



**Vertical Articulation of Physical Science for the
*South Carolina College- and Career-Ready Science
Standards 2021***

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Purpose and Use

The Physical Science (PS) disciplinary core ideas and instructional focus statements describe how students’ understanding of physical and chemical phenomena develops across grade bands. These progressions outline how concepts build over time, from early observational experiences to more formal, model-based explanations, and identify key conceptual shifts without prescribing instruction, pedagogy, or assessment.

Educators and leaders may use these progressions to support curriculum design, instructional planning, professional learning, and alignment across courses and grade levels. Classroom teachers can use this document to clarify the intended depth and breadth of content learning at their grade level. The instructional focus statements describe conceptual targets and are intended to help teachers confirm grade-level emphasis, identify content intentionally deferred to later grades, and avoid over-teaching beyond course expectations.

Instructional focus statements organized by full grades or courses can be found in Appendix A of the Performance Targets on the [Science Instructional Resources webpage](#).

Reading this Resource

This resource uses a consistent structure for the progressions:

Grade, Course, or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
The grade, course, or content is represented here. This also hyperlinks to the Performance Target.	<i>The Disciplinary Core Idea statements from the Performance Expectation (PE) cards are replicated in this section. There are hyperlinks to the appropriate card to view the entire PE.</i>	<i>The Instructional Focus statements are presented in this section. They include statements appropriate for the grade, course, or content, not required activities. They also include “Knowledge Extended Beyond Course Expectations” as a guardrail for depth and breadth of the content. The extended knowledge statements represent a reasonable extension option for students in that grade, course, or content.</i>

Conceptual Vertical Articulation of Physical Science Overview

Physical Science	K	1	2	3	4	5	6	7	8	B1	C	P	ESS
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	•			•		•			•		•	•	
PS3 - Energy													
PS3.A Definitions of Energy					•		•	•				•	
PS3.B Conservation of Energy and Energy Transfer	•				•		•	•			•	•	
PS3.C Relationships 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		•			•				•		•	•	

PS1 – Matter and Its Interactions

PS1 addresses how matter is structured, how it can be classified and identified, and how it changes through physical, chemical, and nuclear processes. Across the grade bands, students move from observing and classifying materials based on their properties to explaining how particles, atoms, and their interactions account for the properties of substances and the changes they undergo. The PS1 progression emphasizes how matter is conserved in chemical processes, how reactions involve the rearrangement of atoms and the transfer of energy, and how changes within atomic nuclei result in nuclear processes that release large amounts of energy and explain natural phenomena across systems and scales.

PS1.A Structure and Properties of Matter

Students begin by describing and classifying different kinds of matter based on observable properties and recognizing that materials can exist as solids or liquids depending on temperature. By upper elementary grades, students analyze how the properties of materials make them suitable for specific purposes, explain how matter can change form when heated or cooled without forming a new substance, and recognize that matter is made of particles. In middle school, students use particle models to explain how the spacing and motion of particles account for the properties of solids, liquids, and gases, connecting these patterns to temperature, pressure, and changes of state. In high school, students explain how atomic structure, electron arrangement, and interactions between particles determine the formation of substances and the characteristic properties of matter.

Progression of PS1.A

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
Second Grade	- 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. A great variety of objects can be built up from a small set of pieces. (2-PS1-2)(2-PS1-3)	- Classify materials based on observable properties such as color, hardness, texture, or flexibility. - Compare how observable properties of the same material change when warmed or cooled, including changes between solid and liquid states. - Explain how observable properties of materials make them suitable for specific familiar purposes. - Demonstrate how objects made from a small set of pieces can be taken apart and reassembled into new objects with different characteristics. <i>Knowledge Extended Beyond Course Expectations</i> - None identified.
Fifth Grade	- 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 (and can be detected by their impact on other objects) 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) - The amount (weight) [sic] 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. 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)	- Explain that matter continues to exist when divided into pieces too small to be visible, supported by observable evidence. - Explain how collisions of moving gas particles with surfaces produce observable effects such as pressure or expansion, providing evidence that gases are matter. - Explain that the total amount of matter remains the same when matter is heated, cooled, mixed, or changes form. - Classify materials by comparing measured properties such as hardness, solubility, or conductivity. - Analyze multiple measurable properties to distinguish among solids, liquids, and gases at the observable scale, without explaining particle mechanisms. <i>Knowledge Extended Beyond Course Expectations</i> - Recognize that matter persists when it is no longer visible by analyzing observable effects.

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
Sixth Grade	Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. 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. The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. (6-PS1-4)	- Describe how differences in particle spacing and motion account for the properties of solids, liquids, and gases. - Explain how adding or removing thermal energy changes particle motion, affecting temperature and resulting in changes of state in a pure substance. - Analyze the relationship between temperature and particle motion to account for observable changes during heating or cooling. - Explain qualitatively that the pressure of a gas is dependent on the number of particles and the average kinetic energy of those particles. <i>Knowledge Extended Beyond Course Expectations</i> - Recognize that matter can be broken apart beyond the particle level into atoms. - Recognize that changes in pressure can affect the conditions under which a substance changes state.
Seventh Grade	- 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. Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals). (7-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. (7-PS1-2) (7-PS1-3)	- Explain how differences in atomic composition and the ways atoms combine account for different pure substances. - Distinguish between substances composed of discrete molecules and substances composed of extended repeating structures such as crystals. - Analyze characteristic physical and chemical properties (for example: boiling point, density, flammability, melting point, odor, and solubility) to identify and distinguish pure substances. <i>Knowledge Extended Beyond Course Expectations</i> - Recognize that atoms are made of smaller particles, including protons, neutrons, and electrons, which influence the identity and properties of elements. - Identify that elements in the periodic table show patterns in their properties based on atomic structure, including repeating trends across rows and columns.

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
Chemistry	- Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. 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. (C-PS1-1) (C-PS1-2) - The structure and interactions of matter at the broader level are determined by various forces within and between atoms. (C-PS1-3) (C-PS2-6) - A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. (C-PS1-4)	- Analyze the charged substructure of atoms, including protons, neutrons, and electrons, to explain element identity, properties, and periodic patterns. - Interpret periodic trends as reflections of patterns in proton number, electron shielding, and outer electron states. - Analyze how forces within and between atoms and molecules determine molecular structure and the macroscopic properties of substances. - Explain that stable molecules have lower energy than the same atoms separated, so energy input is required to break bonds. <i>Knowledge Extended Beyond Course Expectations</i> - None identified.

