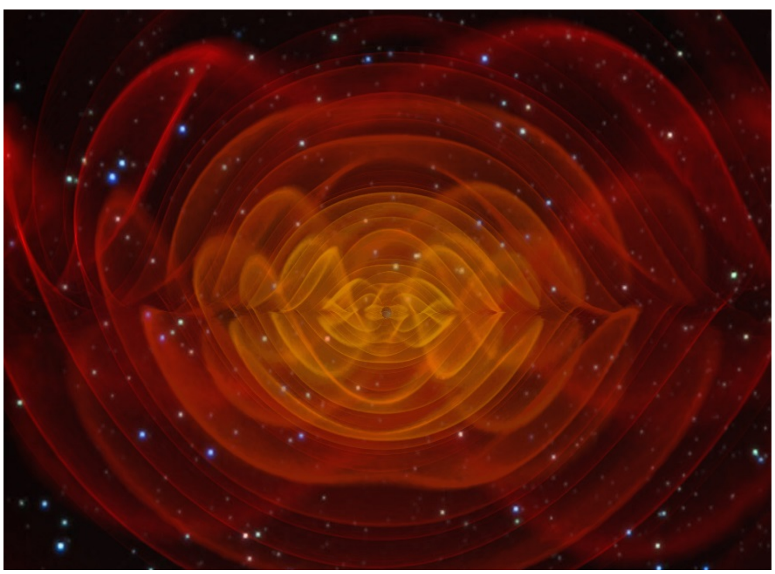
Unpacked Physical Sciences: A Compilation of the *Framework for K-12 Science Education*, NGSS Storylines, and the *New Jersey Student Learning Standards for Science*



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Contents

Introduction

Understanding the Performance Expectations (PE) in the *New Jersey Student Learning Standards for Science* (NJSLS) is made easier when one leverages the documents that accompany it. In an effort to support teachers in developing a clear and accurate understanding of the PEs, this document compiles *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (Framework) (NRC, 2012), *Example Storylines for the NGSS* by *Disciplinary Core Idea* (storyline) (NGSS Lead States, 2016), and the *New Jersey Student Learning Standards for Science* (NGSS Lead States, 2013). Each of these documents provide a different perspective and level of detail about the Performance Expectations in the science standards. This compilation was developed at the request of educators who reported that using all of the documents simultaneously is cumbersome and often confusing.

Educators who have piloted the use of the document make the following recommendations.

a) Take the time to read the essential question and narrative for the Disciplinary Core Ideas. This provides a macro-structure for student learning and a description of how its Component Idea fit together.

b) Read the essential question and overview for each Component Idea. This provides a kindergarten through grade 12 structure for student learning and how the Elements fit together. An Element is the grade specific or grade level expectation.

c) Pay attention to the essential questions throughout the document. These questions provide an organizational structure for student learning.

Credits:

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. Washington, DC: The National Academies Press.

NGSS Lead States. 2013. “Appendix F - Science and Engineering Practices in the NGSS.” Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

NGSS Lead States. 2013. “Appendix G – Crosscutting Concepts in the NGSS.” Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

NGSS Lead States. 2013. “Example Storylines for the NGSS by DCI” doi: http://www.nextgenscience.org/resources/example-storylines-ngss-dci

PS1: Matter and Its Interactions

Overview of Matter and Its Interactions from Kindergarten through Grade 12

How can one explain the structure, properties, and interactions of matter?

The existence of atoms, now supported by evidence from modern instruments, was first postulated as a model that could explain both qualitative and quantitative observations about matter (e.g., Brownian motion, ratios of reactants and products in chemical reactions). Matter can be understood in terms of the types of atoms present and the interactions both between and within them. The states (i.e., solid, liquid, gas, or plasma), properties (e.g., hardness, conductivity), and reactions (both physical and chemical) of matter can be described and predicted based on the types, interactions, and motions of the atoms within it. Chemical reactions, which underlie so many observed phenomena in living and nonliving systems alike, conserve the number of atoms of each type but change their arrangement into molecules. Nuclear reactions involve changes in the types of atomic nuclei present and are key to the energy release from the sun and the balance of isotopes in matter.

PS1.A: Structure and Properties of Matter

Overview of Structure and Properties of Matter from Kindergarten through Grade 12

How do particles combine to form the variety of matter one observes?

While too small to be seen with visible light, atoms have substructures of their own. They have a small central region or nucleus—containing protons and neutrons—surrounded by a larger region containing electrons. The number of protons in the atomic nucleus (atomic number) is the defining characteristic of each element; different isotopes of the same element differ in the number of neutrons only. Despite the immense variation and number of substances, there are only some 100 different stable elements.

Each element has characteristic chemical properties. The periodic table, a systematic representation of known elements, is organized horizontally by increasing atomic number and vertically by families of elements with related chemical properties. The development of the periodic table (which occurred well before atomic substructure was understood) was a major advance, as its patterns suggested and led to the identification of additional elements with particular properties. Moreover, the table's patterns are now recognized as related to the atom's outermost electron patterns, which play an important role in explaining chemical reactivity and bond formation, and the periodic table continues to be a useful way to organize this information.

The substructure of atoms determines how they combine and rearrange to form all of the world's substances. Electrical attractions and repulsions between charged particles (i.e., atomic nuclei and electrons) in matter explain the structure of atoms and the forces between atoms that cause them to form molecules (via chemical bonds), which range in size from two to thousands of atoms (e.g., in biological molecules such as proteins). Atoms also combine due to these forces to form extended structures, such as crystals or metals. The varied properties (e.g., hardness, conductivity) of the materials one encounters, both natural and manufactured, can be understood in terms of the atomic and molecular constituents present and the forces within and between them.

Within matter, atoms and their constituents are constantly in motion. The arrangement and motion of atoms vary in characteristic ways, depending on the substance and its current state (e.g., solid, liquid). Chemical composition, temperature, and pressure affect such arrangements and motions of atoms, as well as the ways in which they interact. Under a given set of conditions, the state and some properties (e.g., density, elasticity, viscosity) are the same for different bulk quantities of a substance, whereas other properties (e.g., volume, mass) provide measures of the size of the sample at hand.

Materials can be characterized by their intensive measureable properties. Different materials with different properties are suited to different uses. The ability to image and manipulate placement of individual atoms in tiny structures allows for the design of new types of materials with particular desired functionality (e.g., plastics, nanoparticles). Moreover, the modern explanation of how particular atoms influence the properties of materials or molecules is critical to understanding the physical and chemical functioning of biological systems.

Grade 2:

How are materials similar and different from one another?

How do the properties of the materials relate to their use?

Different kinds of matter exist (e.g., wood, metal, water), and many of them can be either solid or liquid, depending on temperature. Matter can be described and classified by its observable properties (e.g., visual, aural, textural), by its uses, and by whether it occurs naturally or is manufactured. Different properties are suited to different purposes. A great variety of objects can be built up from a small set of pieces (e.g., blocks, construction sets). Objects or samples of a substance can be weighed, and their size can be described and measured. (Boundary: volume is introduced only for liquid measure.)

Table 1: Performance Expectations for Grade 2

Standard Code	Performance Expectation
2-PS1-1	**Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties.** *[Clarification Statement: Observations could include color, texture, hardness, and flexibility. Patterns could include the similar properties that different materials share.]* Click here for the Evidence Statement for 2-PS1-1.
2-PS1-2	**Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose.*** *[Clarification Statement: Examples of properties could include, strength, flexibility, hardness, texture, and absorbency.]* [Assessment Boundary: Assessment of quantitative measurements is limited to length.*]*

Standard Code	Performance Expectation
	Click here for the Evidence Statement for 2-PS1-2.
2-PS1-3	**Make observations to construct an evidence-based account of how an object made of a small set of pieces can be disassembled and made into a new object.** *[Clarification Statement: Examples of pieces could include blocks, building bricks, or other assorted small objects.]* Click here for the Evidence Statement for 2-PS1-3.

Grade 5:

When matter changes, does its weight change?

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 (e.g., by weighing or by its effects on other objects). For example, a model showing that gases are made from matter particles that are too small to see and are moving freely around in space can explain many observations, including the inflation and shape of a balloon; the effects of air on larger particles or objects (e.g., leaves in wind, dust suspended in air); and the appearance of visible scale water droplets in condensation, fog, and, by extension, also in clouds or the contrails of a jet. The amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish (e.g., sugar in solution, evaporation in a closed container). Measurements of a variety of properties (e.g., hardness, reflectivity) can be used to identify particular 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.)

Table 2: Performance Expectations for Grade 5

Standard Code	Performance Expectation
5-PS1-1	**Develop a model to describe that matter is made of particles too small to be seen.** *[Clarification Statement: Examples of evidence supporting a model could include adding air to expand a basketball, compressing air in a syringe, dissolving sugar in water, and evaporating salt water.]* [Assessment Boundary: Assessment does not include the atomic-scale mechanism of evaporation and condensation or defining the unseen particles.] Click here for the Evidence Statement for 5-PS1-1.
5-PS1-2	**Measure and graph quantities to provide evidence that regardless of the type of change that occurs when heating, cooling, or mixing substances, the total weight of matter is conserved.** *[Clarification Statement: Examples of reactions or changes could include phase changes, dissolving, and mixing that form new substances.]* [Assessment Boundary: Assessment does not include distinguishing mass and weight.]

Standard Code	Performance Expectation
	Click here for the Evidence Statement for 5-PS1-2.
5-PS1-3	**Make observations and measurements to identify materials based on their properties.** *[Clarification Statement: Examples of materials to be identified could include baking soda and other powders, metals, minerals, and liquids. Examples of properties could include color, hardness, reflectivity, electrical conductivity, thermal conductivity, response to magnetic forces, and solubility; density is not intended as an identifiable property.]* [Assessment Boundary: Assessment does not include density or distinguishing mass and weight.*]* Click here for the Evidence Statement for 5-PS1-3.

Grades 6 through 8:

How do atomic and molecular interactions explain the properties of matter that we see and feel?

All substances are made from some 100 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. Pure substances are made from a single type of atom or molecule; each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.

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 each other; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and vibrate in position but do not change relative locations. Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals). The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. (Boundary: Predictions here are qualitative, not quantitative.)

Table 3: Performance Expectations for Grades 6 through 8

Standard Code	Performance Expectation
MS-PS1-1	**Develop models to describe the atomic composition of simple molecules and extended structures.** *[Clarification Statement: Emphasis is on developing models of molecules that vary in complexity. Examples of simple molecules could include ammonia and methanol. Examples of extended structures could include sodium chloride or diamonds. Examples of molecular-level models could include drawings, 3D ball and stick structures, or computer representations showing different molecules with different types of atoms.]* [Assessment Boundary: Assessment does not include valence electrons and bonding energy, discussing the ionic nature of subunits of complex structures, or a complete description of

Standard Code	Performance Expectation
	all individual atoms in a complex molecule or extended structure is not required.*]* Click here for the Evidence Statement for MS-PS1-1.
MS-PS1-2	**Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.** *[Clarification Statement: Examples of reactions could include burning sugar or steel wool, fat reacting with sodium hydroxide, and mixing zinc with hydrogen chloride.] [*Assessment boundary: Assessment is limited to analysis of the following properties: density, melting point, boiling point, solubility, flammability, and odor.*]* Click here for the Evidence Statement for MS-PS1-2.
MS-PS1-3	**Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.** *[Clarification Statement: Emphasis is on natural resources that undergo a chemical process to form the synthetic material. Examples of new materials could include new medicine, foods, and alternative fuels.] [*Assessment Boundary: Assessment is limited to qualitative information.*]* Click here for the Evidence Statement for MS-PS1-3.
MS-PS1-4	**Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.** *[Clarification Statement: Emphasis is on qualitative molecular-level models of solids, liquids, and gases to show that adding or removing thermal energy increases or decreases kinetic energy of the particles until a change of state occurs. Examples of models could include drawing and diagrams. Examples of particles could include molecules or inert atoms. Examples of pure substances could include water, carbon dioxide, and helium.]* Click here for the Evidence Statement for MS-PS1-4.

