) | **PS3.C: Relationship Between Energy and Forces** PS3.C.1 - When objects collide, the contact forces transfer energy so as to change the objects’ motions. (4-PS3-3)  |
| **PS3.D: Energy in Chemical Processes and Everyday Life** PS3.D.1 - The expression “produce energy” typically refers to the conversion of stored energy into a desired form for practical use. (4-PS3-4)  | **PS4.A: Wave Properties** PS4.A.1 - Waves, which are regular patterns of motion, can be made in water by disturbing the surface. When waves move across the surface of deep water, the water goes up and down in place; there is no net motion in the direction of the wave except when the water meets a beach. (Note: This grade band endpoint was moved from K–2.) (4-PS4-1)  |
| **PS4.A: Wave Properties** PS4.A.2 - Waves of the same type can differ in amplitude (height of the wave) and wavelength (spacing between wave peaks). (4-PS4-1)  | **PS4.B: Electromagnetic Radiation** PS4.B.1 - An object can be seen when light reflected from its surface enters the eyes. (4-PS4-2)  |
| **PS4.C: Information Technologies and Instrumentation** PS4.C.1 - Digitized information can be transmitted over long distances without significant degradation. High-tech devices, such as computers or cell phones, can receive and decode information—convert it from digitized form to voice—and vice versa. (4-PS4-3)  | **LS1.A: Structure and Function** LS1.A.1 - Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction. (4-LS1-1)  |
| **LS1.D: Information Processing** LS1D.1 - Different sense receptors are specialized for particular kinds of information, which may be then processed by the animal’s brain. Animals are able to use their perceptions and memories to guide their actions. (4-LS1-2)  | **ESS1.C: The History of Planet Earth** ESS1.C.1 - Local, regional, and global patterns of rock formations reveal changes over time due to earth forces, such as earthquakes. The presence and location of certain fossil types indicate the order in which rock layers were formed. (4-ESS1-1)  |
| **ESS2.A: Earth Materials and Systems** ESS2.A.1 - Rainfall helps to shape the land and affects the types of living things found in a region. Water, ice, wind, living organisms, and gravity break rocks, soils, and sediments into smaller particles and move them around. (4-ESS2-1) | **ESS2.B: Plate Tectonics and Large-Scale System Interactions** ESS2.B.1 - The locations of mountain ranges, deep ocean trenches, ocean floor structures, earthquakes, and volcanoes occur in patterns. Most earthquakes and volcanoes occur in bands that are often along the boundaries between continents and oceans. Major mountain chains form inside continents or near their edges. Maps can help locate the different land and water features areas of Earth. (4-ESS2-2)  |
| **ESS2.E: Biogeology** ESS2.E.1 - Living things affect the physical characteristics of their regions. (4-ESS2-1)  | **ESS3.A: Natural Resources** ESS3.A.1 - Energy and fuels that humans use are derived from natural sources, and their use affects the environment in multiple ways. Some resources are renewable over time, and others are not. (4-ESS3-1)  |
| **ESS3.B: Natural Hazards** ESS3.B.1 - A variety of hazards result from natural processes (e.g., earthquakes, tsunamis, volcanic eruptions). Humans cannot eliminate the hazards but can take steps to reduce their impacts. (4-ESS3-2) (Note: This Disciplinary Core Idea can also be found in 3.WC.)  | **ETS1.A: Defining Engineering Problems** ETS1.A.1 - Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. (secondary to 4-PS3-4) |
| **ETS1.B: Designing Solutions to Engineering Problems** ETS1.B.1 - Testing a solution involves investigating how well it performs under a range of likely conditions. (secondary to 4-ESS3-2)  | **ETS1.C: Optimizing The Design Solution** ETS1.C.1 - Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. (secondary to 4-PS4-3)  |
|  |  |
| **PS1.A: Structure and Properties of Matter** PS1.A.1 - Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means. A model showing that gases are made from matter particles that are too small to see and are moving freely around in space can explain many observations, including the inflation and shape of a balloon and the effects of air on larger particles or objects. (5-PS1-1) | **PS1.A: Structure and Properties of Matter** PS1.A.2 - The amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish. (5-PS1-2)  |