PS1.B Chemical Reactions

Students begin by observing that heating or cooling materials can cause changes and by distinguishing between changes that can be reversed and those that cannot. In upper elementary grades, students compare materials before and after changes to determine whether new substances have formed, using differences in properties as evidence, and explain that matter is conserved even when materials change. In middle school, students explain chemical reactions as processes in which atoms are rearranged to form new molecules, conserving the number of each type of atom and the total mass, and distinguish reactions that release or absorb energy. In high school, students explain how chemical reactions can be described and predicted based on the conservation and rearrangement of atoms, using models of molecular collisions, bond energies, and dynamic equilibria to account for energy changes, reaction rates, and the amounts of substances present.

Progression of PS1.B

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
Second Grade	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)	- Compare how heating and cooling change the observable properties of different familiar materials. - Differentiate between reversible and nonreversible changes by determining whether materials return to their original form under ordinary conditions. <i>Knowledge Extended Beyond Course Expectations</i> - Recognize some changes form new substances with different properties.

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
Fifth Grade	- No matter what reaction or change in properties occurs, the total weight [sic] of the substances does not change. (5-PS1-2) - When two or more different substances are mixed, a new substance with different properties may be formed. (5-PS1-4)	- Explain that mixing two or more substances may result in a new substance with different properties, but that not all mixtures result in new substances. - Recognize that matter is conserved during changes or reactions, including reactions, even when materials change form or seem to “disappear.” - Compare the properties of starting materials and resulting materials to determine whether a new substance has formed. <i>Knowledge Extended Beyond Course Expectations</i> - Explain that matter is conserved across heating, cooling, dissolving, and reactions by comparing total amounts of materials before and after changes.
Seventh Grade	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. (7-PS1-2) (7-PS1-3) The total number of each type of atom is conserved, and thus the mass does not change. The total number of each atom is conserved, and thus the mass does not change. Some chemical reactions release energy, others store energy. (7-PS1-5) (7-PS1-6)	- Analyze whether a change forms new molecules by comparing characteristic properties (for example: boiling point, density, flammability, melting point, odor, and solubility) of reactants and products. - Describe chemical reactions as processes in which atoms are rearranged into new molecules while conserving the number of each type of atom and the total mass. - Differentiate between chemical reactions that release energy and those that absorb energy by examining observable changes, such as temperature or phase changes. <i>Knowledge Extended Beyond Course Expectations</i> - Recognize that chemical equations can be adjusted using coefficients to show that the number of each type of atom is the same in the reactants and products.

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
Chemistry	- 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. (C-PS1-2) (C-PS1-7) - 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. (C-PS1-4) (C-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. (C-PS1-6)	- Apply qualitative and quantitative relationships among particles, moles, and mass to explain and predict conservation of matter in chemical reactions. - Analyze and predict chemical reaction outcomes using conservation of atoms and chemical properties of the species involved. - Explain reaction rates and overall energy changes in chemical reactions in terms of molecular collisions and bond-energy differences. - Analyze qualitatively how changes in temperature or concentration affect reaction rate. - Explain how condition-dependent, dynamic equilibria determine the macroscopic amounts of substances present in reversible reactions. <i>Knowledge Extended Beyond Course Expectations</i> - Differentiate qualitatively between factors that affect reaction rate and factors that affect equilibrium composition.

PS1.C Nuclear Processes

Students do not engage with nuclear processes in elementary or middle school grades, as these ideas build on foundational understandings of atomic structure and chemical change. In high school, students explain that atoms contain a nucleus composed of protons and neutrons and that changes to this nucleus result in nuclear processes such as radioactive decay, fission, and fusion, analyze how these processes differ from chemical reactions by involving changes in atomic nuclei that can produce different elements while conserving the total number of protons and neutrons, and use models to explain how nuclear processes release or absorb large amounts of energy, emit radiation, and follow predictable patterns over time, connecting these ideas to natural phenomena and technological applications.

Progression of PS1.C

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
K-2	PS1.C is not addressed at this grade band.	This grade band does not include PS1.C Nuclear Processes. Students build understanding of observable physical and chemical changes as described in PS1.A and PS1.B, while concepts related to changes in the nucleus, radiation, and conservation of protons and neutrons are deferred to high school courses such as Chemistry and Earth & Space Science.
3-5	PS1.C is not addressed at this grade band.	This grade band does not include PS1.C Nuclear Processes. Students build understanding of observable physical and chemical changes as described in PS1.A and PS1.B, while concepts related to changes in the nucleus, radiation, and conservation of protons and neutrons are deferred to high school courses such as Chemistry and Earth & Space Science.
6-8	PS1.C is not addressed at this grade band.	This grade band does not include PS1.C Nuclear Processes. Students build understanding of observable physical and chemical changes as described in PS1.A and PS1.B, while concepts related to changes in the nucleus, radiation, and conservation of protons and neutrons are deferred to high school courses such as Chemistry and Earth & Space Science.

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
Chemistry	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. (C-PS1-8)	- Explain that radioactive decay, fission, and fusion are nuclear processes that involve very large energy changes and produce different nuclear products that are often more stable. - Analyze nuclear processes to show that the total number of protons plus neutrons remains unchanged, even though the identity of an element may change. - Differentiate alpha, beta, and gamma emissions by comparing what is emitted and how the identity and mass number of the daughter isotope changes. - Compare the scale of energy changes in nuclear processes and chemical processes, noting that nuclear processes release or absorb far greater amounts of energy. <i>Knowledge Extended Beyond Course Expectations</i> - Use simple mathematical models to describe half-life and radioactive decay of unstable nuclei.
Earth and Space Science	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 thereby fixing the scale of geological time. (secondary). (E-ESS1-6)	- Explain that radioactive decay occurs spontaneously and follows predictable, exponential patterns over time. - Analyze how known half-lives of radioactive isotopes are used to determine the absolute ages of rocks and other materials. - Interpret radiometric age evidence from Earth materials, meteorites, and lunar samples to explain Earth's formation, early history, and the scale of geologic time. <i>Knowledge Extended Beyond Course Expectations</i> - None identified.