Grades 9 through 12:

How can one explain the structure, properties, and interactions of matter?

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. The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. Stable forms of matter are those in which the electric and magnetic field energy is minimized. A stable molecule has less energy, by an amount known as the binding energy, than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart.

Table 4: Performance Expectations for Grades 9 through 12

Standard Code	Performance Expectation
HS-PS1-1	**Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.** *[Clarification Statement: Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen.]* [Assessment Boundary: Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.*]* Click here for the Evidence Statement for HS-PS1-1.
HS-PS1-2	**Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.** *[Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.]* [Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.*]* Click here for the Evidence Statement for HS-PS1-2.
HS-PS1-3	**Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.** *[Clarification Statement: Emphasis is on understanding the strengths of forces between particles, not on naming specific intermolecular forces (such as dipole-dipole). Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite). Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.]* [Assessment Boundary: Assessment does not include Raoult's law calculations of vapor pressure.*]* Click here for the Evidence Statement for HS-PS1-3.
HS-PS1-4	**Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.** *[Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.]* [Assessment Boundary: Assessment does not include calculating

Standard Code	Performance Expectation
	the total bond energy changes during a chemical reaction from the bond energies of reactants and products.*]* Click here for the Evidence Statement for HS-PS1-4.

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PS1.B: Chemical Reactions

Overview of Chemical Reactions from Kindergarten through Grade 12

How do substances combine or change (react) to make new substances?

How does one characterize and explain these reactions and make predictions about them?

Many substances react chemically with other substances to form new substances with different properties. This change in properties results from the ways in which atoms from the original substances are combined and rearranged in the new substances. However, the total number of each type of atom is conserved (does not change) in any chemical process, and thus mass does not change either. The property of conservation can be used, along with knowledge of the chemical properties of particular elements, to describe and predict the outcomes of reactions. Changes in matter in which the molecules do not change, but their positions and their motion relative to each other do change also occur (e.g., the forming of a solution, a change of state). Such changes are generally easier to reverse (return to original conditions) than chemical changes.

“Collision theory” provides a qualitative model for explaining the rates of chemical reactions. Higher rates occur at higher temperatures because atoms are typically moving faster and thus collisions are more frequent; also, a larger fraction of the collisions have sufficient energy to initiate the process. Although a solution or a gas may have constant chemical composition—that is, be in a steady state—chemical reactions may be occurring within it that are dynamically balanced with reactions in opposite directions proceeding at equal rates.

Any chemical process involves a change in chemical bonds and the related bond energies and thus in the total chemical binding energy. This change is matched by a difference between the total kinetic energy of the set of reactant molecules before the collision and that of the set of product molecules after the collision (conservation of energy). Some reactions release energy (e.g., burning fuel in the presence of oxygen), and others require energy input (e.g., synthesis of sugars from carbon dioxide and water).

Understanding chemical reactions and the properties of elements is essential not only to the physical sciences but also is foundational knowledge for the life sciences and the earth and space sciences. The cycling of matter and associated transfers of energy in systems, of any scale, depend on physical and chemical processes. The reactivity of hydrogen ions gives rise to many biological and geophysical phenomena. The capacity of carbon atoms to form the backbone of extended molecular structures is essential to the chemistry of life. The carbon cycle involves transfers between carbon in the atmosphere—in the form of carbon dioxide—and carbon in living matter or formerly living matter (including fossil fuels). The proportion of oxygen molecules (i.e., oxygen in the form O_2) in the atmosphere also changes in this cycle.

Grade 2:

How are materials similar and different from one another?

How do the properties of the materials relate to their use?

Heating or cooling a substance may cause changes that can be observed. Sometimes these changes are reversible (e.g., melting and freezing), and sometimes they are not (e.g., baking a cake, burning fuel).

Table 5: Performance Expectation for Grade 2

Standard Code	Performance Expectation
2-PS1-4	**Construct an argument with evidence that some changes caused by heating or cooling can be reversed and some cannot.** *[Clarification Statement: Examples of reversible changes could include materials such as water and butter at different temperatures. Examples of irreversible changes could include cooking an egg, freezing a plant leaf, and heating paper.]* Click here for the Evidence Statement for 2-PS1-4.

Grade 5:

Can new substances be created by combining other substances?

When two or more different substances are mixed, a new substance with different properties may be formed; such occurrences depend on the substances and the temperature. 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.)

Table 6: Performance Expectations for Grade 5

Standard Code	Performance Expectation
5-PS1-2	**Measure and graph quantities to provide evidence that regardless of the type of change that occurs when heating, cooling, or mixing substances, the total weight of matter is conserved.** *[Clarification Statement: Examples of reactions or changes could include phase changes, dissolving, and mixing that form new substances.]* [Assessment Boundary: Assessment does not include distinguishing mass and weight.] Click here for the Evidence Statement for 5-PS1-2.
5-PS1-4	**Conduct an investigation to determine whether the mixing of two or more substances results in new substances.** Click here for the Evidence Statement for 5-PS1-4.

Grades 6 through 8:

How do atomic and molecular interactions explain the properties of matter that we see and feel?

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. The total number of each type of atom is conserved, and thus the mass does not change. Some chemical reactions release energy, others store energy.

Table 7: Performance Expectations for Grades 6 through 8

Standard Code	Performance Expectation
MS-PS1-2	**Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.** *[Clarification Statement: Examples of reactions could include burning sugar or steel wool, fat reacting with sodium hydroxide, and mixing zinc with hydrogen chloride.]* [Assessment boundary: Assessment is limited to analysis of the following properties: density, melting point, boiling point, solubility, flammability, and odor.*]* Click here for the Evidence Statement for MS-PS1-2.
MS-PS1-3	**Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.** *[Clarification Statement: Emphasis is on natural resources that undergo a chemical process to form the synthetic material. Examples of new materials could include new medicine, foods, and alternative fuels.]* [Assessment Boundary: Assessment is limited to qualitative information.*]* Click here for the Evidence Statement for MS-PS1-3.
MS-PS1-5	**Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.** *[Clarification Statement: Emphasis is on law of conservation of matter and on physical models or drawings, including digital forms, which represent atoms.]* [Assessment Boundary: Assessment does not include the use of atomic masses, balancing symbolic equations, or intermolecular forces.*]* Click here for the Evidence Statement for MS-PS1-5.
MS-PS1-6	**Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.*** *[Clarification Statement: Emphasis is on the design, controlling the transfer of energy to the environment, and modification of a device using factors such as type and concentration of a substance. Examples of designs could involve chemical*

Standard Code	Performance Expectation
	reactions such as dissolving ammonium chloride or calcium chloride.] [Assessment Boundary: Assessment is limited to the criteria of amount, time, and temperature of substance in testing the device.*]* Click here for the Evidence Statement for MS-PS1-6.

Grades 9 through 12:

How do substances combine or change (react) to make new substances?

How does one characterize and explain these reactions and make predictions about them?

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 total binding energy (i.e., the sum of all bond energies in the set of molecules) that are matched by changes in kinetic energy. 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.

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. Chemical processes and properties of materials underlie many important biological and geophysical phenomena.

Table 8: Performance Expectations for Grades 9 through 12

Standard Code	Performance Expectation
HS-PS1-2	**Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.** *[Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.] [*Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.*]* Click here for the Evidence Statement for HS-PS1-2.
HS-PS1-4	**Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.** *[Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.] [*Assessment Boundary: Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.*]*

Standard Code	Performance Expectation
	Click here for the Evidence Statement for HS-PS1-4.
HS-PS1-5	**Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.** *[Clarification Statement: Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules.]* [Assessment Boundary: Assessment is limited to simple reactions in which there are only two reactants; evidence from temperature, concentration, and rate data; and qualitative relationships between rate and temperature.*]* Click here for the Evidence Statement for HS-PS1-5.
HS-PS1-6	**Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.*** *[Clarification Statement: Emphasis is on the application of Le Chatelier's Principle and on refining designs of chemical reaction systems, including descriptions of the connection between changes made at the macroscopic level and what happens at the molecular level. Examples of designs could include different ways to increase product formation including adding reactants or removing products.]* [Assessment Boundary: Assessment is limited to specifying the change in only one variable at a time. Assessment does not include calculating equilibrium constants and concentrations.*]* Click here for the Evidence Statement for HS-PS1-6.
HS-PS1-7	**Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.** *[Clarification Statement: Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem-solving techniques.]* [Assessment Boundary: Assessment does not include complex chemical reactions.*]* Click here for the Evidence Statement for HS-PS1-7.

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PS1.C: Nuclear Processes

Overview of Nuclear Processes from Grades 6 through 8

What forces hold nuclei together and mediate nuclear processes?

Phenomena involving nuclei are important to understand, as they explain the formation and abundance of the elements, radioactivity, the release of energy from the sun and other stars, and the generation of nuclear power. To explain and predict nuclear processes, two additional types of interactions—known as strong and weak nuclear interactions—must be introduced. They play a fundamental role in nuclei, although not at larger scales because their effects are very short range.

The strong nuclear interaction provides the primary force that holds nuclei together and determines nuclear binding energies. Without it, the electromagnetic forces between protons would make all nuclei other than hydrogen unstable. Nuclear processes mediated by these interactions include fusion, fission, and the radioactive decays of unstable nuclei. These processes involve changes in nuclear binding energies and masses (as described by E = mc2), and typically they release much more energy per atom involved than do chemical processes.

Nuclear fusion is a process in which a collision of two small nuclei eventually results in the formation of a single more massive nucleus with greater net binding energy and hence a release of energy. It occurs only under conditions of extremely high temperature and pressure. Nuclear fusion occurring in the cores of stars provides the energy released (as light) from those stars. The Big Bang produced matter in the form of hydrogen and smaller amounts of helium and lithium. Over time, stars (including supernova explosions) have produced and dispersed all the more massive atoms, starting from primordial low-mass elements, chiefly hydrogen.

Nuclear fission is a process in which a massive nucleus splits into two or more smaller nuclei, which fly apart at high energy. The produced nuclei are often not stable and undergo subsequent radioactive decays. A common fission fragment is an alpha particle, which is just another name for a helium nucleus, given before this type of “radiation” was identified.