| **PS1.A: Structure and Properties of Matter** PS1.A.3 - Measurements of a variety of properties can be used to identify materials. (Boundary: At this grade level, mass and weight are not distinguished, and no attempt is made to define the unseen particles or explain the atomic-scale mechanism of evaporation and condensation.) (5-PS1-3) | **PS1.B: Chemical Reactions** PS1.B.1 - When two or more different substances are mixed, a new substance with different properties may be formed. (5-PS1-4)  |
| **PS1.B: Chemical Reactions** PS1.B.2 - No matter what reaction or change in properties occurs, the total weight of the substances does not change. (Boundary: Mass and weight are not distinguished at this grade level.) (5-PS1-2)  | **PS2.B: Types of Interactions** PS2.B.1 - The gravitational force of Earth acting on an object near Earth’s surface pulls that object toward the planet’s center. (5-PS2-1)  |
| **PS3.D: Energy in Chemical Processes and Everyday Life** PS3.D.1 - The energy released [from] food was once energy from the sun that was captured by plants in the chemical process that forms plant matter (from air and water). (5-PS3-1)  | **LS1.C: Organization for Matter and Energy Flow in Organisms** LS1.C.1 - Food provides animals with the materials they need for body repair and growth and the energy they need to maintain body warmth and for motion. (secondary to 5-PS3-1)  |
| **LS1.C: Organization for Matter and Energy Flow in Organisms** LS1.C.2 - Plants acquire their material for growth chiefly from air and water. (5-LS1-1)  | **LS2.A: Interdependent Relationships in Ecosystems** LS2.A.1 - The food of almost any kind of animal can be traced back to plants. Organisms are related in food webs in which some animals eat plants for food and other animals eat the animals that eat plants. Some organisms, such as fungi and bacteria, break down dead organisms (both plants or plants parts and animals) and therefore operate as “decomposers.” Decomposition eventually restores (recycles) some materials back to the soil. Organisms can survive only in environments in which their particular needs are met. A healthy ecosystem is one in which multiple species of different types are each able to meet their needs in a relatively stable web of life. Newly introduced species can damage the balance of an ecosystem. (5-LS2-1)  |
| **LS2.B: Cycles of Matter and Energy Transfer in Ecosystems** LS2.B.1 - Matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. Organisms obtain gases, and water, from the environment, and release waste matter (gas, liquid, or solid) back into the environment. (5-LS2-1)  | **ESS1.A: The Universe and its Stars** ESS1.A.1 - The sun is a star that appears larger and brighter than other stars because it is closer. Stars range greatly in their distance from Earth. (5-ESS1-1)  |
| **ESS1.B: Earth and the Solar System** ESS1.B.1 - The orbits of Earth around the sun and of the moon around Earth, together with the rotation of Earth about an axis between its North and South poles, cause observable patterns. These include day and night; daily changes in the length and direction of shadows; and different positions of the sun, moon, and stars at different times of the day, month, and year. (5-ESS1-2)  | **ESS2.A: Earth Materials and Systems** ESS2.A.1 - Earth’s major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth’s surface materials and processes. The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather. (5-ESS2-1) |
| **ESS2.C: The Roles of Water in Earth’s Surface Processes** ESS2.C.1 - Nearly all of Earth’s available water is in the ocean. Most fresh water is in glaciers or underground; only a tiny fraction is in streams, lakes, wetlands, and the atmosphere. (5-ESS2-2)  | **ESS3.C: Human Impacts on Earth Systems** ESS3.C.1 - Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth’s resources and environments. (5-ESS3-1)  |

|  |  |
| --- | --- |
| **ETS1.A: Defining and Delimiting Engineering Problems** A situation that people want to change or create can be approached as a problem to be solved through engineering. (K-2-ETS1-1)  | **ETS1.A: Defining and Delimiting Engineering Problems** Asking questions, making observations, and gathering information are helpful in thinking about problems. (K-2-ETS1-1)  |
| **ETS1.A: Defining and Delimiting Engineering Problems** Before beginning to design a solution, it is important to clearly understand the problem. (K-2-ETS1-1)  | **ETS1.B: Developing Possible Solutions** Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem’s solutions to other people. (K-2-ETS1-2)  |
| **ETS1.C: Optimizing the Design Solution** Because there is always more than one possible solution to a problem, it is useful to compare and test designs. (K-2-ETS1-3)  |  |
|  |  |

|  |  |
| --- | --- |