PS2 – Motion and Stability: Forces and Interactions

PS2 addresses how forces arise from interactions between objects and how these forces affect motion and the stability of physical systems. Across the grade bands, students move from observing pushes and pulls that change motion to explaining how interactions, including contact and field-based forces, determine the behavior of objects and systems. The PS2 progression emphasizes how the combined effects of forces influence motion, how different types of interactions operate across scales, and how these interactions can be used to explain and predict the stability, change, and structure of physical systems over time.

PS2.A Forces and Motion

Students begin by recognizing that pushes and pulls can vary in strength and direction and can change an object’s motion by starting, stopping, or changing its speed or direction. In upper elementary grades, students explain how forces act on objects and how multiple forces can combine, with balanced forces resulting in no change in motion and unbalanced forces causing changes, and analyze patterns in motion to make predictions. In middle school, students explain how forces arise from interactions between objects and how the net force acting on an object determines changes in motion, including the roles of mass and inertia and the use of reference frames to describe motion. In high school, students explain and predict motion using quantitative relationships among force, mass, and acceleration and apply conservation principles, including momentum, to analyze interactions within and among systems.

Progression of PS2.A

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
Kindergarten	Pushes and pulls can have different strengths and directions. 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)	- Recognize that pushes and pulls can vary in strength and direction. - Demonstrate how a push or pull can cause observable changes in an object’s motion, including starting, stopping, or changing speed or direction. <i>Knowledge Extended Beyond Course Expectations</i> - None identified.

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
Third Grade	- 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. (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. (3-PS2-2)	- Distinguish forces (pushes or pulls) by their strength and direction acting on a single object. - Explain that when multiple forces acting on an object add to zero (balanced), its motion does not change, and when they do not add to zero (unbalanced), its speed or direction changes. - Analyze regular patterns in an object's past motion to make qualitative predictions about its future motion (for example, pendulum, see-saw, etc.). <i>Knowledge Extended Beyond Course Expectations</i> - None identified.
Eighth Grade	- 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). (8-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 (inertia). 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. The positions of objects and the directions of forces and motions must be described using a qualitative comparison and scalar quantities. In order to share information with other people, a reference frame must also be shared. (8-PS2-2)	- Analyze interactions to show that forces between two objects are equal in magnitude and opposite in direction (Newton's Third Law). - Explain that an object's velocity changes only when the sum of forces acting on it (net force) is not zero (Newton's First Law). - Describe how changes in an object's motion depend qualitatively on both the net force acting on it and its mass, with greater mass resulting in greater resistance to motion change (inertia) and larger force resulting in larger motion change. - Use a consistent reference frame to describe positions, directions, and one-dimensional motion qualitatively. - Identify the direction of net force to the direction of change in motion in simple one-dimensional cases. <i>Knowledge Extended Beyond Course Expectations</i> - Differentiate net force on an object from action–reaction pairs acting on different objects.

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
Physics	- Newton's second law accurately predicts changes in the motion of macroscopic objects ($F_{\text{net}}=ma$). (P-PS2-1) - Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. 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. (P-PS2-2) (P-PS2-3)	- Analyze proportional relationships among net force, mass, and acceleration using one-dimensional reasoning. - Apply Newton's Second Law ($F_{\text{net}} = ma$) to describe and predict changes in the motion of macroscopic objects in one dimension. - Define momentum ($p = mv$) relative to a stated reference frame and distinguish between system momentum and individual object momentum. - Apply conservation of momentum to two-object, one-dimensional interactions when the net external force on the system is zero. - Relate impulse ($F\Delta t$) to momentum change (Δp) and explain how increasing the time interval reduces average force during collisions. <i>Knowledge Extended Beyond Course Expectations</i> - Differentiate action–reaction pairs from forces summed in net force. - Explain qualitatively why equal and opposite momentum changes do not result in equal speed changes for objects with different masses.

PS2.B Types of Interactions

Students begin by recognizing that when objects touch or collide, they push on one another and can change motion. In upper elementary grades, students explain that some interactions, including electric and magnetic forces, can occur without contact and can either attract or repel, with strengths depending on the properties of the objects and the distance between them, and describe gravitational interactions as forces that act at a distance and pull objects toward one another. In middle school, students explain how gravitational, electric, and magnetic interactions can be described by fields that extend through space and are inferred from their effects on objects, and how the strength of these interactions depends on properties such as mass or charge and distance. In high school, students apply mathematical and field models to describe and predict interactions, including gravitational and electrostatic forces, and explain how electrical interactions among particles underlie the structure, properties, and transformations of matter as well as the contact forces experienced by objects.

Progression of PS2.B

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
Kindergarten	When objects touch or collide, they push on one another and can change motion. (K-PS2-1)	- Recognize that touching or colliding objects push on each other. - Describe how contact pushes can cause observable changes in an object's motion. <i>Knowledge Extended Beyond Course Expectation</i> - Recognize magnetic interactions occur without contact.

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
Third Grade	- Objects in contact exert forces on each other. (3-PS2-1) - Electric and magnetic forces between a pair of objects do not require that the objects be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other. (3-PS2-3) (3-PS2-4)	- Explain that when objects interact, they exert pushes or pulls on each other that can start, stop, or change an object's motion. - Explain that electric and magnetic interactions can occur without contact, acting at a distance. - Describe qualitatively how the strength of electric or magnetic interactions depends on object properties and the distance between interacting objects. - Demonstrate how magnetic attraction and repulsion are based on the relative orientation of magnets. <i>Knowledge Extended Beyond Course Expectation</i> - Recognize, using qualitative patterns, that closer interactions are stronger and farther interactions are weaker.
Fifth Grade	The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center. (5-PS2-1)	- Describe that Earth's gravity is a force that pulls objects near Earth's surface toward Earth's center without requiring contact. <i>Knowledge Extended Beyond Course Expectation</i> - Recognize that all unsupported objects near Earth's surface fall toward Earth due to gravity, regardless of their mass (ignoring air resistance).
Eighth Grade	- 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. (8-PS2-3) - The magnitude of the gravitational force depends on the masses and distances between interacting objects. Long-range gravitational interactions govern the evolution and maintenance of large-scale structures in the universe and the patterns of motion within them. (8-PS2-4) - Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be illustrated by their effect on a test object (a charged object, or a ball, respectively). (8-PS2-5)	- Describe that electric and magnetic interactions can attract or repel and that the interaction size depends qualitatively on object properties and the distance between interacting objects. - Explain that gravitational interactions are attractive and depend on the masses of objects and the distance between them, influencing large-scale structures and motion patterns in the universe. - Explain that gravitational, electric, and magnetic interactions act through fields that extend through space and are inferred from their effects on a test object. <i>Knowledge Extended Beyond Course Expectation</i> - Recognize across electric, magnetic, and gravitational cases that greater distance qualitatively weakens the interaction (no inverse-square math).