In addition to alpha particles, other types of radioactive decays produce other forms of radiation, originally labeled as “beta” and “gamma” particles and now recognized as electrons or positrons, and photons (i.e., high-frequency electromagnetic radiation), respectively. Because of the high-energy release in nuclear transitions, the emitted radiation (whether it be alpha, beta, or gamma type) can ionize atoms and may thereby cause damage to biological tissue.

Nuclear fission and radioactive decays limit the set of stable isotopes of elements and the size of the largest stable nucleus. Spontaneous radioactive decays follow a characteristic exponential decay law, with a specific lifetime (time scale) for each such process; the lifetimes of different nuclear decay processes range from fractions of a second to thousands of years. Some unstable but long-lived isotopes are present in rocks and minerals. Knowledge of their nuclear lifetimes allows radiometric dating to be used to determine the ages of rocks and other materials from the isotope ratios present.

In fission, fusion, and beta decay processes, atoms change type, but the total number of protons plus neutrons is conserved. Beta processes involve an additional type of interaction (the weak interaction) that can change neutrons into protons or vice versa, along with the emission or absorption of electrons or positrons and of neutrinos. Isolated neutrons decay by this process.

Grades K, 1, and 2: [Intentionally left blank.]

Grades 3, 4, and 5: [Intentionally left blank.]

Grades 6 through 8: There are no Performance Expectations for **PS1.C** in grades 6 through 8.

Nuclear fusion can result in the merging of two nuclei to form a larger one, along with the release of significantly more energy per atom than any chemical process. It occurs only under conditions of extremely high temperature and pressure. Nuclear fusion taking place in the cores of stars provides the energy released (as light) from those stars and produced all of the more massive atoms from primordial hydrogen. Thus the elements found on Earth and throughout the universe (other than hydrogen and most of helium, which are primordial) were formed in the stars or supernovas by fusion processes.

Grades 9 through 12:

What forces hold nuclei together and mediate nuclear processes?

Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve changes in nuclear binding energies. The total number of neutrons plus protons does not change in any nuclear process. Strong and weak nuclear interactions determine nuclear stability and processes. Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials from the isotope ratios present. (*Secondary to HS-ESS1-5 and HS-ESS1-6*)

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.

Table 9: Performance Expectation for Grades 9 through 12

Standard Code	Performance Expectation
HS-PS1-8	**Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.** *[Clarification Statement: Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations.]* [Assessment Boundary: Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.*]* Click here for the Evidence Statement for HS-PS1-8.

PS2: Motion and Stability: Forces and Interactions

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Overview of Motion and Stability: Forces and Interactions from Kindergart

How can one explain and predict interactions between objects and within systems of objects?

Interactions between any two objects can cause changes in one or both of them. An understanding of the forces between objects is important for describing how their motions change, as well as for predicting stability or instability in systems at any scale. All forces between objects arise from a few types of interactions: gravity, electromagnetism, and the strong and weak nuclear interactions.

PS2.A: Forces and Motion

Overview of Forces and Motion from Kindergarten through Grade 12

How can one predict an object's continued motion, changes in motion, or stability?

Interactions of an object with another object can be explained and predicted using the concept of forces, which can cause a change in motion of one or both of the interacting objects. An individual force acts on one particular object and is described by its strength and direction. The strengths of forces can be measured and their values compared.

What happens when a force is applied to an object depends not only on that force but also on all the other forces acting on that object. A static object typically has multiple forces acting on it, but they sum to zero. If the total (vector sum) force on an object is not zero, however, its motion will change. Sometimes forces on an object can also change its shape or orientation. 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).

At the macroscale, the motion of an object subject to forces is governed by Newton's second law of motion. Under everyday circumstances, the mathematical expression of this law in the form $F = ma$ (total force = mass times acceleration) accurately predicts changes in the motion of a single macroscopic object of a given mass due to the total force on it. But at speeds close to the speed of light, the second law is not applicable without modification. Nor does it apply to objects at the molecular, atomic, and subatomic scales, or to an object whose mass is changing at the same time as its speed.

For speeds that are small compared with the speed of light, the momentum of an object is defined as its mass times its velocity. For any system of interacting objects, the total momentum within the system changes only due to transfer of momentum into or out of the system, either because of external forces acting on the system or because of matter flows. Within an isolated system of interacting objects, any change in momentum of one object is balanced by an equal and oppositely directed change in the total momentum of the other objects. Thus total momentum is a conserved quantity.

Kindergarten:

What happens if you push or pull an object harder?

Objects pull or push each other when they collide or are connected. 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. An object sliding on a surface or sitting on a slope experiences a pull due to friction on the object due to the surface that opposes the object's motion.

Table 10: Performance Expectation for Kindergarten

Standard Code	Performance Expectation
K-PS2-1[1]	**Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.** *[Clarification Statement: Examples of pushes or pulls could include a string attached to an object being pulled, a person pushing an object, a person stopping a rolling ball, and two objects colliding and pushing on each other.]* *[*Assessment Boundary: Assessment is limited to different relative strengths or different directions, but not both at the same time. Assessment does not include non-contact pushes or pulls such as those produced by magnets.*]* Click here for the Evidence Statement K-PS2-1.
K-PS2-2	**Analyze data to determine if a design solution works as intended to change the speed or direction of an object with a push or a pull.*** *[Clarification Statement: Examples of problems requiring a solution could include having a marble or other object move a certain distance, follow a particular path, and knock down other objects. Examples of solutions could include tools such as a ramp to increase the speed of the object and a structure that would cause an object such as a marble or ball to turn.]* [Assessment Boundary: Assessment does not include friction as a mechanism for change in speed.*]* Click here for the Evidence Statement K-PS2-2.

Grade 3:

How do equal and unequal forces on an object affect the object?

Each force acts on one particular object and has both a 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.) The patterns of an object's motion in various situations can be observed and measured; when 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.)

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[1] K-PS2-1 appears in kindergarten PS2.A: Forces and Motion, PS2.B: Types of Interactions and PS3.C: Relationship between Energy and Forces.

Table 11: Performance Expectations for Grade 3

Standard Code	Performance Expectation
3-PS2-1	**Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.** *[Clarification Statement: Examples could include an unbalanced force on one side of a ball can make it start moving; and, balanced forces pushing on a box from both sides will not produce any motion at all.]* [Assessment Boundary: Assessment is limited to one variable at a time: number, size, or direction of forces. Assessment does not include quantitative force size, only qualitative and relative. Assessment is limited to gravity being addressed as a force that pulls objects down.] Click here for the Evidence Statement for 3-PS2-1.
3-PS2-2	**Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.** *[Clarification Statement: Examples of motion with a predictable pattern could include a child swinging in a swing, a ball rolling back and forth in a bowl, and two children on a see-saw.]* [Assessment Boundary: Assessment does not include technical terms such as period and frequency.] Click here for the Evidence Statement for 3-PS2-2.

Grades 6 through 8:

How can one explain and predict interactions between objects and within systems of objects?

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). 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. Forces on an object can also change its shape or orientation. 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.

Table 12: Performance Expectations for Grades 6 through 8

Standard Code	Performance Expectation
MS-PS2-1	**Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.*** *[Clarification Statement: Examples of practical problems could include the impact of collisions between two cars, between a car and stationary objects, and between a meteor and a space*

Standard Code	Performance Expectation
	*vehicle.] [*Assessment Boundary: Assessment is limited to vertical or horizontal interactions in one dimension.*]* Click here for the [Evidence Statement for MS-PS2-1]().
MS-PS2-2	**Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.** *[Clarification Statement: Emphasis is on balanced (Newton's First Law) and unbalanced forces in a system, qualitative comparisons of forces, mass and changes in motion (Newton's Second Law), frame of reference, and specification of units.] [*Assessment Boundary: Assessment is limited to forces and changes in motion in one-dimension in an inertial reference frame and to change in one variable at a time. Assessment does not include the use of trigonometry.*]* Click here for the [Evidence Statement for MS-PS2-2]().

Grades 9 through12:

How can one explain and predict interactions between objects and within systems of objects?

Newton's second law accurately predicts changes in the motion of macroscopic objects, but it requires revision for subatomic scales or for speeds close to the speed of light. (Boundary: No details of quantum physics or relativity are included at this grade level.)

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. 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.

Table 13: Performance Expectations for Grades 9 through 12

Standard Code	Performance Expectation
HS-PS2-1	**Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration**. *[Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.] [*Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.*]* Click here for the [Evidence Statement for HS-PS2-1]().
HS-PS2-2	**Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on**

Standard Code	Performance Expectation
	the system. *[Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.]* *[*Assessment Boundary: Assessment is limited to systems of two macroscopic bodies moving in one dimension.*]* Click here for the Evidence Statement for HS-PS2-2.
HS-PS2-3	**Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.*** *[Clarification Statement: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.]* *[*Assessment Boundary: Assessment is limited to qualitative evaluations and/or algebraic manipulations.*]* Click here for the Evidence Statement for HS-PS2-3.

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PS2.B: Types of Interactions

Overview of Types of Interactions from Kindergarten through Grade 12

What underlying forces explain the variety of interactions we observe?

All forces between objects arise from a few types of interactions: gravity, electromagnetism, and strong and weak nuclear interactions. Collisions between objects involve forces between them that can change their motion. Any two objects in contact also exert forces on each other that are electromagnetic in origin. These forces result from deformations of the objects' substructures and the electric charges of the particles that form those substructures (e.g., a table supporting a book, friction forces).

Gravitational, electric, and magnetic forces between a pair of objects do not require that they be in contact. These forces are explained by force fields that contain energy and can transfer energy through space. These fields can be mapped by their effect on a test object (mass, charge, or magnet, respectively).

Objects with mass are sources of gravitational fields and are affected by the gravitational fields of all other objects with mass. Gravitational forces are always attractive. For two human-scale objects, these forces are too small to observe without sensitive instrumentation. Gravitational interactions are non-negligible, however, when very massive objects are involved. Thus the gravitational force due to Earth, acting on an object near Earth's surface, pulls that object toward the planet's center. Newton's law of universal gravitation provides the mathematical model to describe and predict the effects of gravitational forces between distant objects. These long-range gravitational interactions govern the evolution and maintenance of large-scale structures in the universe (e.g., the solar system, galaxies) and the patterns of motion within them.

Electric forces and magnetic forces are different aspects of a single electromagnetic interaction. Such forces can be attractive or repulsive, depending on the relative sign of the electric charges involved, the direction of current flow, and the orientation of magnets. The forces' magnitudes depend on the magnitudes of the charges, currents, and magnetic strengths as well as on the distances between the interacting objects. All objects with electrical charge or magnetization are sources of electric or magnetic fields and can be affected by the electric or magnetic fields of other such objects. Attraction and repulsion of electric charges at the atomic scale explain the structure, properties, and transformations of matter and the contact forces between material objects (link to PS1.A and PS1.B). Coulomb's law provides the mathematical model to describe and predict the effects of electrostatic forces (relating to stationary electric charges or fields) between distant objects.

The strong and weak nuclear interactions are important inside atomic nuclei. These short-range interactions determine nuclear sizes, stability, and rates of radioactive decay (see PS1.C).

Kindergarten:

What happens if you push or pull an object harder?

When objects touch or collide, they push on one another and can change motion or shape.

