MS.PS-SPM Structure and Properties of Matter

How to read the standards »

Go to the NGSS Survey

Students who demonstrate understanding can:

a. **Construct and use models to explain that atoms combine to form new substances of varying complexity in terms of the number of atoms and repeating subunits. [Clarification Statement: Examples of atoms combining can include Hydrogen (H_2) and Oxygen (O_2) combining to form hydrogen peroxide (H_2O_2) or water (H_2O).] [*Assessment Boundary: Valence electrons and bonding energy are not addressed.*]**

b. **Plan investigations to generate evidence supporting the claim that one pure substance can be distinguished from another based on characteristic properties. [Clarification Statement: Properties of substances can include melting and boiling points, density, solubility, reactivity, flammability, and phase.]**

c. **Use a simulation or mechanical model to determine the effect on the temperature and motion of atoms and molecules of different substances when thermal energy is added or removed from the substance. [*Assessment Boundary: Quantification of the model or use of mathematical formulas are not intended.*]**

d. **Construct an argument that explains the effect of adding or removing thermal energy to a pure substance in different phases and during a phase change in terms of atomic and molecular motion. [*Assessment Boundary: The use of mathematical formulas is not intended.*]**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to explain, explore, and predict more abstract phenomena and design systems.
- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (a),(c)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.
- Plan and carry out investigations individually and collaboratively, identifying independent and dependent variables, and controls. (b)
- Collect data and generate evidence to answer scientific questions or test design solutions under a range of conditions. (b)

Engaging in Argument from Evidence
Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.
- Use oral and written arguments supported by empirical evidence and reasoning to support or refute an explanation for a phenomenon or a solution to a problem. (d)

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter
- 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. (a)
- 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. (b)
- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. (d)
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. (c),(d)
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals). (a)
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. (c),(d)

PS3.A: Definitions of Energy
- The term "heat" as used in everyday language refers both to thermal motion (the motion of atoms or molecules within a substance) and radiation (particularly infrared and light). (c),(d)
- Temperature is not a measure of energy; the relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. (c),(d)

Crosscutting Concepts

Patterns
Macroscopic patterns are related to the nature of microscopic and atomic-level structure. Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems. Patterns can be used to identify cause and effect relationships. Graphs and charts can be used to identify patterns in data. (a)

Cause and Effect
Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Cause and effect relationships may be used to predict phenomena in natural or designed systems. Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (c), (d)

Structure and Function
Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts, therefore complex natural and designed structures/systems can be analyzed to determine how they function. Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (b)

Connections to other DCIs in this grade-level: **MS.ESS-ESP, MS.ESS-SS, MS.LS-MEOE**

Articulation of DCIs across grade-levels: **3.IF, 5.SPM, HS.PS-SPM, HS.PS-NP, HS.PS-E**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA

W.5.2	Write informative/explanatory texts to examine a topic and convey ideas and information clearly.
W.6.1	Write arguments to support claims with clear reasons and relevant evidence.
W.7.1	Write arguments to support claims with clear reasons and relevant evidence.
SL.5.4	Report on a topic or text or present an opinion, sequencing ideas logically and using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace.
SL.6.4	Present claims and findings, sequencing ideas logically and using pertinent descriptions, facts, and details to accentuate main ideas or themes; use appropriate eye contact, adequate volume, and clear pronunciation.
SL.7.4	Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details, and examples; use appropriate eye contact, adequate volume, and clear pronunciation.
WHST.6-8.1	Write arguments focused on discipline-specific content.
RST.6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

Mathematics	
MP.4	Model with mathematics.
MP.8	Look for and express regularity in repeated reasoning.
6.SP	Develop understanding of statistical variability.
	Summarize and describe distributions.