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
Chemistry	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. (C-PS1-3) (C-PS2-6)	- Explain that electrical attraction and repulsion among charges at the atomic scale determine structures, properties, and phase changes. - Relate macroscopic properties (e.g., conductivity, melting and boiling behavior, volatility, solubility, malleability) to relative particle-particle attraction strengths without using equations. <i>Knowledge Extended Beyond Course Expectation</i> - Differentiate qualitatively among interactions within atoms, within molecules or ionic lattices, and between particles.
Physics	- 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. 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. (P-PS2-4) (P-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. The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (P-PS2-6)	- Apply Newton's Law of Universal Gravitation and Coulomb's Law as two-body mathematical models to describe and predict gravitational or electrostatic forces based on mass or charge and the distance between objects. - Explain that gravitational, electric, and magnetic interactions act through fields that permeate space and can transfer energy; magnets or currents produce magnetic fields, and electric charges or changing magnetic fields produce electric fields. - Recognize that electrostatic attraction and repulsion at the atomic scale underlie bulk material properties and macroscopic contact forces. <i>Knowledge Extended Beyond Course Expectation</i> - Interpret qualitatively or algebraically inverse-square relationships in two-object cases (no superposition). - Recognize induction relationships (changing magnetic fields producing electric fields; moving charges producing magnetic fields), without Maxwell's equations.

PS3 – Energy

PS3 addresses how energy is defined, how it is transferred and conserved, and how it is transformed within physical, chemical, and biological systems. Across the grade bands, students move from observing how energy from sources such as the Sun causes changes in objects to explaining how energy is stored, transferred, and transformed within and between systems. The PS3 progression emphasizes how energy is conserved as it flows through interactions and processes, how forces transfer and store energy within systems, and how energy transformations support processes in natural and designed systems while becoming increasingly dispersed over time.

PS3.A Definitions of Energy

Students are not expected to engage directly with definitions of energy in early grades, as these ideas build on foundational understandings of motion, interactions, and system changes. In upper elementary grades, students recognize that energy is associated with motion and can be transferred from place to place through moving objects, sound, light, thermal energy, and electric currents. In middle school, students relate temperature to the motion of particles while distinguishing it from the total thermal energy of a system and explain energy as a property of systems, using the concepts of kinetic energy associated with motion and potential energy associated with the positions and interactions of objects. In high school, students explain energy as a conserved quantitative property of systems, distinguishing energy stored within systems from energy transferred between them and using particle and field models to account for how energy is distributed, transformed, and expressed across different phenomena.

Progression of PS3.A

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
K-2	PS3.A is not addressed at this grade band.	<i>This grade band does not include PS3.A Definitions of Energy. Students build understanding of motion, interactions, and observable changes in systems as described in PS2 and PS1, while concepts related to kinetic and potential energy and energy as a system-level property are deferred to Grade 4.</i>

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
Fourth Grade	- The faster a given object is moving, the more energy it possesses. (4-PS3-1) - Energy can be moved [transferred] from place to place by moving objects or through sound, light, or electric currents. (4-PS3-2) (4-PS3-3)	- Describe that a faster-moving object has relatively more energy than the same object moving more slowly. - Analyze familiar outcomes (such as faster/slower, brighter/dimmer, hotter/colder) as qualitative evidence of differences in energy. - Explain that closed circuits can transfer energy to produce motion, light, or sound. - Describe that energy can move from place to place through moving objects or by sound, light, thermal energy, and electric currents in everyday contexts. - Explain that friction can slow an object's motion while increasing thermal energy. <i>Knowledge Extended Beyond Course Expectations</i> - Compare how changing only the initial speed of the same object affects observed outcomes. - Recognize sound, light, thermal energy, and electric currents as ways energy transfers, and identify examples in unfamiliar contexts.

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
Sixth Grade	- The term “heat” as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and energy transfers by convection, conduction, and radiation (particularly infrared and light). (6-PS3-3) In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects. 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. (6-PS1-4) - 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. (6-PS3-4)	- Define heat as energy transferred due to a temperature difference between systems, rather than energy contained within an object. - Describe temperature as a measure of the average kinetic energy of particles in a substance. - Differentiate temperature from total thermal energy, recognizing that total thermal energy depends on temperature, the amount of matter, and the state of the matter (for example, comparing same-temperature samples of different amounts, mixing hot and cold water, or comparing ice and liquid water, etc.). - Analyze examples of conduction, convection, and radiation as processes that move energy from hotter to colder regions, without calculation. - Explain observed heating and cooling by comparing relative amounts of energy transfer and relative temperatures, qualitatively. <i>Knowledge Extended Beyond Course Expectations</i> - Relate differences in temperature change to material type, mass, and state without specific-heat calculations.

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
Seventh Grade	• 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 [sic]. (7-PS3-1) • A system of objects may also contain stored (potential) energy, depending on their relative positions. (7-PS3-2)	• Differentiate speed and velocity by explaining that speed describes how fast an object moves, while velocity describes both speed and direction of motion. • Explain that motion energy is called kinetic energy and depends on the mass of an object and its velocity. • Analyze why changes in speed change kinetic energy, while changes in direction at constant speed do not change kinetic energy. • Explain that, for objects moving at the same velocity, greater mass corresponds to greater kinetic energy. • Describe that potential energy is energy stored in a system of interacting objects and depends on their relative positions and the type of interaction (gravitational, electric, or magnetic). • Explain that changing the distance or orientation between interacting objects can change the system's potential energy. <i>Knowledge Extended Beyond Course Expectations</i> • Represent kinetic energy quantitatively using $KE = \frac{1}{2}mv^2$ and use proportional reasoning to compare how kinetic energy changes when mass or velocity changes, limited to single-step, unit-consistent cases. • Recognize that separating attracting objects or pushing together repelling objects requires energy transfer into the system, increasing potential energy.