Table 14: Performance Expectation for Kindergarten

Standard Code	Performance Expectation
K-PS2-1[2]	**Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.** *[Clarification Statement: Examples of pushes or pulls could include a string attached to an object being pulled, a person pushing an object, a person stopping a rolling ball, and two objects colliding and pushing on each other.]* *[*Assessment Boundary: Assessment is limited to different relative strengths or different directions, but not both at the same time. Assessment does not include non-contact pushes or pulls such as those produced by magnets.*]* Click here for the Evidence Statement for K-PS2-1.

Grade 3:

How do equal and unequal forces on an object affect the object? How can magnets be used?

Objects in contact exert forces on each other (friction, elastic pushes and pulls). Electric, magnetic, and gravitational forces between a pair of objects do not require that the objects be in contact—for example, magnets push or pull at a distance. 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.

Table 15: Performance Expectations for Grade 3

Standard Code	Performance Expectation
3-PS2-1	**Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.** *[Clarification Statement: Examples could include an unbalanced force on one side of a ball can make it start moving; and, balanced forces pushing on a box from both sides will not produce any motion at all.]* [Assessment Boundary: Assessment is limited to one variable at a time: number, size, or direction of forces. Assessment does not include quantitative force size, only qualitative and relative. Assessment is limited to gravity being addressed as a force that pulls objects down.*]* Click here for the Evidence Statement for 3-PS2-1.

[2] K-PS2-1 appears in kindergarten PS2.A: Forces and Motion, PS2.B: Types of Interactions and PS3.C: Relationship between Energy and Forces.

Standard Code	Performance Expectation
3-PS2-3	**Ask questions to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other.** *[Clarification Statement: Examples of an electric force could include the force on hair from an electrically charged balloon and the electrical forces between a charged rod and pieces of paper; examples of a magnetic force could include the force between two permanent magnets, the force between an electromagnet and steel paperclips, and the force exerted by one magnet versus the force exerted by two magnets. Examples of cause and effect relationships could include how the distance between objects affects strength of the force and how the orientation of magnets affects the direction of the magnetic force.]* *[*Assessment Boundary: Assessment is limited to forces produced by objects that can be manipulated by students, and electrical interactions are limited to static electricity.*]* Click here for the Evidence Statement for 3-PS2-3.
3-PS2-4	**Define a simple design problem that can be solved by applying scientific ideas about magnets.*** *[Clarification Statement: Examples of problems could include constructing a latch to keep a door shut and creating a device to keep two moving objects from touching each other.]* Click here for the Evidence Statement for 3-PS2-4.

Grade 5:

How can we explain why objects do not fall sideways?

The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center.

Table 16: Performance Expectation for Grade 5

Standard Code	Performance Expectation
5-PS2-1	**Support an argument that the gravitational force exerted by Earth on objects is directed down.** *[Clarification Statement: "Down" is a local description of the direction that points toward the center of the spherical Earth.]* *[*Assessment Boundary: Assessment does not include mathematical representation of gravitational force.*]* Click here for the Evidence Statement for 5-PS2-1.

Grades 6 through 8:

Why are some materials attracted to each other?

Why do some materials attract each other while others repel?

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. 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—for example, Earth and the sun. Long-range gravitational interactions govern the evolution and maintenance of large-scale systems in space, such as galaxies or the solar system, and determine the patterns of motion within those structures.

Forces that act at a distance (gravitational, electric, and magnetic) can be explained by force 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).

Table 17: Performance Expectations for Grades 6 through 8

Standard Code	Performance Expectation
MS-PS2-3	**Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.** *[Clarification Statement: Examples of devices that use electric and magnetic forces could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or the effect of increasing the number or strength of magnets on the speed of an electric motor.]* [Assessment Boundary: Assessment about questions that require quantitative answers is limited to proportional reasoning and algebraic thinking.*]* Click here for the Evidence Statement for MS-PS2-3.
MS-PS2-4	**Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.** *[Clarification Statement: Examples of evidence for arguments could include data generated from simulations or digital tools; and charts displaying mass, strength of interaction, distance from the Sun, and orbital periods of objects within the solar system.]* [Assessment Boundary: Assessment does not include Newton's Law of Gravitation or Kepler's Laws.*]* Click here for the Evidence Statement for MS-PS2-4.
MS-PS2-5	**Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.** *[Clarification Statement: Examples of this phenomenon could include the interactions of magnets, electrically-charged strips of tape, and electrically-charged pith balls. Examples of investigations*

Standard Code	Performance Expectation
	could include first-hand experiences or simulations.] [Assessment Boundary: Assessment is limited to electric and magnetic fields, and limited to qualitative evidence for the existence of fields.*]* Click here for the Evidence Statement for MS-PS2-5.

Grades 9 through 12:

What underlying forces explain the variety of interactions we observe?

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 permeating space that can transfer energy through space. Magnets or changing electric fields cause magnetic fields; electric charges or changing magnetic fields cause electric fields. 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 strong and weak nuclear interactions are important inside atomic nuclei—for example, they determine the patterns of which nuclear isotopes are stable and what kind of decays occur for unstable ones.

Table 18: Performance Expectations for Grades 9 through 12

Standard Code	Performance Expectation
HS-PS2-4	**Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.** *[Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.]* *[*Assessment Boundary: Assessment is limited to systems with two objects.*]* Click here for the Evidence Statement for HS-PS2-4.
HS-PS2-5	**Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.** *[*Assessment Boundary: Assessment is limited to designing and conducting investigations with provided materials and tools.*]* Click here for the Evidence Statement for HS-PS2-5.
HS-PS2-6	**Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.*** *[Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals*

Standard Code	Performance Expectation
	are designed to interact with specific receptors.] [Assessment Boundary: Assessment is limited to provided molecular structures of specific designed materials.*]* Click here for the Evidence Statement for HS-PS2-6.

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PS2.C: Stability and Instability in Physical Systems

Overview of Stability and Instability in Physical Systems from Kindergarten through Grade 12

Why are some physical systems more stable than others?

Events and processes in a system typically involve multiple interactions occurring simultaneously or in sequence. The system's stability or instability and its rate of evolution depend on the balance or imbalance among these multiple effects.

A stable system is one in which the internal and external forces are such that any small change results in forces that return the system to its prior state (e.g., a weight hanging from a string). A system can be static but unstable, with any small change leading to forces that tend to increase that change (e.g., a ball at the top of a hill). A system can be changing but have a stable repeating cycle of changes, with regular patterns of change that allow predictions about the system's future (e.g., Earth orbiting the sun). And a stable system can appear to be unchanging when flows or processes within it are going on at opposite but equal rates (e.g., water in a dam at a constant height but with water flowing in that offsets the water flowing out; a person maintaining steady weight but eating food, burning calories, and excreting waste).

Stability and instability in any system depend on the balance of competing effects. A steady state of a complex system can be maintained through a set of feedback mechanisms, but changes in conditions can move the system out of its range of stability (e.g., homeostasis breaks down at too high or too low a temperature). With no energy inputs, a system starting out in an unstable state will continue to change until it reaches a stable configuration (e.g., the temperatures of hot and cold objects in contact). Viewed at a given scale, stable systems may appear static or dynamic. Conditions and properties of the objects within a system affect the rates of energy transfer and thus how fast or slowly a process occurs (e.g., heat conduction, the diffusion of particles in a fluid).

When a system has a great number of component pieces, one may not be able to predict much about its precise future. For such systems (e.g., with very many colliding molecules), one can often predict average but not detailed properties and behaviors (e.g., average temperature, motion, and rates of chemical change but not the trajectories of particular molecules).

By the end of grade 2: PS2.C supports learning about pushes and pulls in kindergarten. **PS2.C** does not have independent Performance Expectations.

Whether an object stays still or moves often depends on the effects of multiple pushes and pulls on it (e.g., multiple players trying to pull an object in different directions). It is useful to investigate what pushes and pulls keep something in place (e.g., a ball on a slope, a ladder leaning on a wall) as well as what makes something change or move.

By the end of grade 5: PS2.C supports learning in physical science, life science, and Earth and space sciences in grades 3 through 5. **PS2.C** does not have independent Performance Expectations in grades 3, 4, or 5.

A system can change as it moves in one direction (e.g., a ball rolling down a hill), shifts back and forth (e.g., a swinging pendulum), or goes through cyclical patterns (e.g., day and night). Examining how the forces on and within the system change as it moves can help to explain the system's patterns of change.

A system can appear to be unchanging when processes within the system are occurring at opposite but equal rates (e.g., water behind a dam is at a constant height because water is flowing in at the same rate that water is flowing out). Changes can happen very quickly or very slowly and are sometimes hard to see (e.g., plant growth). Conditions and properties of the objects within a system affect how fast or slowly a process occurs (e.g., heat conduction rates).

Grades 6 through 8: PS2.C supports learning in physical science, life science, and Earth and space sciences in grades 3 through 5. PS2.C does not have independent Performance Expectations in grades 6, 7, or 8.

A stable system is one in which any small change results in forces that return the system to its prior state (e.g., a weight hanging from a string). A system can be static but unstable (e.g., a pencil standing on end).

A system can be changing but have a stable repeating cycle of changes; such observed regular patterns allow predictions about the system's future (e.g., Earth orbiting the sun). Many systems, both natural and engineered, rely on feedback mechanisms to maintain stability, but they can function only within a limited range of conditions. With no energy inputs, a system starting out in an unstable state will continue to change until it reaches a stable configuration (e.g., sand in an hourglass).

Grades 9 through 12: PS2.C supports learning in physical science, life science, and Earth and space sciences in grades 3 through 5. **PS2.C** does not have independent Performance Expectations in grades 9, 10, 11, or 12.

Systems often change in predictable ways; understanding the forces that drive the transformations and cycles within a system, as well as the forces imposed on the system from the outside, helps predict its behavior under a variety of conditions.

When a system has a great number of component pieces, one may not be able to predict much about its precise future. For such systems (e.g., with very many colliding molecules), one can often predict average but not detailed properties and behaviors (e.g., average temperature, motion, and rates of chemical change but not the trajectories or other changes of particular molecules). Systems may evolve in unpredictable ways when the outcome depends sensitively on the starting condition and the starting condition cannot be specified precisely enough to distinguish between different possible outcomes.

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PS3: Energy

Overview of Energy from Kindergarten through Grade 12

How is energy transferred and conserved?

Interactions of objects can be explained and predicted using the concept of transfer of energy from one object or system of objects to another. The total energy within a defined system changes only by the transfer of energy into or out of the system.

PS3.A: Definitions of Energy

Overview of Definitions of Energy from Kindergarten through Grade 12

What is energy?

That there is a single quantity called energy is due to the remarkable fact that a system's *total* energy is conserved. Regardless of the quantities of energy transferred between subsystems and stored in various ways within the system, the total energy of a system changes only by the amount of energy transferred into and out of the system.

At the macroscopic scale, energy manifests itself in multiple phenomena, such as motion, light, sound, electrical and magnetic fields, and thermal energy. Historically, different units were introduced for the energy present in these different phenomena, and it took some time before the relationships among them were recognized. Energy is best understood at the microscopic scale, at which it can be modeled as either motions of particles or as stored in force fields (electric, magnetic, gravitational) that mediate interactions between particles. This last concept includes electromagnetic radiation, a phenomenon in which energy stored in fields moves across space (light, radio waves) with no supporting matter medium.