| **ETS1.A: Defining and Delimiting Engineering Problems** Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. (3-5-ETS1-1)  | **ETS1.B: Developing Possible Solutions** Research on a problem should be carried out before beginning to design a solution. Testing a solution involves investigating how well it performs under a range of likely conditions. (3-5-ETS1-2)  |
| **ETS1.B: Developing Possible Solutions** At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs. (3-5-ETS1-2)  | **ETS1.B: Developing Possible Solutions** Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved. (3-5-ETS1-3)  |
| **ETS1.C: Optimizing the Design Solution** Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. (3-5-ETS1-3)  |  |
|  |  |

|  |  |
| --- | --- |
| **PS1.A: Structure & Properties of Matter**PS1.A.1 – Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (MS-PS1-2, MS-PS1-3) | **PS1.A: Structure & Properties of Matter**PS1.A.2 – Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (MS-PS1-1) |
| **PS1.A: Structure & Properties of Matter**PS1.A.3 – Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. (MS-PS1-4) | **PS1.A: Structure & Properties of Matter**PS1.A.4 – In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. (MS-PS1-4) |
| **PS1.A: Structure & Properties of Matter**PS1.A.5 – Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals). (MS-PS1-1) | **PS1.A: Structure & Properties of Matter**PS1.A.6 – The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. (MS-PS1-4) |
| **PS1.B: Chemical Reactions**PS1.B.1 – Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS-PS1-2, MS-PS1-3, MS-PS1-5) | **PS1.B: Chemical Reactions**PS1.B.2 – The total number of each type of atom is conserved, and thus the mass does not change. (MS-PS1-5) |
| **PS1.B: Chemical Reactions**PS1.B.3 – Some chemical reactions release energy, others store energy. (MS-PS1-6) | **PS2.A: Forces and Motion**PS2.A.1 – For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton’s 3rd Law). (MS-PS2-1) |
| **PS2.A: Forces and Motion**PS2.A.2 – The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. (MS-PS2-2) | **PS2.A: Forces and Motion**PS2.A.3 – All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared. (MS-PS2-2) |
| **PS2.B: Types of Interactions**PS2.B.1 – Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. (MS-PS2-3) | **PS2.B: Types of Interactions**PS2.B.2 – Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass – e.g., Earth and the sun. (MS-PS2-4) |
| **PS2.B: Types of Interactions**PS2.B.3 – Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively). (MS-PS2-5) | **PS3.A: Definitions of Energy** PS3.A.1 – The term “heat” as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects. (MS-PS1-4) |
| **PS3.A: Definitions of Energy** PS3.A.2 – The temperature of a system is proportional to the average internal kinetic energy and potential energy per atom or molecule (whichever is the appropriate building block for the system’s material). The details of that relationship depend on the type of atom or molecule and the interactions among the atoms in the material. Temperature is not a direct measure of a system’s total thermal energy. The total thermal energy (sometimes called the total internal energy) of a system depends jointly on the temperature, the total number of atoms in the system, and the state of the material. (MS-PS1-4) | **PS3.A: Definitions of Energy** PS3.A.3 – Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed (MS-PS3-2). |
| **PS3.A: Definitions of Energy** PS3.A.4 – A system of objects may also contain stored (potential) energy, depending on their relative positions. (MS-PS3-2) | **PS3.A: Definitions of Energy** PS3.A.5 – Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and total energy of a system depends on the types, states, and amounts of matter present. (MS-PS3-3, MS-PS3-4) |
| **PS3.B: Conservation of Energy and Energy Transfer**PS3.B.1 – When the motion energy of an object changes, there is inevitably some other change in energy at the same time. (MS-PS3-5) | **PS3.B: Conservation of Energy and Energy Transfer**PS3.B.2 – The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment. (MS-PS3-4) |
| **PS3.B: Conservation of Energy and Energy Transfer**PS3.B.3 – Energy is spontaneously transferred out of hotter regions or objects and into colder ones. (MS-PS3-3) | **PS3.C: Relationship Between Energy and Forces**PS3.C.1 – When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object. (MS-PS3-2) |
| **PS3.D: Energy in Chemical Processes and Everyday Life**PS3.D.1 – The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen. (secondary to MS-LS1-6) | **PS3.D: Energy in Chemical Processes and Everyday Life**PS3.D.2 – Cellular respiration in plants and animals involves chemical reactions with oxygen that releases stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials. (secondary to MS-LS1-7) |