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
Physics	• "Electrical Energy" may mean energy stored in battery or energy transmitted by electric current. (P-PS2-5) • Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. A system's total energy is 1) conserved as energy is transferred within the system from one object to another and between its various possible forms and 2) always equal to the energy transferred into or out of the system and between its various possible forms [sic]. (P-PS3-1) At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (P-PS3-3) Energy at the macroscopic level can be better understood, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases, the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. (P-PS3-2)	• Differentiate energy stored in a system (such as a battery) from energy transferred by a process (such as an electric current). • Analyze a defined system to explain that total energy is conserved and can be redistributed among objects and forms such as kinetic, thermal, and energy stored in fields. • Explain that motion, sound, light, and thermal energy are macroscopic expressions of a single conserved quantity, energy. • Describe macroscopic energy in terms of energy associated with particle motion and energy associated with configuration (relative position), including energy stored in fields. • Explain radiation as energy stored in fields that moves through space. <i>Knowledge Extended Beyond Course Expectations</i> • Relate qualitative statements about conservation and energy flows to simple algebraic descriptions for two- or three-component systems, without derivations.

PS3.B Conservation of Energy and Energy Transfer

Students begin by recognizing that energy from the Sun can be transferred to objects and cause changes such as warming. In upper elementary grades, students explain how energy is transferred between objects through interactions such as collisions, light, and electric currents, describe how energy can change form and be redistributed to the surroundings, and recognize that energy is not lost even when it is no longer directly observable. In middle school, students explain how energy transfer depends on the properties of a system and its environment, how thermal energy flows from warmer to cooler regions, and how changes in a system's motion or temperature require corresponding transfers of energy within the system. In high school, students apply conservation of energy to analyze and predict system behavior, using mathematical relationships to account for energy transfers and storage and recognizing that the amount of available energy constrains which changes can occur.

Progression of PS3.B

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
Kindergarten	Sunlight warms Earth's surface. (K-PS3-1) (K-PS3-2)	- Describe that sunlight causes Earth's surface (sand, soil, rocks, water) to become warmer using familiar examples. - Compare the same surface in sunlight and shade using qualitative terms such as warmer and cooler. - Identify shade as a way to reduce warming of a surface by sunlight. <i>Knowledge Extended Beyond Course Expectations</i> - Recognize that sunlight is a form of energy that can warm objects and surfaces.

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
Fourth Grade	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-PS3-3) Light also transfers energy from place to place. 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. (4-PS3-2) The currents may have been produced to begin with by transforming the energy of motion into electrical energy. (4-PS3-4)	- Describe that light transfers energy from place to place. - Demonstrate that electric currents transfer energy from place to place. - Explain that collisions transfer energy between objects, can result in a change in motion, or can transfer energy as motion, sound, thermal energy, or light. - Explain that friction causes objects to slow while transferring energy to the surroundings as thermal energy. - Demonstrate how energy of motion can be transformed into electrical energy in simple systems (for example, generators). <i>Knowledge Extended Beyond Course Expectations</i> - Recognize that when energy seems to “disappear” in simple scenarios, it has been transferred to the surroundings, mainly as heat and sound.
Sixth Grade	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. (6-PS3-4) Energy is spontaneously transferred out of hotter regions or objects and into colder ones by the processes of conduction, convection, and radiation. (6-PS3-3)	- Analyze how the amount of energy transfer required to change the temperature of a system depends on material type, the amount of matter present, and environmental conditions. - Explain that as thermal energy is transferred, the temperature of a system changes because the average kinetic energy of its particles changes. - Demonstrate how thermal energy is transferred spontaneously from hotter objects or regions to colder ones by conduction, convection, and radiation. <i>Knowledge Extended Beyond Course Expectations</i> - Recognize that during thermal energy transfer, some energy may be absorbed, stored, or redistributed within a system without being immediately observable as a temperature change.

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
Seventh Grade	When the motion energy of an object changes, there is inevitably some other change in energy at the same time. (7-PS3-5)	- Explain that a change in an object’s kinetic energy requires energy transfer to or from the object as part of a system. - Interpret observable changes such as motion, temperature, and sound to determine where energy was transferred within a system. - Analyze a system to identify accompanying energy changes when an object’s kinetic energy increases or decreases. <i>Knowledge Extended Beyond Course Expectations</i> - None identified.
Chemistry	Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. 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). (C-PS3-4)	- Describe that, in closed systems, thermal energy flows from regions of higher temperature to regions of lower temperature until the temperature becomes more uniform. - Explain that in uncontrolled systems, energy tends to spread out so that energy becomes more uniformly distributed (for example, hot objects cool toward their surroundings). - Analyze temperature changes in interacting hot and cold systems to infer the direction of energy transfer and increasing uniformity of energy distribution. <i>Knowledge Extended Beyond Course Expectations</i> - Recognize that although energy is conserved, it can become less useful for doing work as it spreads into the surroundings as thermal energy, consistent with increasing uniformity of energy distribution.

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
Physics	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. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. Mathematical expressions allow the concept of conservation of energy to be used to predict and describe system behavior. Mathematical expressions quantify how the stored energy in a system depends on its configurations (such as relative positions of charged particles or compression of a spring) and how kinetic energy depends on mass and speed. The availability of energy limits what can occur in any system. (P-PS3-1)	- Explain conservation of energy by describing that the total change in energy of a defined system equals the energy transferred into or out of the system. - Apply mathematical expressions to describe or predict system behavior using energy-conservation reasoning. - Determine how stored energy in a system depends on its configuration, such as the relative positions of interacting objects or compression of a spring. - Determine how kinetic energy depends on the mass of an object and the magnitude of its velocity. - Explain that the amount of available energy limits the changes that can occur within a system. <i>Knowledge Extended Beyond Course Expectations</i> - Formulate a simple algebraic energy-accounting model to determine a component's energy change from known energy transfers and other component changes, while clearly stating assumptions and system boundaries.

PS3.C Relationships Between Energy and Forces

Students begin by recognizing that stronger pushes and pulls cause greater changes in the motion of objects. In upper elementary grades, students explain how forces acting during interactions, such as collisions, transfer energy between objects and result in changes in motion and other observable effects, and describe how this energy can be distributed among motion, sound, and thermal energy. In middle school, students explain how forces between interacting objects transfer energy to or from each object within a system and analyze the direction and effects of this transfer. In high school, students apply work–energy relationships and field models to explain and predict how forces transfer energy, including how interactions through fields change stored energy and how forces act to reduce that energy as objects move within systems.