Motion energy is also called kinetic energy; defined in a given reference frame, it is proportional to the mass of the moving object and grows with the square of its speed. Matter at any temperature above absolute zero contains thermal energy. Thermal energy is the random motion of particles (whether vibrations in solid matter or molecules or free motion in a gas), this energy is distributed among all the particles in a system through collisions and interactions at a distance. In contrast, a sound wave is a moving pattern of particle vibrations that transmits energy through a medium.

Electric and magnetic fields also contain energy; any change in the relative positions of charged objects (or in the positions or orientations of magnets) changes the fields between them and thus the amount of energy stored in those fields. When a particle in a molecule of solid matter vibrates, energy is continually being transformed back and forth between the energy of motion and the energy stored in the electric and magnetic fields within the matter. Matter in a stable form minimizes the stored energy in the electric and magnetic fields within it; this defines the equilibrium positions and spacing of the atomic nuclei in a molecule or an extended solid and the form of their combined electron charge distributions (e.g., chemical bonds, metals).

Energy stored in fields within a system can also be described as potential energy. For any system where the stored energy depends only on the spatial configuration of the system and not on its history, potential energy is a useful concept (e.g., a massive object above Earth's surface, a compressed or stretched spring). It is defined as a difference in energy compared to some arbitrary reference configuration of a system. For example, lifting an object increases the stored energy in the gravitational field between that object and Earth (gravitational potential energy) compared to that for the object at Earth's surface; when the object falls, the stored energy decreases and the object's kinetic energy increases. When a pendulum swings, some stored energy is transformed into kinetic energy and back again into stored energy during each swing. (In both examples energy is transferred out of the system due to collisions with air and for the pendulum also by friction in its support.) Any change in potential energy is accompanied by changes in other forms of energy within the system, or by energy transfers into or out of the system.

Electromagnetic radiation (such as light and X-rays) can be modeled as a wave of changing electric and magnetic fields. At the subatomic scale (i.e., in quantum theory), many phenomena involving electromagnetic radiation (e.g., photoelectric effect) are best modeled as a stream of particles called photons.

Electromagnetic radiation from the sun is a major source of energy for life on Earth. The idea that there are different forms of energy, such as thermal energy, mechanical energy, and chemical energy, is misleading, as it implies that the nature of the energy in each of these manifestations is distinct when in fact they all are ultimately, at the atomic scale, some mixture of kinetic energy, stored energy, and radiation. It is likewise misleading to call sound or light a form of energy; they are phenomena that, among their other properties, transfer energy from place to place and between objects.

Kindergarten, Grades 1 and 2: [Intentionally left blank.]

Grade 4:

What is energy and how is it related to motion?

How is energy transferred?

How can energy be used to solve a problem?

The faster a given object is moving, the more energy it possesses. Energy can be moved from place to place by moving objects or through sound, light, or electric currents. (Boundary: At this grade level, no attempt is made to give a precise or complete definition of energy.)

Table 19: Performance Expectations for Grade 4

Standard Code	Performance Expectation
4-PS3-1	**Use evidence to construct an explanation relating the speed of an object to the energy of that object.** *[*Assessment Boundary: Assessment does not include quantitative measures of changes in the speed of an object or on any precise or quantitative definition of energy.*]* Click **here** for the Evidence Statement for 4-PS3-1.
4-PS3-2	**Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.** *[*Assessment Boundary: Assessment does not include quantitative measurements of energy.*]* Click **here** for the Evidence Statement for 4-PS3-2.
4-PS3-3	**Ask questions and predict outcomes about the changes in energy that occur when objects collide.** *[Clarification Statement: Emphasis is on the change in the energy due to the change in speed, not on the forces, as objects interact.]* *[*Assessment Boundary: Assessment does not include quantitative measurements of energy.*]* Click here for the Evidence Statement for 4-PS3-3.

Grades 6 through 8:

How can energy be transferred from one object or system to another?

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. A system of objects may also contain stored (potential) energy, depending on their relative positions. For example, energy is stored—in gravitational interaction with Earth—when an object is raised, and energy is released when the object falls or is lowered. Energy is also stored in the electric fields between charged particles and the magnetic fields between magnets, and it changes when these objects are moved relative to one another. Stored energy is decreased in some chemical reactions and increased in others.

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). In science, heat is used only for this second meaning; it refers to energy transferred when two objects or systems are at different temperatures. 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.

Table 20: Performance Expectations for Grades 6 through 8

Standard Code	Performance Expectation
MS-PS3-1	**Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.** *[Clarification Statement: Emphasis is on descriptive relationships between kinetic energy and mass separately from kinetic energy and speed. Examples could include riding a bicycle at different speeds, rolling different sizes of rocks downhill, and getting hit by a wiffle ball versus a tennis ball.]* Click here for the Evidence Statement for MS-PS3-1.
MS-PS3-2	**Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.** *[Clarification Statement: Emphasis is on relative amounts of potential energy, not on calculations of potential energy. Examples of objects within systems interacting at varying distances could include: the Earth and either a roller coaster cart at varying positions on a hill or objects at varying heights on shelves, changing the direction/orientation of a magnet, and a balloon with static electrical charge being brought closer to a classmate's hair. Examples of models could include representations, diagrams, pictures, and written descriptions of systems.]* [Assessment Boundary: Assessment is limited to two objects and electric, magnetic, and gravitational interactions.*]* Click here for the Evidence Statement for MS-PS3-2.
MS-PS3-3	**Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.*** *[Clarification Statement: Examples of devices could include an insulated box, a solar cooker, and a Styrofoam cup.]* *[*Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.*]* Click here for the Evidence Statement for MS-PS3-3.
MS-PS3-4	**Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.** *[Clarification Statement: Examples of experiments could include comparing final water temperatures after different masses of ice melted in the same volume of water with the same initial temperature, the temperature change of samples of different materials with the same mass as they cool or heat in the environment, or the same material with different masses when a specific amount of energy is added.]* *[*Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.*]* Click here for the Evidence Statement for MS-PS3-4.

Grades 9 through 12:

How is energy transferred and conserved?

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. At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. "Mechanical energy" generally refers to some combination of motion and stored energy in an operating machine. "Chemical energy" generally is used to mean the energy that can be released or stored in chemical processes, and "electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. Historically, different units and names were used for the energy present in these different phenomena, and it took some time before the relationships between them were recognized. 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.

Table 21: Performance Expectations for Grades 9 through 12

Standard Code	Performance Expectation
HS-PS3-1	**Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.** *[Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.]* [Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.] Click here for the Evidence Statement for HS-PS3-1.
HS-PS3-2	**Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative positions of particles (objects).** *[Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically-charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.]* Click here for the Evidence Statement for HS-PS3-2.

Standard Code	Performance Expectation
HS-PS3-3	**Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.*** *[Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency.]* [Assessment Boundary: Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students.*]* Click here for the Evidence Statement for HS-PS3-3.

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PS3.B: Conservation Of Energy and Energy Transfer

Overview of Conservation of Energy and Energy Transfer from Kindergarten through Grade 12

What is meant by conservation of energy?

How is energy transferred between objects or systems?

The total change of energy in any system is always equal to the total energy transferred into or out of the system. This is called conservation of energy. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. Many different types of phenomena can be explained in terms of energy transfers. Mathematical expressions, which quantify changes in the forms of energy within a system and transfers of energy into or out of the system, allow the concept of conservation of energy to be used to predict and describe the behavior of a system.

When objects collide or otherwise come in contact, the motion energy of one object can be transferred to change the motion or stored energy (e.g., change in shape or temperature) of the other objects. For macroscopic objects, any such process (e.g., collisions, sliding contact) also transfers some of the energy to the surrounding air by sound or heat. For molecules, collisions can also result in energy transfers through chemical processes, which increase or decrease the total amount of stored energy within a system of atoms; the change in stored energy is always balanced by a change in total kinetic energy—that of the molecules present after the process compared with the kinetic energy of the molecules present before it.

Energy can also be transferred from place to place by electric currents. Heating is another process for transferring energy. Heat transfer occurs when two objects or systems are at different temperatures. Energy moves out of higher temperature objects and into lower temperature ones, cooling the former and heating the latter. This transfer happens in three different ways—by conduction within solids, by the flow of liquid or gas (convection), and by radiation, which can travel across space. Even when a system is isolated (such as Earth in space), energy is continually being transferred into and out of it by radiation. The processes underlying convection and conduction can be understood in terms of models of the possible motions of particles in matter.

Radiation can be emitted or absorbed by matter. When matter absorbs light or infrared radiation, the energy of that radiation is transformed to thermal motion of particles in the matter, or, for shorter wavelengths (ultraviolet, X-ray), the radiation's energy is absorbed within the atoms or molecules and may possibly ionize them by knocking out an electron.

Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution within the system or between the system and its environment (e.g., water flows downhill, objects that are hotter than their surrounding environment cool down). Any object or system that can degrade with no added energy is unstable. Eventually it will change or fall apart, although in some cases it may remain in the unstable state for a long time before decaying (e.g., long-lived radioactive isotopes).

Kindergarten:

How can we prevent the Sun's energy from heating the surface of a playground?

Sunlight warms Earth's surface.

Table 22: Performance Expectations for Kindergarten

Standard Code	Performance Expectation
K-PS3-1	**Make observations to determine the effect of sunlight on Earth's surface.** *[Clarification Statement: Examples of Earth's surface could include sand, soil, rocks, and water.]* [Assessment Boundary: Assessment of temperature is limited to relative measures such as warmer/cooler.] Click here for the Evidence Statement for K-PS3-1.
K-PS3-2	**Use tools and materials to design and build a structure that will reduce the warming effect of sunlight on an area.*** *[Clarification Statement: Examples of structures could include umbrellas, canopies, and tents that minimize the warming effect of the sun.]* Click here for the Evidence Statement for K-PS3-2.

Grade 4:

How is energy transferred? How can energy be used to solve a problem?

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.

Light also transfers energy from place to place. For example, energy radiated from the sun is transferred to Earth by light. When this light is absorbed, it warms Earth's land, air, and water and facilitates plant growth.

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 (e.g., moving water driving a spinning turbine which generates electric currents).

Table 23: Performance Expectations for Grade 4

Standard Code	Performance Expectation
4-PS3-2	**Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.** *[*Assessment Boundary: Assessment does not include quantitative measurements of energy.*]* Click here for the Evidence Statement for 4-PS3-2.
4-PS3-3	**Ask questions and predict outcomes about the changes in energy that occur when objects collide.** *[Clarification Statement: Emphasis is on the change in the energy due to the change in speed, not on the forces, as objects interact.]* *[*Assessment Boundary: Assessment does not include quantitative measurements of energy.*]* Click here for the Evidence Statement for 4-PS3-3.
4-PS3-4	**Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.*** *[Clarification Statement: Examples of devices could include electric circuits that convert electrical energy into motion energy of a vehicle, light, or sound; and, a passive solar heater that converts light into heat. Examples of constraints could include the materials, cost, or time to design the device.]* *[*Assessment Boundary: Devices should be limited to those that convert motion energy to electric energy or use stored energy to cause motion or produce light or sound.*]* Click here for the Evidence Statement for 4-PS3-4.