| **PS4.A: Wave Properties**PS4.A.1 – A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. (MS-PS4-1) | **PS4.A: Wave Properties**PS4.A.2 – A sound wave needs a medium through which it is transmitted. (MS-PS4-2) |
| **PS4.B: Electromagnetic Radiation**PS4.B.1 – When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object’s material and the frequency (color) of the light. (MS-PS4-2) | **PS4.B: Electromagnetic Radiation**PS4.B.2 – The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) when the light path bends. (MS-PS4-2) |
| **PS4.B: Electromagnetic Radiation**PS4.B.3 – A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media. (MS-PS4-2) | **PS4.B: Electromagnetic Radiation**PS4.B.4 – Because light can travel through space, it cannot be a matter wave, like sound or water waves. (MS-PS4-2) |
| **PS4.C: Information Technologies and Instrumentation**PS4.C.1 – Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information. (MS-PS4-3) | **LS1.A: Structure & Function**LS1.A.1 – All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular). (MS-LS1-1) |
| **LS1.A: Structure & Function**LS1.A.2 – Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell. (MS-LS1-2) | **LS1.A: Structure & Function**LS1.A.3 – In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions. (MS-LS1-3) |
| **LS1.B: Growth and Development of Organisms**LS1.B.1 – Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. (secondary to MS-LS3-2) | **LS1.B: Growth and Development of Organisms**LS1.B.2 – Animals engage in characteristic behaviors that increase the odds of reproduction. (MS-LS1-4) |
| **LS1.B: Growth and Development of Organisms**LS1.B.3 – Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction. (MS-LS1-4) | **LS1.B: Growth and Development of Organisms**LS1.B.4 – Genetic factors as well as local conditions affect the growth of the adult plant. (MS-LS1-5) |
| **LS1.C: Organization for Matter and Energy Flow in Organisms**LS1.C.1 – Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use. (MS-LS1-6) | **LS1.C: Organization for Matter and Energy Flow in Organisms**LS1.C.2 – Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy. (MS-LS1-7) |
| **LS1.D: Information Processing**LS1.D.1 – Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical) transmitting them as signals that travel along nerve cells to the brain. The signals are then processed in the brain, resulting in immediate behaviors or memories. (MS-LS1-8) | **LS2.A: Interdependent Relationships in Ecosystems**LS2.A.1 – Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. (MS-LS2-1) |
| **LS2.A: Interdependent Relationships in Ecosystems**LS2.A.2 – In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. (MS-LS2-1) | **LS2.A: Interdependent Relationships in Ecosystems**LS2.A.3 – Growth of organisms and population increases are limited by access to resources. (MS-LS2-1) |
| **LS2.A: Interdependent Relationships in Ecosystems**LS2.A.4 – Predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared. (MS-LS2-2) | **LS2.B: Cycle of Matter and Energy Transfer in Ecosystems**LS2.B.1 – Food webs are models that demonstrate how matter and energy is transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. (MS-LS2-3) |
| **LS2.C: Ecosystem Dynamics, Functioning, and Resilience**LS2.C.1 – Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. (MS-LS2-4) | **LS2.C: Ecosystem Dynamics, Functioning, and Resilience**LS2.C.2 – Biodiversity describes the variety of species found in Earth’s terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem’s biodiversity is often used as a measure of its health. (MS-LS2-5) |
| **LS3.A: Inheritance of Traits**LS3.A.1 – Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affects traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organisms, and thereby change traits. (MS-LS3-1) | **LS3.A: Inheritance of Traits**LS3.A.2 – Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited. (MS-LS3-2) |
| **LS3.B: Variation of Traits**LS3.B.1 – In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other. (MS-LS3-2) | **LS3.B: Variation of Traits**LS3.B.2 – In addition to variations that arise from sexual reproduction, genetic information can be altered because of mutations. Though rare, mutations may result in changes to the structure and function of proteins. Some changes are beneficial, others harmful, and some neutral to the organism. (MS-LS3-1) |