MS.PS-CR Chemical Reactions

How to read the standards »

Go to the NGSS Survey

Students who demonstrate understanding can:

a. **Develop representations showing how atoms regroup during chemical reactions to account for the conservation of mass.** [*Assessment Boundary: Representations should not involve bonding energy or valence electrons. Balancing equations are also not employed here.*]

b. **Generate and revise explanations from the comparison of the physical and chemical properties of reacting substances to the properties of new substances produced through chemical reactions to show that new properties have emerged.** [*Assessment Boundary: Comparison and analysis should not involve statistical techniques.*]

c. **Construct explanations of energy being released or absorbed when simpler molecules are combined into complex molecules or complex molecules are broken down to simpler molecules.** [Clarification Statement: Simple molecules can include H_2O and CO_2, and complex molecules can include $C_6H_{12}O_6$ in photosynthesis.] [*Assessment Boundary: Further details of the photosynthesis process are not addressed.*]

d. **Develop models to represent the movement of matter and energy in the cycling of carbon.** [Clarification Statement: Examples of the movement of matter and energy could include the cycling from carbon in the atmosphere to carbon in living things.] [*Assessment Boundary: Further details of the photosynthesis process are not addressed.*]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to explain, explore, and predict more abstract phenomena and design systems.
- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (d)
- Pose models to describe mechanisms at unobservable scales. (a)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.
- Construct explanations for either qualitative or quantitative relationships between variables. (b)
- Apply scientific reasoning to show why the data is adequate for the explanation or conclusion. (c)

Disciplinary Core Ideas

PS1.B: Chemical Reactions
- 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. (a),(b)
- The total number of each type of atom is conserved, and thus the mass does not change. (a),(c)
- Some chemical reactions release energy, others store energy. (c)

PS3.D: Energy in Chemical Processes and Everyday Life
- 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. (c),(d)
- 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. (d)

Crosscutting Concepts

Patterns
Macroscopic patterns are related to the nature of microscopic and atomic-level structure. Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems. Patterns can be used to identify cause and effect relationships. Graphs and charts can be used to identify patterns in data. (b)
- [Clarification Statement for b: Comparing properties is a search for patterns; finding a change in pattern indicates a new substance.]

Energy and Matter
Matter is conserved because atoms are conserved in physical and chemical processes. Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. (a),(d)
Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). The transfer of energy can be tracked as energy flows through a designed or natural system. (c)

Connections to other DCIs in this grade-level: **MS.LS-SFIP, MS.LS-GDRO, MS.LS-MEOE, MS.ESS-WC, MS.ESS-ESP**

Articulation of DCIs across grade-levels: **5.SPM, HS.PS-CR, HS.PS-E, HS.LS-MEOE**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA -

RI.6.7	Integrate information presented in different media or formats (e.g., visually, quantitatively) as well as in words to develop a coherent understanding of a topic or issue.
W.5.9	Draw evidence from literary or informational texts to support analysis, reflection, and research.
W.6.8	Gather relevant information from multiple print and digital sources; assess the credibility of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and providing basic bibliographic information for sources.
W.7.8	Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.

Mathematics -

MP.2	Reason abstractly and quantitatively.
MP.4	Model with mathematics.
MP.7	Look for and make use of structure.
MP.8	Look for and express regularity in repeated reasoning.
6.SP	Develop understanding of statistical variability
6.EE	Represent and analyze quantitative relationships between dependent and independent variables
7.SP.3	Draw informal comparative inferences about two populations

MS.PS-FM Forces and Motion

How to read the standards »

Go to the NGSS Survey

Students who demonstrate understanding can:

a. **Formulate questions arising from investigating how an observer's frame of reference and the choice of units influence how the motion and position of an object can be described and communicated to others. [Clarification Statement: Examples of different reference frames or choices of units are: A moving observer versus a stationary observer; observers facing different directions; and cm for short distances but km for long distances.] [*Assessment Boundary: Observations are made at the macroscopic scale only.*]**

b. **Communicate observations and information graphically and mathematically to represent how an object's relative position, velocity, and direction of motion are affected by forces acting on the object. [*Assessment Boundary: Restricted to motion in one dimension. The use of vectors is not an expectation.*]**