Grades 6 through 8:

How can energy be transferred from one object or system to another?

When the motion energy of an object changes, there is inevitably some other change in energy at the same time. For example, the friction that causes a moving object to stop also results in an increase in the thermal energy in both surfaces; eventually heat energy is transferred to the surrounding environment as the surfaces cool. Similarly, to make an object start moving or to keep it moving when friction forces transfer energy away from it, energy must be provided from, say, chemical (e.g., burning fuel) or electrical (e.g., an electric motor and a battery) processes.

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. Energy is transferred out of hotter regions or objects and into colder ones by the processes of conduction, convection, and radiation.

Table 24: Performance Expectations for Grades 6 through 8

Standard Code	Performance Expectation
MS-PS3-3	**Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.*** *[Clarification Statement: Examples of devices could include an insulated box, a solar cooker, and a Styrofoam cup.]* [Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.] Click here for the [Evidence Statement for MS-PS3-3]().
MS-PS3-4	**Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.** *[Clarification Statement: Examples of experiments could include comparing final water temperatures after different masses of ice melted in the same volume of water with the same initial temperature, the temperature change of samples of different materials with the same mass as they cool or heat in the environment, or the same material with different masses when a specific amount of energy is added.]* [Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.] Click here for the [Evidence Statement for MS-PS3-4]().
MS-PS3-5	**Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.** *[Clarification Statement: Examples of empirical evidence used in arguments could include an inventory or other representation of the energy before and after the transfer in the form of temperature changes or motion of object.]* [Assessment Boundary: Assessment does not include calculations of energy.] Click here for the [Evidence Statement for MS-PS3-5]().

Grades 9 through 12:

What is meant by conservation of energy?

How is energy transferred between objects or systems?

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, 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. The availability of energy limits what can occur in any system.

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). Any object or system that can degrade with no added energy is unstable. Eventually it will do so, but if the energy releases throughout the transition are small, the process duration can be very long (e.g., long-lived radioactive isotopes).

Table 25: Performance Expectations for Grades 9 through 12

Standard Code	Performance Expectation
HS-PS3-1	**Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.** *[Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.]* *[*Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.*]* Click here for the Evidence Statement for HS-PS3-1.
HS-PS3-4	**Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).** *[Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.]* *[*Assessment Boundary: Assessment is limited to investigations based on materials and tools provided to students.*]* Click here for the Evidence Statement for HS-PS3-4.

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PS3.C: Relationship between Energy and Forces

Overview of Relationship between Energy and Forces from Kindergarten through Grade 12

How are forces related to energy?

When two objects interact, each one exerts a force on the other. These forces can transfer energy between the objects. Forces between two objects at a distance are explained by force fields (gravitational, electric, or magnetic) between them.

Contact forces between colliding objects can be modeled at the microscopic level as due to electromagnetic force fields between the surface particles. When two objects interacting via a force field change their relative position, the energy in the force field between them changes. For any such pair of objects the force on each object acts in the direction such that motion of that object in that direction would reduce the energy in the force field between the two objects. However, prior motion and other forces also affect the actual direction of motion.

Patterns of motion, such as a weight bobbing on a spring or a swinging pendulum, can be understood in terms of forces at each instant or in terms of transformation of energy between the motion and one or more forms of stored energy. Elastic collisions between two objects can be modeled at the macroscopic scale using conservation of energy without having to examine the detailed microscopic forces.

Kindergarten:

What happens if you push or pull an object harder?

A bigger push or pull makes things go faster. Faster speeds during a collision can cause a bigger change in shape of the colliding objects.

Table 26: Performance Expectation for Kindergarten

Standard Code	Performance Expectation
K-PS2-1[3]	**Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.** *[Clarification Statement: Examples of pushes or pulls could include a string attached to an object being pulled, a person pushing an object, a person stopping a rolling ball, and two objects colliding and pushing on each other.]* *[*Assessment Boundary: Assessment is limited to different relative strengths or different directions, but not both at the same time. Assessment does not include non-contact pushes or pulls such as those produced by magnets.*]* Click here for the Evidence Statement K-PS2-1.

[3] K-PS2-1 appears in kindergarten PS2.A: Forces and Motion, PS2.B: Types of Interactions and PS3.C: Relationship between Energy and Forces.

Grade 4:

What is energy and how is it related to motion? How is energy transferred?

When objects collide, the contact forces transfer energy so as to change the objects' motions. Magnets can exert forces on other magnets or on magnetizable materials, causing energy transfer between them (e.g., leading to changes in motion) even when the objects are not touching.

Table 27: Performance Expectation for Grade 4

Standard Code	Performance Expectation
4-PS3-3	**Ask questions and predict outcomes about the changes in energy that occur when objects collide.** *[Clarification Statement: Emphasis is on the change in the energy due to the change in speed, not on the forces, as objects interact.]* *[*Assessment Boundary: Assessment does not include quantitative measurements of energy.*]* Click here for the [Evidence Statement 4-PS3-3]().

Grades 6 through 8:

How can energy be transferred from one object or system to another?

When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object. For example, when energy is transferred to an Earth-object system as an object is raised, the gravitational field energy of the system increases. This energy is released as the object falls; the mechanism of this release is the gravitational force. Likewise, two magnetic and electrically charged objects interacting at a distance exert forces on each other that can transfer energy between the interacting objects.

Table 28: Performance Expectation for Grades 6 through 8

Standard Code	Performance Expectation
MS-PS3-2	**Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.** *[Clarification Statement: Emphasis is on relative amounts of potential energy, not on calculations of potential energy. Examples of objects within systems interacting at varying distances could include: the Earth and either a roller coaster cart at varying positions on a hill or objects at varying heights on shelves, changing the direction/orientation of a magnet, and a balloon with static electrical charge being brought closer to a classmate's hair. Examples of models could include representations, diagrams, pictures, and written descriptions of systems.]* *[*Assessment Boundary: Assessment is limited to two objects and electric, magnetic, and gravitational interactions.*]* Click here for the [Evidence Statement MS-PS3-2]().

Grades 9 through 12:

How is energy transferred and conserved?

Force fields (gravitational, electric, and magnetic) contain energy and can transmit energy across space from one object to another.

When two objects interacting through a force field change relative position, the energy stored in the force field is changed. Each force between the two interacting objects acts in the direction such that motion in that direction would reduce the energy in the force field between the objects. However, prior motion and other forces also affect the actual direction of motion.

Table 29: Performance Expectation for Grades 9 through 12

Standard Code	Performance Expectation
HS-PS3-5	**Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.** *[Clarification Statement: Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.]* [Assessment Boundary: Assessment is limited to systems containing two objects.*]* Click here for the Assessment Boundary HS-PS3-5.

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PS3.D: Energy in Chemical Processes and Everyday Life

Overview of Energy in Chemical Processes and Everyday Life from Kindergarten through Grade 12

How do food and fuel provide energy?

If energy is conserved, why do people say it is produced or used?

In ordinary language, people speak of "producing" or "using" energy. This refers to the fact that energy in concentrated form is useful for generating electricity, moving or heating objects, and producing light, whereas diffuse energy in the environment is not readily captured for practical use. Therefore, to produce energy typically means to convert some stored energy into a desired form—for example, the stored energy of water behind a dam is released as the water flows downhill and drives a turbine generator to produce electricity, which is then delivered to users through distribution systems. Food, fuel, and batteries are especially convenient energy resources because they can be moved from place to place to provide processes that release energy where needed. A system does not destroy energy when carrying out any process. However, the process cannot occur without energy being available. The energy is also not destroyed by the end of the process. Most often some or all of it has been transferred to heat the surrounding environment; in the same sense that paper is not destroyed when it is written on, it still exists but is not readily available for further use.

Naturally occurring food and fuel contain complex carbon-based molecules, chiefly derived from plant matter that has been formed by photosynthesis. The chemical reaction of these molecules with oxygen releases energy; such reactions provide energy for most animal life and for residential, commercial, and industrial activities.

Electric power generation is based on fossil fuels (i.e., coal, oil, and natural gas), nuclear fission, or renewable resources (e.g., solar, wind, tidal, geothermal, and hydro power). Transportation today chiefly depends on fossil fuels, but the use of electric and alternative fuel (e.g., hydrogen, biofuel) vehicles is increasing. All forms of electricity generation and transportation fuels have associated economic, social, and environmental costs and benefits, both short and long term. Technological advances and regulatory decisions can change the balance of those costs and benefits.

Although energy cannot be destroyed, it can be converted to less useful forms. In designing a system for energy storage, for energy distribution, or to perform some practical task (e.g., to power an airplane), it is important to design for maximum efficiency—thereby ensuring that the largest possible fraction of the energy is used for the desired purpose rather than being transferred out of the Grade Band Endpoints for PS3.D

Kindergarten and Grade 1: There are no Performance Expectations for PS3.D in kindergarten or grade 1.

When two objects rub against each other, this interaction is called friction. Friction between two surfaces can warm of both of them (e.g., rubbing hands together). There are ways to reduce the friction between two objects.

Grade 4:

How is energy stored for later use?

The expression “produce energy” typically refers to the conversion of stored energy into a desired form for practical use—for example, the stored energy of water behind a dam is released so that it flows downhill and drives a turbine generator to produce electricity. Food and fuel also release energy when they are digested or burned. When machines or animals “use” energy (e.g., to move around), most often the energy is transferred to heat the surrounding environment.

It is important to be able to concentrate energy so that it is available for use where and when it is needed. For example, batteries are physically transportable energy storage devices, whereas electricity generated by power plants is transferred from place to place through distribution systems.

Table 30: Performance Expectation for Grade 4

Standard Code	Performance Expectation
4-PS3-4	**Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.*** *[Clarification Statement: Examples of devices could include electric circuits that convert electrical energy into motion energy of a vehicle, light, or sound; and, a passive solar heater that converts light into heat. Examples of constraints could include the materials, cost, or time to design the device.]* [Assessment Boundary: Devices should be limited to those that convert motion energy to electric energy or use stored energy to cause motion or produce light or sound.] Click here for the Evidence Statement for 4-PS3-4.

Grade 5:

Where does the energy in food come from and what is it used for?

The energy released by burning fuel or digesting food was once energy from the sun that was captured by plants in the chemical process that forms plant matter (from air and water). (Boundary: The fact that plants capture energy from sunlight is introduced at this grade level, but details of photosynthesis are not.)

Table 31: Performance Expectation for Grade 5

Standard Code	Performance Expectation
5-PS3-1	**Use models to describe that energy in animals' food (used for body repair, growth, and motion and to maintain body warmth) was once energy from the sun.** *[Clarification Statement: Examples of models could include diagrams, and flow charts.]* Click here for the Evidence Statement for 5-PS3-1.

Grades 6 through 8:

How can energy be transferred from one object or system to another?

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. (Boundary: Further details of the photosynthesis process are not taught at this grade level.)

Both the burning of fuel and cellular digestion 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.

Machines can be made more efficient, that is, require less fuel input to perform a given task, by reducing friction between their moving parts and through aerodynamic design. Friction increases energy transfer to the surrounding environment by heating the affected materials.