Progression of PS3.C

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
Kindergarten	A bigger push or pull makes things speed up or slow down more quickly. (K-PS2-1)	- Describe that a stronger push or pull makes an object speed up or slow down more quickly. - Compare how an object’s motion changes after gentle versus strong pushes or pulls using qualitative terms. - Describe how a push or pull during contact can change an object’s direction or stop its motion. <i>Knowledge Extended Beyond Course Expectations</i> - Recognize that during a collision, some energy is transferred to the air as sound or heat, while other energy transfer changes the objects’ motion.
Fourth Grade	When objects collide, the contact forces transfer energy so as to change the objects’ motions. (4-PS3-3)	- Explain that during a collision, contact forces transfer energy between interacting objects, resulting in changes to their motion. - Describe observable collision outcomes (such as objects slowing or stopping, sound production, or warming) as evidence of energy transfer. - Analyze how an object’s speed before a collision relates qualitatively to changes in motion after the collision. <i>Knowledge Extended Beyond Course Expectations</i> - Recognize that sound and warming of the surrounding air indicate that some energy is transferred out of the objects, even as other energy transfer changes their motion.

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
Seventh Grade	When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object. (7-PS3-2)	- Explain that when two objects interact, each exerts a force that can transfer energy to or from the objects as part of a system. - Describe observable evidence (speed change, temperature change, sound production) as indicators of energy transfer during interactions. - Analyze interactions to identify the direction of energy transfer and the resulting changes in each object. <i>Knowledge Extended Beyond Course Expectations</i> - Differentiate qualitatively between energy transfer between objects and energy transformation within a system.
Physics	When two objects interacting through a field change relative position, the energy stored in the field is changed. Each force between the two interacting objects acts in the direction such that the motion in that direction would reduce the energy in the force field between the objects. (P-PS3-5)	- Explain that when objects interact through a field, changes in their relative position or configuration change the energy stored in the field. - Explain that each force on an interacting object acts in the direction that would reduce the energy stored in the field. - Analyze how changes in distance or configuration affect field-stored energy and the resulting motion of objects. - Interpret attraction and repulsion scenarios to determine whether field-stored energy increases or decreases as object positions change. <i>Knowledge Extended Beyond Course Expectations</i> - None identified.

PS3.D Energy in Chemical Processes and Everyday Life

Students are not expected to engage directly with energy in chemical processes and everyday life in early grades, as these ideas build on foundational understandings of simple energy transfers and basic organism needs. In upper elementary grades, students explain that energy can be converted between forms for practical use and that energy from the Sun is captured by plants and transferred through food to other organisms, and trace energy pathways from sources through systems. In middle school, students explain how chemical processes, including photosynthesis and cellular respiration, involve energy transformations that store or release energy in biological systems. In high school, students explain how energy transformations in chemical and biological systems can be analyzed as part of larger systems, recognizing that energy reaching Earth originates from nuclear processes in the Sun and is captured, transformed, and dispersed into less useful forms as it flows through natural and designed systems.

Progression of PS3.D

Grade, Course, or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
K-2	PS3.D is not addressed at this grade band.	<i>This grade band does not include PS3.D: Energy in Chemical Processes and Everyday Life. Students build understanding of observable energy effects and simple energy transfers as described in PS3.B and basic organism needs as described in LS1, while concepts related to energy storage and release in chemical processes and energy flow through biological systems are deferred to Grade 4.</i>

Grade, Course, or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
Fourth Grade	The expression “produce energy” typically refers to the conversion of stored energy into a desired form for practical use (4-PS3-4)	- Recognize that the phrase “produce energy” means converting stored energy into a desired form, not creating energy. - Identify the initial stored energy (for example, batteries, elevated mass, coiled springs) and the final output form (motion, light, sound, or thermal energy). - Demonstrate how a simple device converts stored energy into a targeted output through a conversion pathway (for example, electrical energy, motion, light). <i>Knowledge Extended Beyond Course Expectations</i> - Differentiate energy transfer (movement from place to place) from energy conversion (change in form within a device) using grade-appropriate examples.
Fifth Grade	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)	- Identify that plants capture sunlight and store that energy in food. - Explain that animals obtain energy by eating plants or other animals. - Demonstrate that energy flows qualitatively from the Sun to plants and then to animals. <i>Knowledge Extended Beyond Course Expectations</i> - Differentiate energy flow from matter cycling using simple diagrams or labels only.
Seventh Grade	- The chemical reaction by which plants produce complex food molecules (sugars) required 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) (7-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) (7-LS1-7)	- Explain that photosynthesis is a chemical process that requires energy input from sunlight to form sugars and release oxygen. - Describe that cellular respiration is a chemical process that uses oxygen to release stored chemical energy from sugars and produces carbon dioxide. - Demonstrate that energy flows qualitatively from sunlight → stored chemical energy in sugars → usable energy released during respiration. <i>Knowledge Extended Beyond Course Expectations</i> - Differentiate energy transfer (sunlight entering the plant system) from energy transformation (light energy stored chemically in sugars and later released during respiration).

Grade, Course, or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
Biology 1	The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. (secondary) (B-LS2-5)	- Communicate how photosynthesis is the primary process by which solar energy is captured and stored as chemical energy in sugars on Earth. - Trace energy flow qualitatively from the Sun to stored chemical energy in sugars and into biological systems within the carbon cycle. - Recognize that stored chemical energy in sugars is released during cellular respiration and can be used to form macromolecules that support organismal structure and function. <i>Knowledge Extended Beyond Course Expectations</i> - None identified.
Chemistry	Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. (C-PS3-4)	- Identify energy dissipation to the environment as a common outcome of chemical and physical processes, even when total energy is conserved. - Explain qualitatively how energy spreading into the surroundings reduces the amount of energy available to do useful work in a system. <i>Knowledge Extended Beyond Course Expectations</i> - None identified.
Physics	Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. (P-PS3-3)	- Identify energy dissipation (heating of air or components, sound) as a typical outcome of energy conversions in systems. - Explain qualitatively how the spreading of energy into the environment limits the ability of a system or device to do useful work. <i>Knowledge Extended Beyond Course Expectations</i> - None identified.
Earth and Space Science	Nuclear Fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. (secondary) (E-ESS1-1)	- State that nuclear fusion in the Sun’s core releases energy that is transported outward and reaches Earth as electromagnetic radiation. - Recognize that changes in solar output can affect the energy input to Earth systems. <i>Knowledge Extended Beyond Course Expectations</i> - Recognize that hydrogen fuses to helium in the Sun, producing photons that radiate through space and influence orbiting planets.