c. **Collect data to generate reliable evidence supporting Newton's Third Law, which states that when two objects interact they exert equal and opposite forces on each other. [Clarification Statement: Examples of interacting objects can include a book resting on a table; and skaters facing one another with hands together, then pushing off of one another.] [*Assessment Boundary: Restrict to vertical or horizontal interactions; interactions at angles requiring trigonometry is not an expectation.*]**

d. **Use mathematical concepts and observations to describe the proportional relationship between the acceleration of an object and the force applied upon the object, and the inversely proportional relationship of acceleration to its mass. [Clarification Statement: Examples of these proportional and inversely proportional relationships can include a large truck requiring more force to slow down from a given speed to a stop than does a small truck and a ball pushed with a given force having a greater change in motion if the force is greater.] [*Assessment Boundary: Simple formulas such as F=ma and w=mg could be used quantitatively; the use of trigonometry is not an expectation.*]**

e. **Plan and carry out investigations to identify the effect forces have on an object's shape and orientation. [Clarification Statement: Effects of forces can include a small ball of mud or clay changing shape if force is added, such as pushing down on it or rolling it in your hands; and the orientation of a pencil on a desk changing if a force is applied to it.] [*Assessment Boundary: When discussing an object's shape, description is purely qualitative. Simple formulas such as s=d/t and F=ma can be used quantitatively.*]**

f. **Analyze and interpret data to determine the cause and effect relationship between the motion of an object and the sum of the forces acting upon it. [Clarification Statement: An example of the additive impact of forces on the motion of an object could include a situation in which one person may not be able to push a heavy object, but several people pushing and pulling in the same direction may move it.] [*Assessment Boundary: Simple free-body diagrams are acceptable. The use of trigonometry is not an expectation. Assessments should include situations with both balanced and unbalanced forces.*]**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Asking Questions and Defining Problems
Asking questions and defining problems in grades 6–8 builds from grades K–5 experiences and progresses to formulating and refining empirically testable questions and explanatory models.
- Ask questions that arise from phenomena, models, or unexpected results. (a)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.
- Collect data and generate evidence to answer scientific questions or test design solutions under a range of conditions. (c),(e)

Analyzing and Interpreting Data
Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.
- Distinguish between causal and correlational relationships. (f)

Mathematics and Computational Thinking
Mathematical and computational thinking at the 6–8 level builds on K–5 and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments.
- Use mathematical concepts such as ratios, averages, basic probability, and simple functions, including linear relationships, to analyze data. (d)

Disciplinary Core Ideas

PS2.A: Forces and Motion
- 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). (c)
- 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. (b),(f)
- 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. (d)
- Forces on an object can also change its shape or orientation. (e)
- 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. (a)

Crosscutting Concepts

Scale, Proportion, and Quantity
Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. The observed function of natural and designed systems may change with scale. (a)

Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes. Scientific relationships can be represented through the use of algebraic expressions and equations. (b),(d)

Stability and Change
Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale. Small changes in one part of a system might cause large changes in another part. Stability might be disturbed either by sudden events or gradual changes that accumulate over time. Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms. (c),(e),(f)

Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 3–5 builds on K–2 and progresses to evaluate the merit and accuracy of ideas and methods. • Communicate understanding of scientific information that is presented in different formats (e.g., verbally, graphically, textually, mathematically). (b)		

Connections to other DCIs in this grade-level: **MS.ESS-EIP, MS.ESS-SS**

Articulation of DCIs across grade-levels: **3.IF, HS.PS-FM, HS.PS-IF**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA

RST.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
WHST.9	Draw evidence from informational texts to support analysis reflection, and research.

Mathematics

MP.1	Make sense of problems and persevere in solving them.
MP.2	Reason abstractly and quantitatively.
MP.4	Model with mathematics.
MP.6	Attend to precision.
5.OA	Analyze patterns and relationships.
6.RP	Understand ratio concepts and use ratio reasoning to solve problems.
6.EE	Apply and extend previous understandings of arithmetic to algebraic expressions. Reason about and solve one-variable equations and inequalities. Represent and analyze quantitative relationships between dependent and independent variables.
7.RP	Analyze proportional relationships and use them to solve real-world and mathematical problems.
7.EE	Solve real-life and mathematical problems using numerical and algebraic expressions and equations.