| **LS4.A: Evidence of Common Ancestry and Diversity**LS4.A.1 – The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found or through radioactive dating) is known as the fossil record. It documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth. (MS-LS4-1) | **LS4.A: Evidence of Common Ancestry and Diversity**LS4.A.2 – Anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record, enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent. (MS-LS4-2) |
| **LS4.A: Evidence of Common Ancestry and Diversity**LS4.A.3 – Comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully-formed anatomy. (MS-LS4-3) | **LS4.B: Natural Selection**LS4.B.1 – Natural selection leads to the predominance of certain traits in a population, and the suppression of others. (MS-LS4-4) |
| **LS4.B: Natural Selection**LS4.B.2 – In *artificial* selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring. (MS-LS4-5) | **LS4.C: Adaptation**LS4.C.1 – Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not, become less common. Thus, the distribution of traits in a population changes. (MS-LS4-6) |
| **LS4.D: Biodiversity and Humans**LS4.D.1 – Changes in biodiversity can influence humans’ resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on – for example, water purification and recycling. (secondary to MS-LS2-5) | **ESS1.A: The Universe and Its Stars**ESS1.A.1 – Patterns of the apparent motion of the sun, the moon, and the stars in the sky can be observed, described, predicted, and explained with models. (MS-ESS1-1) |
| **ESS1.A: The Universe and Its Stars**ESS1.A.2 – Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe. (MS-ESS1-2) | **ESS1.B: Earth and the Solar System**ESS1.B.1 – The solar system consists of the sun and a collection of objects, including planets, their moons, and the asteroids that are held in orbit around the sun by its gravitational pull on them. (MS-ESS1-2) |
| **ESS1.B: Earth and the Solar System**ESS1.B.2 – This model of the solar system can explain eclipses of the sun and the moon. Earth’s spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year. (MS-ESS1.1) | **ESS1.B: Earth and the Solar System**ESS1.B.3 – The solar system appears to have formed from a disk of dust and gas, drawn together by gravity. (MS-ESS1-2) |
| **ESS1.C: The History of Planet Earth**ESS1.C.1 – The geologic time scale interpreted from rock strata provides a way to organize Earth’s history. Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale. (MS-ESS1-4) | **ESS1.C: The History of Planet Earth**ESS1.C.2 – Tectonic processes continually generate new ocean sea floor at ridges and destroy old sea floor at trenches. (secondary to MS-ESS2-3) |
| **ESS2.A: Earth’s Materials and Systems**ESS2.A.1 – The planet’s systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth’s history and will determine its future. (MS-ESS2-2) | **ESS2.A: Earth’s Materials and Systems**ESS2.A.2 – All Earth processes are the result of energy flowing and matter cycling within and among the planet’s systems. This energy is derived from the sun and Earth’s hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth’s materials and living organisms. (MS-ESS2-1) |
| **ESS2.B: Plate Tectonics and Large-Scale System Interactions**ESS2.B.1 – Maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth’s plates have moved great distances, collided, and spread apart. (MS-ESS2-3) | **ESS2.C: The Roles of Water in Earth’s Surface Processes**ESS2.C.1 – Water’s movements – both on the land and underground – cause weathering and erosion, which change the land’s surface features and create underground formations. (MS-ESS2-2) |
| **ESS2.C: The Roles of Water in Earth’s Surface Processes**ESS2.C.2 – Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land. (MS-ESS2-4) | **ESS2.C: The Roles of Water in Earth’s Surface Processes**ESS2.C.3 – Global movements of water and its changes in form are propelled by sunlight and gravity. (MS-ESS2-4) |
| **ESS2.C: The Roles of Water in Earth’s Surface Processes**ESS2.C.4 – The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns. (MS-ESS2-5) | **ESS2.C: The Roles of Water in Earth’s Surface Processes**ESS2.C.5 – Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents. (MS-ESS2-6) |
| **ESS2.D: Weather and Climate**ESS2.D.1 – Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. (MS-ESS2-6) | **ESS2.D: Weather and Climate**ESS2.D.2 – Because oceanic and atmospheric flow patterns are so complex, weather can only be predicted probabilistically. (MS-ESS2-5) |
| **ESS2.D: Weather and Climate**ESS2.D.3 – The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents. (MS-ESS2-6) | **ESS3.A: Natural Resources**ESS3.A.1 – Humans depend on Earth’s land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes. (MS-ESS3-1) |