Table 32: Performance Expectations for Grades 6 through 8

Standard Code	Performance Expectation
MS-LS1-6[4]	**Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.** *[Clarification Statement: Emphasis is on tracing movement of matter and flow of energy.]* [Assessment Boundary: Assessment does not include the biochemical mechanisms of photosynthesis.*]* Click here for the Evidence Statement for MS-LS1-6.
MS-LS1-7[5]	**Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism.** *[Clarification Statement: Emphasis is on describing that molecules are broken apart and put back together and that in this process, energy is released.]* [Assessment Boundary: Assessment does not include details of the chemical reactions for photosynthesis or respiration.*]* Click here for the Evidence Statement for MS-LS1-7.

Grades 9 through 12:

How is energy transferred and conserved?

Nuclear fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. The main way in which that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy.

A variety of multistage physical and chemical processes in living organisms, particularly within their cells, account for the transport and transfer (release or uptake) of energy needed for life functions.

All forms of electricity generation and transportation fuels have associated economic, social, and environmental costs and benefits, both short and long term.

Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. Machines are judged as efficient or inefficient based on the amount of energy input needed to perform a particular useful task. Inefficient machines are those that produce more waste heat while performing a task and thus require more

[4] Secondary to LS1.C: Organization for Matter and Energy Flow in Organisms

[5] Secondary to LS1.C: Organization for Matter and Energy Flow in Organisms

energy input. It is therefore important to design for high efficiency so as to reduce costs, waste materials, and many environmental impacts.

Table 33: Performance Expectations for Grades 9 through 12

Standard Code	Performance Expectation
HS-PS3-3	**Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.*** *[Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency.]* [Assessment Boundary: Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students.*]* Click here for the Evidence Statement for HS-PS3-3.
HS-PS3-4	**Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).** *[Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.] [*Assessment Boundary: Assessment is limited to investigations based on materials and tools provided to students.*]* Click here for the Evidence Statement for HS-PS3-4.

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PS4: Waves and Their Applications in Technologies for Information Transfer

Overview of Waves and their Applications in Technologies for Information Transfer from Kindergarten through Grade 12

How are waves used to transfer energy and information?

Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. Light and sound are wavelike phenomena. By understanding wave properties and the interactions of electromagnetic radiation with matter, scientists and engineers can design systems for transferring information across long distances, storing information, and investigating nature on many scales—some of them far beyond direct human perception.

PS4.A: Wave Properties

Overview of Wave Properties from Kindergarten through Grade 12

What are the characteristic properties and behaviors of waves?

Whether a wave in water, a sound wave, or a light wave, all waves have some features in common. A simple wave has a repeating pattern of specific wavelength, frequency, and amplitude. The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which, for each type of wave, depends on the medium in which the wave is traveling. Waves can be combined with other waves of the same type to produce complex information-containing patterns that can be decoded at the receiving end. Waves, which transfer energy and any encoded information without the bulk motion of matter, can travel unchanged over long distances, pass through other waves undisturbed, and be detected and decoded far from where they were produced. Information can be digitized (converted into a numerical representation), sent over long distances as a series of wave pulses, and reliably stored in computer memory.

Sound is a pressure wave in air or any other material medium. The human ear and brain working together are very good at detecting and decoding patterns of information in sound (e.g., speech and music) and distinguishing them from random noise.

Resonance is a phenomenon in which waves add up in phase (i.e., matched peaks and valleys), thus growing in amplitude. Structures have particular frequencies at which they resonate when some time-varying force acting on them transfers energy to them. This phenomenon (e.g., waves in a stretched string, vibrating air in a pipe) is used in the design of all musical instruments and in the production of sound by the human voice. When a wave passes an object that is small compared with its wavelength, the wave is not much affected; for this reason, some things are too small to see with visible light, which is a wave phenomenon with a limited range of wavelengths corresponding to each color. When a wave meets the surface between two different materials or conditions (e.g., air to water), part of the wave is reflected at that surface and another part continues on, but at a different speed. The change of speed of the wave when passing from one medium to another can cause the wave to change direction or refract. These wave properties are used in many applications (e.g., lenses, seismic probing of Earth).

Grade 1:

What happens when materials vibrate?

What happens when there is no light?

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—observe, for example, a bobbing cork or seabird—except when the water meets the beach.

Sound can make matter vibrate, and vibrating matter can make sound.

Table 34: Performance Expectation for 1-PS4-1

Standard Code	Performance Expectation
1-PS4-1	**Plan and conduct investigations to provide evidence that vibrating materials can make sound and that sound can make materials vibrate.** *[Clarification Statement: Examples of vibrating materials that make sound could include tuning forks and plucking a stretched string. Examples of how sound can make matter vibrate could include holding a piece of paper near a speaker making sound and holding an object near a vibrating tuning fork.]* Click here for the Evidence Statement 1-PS4-1.

Grade 4:

What are waves and what are some things they can do?

Waves of the same type can differ in amplitude (height of the wave) and wavelength (spacing between wave peaks). 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.)

Earthquakes cause seismic waves, which are waves of motion in Earth's crust.

Table 35: Performance Expectation for Grade 4

Standard Code	Performance Expectation
4-PS4-1	**Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can cause objects to move.** *[Clarification Statement: Examples of models could include diagrams, analogies, and physical models using wire to illustrate wavelength and amplitude of waves.]* *[*Assessment Boundary: Assessment does not include interference effects, electromagnetic waves, non-periodic waves, or quantitative models of amplitude and wavelength.*]* Click here for the Evidence Statement 4-PS4-1.

Grades 6 through 8:

What are the characteristic properties of waves and how can they be used?

A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. A sound wave needs a medium through which it is transmitted.

Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet.

Table 36: Performance Expectations for Grades 6 through 8

Standard Code	Performance Expectation
MS-PS4-1	**Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.** *[Clarification Statement: Emphasis is on describing waves with both qualitative and quantitative thinking.] [*Assessment Boundary: Assessment does not include electromagnetic waves and is limited to standard repeating waves.*]* Click here for the Evidence Statement MS-PS4-1.
MS-PS4-2	**Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.** *[Clarification Statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, simulations, and written descriptions.] [*Assessment Boundary: Assessment is limited to qualitative applications pertaining to light and mechanical waves.*]* Click here for the Evidence Statement MS-PS4-2.

Grades 9 through 12:

How are waves used to transfer energy and send and store information?

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 basis of these properties.

Combining waves of different frequencies can make a wide variety of patterns and thereby encode and transmit information. 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.

Resonance is a phenomenon in which waves add up in phase in a structure, growing in amplitude due to energy input near the natural vibration frequency. Structures have particular frequencies at which they resonate. This phenomenon (e.g., waves in a stretched string, vibrating air in a pipe) is used in speech and in the design of all musical instruments.

Table 37: Performance Expectations for Grades 9 through 12

Standard Code	Performance Expectation
HS-PS4-1	**Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.** *[Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.]* *[*Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.*]* Click here for the Evidence Statement HS-PS4-1.
HS-PS4-2	**Evaluate questions about the advantages of using digital transmission and storage of information.** *[Clarification Statement: Examples of advantages could include that digital information is stable because it can be stored reliably in computer memory, transferred easily, and copied and shared rapidly. Disadvantages could include issues of easy deletion, security, and theft.]* Click here for the Evidence Statement HS-PS4-2.
HS-PS4-3	**Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.** *[Clarification Statement: Emphasis is on how the experimental evidence supports the claim and how a theory is generally modified in light of new evidence. Examples of a phenomenon could include resonance, interference, diffraction, and photoelectric effect.]* [Assessment Boundary: Assessment does not include using quantum theory.*]* Click here for the Evidence Statement HS-PS4-3.
HS-PS4-5	**Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.*** *[Clarification Statement: Examples could include solar cells capturing light and converting it to electricity; medical imaging; and communications technology.]* [Assessment Boundary: Assessments are limited to qualitative information. Assessments do not include band theory.*]* Click here for the Evidence Statement HS-PS4-5.

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PS4.B: Electromagnetic Radiation

Overview of Electromagnetic Radiation from Kindergarten through Grade 12

What is light?

How can one explain the varied effects that involve light?

What other forms of electromagnetic radiation are there?

Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave pattern of changing electric and magnetic fields or, alternatively, as particles. Each model is useful for understanding aspects of the phenomenon and its interactions with matter, and quantum theory relates the two models. Electromagnetic waves can be detected over a wide range of frequencies, of which the visible spectrum of colors detectable by human eyes is just a small part. Many modern technologies are based on the manipulation of electromagnetic waves.

All electromagnetic radiation travels through a vacuum at the same speed, called the speed of light. Its speed in any given medium depends on its wavelength and the properties of that medium. At the surface between two media, like any wave, light can be reflected, refracted (its path bent), or absorbed. What occurs depends on properties of the surface and the wavelength of the light. When shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) is absorbed in matter, it can ionize atoms and cause damage to living cells. However, because X-rays can travel through soft body matter for some distance but are more rapidly absorbed by denser matter, particularly bone, they are useful for medical imaging. Photovoltaic materials emit electrons when they absorb light of a high-enough frequency. This phenomenon is used in barcode scanners and “electric eye” systems, as well as in solar cells. It is best explained using a particle model of light.

Any object emits a spectrum of electromagnetic radiation that depends on its temperature. In addition, atoms of each element emit and preferentially absorb characteristic frequencies of light. These spectral lines allow identification of the presence of the element, even in microscopic quantities or for remote objects, such as a star. Nuclear transitions that emit or absorb gamma radiation also have distinctive gamma ray wavelengths, a phenomenon that can be used to identify and trace specific radioactive isotopes.

Grade 1:

What happens when there is no light?

Objects can be seen only when light is available to illuminate them. Very hot objects give off light (e.g., a fire, the sun).

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 (i.e., on the other side from the light source), where the light cannot reach. Mirrors and prisms 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.)

Table 38: Performance Expectations for Grade 1

Standard Code	Performance Expectation
1-PS4-2	**Make observations to construct an evidence-based account that objects in darkness can be seen only when illuminated.** *[Clarification Statement: Examples of observations could include those made in a completely dark room, a pinhole box, and a video of a cave explorer with a flashlight. Illumination could be from an external light source or by an object giving off its own light.]* Click here for the Evidence Statement 1-PS4-2.
1-PS4-3	**Plan and conduct investigations to determine the effect of placing objects made with different materials in the path of a beam of light.** *[Clarification Statement: Examples of materials could include those that are transparent (such as clear plastic), translucent (such as wax paper), opaque (such as cardboard), and reflective (such as a mirror).]* [Assessment Boundary: Assessment does not include the speed of light.*]* Click here for the Evidence Statement 1-PS4-3.

Grade 4:

How and why do we see things?

A great deal of light travels through space to Earth from the sun and from distant stars.

An object can be seen when light reflected from its surface enters the eyes; the color people see depends on the color of the available light sources as well as the properties of the surface. (Boundary: This phenomenon is observed, but no attempt is made to discuss what confers the color reflection and absorption properties on a surface. The stress is on understanding that light traveling from the object to the eye determines what is seen.)