PS4 – Waves and Their Applications in Technologies for Information Transfer

PS4 addresses how waves behave, how electromagnetic radiation interacts with matter, and how waves are used to transmit and process information in technological systems. Across the grade bands, students move from observing how light and sound travel and interact with objects to explaining how wave properties and electromagnetic radiation can be used to describe, predict, and model interactions within and across systems. The PS4 progression emphasizes how waves transfer energy without transporting matter, how electromagnetic radiation interacts with matter in ways that depend on wave properties and energy, and how wave-based systems encode, transmit, and interpret information to support communication, imaging, and measurement technologies across scales.

PS4.A Wave Properties

Students begin by recognizing that vibrating objects produce sound and that sound can cause other objects to vibrate. In upper elementary grades, students explain that waves are repeating patterns of motion produced by disturbances that transfer energy through a medium without transporting matter, and describe waves using properties such as amplitude and wavelength. In middle school, students explain how waves can be described by properties including wavelength, frequency, and amplitude, how these properties determine wave patterns and the energy carried by a wave, and how different types of waves behave depending on the medium and their interactions with materials. In high school, students apply mathematical and conceptual models to describe and predict wave behavior, using relationships among wave speed, wavelength, and frequency and principles such as reflection, refraction, transmission, and interference to explain how waves propagate, interact, and can be used to infer the structure of systems and transmit information across scales.

Progression of PS4.A

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
First Grade	Sound can make matter vibrate and vibrating matter can make sound. (1-PS4-1)	- Recognize that vibrating objects can make sound. - Describe that sound can cause objects to vibrate, even when they are not touching. <i>Knowledge Extended Beyond Course Expectations</i> - Recognize that changing how an object vibrates can change the sound produced, without naming sound properties.

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
Fourth Grade	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. Waves of the same type can differ in amplitude (height of the wave) and wavelength (spacing between wave peaks). (4-PS4-1)	- Describe mechanical waves moving through a material (such as water) as a repeating pattern of motion produced by a disturbance. - Describe differences among waves of the same type using amplitude and wavelength. - Compare the motion of a wave pattern with the motion of the material the wave passes through. - Explain how changes in amplitude or wavelength affect the motion caused by a passing wave. <i>Knowledge Extended Beyond Course Expectations</i> - Identify that a single disturbance can generate a continuing wave pattern even though the material itself does not travel. - Recognize that sound involves vibrations moving through materials without transporting the material itself.
Sixth Grade	A sound wave needs a medium through which it is transmitted. (6-PS4-2)	- Identify sound as a mechanical wave that requires a medium to travel. - Compare mechanical waves and light waves based on whether a medium is required. - Explain that sound waves can be reflected, absorbed, or transmitted when they interact with different materials. <i>Knowledge Extended Beyond Course Expectations</i> - Recognize that sound behaves differently in solids, liquids, and gases without comparing speeds. - Identify that some materials tend to absorb sound while others tend to reflect sound.

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
Eighth Grade	A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. (8-PS4-1)	- Identify a simple wave by describing its wavelength, frequency, and amplitude. - Compare wave patterns by examining differences in wavelength, frequency, or amplitude. - Explain how changes in amplitude correspond to changes in the energy carried by a wave, qualitatively. <i>Knowledge Extended Beyond Course Expectations</i> - Identify frequency as how often a wave repeats over time, without relating it to speed, pitch, or equations. - Analyze how changing one wave property alters the overall repeating pattern of the wave.
Physics	- 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. The reflection, refraction, and transmission of waves at an interface between two media can be modeled on the bases of wave properties. (P-PS4-1) - Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this stable form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. (P-PS4-5) Combining waves of different frequencies can make a wide variety of patterns and thereby encode and transmit information. (P-PS4-2) - 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. (P-PS4-3)	- Apply the relationship among wave speed, wavelength, and frequency to describe how waves change when moving through different media. - Explain reflection, refraction, and transmission by linking wave behavior to changes in medium properties and wave speed. - Analyze constructive and destructive interference by comparing the relative phase of interacting waves. - Explain how combining waves allows information to be encoded and transmitted. <i>Knowledge Extended Beyond Course Expectations</i> - Identify that complex wave patterns can be described as combinations of simpler waves without mathematical decomposition.

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
Earth and Space Science	Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet. (secondary) (E-ESS2-3)	- Describe how seismic waves travel through Earth and change behavior at boundaries between layers, providing evidence of Earth’s interior structure. - Compare seismic wave behaviors to infer differences in Earth’s internal structure. - Explain how reflected and refracted seismic waves provide evidence used to develop models of Earth’s interior. <i>Knowledge Extended Beyond Course Expectations</i> - None identified.

PS4.B Electromagnetic Radiation

Students begin by recognizing that light allows objects to be seen, travels from place to place, and interacts with materials through reflection, transmission, and blocking, producing effects such as shadows. In upper elementary grades, students explain how light travels from a source to objects and reflects from their surfaces to the eye, describe how light interactions vary across materials, and trace light paths through systems to compare how reflection and transmission affect observable outcomes. In middle school, students explain light as a wave that can be reflected, absorbed, transmitted, or refracted, and that differs from mechanical waves in that it does not require a medium. In high school, students apply models of electromagnetic radiation as both waves and particles to describe and predict how light interacts with matter, explaining how frequency determines energy transfer and interactions such as heating, ionization, emission, and electron release, and using these models to interpret phenomena and technologies across systems.

Progression of PS4.B

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
First Grade	• Objects can only be seen if light is available to illuminate them or if they give off their own light. (1-PS4-2) • Light travels from place to place. 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. (1-PS4-3)	• Recognize that objects are visible only when light is present, either because the object gives off light or because light reflects from it. • Describe that light travels from place to place, allowing objects to be visible without direct contact with the light source. • Demonstrate that different materials affect whether light passes through, passes through partially, or is blocked, producing shadows. • Communicate that mirrors can change the direction of light, allowing light to reach new locations. <i>Knowledge Extended Beyond Course Expectations</i> • Recognize that changing the position of a light source changes where light and shadows are visible. • Identify that brighter or dimmer light can change how clearly an object is visible.

