State of New Jersey
Department of Education

Physical Science Disciplinary Core Ideas Learning Progressions

Introduction

The New Jersey Student Learning Standards for Science (NJSLS-S) are built on the notion of learning as a developmental progression. They are designed to help children continually build on and revise their knowledge and abilities, starting from their curiosity about what they see around them and their initial conceptions about how the world works. The goal of science education is to guide their knowledge toward a more evidence - based and coherent view of the natural sciences and engineering (NGSS Lead States, 2013).

The following tables provide readers with the progression of increasing complexity that each disciplinary core idea undergoes from kindergarten through grade 12. The tables provide invaluable insight into what the current focus of learning should be and provides insight into what the students learned before they came to your classroom, and what they will learn in a future course. The full range of information enables educators to scaffold learning experiences when there is unfinished learning from the previous year. It also provides a clear stopping point for current learning experiences.

Physical Sciences Disciplinary Core and Component Ideas

PS1: Matter and Its Interactions

- **PS1.A:** Structure and Properties of Matter
- **PS1.B:** Chemical Reactions
- **PS1.C:** Nuclear Processes

PS2: Motion and Stability: Forces and Interactions

- **PS2.A:** Forces and Motion
- **PS2.B:** Types of Interactions
- **PS2.C:** Stability and Instability in Physical Systems

PS3: Energy

- **PS3.A:** Definitions of Energy
- **PS3.B:** Conservation of Energy and Energy Transfer
- **PS3.C:** Relationship Between Energy and Forces
- **PS3.D:** Energy in Chemical Processes and Everyday Life

PS4: Waves and Their Applications in Technologies for Information Transfer

- **PS4.A:** Wave Properties
- **PS4.B:** Electromagnetic Radiation
- **PS4.C:** Information Technologies and Instrumentation

PS.1: Matter and its Interactions

Overarching Question for PS1: How can one explain the structure, properties, and interactions of matter (NRC, 2012, p. 106 – 113)?

Component Ideas	Grades K – 2	Grades 3 – 5	Grades 6 – 8	Grades 9 – 12
PS1.A: Structures and Properties of Matter How do particles combine to form the variety of matter one observes? (p. 106-109)	• Different kinds of matter exist and many of them can be either solid or liquid, depending on temperature. Matter can be described and classified by its observable properties. (2-PS1-1) • Different properties are suited to different purposes. (2-PS1- 2), (2-PS1-3) • A great variety of objects can be built up from a small set of pieces. (2-PS1-3)	• 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 shows 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; the effects of air on larger particles or objects. (5-PS1-1) • The amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish. (5-PS1-2) • 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)	• 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) • 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) • Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. (MS-PS1-4) • 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) • Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals). (MS-PS1-1) • 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)	• Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. (HS-PS1-1) • The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. (HS-PS1-1), (HS- PS1-2) • 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) • Stable forms of matter are those in which the electric and magnetic field energy is minimized. 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)

Component Ideas	Grades K – 2	Grades 3 – 5	Grades 6 – 8	Grades 9 – 12
PS1.B: Chemical Reactions How do substances combine or change (react) to make new substances? How does one characterize and explain these reactions and make predictions about them? (p. 109-111)	• 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)	• When two or more different substances are mixed, a new substance with different properties may be formed. (5-PS1-4) • 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)	• 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) • The total number of each type of atom is conserved, and thus the mass does not change. (MS-PS1-5) • Some chemical reactions release energy, others store energy. (MS-PS1-6)	• 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. (HSPS1-4), (HS-PS1-5) • In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. (HS-PS1-6) • The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. (HS-PS1-2), (HS-PS1- 7)
PS1.C: Nuclear Processes What forces hold nuclei together and mediate nuclear processes? (p. 111-113)				• 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. (HSPS1-8) • 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*), (*secondary to HS-ESS1-6*)

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				• Normal stars cease producing light after having converted all of the material in their cores to carbon or, for more massive stars, to iron. Elements more massive than iron are formed by fusion processes but only in the extreme conditions of supernova explosions, which explains why they are relatively rare. (HS-ESS1-5), (HS-ESS1-6))

PS2: Motion and Stability: Forces and Interactions

Overarching Question for PS2: How can one explain and predict interactions between objects and within systems of objects (NRC, 2012. pp. 113 – 120)?