Because lenses bend light beams, they can be used, singly or in combination, to provide magnified images of objects too small or too far away to be seen with the naked eye.

Table 39: Performance Expectation for Grade 4

Standard Code	Performance Expectation
4-PS4-2	**Develop a model to describe that light reflecting from objects and entering the eye allows objects to be seen.** *[*Assessment Boundary: Assessment does not include knowledge of specific colors reflected and seen, the cellular mechanisms of vision, or how the retina works.*]* Click here for the Evidence Statement 4-PS4-2.

Grades 6 through 8:

What are the characteristic properties of waves and how can they be used?

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 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. Lenses and prisms are applications of this effect.

A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media (prisms). However, because light can travel through space, it cannot be a matter wave, like sound or water waves.

Table 40: Performance Expectation for Grades 6 through 12

Standard Code	Performance Expectation
MS-PS4-2	**Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.** *[Clarification Statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, simulations, and written descriptions.] [*Assessment Boundary: Assessment is limited to qualitative applications pertaining to light and mechanical waves.*]* Click here for the Evidence Statement MS-PS4-2.

Grades 9 through 12:

How are waves used to collect, store, and transfer information?

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. Quantum theory relates the two models. (Boundary: Quantum theory is not explained further at this grade level.)

Because a wave is not much disturbed by objects that are small compared with its wavelength, visible light cannot be used to see such objects as individual atoms. All electromagnetic radiation travels through a vacuum at the same speed, called the speed of light. Its speed in any other given medium depends on its wavelength and the properties of that medium.

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. Photovoltaic materials emit electrons when they absorb light of a high-enough frequency.

Atoms of each element emit and absorb characteristic frequencies of light, and nuclear transitions have distinctive gamma ray wavelengths. These characteristics allow identification of the presence of an element, even in microscopic quantities.

Table 41: Performance Expectations for Grades 9 through 12

Standard Code	Performance Expectation
HS-PS4-3	**Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.** *[Clarification Statement: Emphasis is on how the experimental evidence supports the claim and how a theory is generally modified in light of new evidence. Examples of a phenomenon could include resonance, interference, diffraction, and photoelectric effect.]* [Assessment Boundary: Assessment does not include using quantum theory.*]* Click here for the Evidence Statement HS-PS4-3.
HS-PS4-4	**Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.** *[Clarification Statement: Emphasis is on the idea that photons associated with different frequencies of light have different energies, and the damage to living tissue from electromagnetic radiation depends on the energy of the radiation. Examples of published materials could include trade books, magazines, web resources, videos, and other passages that may reflect bias.]* [Assessment Boundary: Assessment is limited to qualitative descriptions.*]* Click here for the Evidence Statement HS-PS4-4.
HS-PS4-5	**Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.*** *[Clarification Statement: Examples could include solar cells capturing light and converting it to electricity; medical imaging; and communications technology.]* [Assessment Boundary: Assessments are limited to qualitative information. Assessments do not include band theory.*]* Click here for the Evidence Statement HS-PS4-5.

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PS4.C: Information Technologies and Instrumentation

Overview of Information Technologies and Instrumentation from Kindergarten through Grade 12

How are instruments that transmit and detect waves used to extend human senses?

Understanding of waves and their interactions with matter has been used to design technologies and instruments that greatly extend the range of phenomena that can be investigated by science (e.g., telescopes, microscopes) and have many useful applications in the modern world.

Light waves, radio waves, microwaves, and infrared waves are applied to communications systems, many of which use digitized signals (i.e., sent as wave pulses) as a more reliable way to convey information. Signals that humans cannot sense directly can be detected by appropriately designed devices (e.g., telescopes, cell phones, wired or wireless computer networks). When in digitized form, information can be recorded, stored for future recovery, and transmitted over long distances without significant degradation.

Medical imaging devices collect and interpret signals from waves that can travel through the body and are affected by, and thus gather information about, structures and motion within it (e.g., ultrasound, X-rays). Sonar (based on sound pulses) can be used to measure the depth of the sea, and a system based on laser pulses can measure the distance to objects in space, because it is known how fast sound travels in water and light travels in a vacuum. The better the interaction of the wave with the medium is understood, the more detailed the information that can be extracted (e.g., medical imaging or astronomical observations at multiple frequencies).

Grade 1:

How can we use light and sound to communicate with other people over great distances?

People use their senses to learn about the world around them. Their eyes detect light, their ears detect sound, and they can feel vibrations by touch.

People also use a variety of devices to communicate (send and receive information) over long distances.

Table 42: Performance Expectation for Grade 1

Standard Code	Performance Expectation
1-PS4-4	**Use tools and materials to design and build a device that uses light or sound to solve the problem of communicating over a distance.*** *[Clarification Statement: Examples of devices could include a light source to send signals, paper cup and string "telephones," and a pattern of drum beats.]* [Assessment Boundary: Assessment does not include technological details for how communication devices work.*]* Click here for Evidence Statement 1-PS4-4.

Grade 4:

How can we use light and sound to share information?

Lenses can be used to make eyeglasses, telescopes, or microscopes in order to extend what can be seen. The design of such instruments is based on understanding how the path of light bends at the surface of a lens.

Digitized information (e.g., the pixels of a picture) can be stored for future recovery or 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.

Table 43: Performance Expectation for Grade 4

Standard Code	Performance Expectation
4-PS4-3	**Generate and compare multiple solutions that use patterns to transfer information.*** *[Clarification Statement: Examples of solutions could include drums sending coded information through sound waves, using a grid of 1's and 0's representing black and white to send information about a picture, and using Morse code to send text.]* Click here for Evidence Statement 4-PS4-3.

Grades 6 through 8:

How can we use waves to share information?

Appropriately designed technologies (e.g., radio, television, cell phones, wired and wireless computer networks) make it possible to detect and interpret many types of signals that cannot be sensed directly. Designers of such devices must understand both the signal and its interactions with matter.

Many modern communication devices use digitized signals (sent as wave pulses) as a more reliable way to encode and transmit information.

Table 44: Performance Expectations for Grades 6 through 12

Standard Code	Performance Expectation
MS-PS4-3	**Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals.** *[Clarification Statement: Emphasis is on a basic understanding that waves can be used for communication purposes. Examples could include using fiber optic cable to transmit light pulses, radio wave pulses in wifi devices, and conversion of stored binary patterns to make sound or text on a computer screen.]* [Assessment Boundary: Assessment does

Standard Code	Performance Expectation
	not include binary counting. Assessment does not include the specific mechanism of any given device.*]* Click here for Evidence Statement MS-PS4-3.

Grades 9 through 12:

How are instruments that transmit and detect waves used to extend human senses?

Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them.

Knowledge of quantum physics enabled the development of semiconductors, computer chips, and lasers, all of which are now essential components of modern imaging, communications, and information technologies. (Boundary: Details of quantum physics are not formally taught at this grade level.)

Table 45: Performance Expectation for Grades 9 through 12

Standard Code	Performance Expectation
HS-PS4-5	**Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.*** *[Clarification Statement: Examples could include solar cells capturing light and converting it to electricity; medical imaging; and communications technology.]* [Assessment Boundary: Assessments are limited to qualitative information. Assessments do not include band theory.*]* Click here for Evidence Statement HS-PS4-5.

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Appendix A: Vocabulary in the New Jersey Student Learning Standards for Science

Many vocabulary words do not explicitly appear in the standards, because the New Jersey Student Learning Standards for Science (science standards) focus on a deep understanding of the concept behind a vocabulary word. Vocabulary can be introduced and applied, as needed, for instructional purposes.

Acids / Bases: The science standards do not include specific names of chemical reactions and instead focus on conceptual understanding of how chemical reactions occur. This ensures that students have a conceptual understanding that they can apply to any type of chemical reaction. Classes of chemical reactions such as oxidation and reduction, acid and base, or decomposition and synthesis can be used in instruction depending on the context, but instruction should ensure that students have an understanding of the underlying concepts. (Grades 6 through 8 and 9 through 12)

Bonding: Bonding is a result of forces, proximity, and energy. This provides a basis for understanding all types of bonding, including ionic, covalent, metallic, and hydrogen bonding. (Grades 9 through 12)

Chemical Equation: The science standards describe balanced chemical equations and the idea of quantifying numbers of atoms. Chemical equations can be integrated in instruction when building towards performance expectations that address the concepts of bonding and chemical reactions. (Grades 9 through 12)

Chemical Formula: Chemical formulas can be integrated in instruction when describing the basic composition of molecules, quantifying the numbers of atoms, balancing chemical equations, and in general, when building towards performance expectations that address the concepts of bonding and chemical reactions. (Grades 6 through 8 and 9 through 12)

Circuit: The science standards do not include specific examples of circuits, such as parallel and series circuits, because the focus is on understanding the core concept of energy transfer. Examples of circuits can be included for instructional purposes when appropriate. (Grade 4)

Decomposition / Synthesis: The science standards do not include specific names of chemical reactions and instead focus on conceptual understanding of how chemical reactions occur. This ensures that students have a conceptual understanding that they can apply to any type of chemical reaction. Classes of chemical reactions such as oxidation and reduction, acid and base, or decomposition and synthesis can be used in instruction depending on the context, but instruction should ensure that students have an understanding of the underlying concepts. (Grades 6 through 8 and 9 through 12)

Endothermic / Exothermic: The science standards describe that chemical reactions can either store energy (endothermic) or release energy (exothermic). Exothermic and endothermic reactions are addressed in the performance expectations that look at the change in energy in components of a system while considering the inputs and outputs of energy of the system. (Grades 9 through 12)

Gas Laws: The science standards describe gases and the intermolecular interactions that govern the behavior of gases. The NJSLS-S build the foundation for the discussion of different states of matter in middle school, and then build the foundation for mathematical representations of gas laws through a thorough coverage of intermolecular forces and energy in the high school standards. (Grades 6 through 8 and 9 through 12)

Oxidation / Reduction: The science standards do not include specific names of chemical reactions and instead focus on conceptual understanding of how chemical reactions occur. This ensures that students have a conceptual understanding that they can apply to any type of chemical reaction. Classes of chemical reactions such as oxidation and reduction, acid and base, or decomposition and synthesis can be used in instruction depending on the context, but instruction should ensure that students have an understanding of the underlying concepts. (Grades 6 through 8 and 9 through 12)

Power: The science standards focus on a conceptual understanding of core ideas. The standards include the core ideas of energy transfer into and out of systems, providing a basis for understanding the concept of power. The equation for power can be introduced and applied, as needed, for instructional purposes. (Grades 9 through 12)

Stoichiometry: Stoichiometery involves calculations of the quantities of reactants and products in a chemical reaction. The science standards focus on the deep understanding of core ideas, and stoichiometery can be integrated in instruction when building towards performance expectations that address chemical reactions and conservation of atoms during chemical reactions. (Grades 9 through 12)

Valence Electrons: Valence electrons are electrons in the outermost energy level of atoms. These electrons contribute towards the properties of elements. (Grades 9 through 12)

Work: The science standards focus on a conceptual understanding of core ideas, including the interaction between energy transfer and forces, which provide a basis for understanding the concept of work. The equation for work can be introduced and applied, as needed, for instructional purposes. (Grades 6 through 8)