| **ESS3.B: Natural Hazards**ESS3.B.1 – Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces, can help forecast the locations and likelihoods of future events. (MS-ESS3-2) | **ESS3.C: Human Impacts on Earth Systems**ESS3.C.1 – Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth’s environments can have different impacts (negative and positive) for different living things. (MS-ESS3-3) |
| **ESS3.C: Human Impacts on Earth Systems**ESS3.C.2 – Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise. (MS-ESS3-3, MS-ESS3-4) | **ESS3.D: Global Climate Change**ESS3.D.1 – Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth’s mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities. (MS-ESS3-5) |
| **PS1.A: Structure & Properties of Matter**PS1.A.1 – Each atom has a charge substructure consisting of a nucleus, which is made of protons and neutrons, surrounding by electrons. (HS-PS1-1, HS-PS1-2) | **PS1.A: Structure & Properties of Matter**PS1.A.2 – 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 electrons states. (HS-PS1-1) |
| **PS1.A: Structure & Properties of Matter**PS1.A.3 – 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) | **PS1.A: Structure & Properties of Matter**PS1.A.4 – 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) |
| **PS1.B: Chemical Reactions**PS1.B.1 – 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) | **PS1.B: Chemical Reactions**PS1.B.2 – 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) |
| **PS1.B: Chemical Reactions**PS1.B.3 – The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. (HS-PS1-2, HS-PS1-7) | **PS1.C: Nuclear Processes**PS1.C.1 – 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) |
| **PS1.C: Nuclear Processes**PS.1C.2 – 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. (secondary to HS-ESS1-5, HS-ESS1-6) | **PS2.A: Forces and Motion**PS2.A.1 – Newton’s second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1) |
| **PS2.A: Forces and Motion**PS2.A.2 – Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (HS-PS2-2) | **PS2.A: Forces and Motion**PS2.A.3 – If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balance by changes in the momentum of objects outside the system. (HS-PS2-2, HS-PS2-3) |
| **PS2.B: Types of Interactions**PS2.B.1 – 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-PS1-1, HS-PS1-3, HS-PS2-6) | **PS2.B: Types of Interactions**PS2.B.2 – 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) |
| **PS2.B: Types of Interactions**PS2.B.3 – 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) | **PS3.A: Definitions of Energy**PS3.A.1 – Energy is a quantitative property of a systems 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) |
| **PS3.A: Definitions of Energy**PS3.A.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) | **PS3.A: Definitions of Energy**PS3.A.3 – Energy 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 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) |
| **PS3.A: Definitions of Energy**PS3.A.4 – “Electrical energy” may mean energy stored in a battery or energy transmitted by electric currents. (secondary to HS-PS2-5) | **PS3.B: Conservation of Energy and Energy Transfer**PS3.B.1 – 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) |
| **PS3.B: Conservation of Energy and Energy Transfer**PS3.B.2 – 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) | **PS3.B: Conservation of Energy and Energy Transfer**PS3.B.3 – 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) |
| **PS3.B: Conservation of Energy and Energy Transfer**PS3.B.4 – The availability of energy limits what can occur in any system. (HS-PS3-1) | **PS3.B: Conservation of Energy and Energy Transfer**PS3.B.5 – Uncontrolled systems always evolve toward more stable states – that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). (HS-PS3-4) |
| **PS3.C: Relationship Between Energy and Forces**PS3.C.1 – When two objects interacting through a field change relative position, the energy stored in the field has changed. (HS-PS3-5) | **PS3.D: Energy in Chemical Processes and Everyday Life**PS3.D.1 – Although energy cannot be destroyed, it can be converted to less useful forms – for example, to thermal energy in the surrounding environment. (HS-PS3-3, HS-PS3-4) |
| **PS3.D: Energy in Chemical Processes and Everyday Life**PS3.D.2 – Solar cells are human-made devices that capture the sun’s energy and produce electrical energy. (secondary to HS-PS4-5) | **PS3.D: Energy in Chemical Processes and Everyday Life**PS3.D.3 – The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. (secondary to HS-LS2-5) |
| **PS3.D: Energy in Chemical Processes and Everyday Life**PS3.D.4 – Nuclear fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. (secondary to HS-ESS1-1) | **PS4.A: Wave Properties**PS4.A.1 – 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) |