Component Ideas	Grades K – 2	Grades 3 – 5	Grades 6 – 8	Grades 9 – 12
PS2.A: Forces and Motion How can one predict an object's continued motion, changes in motion, or stability? (p. 114-116)	• Pushes and pulls can have different strengths and directions. (KPS2-1), (K-PS2-2) • Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. (K-PS2-1), (K-PS2- 2)	• Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object's speed or direction of motion. (Boundary: Qualitative and conceptual, but not quantitative addition of forces are used at this level.) (3-PS2-1) • The patterns of an object's motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it. (Boundary: Technical terms, such as magnitude, velocity, momentum, and vector quantity, are not introduced at this level, but the concept that some quantities need both size and direction to be described is developed.) (3-PS2-2)	• For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law). (MS-PS2-1) • The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. (MS-PS2-2) • All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared. (MS-PS2-2)	• Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1) • Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. In any system, total momentum is always conserved. (HS-PS2-2) • If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. (HS-PS2-2), (HS-PS2-3)
PS2.B: Types of Interactions What underlying forces explain the	• When objects touch or collide, they push on one another and can change motion. (K-PS2-1)	• Objects in contact exert forces on each other. (3-PS2-1) • Electric, and magnetic forces between a pair of objects do not	• Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or	• Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and

Component Ideas	Grades K – 2	Grades 3 – 5	Grades 6 – 8	Grades 9 – 12
variety of interactions observed? (p. 116-118)		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) • The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center. (5-PS2-1)	magnetic strengths involved and on the distances between the interacting objects. (MS-PS2-3) • Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun. (MS-PS2-4) • Forces that act at a distance (electric and magnetic) can be explained by fields that extend through space and can be mapped by their effect on a test object (a ball, a charged object, or a magnet, respectively). (MS-PS2-5)	electrostatic forces between distant objects. (HS-PS2-4) • Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. (HS-PS2-4), (HS-PS2-5) • Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. (HS-PS2-6), (*secondary to HS-PS1-1*), (*secondary to HS-PS1-3*)
PS2.C: Stability and Instability in Physical Systems Why are some physical systems more stable than others (p. 118-120)				• …and "electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. (*secondary to HS-PS2-5*)

PS3: Energy

Overarching Question for PS3: How is energy transferred and conserved (NRC, 2012, p. 120 – 130)?

Component Ideas	Grades K – 2	Grades 3 – 5	Grades 6 – 8	Grades 9 – 12
PS3.A: Definitions of Energy What is energy? (p. 120-124)		• The faster a given object is moving, the more energy it possesses. (4-PS3-1) • Energy can be moved from place to place by moving objects or through sound, light, or electric currents. (4-PS3-2), (4-PS3-3)	• Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed. (MS-PS3-1) • A system of objects may also contain stored (potential) energy, depending on their relative positions. (MS-PS3-2) Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. (MS-PS3-3), (MS-PS3-4) • The term "heat" as used in everyday language refers both to thermal motion (the motion of atoms or molecules within a substance) and radiation (particularly infrared and light). In science, heat is used only for this second meaning; it refers to energy transferred when two objects or systems are at different temperatures. (*secondary to MS-PS1-4*) • Temperature is not a measure of energy; the relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. (*secondary to MS-PS1-4*)	• 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. (HSPS3-1), (HS-PS3-2) • At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HSPS3-2), (HS-PS3-3) • These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as either motions of particles or energy stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. (HS- PS3-2)

Component Ideas	Grades K – 2	Grades 3 – 5	Grades 6 – 8	Grades 9 – 12
PS3.B: Conservation of Energy and Energy Transfer What is meant by conservation of energy? How is energy transferred between objects or systems? (p. 124-126)	• Sunlight warms Earth's surface. (K-PS3-1), (K-PS3-2)	• Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced. (4-PS3-2), (4-PS3-3) • Light also transfers energy from place to place. (4-PS3-2) • Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy. (4- PS3-2), (4-PS3-4)	• When the motion energy of an object changes, there is inevitably some other change in energy at the same time. (MS-PS3-5) • The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment. (MS-PS3-4) • Energy is spontaneously transferred out of hotter regions or objects and into colder ones. (MS-PS3-3)	• Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. (HS-PS3-1) Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-1), (HS- PS3-4) • Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (HS-PS3-1) • The availability of energy limits what can occur in any system. (HS-PS3-1) • Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). (HS-PS3- 4)
PS3.C Relationship Between Energy and Forces How are forces related to energy? (p. 126-127)	• A bigger push or pull makes things go faster. (*secondary to K-PS2-1*)	• When objects collide, the contact forces transfer energy so as to change the objects' motions. (4-PS3-3)	• 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)	• When two objects interacting through a field change relative position, the energy stored in the field is changed. (HS-PS3-5)