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
Fourth Grade	An object can be seen when light reflected from its surface enters the eyes. (4-PS4-2)	- Describe how light travels from a source to an object and reflects from its surface. - Explain that objects are visible when light reflected from their surfaces enters the eyes. - Compare how light reflects from different surfaces and how this affects object visibility. <i>Knowledge Extended Beyond Course Expectations</i> - Recognize that rough and smooth surfaces reflect light differently without describing image formation.
Sixth Grade	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. The path that lights 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. A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media. However, because light can travel through space, it cannot be a matter [sic] wave, like sound or water waves. (6-PS4-2)	- Describe that when light interacts with matter, it may be reflected, absorbed, refracted, or transmitted, depending on the material. - Use a wave model of light to explain differences in brightness and color qualitatively. - Compare light waves and mechanical waves based on whether a medium is required for travel. <i>Knowledge Extended Beyond Course Expectations</i> - None identified.

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
Chemistry	- 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. Atoms of each element emit and absorb characteristic frequencies of light and nuclear transitions have distinctive gamma ray wavelengths, which allows identification of the presence of an element. (C-PS4-4) - Photoelectric materials emit electrons when they absorb light of a high-enough frequency. (C-PS4-5)	- Explain that absorption of longer-wavelength electromagnetic radiation typically results in increased thermal energy in matter. - Explain that absorption of shorter-wavelength electromagnetic radiation can ionize atoms and cause changes to matter, including damage to living cells. - Describe how the characteristic absorption and emission of electromagnetic radiation can be used to identify elements. - Demonstrate that photoelectric materials emit electrons only when electromagnetic radiation of sufficiently high frequency is absorbed. <i>Knowledge Extended Beyond Course Expectation</i> - None identified.
Physics	- 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. (P-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. (P-PS4-4) - Photoelectric materials emit electrons when they absorb light of a high-enough frequency. (P-PS4-5)	- Explain electromagnetic radiation using both wave and particle (photon) models, and describe the strengths and limitations of each. - Analyze electromagnetic phenomena to determine whether a wave or particle model better explains observed behavior. - Explain how electromagnetic radiation transfers energy to matter across the spectrum, depending on frequency. - Analyze the photoelectric effect as evidence that energy transfer depends on frequency rather than intensity. <i>Knowledge Extended Beyond Course Expectations</i> - Identify that energy exchange occurs in discrete amounts, even though electromagnetic wavelengths form a continuous spectrum.

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
Earth and Space Science	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) (E-ESS1-2)	- Explain that elements produce characteristic absorption and emission spectra that can be used to identify their presence. - Describe how spectral data from electromagnetic radiation are used as evidence to determine the composition of Earth and space systems. <i>Knowledge Extended Beyond Course Expectations</i> - Apply spectroscopic evidence to infer material composition where direct sampling is not possible.

PS4.C Information Technologies and Instrumentation

Students begin by recognizing that people use devices to send and receive information over distance. In upper elementary grades, students explain how information can be represented as patterns and transmitted between systems, and describe how information can be digitized, stored, and transmitted as discrete patterns that can be reliably communicated over long distances. In middle school, students explain how waves carry information using encoded patterns and compare digital and continuous signals in terms of reliability, storage, and transmission. In high school, students apply models of wave-based systems to explain and design ways to encode, transmit, store, and decode information, recognizing that controlled interactions between energy and matter generate and detect signals that can be reliably measured, stored, and interpreted in communication, imaging, and scientific instrumentation across systems.

Progression of PS4.C

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
First Grade	People also use a variety of devices to communicate (send and receive information) over long distances. (1-PS4-4)	- Compare ways information is shared over short distances and long distances. - Identify which communication device best allows messages to reach people who are far away. <i>Knowledge Extended Beyond Course Expectations</i> - Recognize that some communication devices are better suited for certain messages than others.
Fourth Grade	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. When in digitized form, information can be recorded, stored for future recovery, and transmitted over long distances without significant degradation of the wave. (4-PS4-3)	- Explain that digitized information can be sent over long distances with little loss of the original message. - Explain that digitized information can be stored and retrieved later without changing the original message. <i>Knowledge Extended Beyond Course Expectations</i> - Recognize that digitized information can be copied repeatedly without altering the message. - Explain that information can be digitized and represented as repeating, discrete patterns. - Describe, at a conceptual level, how information is encoded, transmitted, and decoded in digital communication.

Grade or Content	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked	Disciplinary Core Idea-Aligned Instructional Focus
Eighth Grade	Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information. (8-PS4-3)	- Describe how information is encoded digitally as repeating patterns of wave pulses carried by electromagnetic radiation. - Explain that digitized signals allow information to be copied, stored, and transmitted with less loss than continuous signals. - Identify that the same digital information can be transmitted using different parts of the electromagnetic spectrum. <i>Knowledge Extended Beyond Course Expectations</i> - Recognize that digital information can still be recovered even when parts of the signal are disrupted. - Identify that the same digital information can represent sound, text, or images, regardless of the electromagnetic carrier used.
Chemistry	Multiple technologies based on the understanding of energy 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. (C-PS4-5)	- Describe how electromagnetic radiation interacting with matter is used to produce signals in imaging and communication technologies. - Identify how these technologies support everyday applications and scientific investigation. - Recognize that different technologies rely on different regions of the electromagnetic spectrum. <i>Knowledge Extended Beyond Course Expectations</i> - Identify that instruments convert energy–matter interactions into digital data for analysis or storage.
Physics	Multiple technologies based on the understanding of energy 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. (P-PS4-5)	- Explain how controlled interactions between energy and matter enable technologies to generate and detect signals that carry information. - Describe how energy transfers allow information to be encoded, transmitted, and decoded within communication and measurement systems. - Analyze how predictable wave behavior and signal detection support the reliable storage and interpretation of information. <i>Knowledge Extended Beyond Course Expectations</i> - Explain how scientific instruments extend observation by converting physical signals into data that can be analyzed.

References

- National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: The National Academies Press.
- NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States (Appendix E: Disciplinary Core Idea Progression)*. Retrieved from <https://www.nextgenscience.org/>