| **PS4.A: Wave Properties**PS4.A.2 – Information can be digitized (e.g., a picture stored as the value of an array of pixels); in this form, it can be stored reliably in computer memory and set over long distances as a series of wave pulses. (HS-PS4-2, HS-PS4-5) | **PS4.A: Wave Properties**PS4.A.3 – 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. (HS-PS4-3) |
| **PS4.A: Wave Properties**PS4.A.4 – Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet. (secondary to HS-ESS2-3) | **PS4.B: Electromagnetic Radiation**PS4.B.1 – 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) |
| **PS4.B: Electromagnetic Radiation**PS4.B.2 – 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) | **PS4.B: Electromagnetic Radiation**PS4.B.3 – Photoelectric materials emit electrons when they absorb light of a high-enough frequency. (HS-PS4-5) |
| **PS4.B: Electromagnetic Radiation**PS4.B.4 – 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. (secondary to HS-ESS1-2) | **PS4.C: Information Technologies and Instrumentation**PS4.C.1 – 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) |
| **LS1.A: Structure and Function**LS1.A.1 – Systems of specialized cells within organisms help them perform the essential functions of life. (HS-LS-1-1) | **LS1.A: Structure and Function**LS1.A.2 – Nearly 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, secondary to HS-LS3-1) |
| **LS1.A: Structure and Function**LS1.A.3 – 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) | **LS1.A: Structure and Function**LS1.A.4 – 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 (through negative feedback) what is going on inside the living system. (HS-LS1-3) |
| **LS1.B: Growth and Development of Organisms**LS1.B.1 – 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**LS1.C.1 – 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) |
| **LS1.C: Organization for Matter and Energy Flow in Organisms**LS1.C.2 – The sugar molecules formed by photosynthesis 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) | **LS1.C: Organization for Matter and Energy Flow in Organisms**LS1.C.3 – As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. (HS-LS1-6, HS-LS1-7) |
| **LS1.C: Organization for Matter and Energy Flow in Organisms**LS1.C.4 – As a result of chemical reactions in living systems, energy is transferred from one system of interacting molecules to another and is released to the surrounding environment and to maintain body temperature. Cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. (HS-LS1-7) | **LS2.A: Interdependent Relationships in Ecosystems**LS2.A.1 – 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**LS2.B.1 – Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. (HS-LS2-3) | **LS2.B: Cycles of Matter and Energy Transfer in Ecosystems**LS2.B.2 – 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) |
| **LS2.B: Cycles of Matter and Energy Transfer in Ecosystems**LS2.B.3 – 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**LS2.C.1 – 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) |
| **LS2.C: Ecosystem Dynamics, Functioning, and Resilience**LS2.C.2 – Anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species. (HS-LS2-7) | **LS2.D: Social Interactions and Group Behavior**LS2.D.1 – Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives. (HS-LS2-8) |
| **LS3.A: Inheritance of Traits**LS3.A.1 – 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) | **LS3.B: Variation of Traits**LS3.B.1 – 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) |
| **LS3.B: Variation of Traits**LS3.B.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) | **LS4.A: Evidence of Common Ancestry and Diversity**LS4.A.1 – 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) |
| **LS4.B: Natural Selection**LS4.B.1 – 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) | **LS4.B: Natural Selection**LS4.B.2 – The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. (HS-LS4-3) |
| **LS4.C: Adaptation**LS4.C.1 - 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) | **LS4.C: Adaptation**LS4.C.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) |
| **LS4.C: Adaptation**LS4.C.3 – Adaptation also means that the distribution of traits in a population can change when conditions change. (HS-LS4-3) | **LS4.C: Adaptation**LS4.C.4 – 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) |
| **LS4.C: Adaptation**LS4.C.5 – 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) | **LS4.D: Biodiversity and Humans**LS4.D.1 – Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). (secondary to HS-LS2-7) |