Component Ideas	Grades K – 2	Grades 3 – 5	Grades 6 – 8	Grades 9 – 12
PS3.D: Energy in Chemical Processes and Everyday Life How do food and fuel provide energy? If energy is conserved, why do people say it is produced or used? (p. 128-130)		• The expression “produce energy” typically refers to the conversion of stored energy into a desired form for practical use. (4-PS3- 4) • 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)	• 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*) • Cellular respiration in plants and animals involve chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials. (*secondary to MS-LS1-7*)	• 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) • Solar cells are human-made devices that likewise capture the sun’s energy and produce electrical energy. (*secondary to HS-PS4-5*) • 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*) • Nuclear Fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. (*secondary to HS-ESS1-1*)

PS4: Waves and Their Applications in Technologies for Information Transfer

Overarching Question for PS4: How are waves used to transfer energy and information (NRC, 2012, p. 130 – 138)?

Component Ideas	Grades K – 2	Grades 3 – 5	Grades 6 – 8	Grades 9 – 12
PS4.A: Wave Properties What are the characteristic properties and behaviors of waves? (p. 131-133)	• Sound can make matter vibrate, and vibrating matter can make sound. (1-PS4-1)	• 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; it does not move in the direction of the wave except when the water meets the beach. (Note: This grade band endpoint was moved from K–2.) (4- PS4-1) • Waves of the same type can differ in amplitude (height of the wave) and wavelength (spacing between wave peaks). (4-PS4-1)	• A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. (MS-PS4-1) • A sound wave needs a medium through which it is transmitted. (MS-PS4-2)	• The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing. (HS-PS4-1) • Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. (HS-PS4-2), (HSPS4-5) • [From the 3–5 grade band endpoints] Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.) (HS-PS4-3) • Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet. (*secondary to HS-ESS2-3*)

Component Ideas	Grades K – 2	Grades 3 – 5	Grades 6 – 8	Grades 9 – 12
PS4.B: Electromagnetic Radiation What is light? How can one explain the varied effects that involve light? What other forms of electromagnetic radiation are there? (p. 133-136)	• Objects can be seen only when light is available to illuminate them. Some objects give off their own light. (1-PS4-2) • Some materials allow light to pass through them, others allow only some light through and others block all the light and create a dark shadow on any surface beyond them, where the light cannot reach. Mirrors can be used to redirect a light beam. (Boundary: The idea that light travels from place to place is developed through experiences with light sources, mirrors, and shadows, but no attempt is made to discuss the speed of light.) (1- PS4-3)	• An object can be seen when light reflected from its surface enters the eyes. (4-PS4-2)	• When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. (MS-PS4-2) • The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends. (MS-PS4-2) • A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media. (MS-PS4-2) However, because light can travel through space, it cannot be a matter wave, like sound or water waves. (MS-PS4-2)	• Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. (HS-PS4-3) • When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells. (HS-PS4-4) • Photovoltaic materials emit electrons when they absorb light of a high-enough frequency. (HS-PS4-5) • 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 How are instruments that transmit and detect waves used to extend human senses? (p. 136-138)	• People also use a variety of devices to communicate (send and receive information) over long distances. (1-PS4-4)	• Digitized information transmitted over long distances without significant degradation. High-tech devices, such as computers or cell phones, can receive and decode information—convert it from digitized form to voice—and vice versa. (4-PS4-3)	• Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information. (MS-PS4-3)	• 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

Component Ideas	Grades K – 2	Grades 3 – 5	Grades 6 – 8	Grades 9 – 12
				interpreting the information contained in them. (HS-PS4-5)

References

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