| **LS4.D: Biodiversity and Humans**LS4.D.2 – 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 overpopulationoverexploitation, 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, secondary to HS-LS2-7) | **ESS1.A: The Universe and Its Stars**ESS1.A.1 – The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. (HS-ESS1-1) |
| **ESS1.A: The Universe and Its Stars**ESS1.A.2 – 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) | **ESS1.A: The Universe and Its Stars**ESS1.A.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 the spectra of the primordial radiation (cosmic microwave background) that still fills the universe. (HS-ESS1-2) |
| **ESS1.A: The Universe and Its Stars**ESS1.A.4 – 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) | **ESS1.B: Earth and the Solar System**ESS.1.B.1 – 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) |
| **ESS1.B: Earth and the Solar System**ESS.1.B.2 – 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. (secondary to HS-ESS2-4) | **ESS1.C: The History of Planet Earth**ESS1.C.1 – 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) |
| **ESS1.C: The History of Planet Earth**ESS1.C.2 – 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) | **ESS2.A: Earth Materials and Systems**ESS2.A.1 – Earth’s systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. A deep knowledge of how feedbacks work within and among Earth’s systems is still lacking, thus limiting scientists’ ability to predict some changes and their impacts. (HS-ESS2-1, HS-ESS2-2) |
| **ESS2.A: Earth Materials and Systems**ESS2.A.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) | **ESS2.A: Earth Materials and Systems**ESS2.A.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) |
| **ESS2.B: Plate Tectonics and Large-Scale System Interactions**ESS2.B.1 – Plate tectonics is the unifying theory that explains the past and current movements of the rocks at the Earth’s surface and provides a framework for understanding its geologic history. (HS-ESS2-1, secondary to HS-ESS1-5) | **ESS2.B: Plate Tectonics and Large-Scale System Interactions**ESS2.B.2 – 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-ESS2-1) |
| **ESS2.B: Plate Tectonics and Large-Scale System Interactions**ESS2.B.3 – 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) | **ESS2.C: The Roles of Water in Earth’s Surface Processes**ESS2.C.1 – 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) |
| **ESS2.D: Weather and Climate**ESS2.D.1 – 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, secondary to HS-ESS2-2) | **ESS2.D: Weather and Climate**ESS2.D.2 – Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. (HS-ESS2-6, HS-ESS2-7) |
| **ESS2.D: Weather and Climate**ESS2.D.3 – Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect the climate. (HS-ESS2-6, HS-ESS2-4) | **ESS2.D: Weather and Climate**ESS2.D.4 – 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. (secondary to HS-ESS3-6) |
| **ESS2.E: Biogeology**ESS2.E.1 – The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual coevolution of Earth’s surface and the life that exists on it. (HS-ESS2-7) | **ESS3.A: Natural Resources**ESS3.A.1 – Resource availability has guided the development of human society. (HS-ESS3-1) |
| **ESS3.A: Natural Resources**ESS3.A.2 – 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) | **ESS3.B: Natural Hazards**ESS3.B.1 – 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) |
| **ESS3.C: Human Impacts on Earth Systems**ESS3.C.1 – The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. (HS-ESS3-3) | **ESS3.C: Human Impacts on Earth Systems**ESS3.C.2 – Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (HS-ESS3-4) |
| **ESS3.D: Global Climate Change**ESS3.D.1 – 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) | **ESS3.D: Global Climate Change**ESS3.D.2 – 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) |
| **ETS1.A: Defining and Delimiting an Engineering Problem**ETS1.A.1 – Criteria and constraints also include satisfying any requirements set by society, such as taking issue 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, secondary to HS-PS2-3, HS-PS3-3) | **ETS1.A: Defining and Delimiting an Engineering Problem**ETS1.A.2 – Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1) |
| **ETS1.B: Developing Possible Solutions**ETS1.B.1 – 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, secondary to HS-LS2-7, HS-LS4-6, HS-ESS3-2, HS-ESS3-4) | **ETS1.B: Developing Possible Solutions**ETS1.B.2 – 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, secondary to HS-LS4-6) |
| **ETS1.C: Optimizing the Design Solution**ETS1.C.1 – 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, secondary to HS-PS1-6) |  |
|  |  |