MS.PS-IF Interactions of Forces

How to read the standards »

Go to the NGSS Survey

Students who demonstrate understanding can:

a. **Plan and carry out investigations to illustrate the factors that affect the strength of electric and magnetic forces. [Clarification Statement: Investigations can include observing the electric force produced between two charged objects at different distances; and measuring the magnetic force produced by an electromagnet with a varying number of wire turns, number or size of dry cells, or size of iron core.] [*Assessment Boundary: Qualitative, not quantitative; no assessment of Coulomb's law.*]**

b. **Use a model or various representations to describe the relationship among gravitational force, the mass of the interacting objects, and the distance between them. [Clarification Statement: Examples of models and representations can include labeled diagrams of the relationship between Earth and man-made satellites, the International Space Station, and an airplane taking off.] [*Assessment Boundary: Qualitative, not quantitative.*]**

c. **Plan and carry out investigations to demonstrate that some forces act at a distance through fields. [*Assessment Boundary: Fields included are limited to gravitational, electric, and magnetic. Determination of fields are qualitative not quantitative (e.g., forces between two human–scale objects are too small to measure without sensitive instrumentation.)*]**

d. **Develop a simple model using given data that represents the relationship of gravitational interactions and the motion of objects in space. [Clarification Statement: Examples of simple models can include charts displaying mass, distance from the sun, and orbital periods of objects within the solar system.] [*Assessment Boundary: Use models to determine a relationship conceptually. Qualitative, not quantitative.*]**

e. **Develop or modify models to demonstrate that systems can withstand small changes, relying on feedback mechanisms to maintain stability. [*Assessment Boundary: Use models to determine a relationship conceptually -- not quantitatively.*]**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to explain, explore, and predict more abstract phenomena and design systems.
- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (b),(d)
- Pose models to describe mechanisms at unobservable scales. (b),(d)
- Modify models – based on their limitations – to increase detail or clarity, or to explore what will happen if a component is changed. (e)
- Use and construct models of simple systems with uncertain and less predictable factors. (e)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.
- Collect data and generate evidence to answer scientific questions or test design solutions under a range of conditions. (a),(c)

Disciplinary Core Ideas

PS2.B: Types of Interactions
- 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. (a)
- Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun. (d)
- 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. (b),(d)
- 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). (c)

PS2.C: Stability and Instability in Physical Systems
- 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). (e)
- 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). (e)

Crosscutting Concepts

Cause and Effect
Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Cause and effect relationships may be used to predict phenomena in natural or designed systems. Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (a), (b),(e)

Scale, Proportion, and Quantity
Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. The observed function of natural and designed systems may change with scale. (c),(d)

Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes. Scientific relationships can be represented through the use of algebraic expressions and equations. (d)

Connections to other DCIs in this grade-level: **MS.ESS-SS, MS.ESS-EIP, MS.ESS-ESP, MS.ESS-WC**

Articulation of DCIs across grade-levels: **3.IF, HS.PS-IF**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA

RST.6.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
WHST.7	Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

Mathematics

MP.1	Make sense of problems and persevere in solving them.
MP.2	Reason abstractly and quantitatively.
MP.4	Model with mathematics.

MP.6	Attend to precision.
5.OA	Analyze patterns and relationships.
6.EE	Represent and analyze quantitative relationships between dependent and independent variables.
7.RP	Analyze proportional relationship and use them to solve real-world and mathematical problems.
7.EE	Solve real-life and mathematical problems using numerical and algebraic expressions and equations.

MS.PS-E Energy

How to read the standards »

Go to the NGSS Survey

Students who demonstrate understanding can:

a. **Construct an explanation of the proportional relationship pattern between the kinetic energy of an object and its mass and speed.** [*Assessment Boundary: Not intended to solely require use of $KE=1/2mv^2$—the explanation requires a qualitative description of the relationship and patterns.*]

b. **Use representations of potential energy to construct an explanation of how much energy an object has when it's in different positions in an electrical, gravitational, and magnetic field.** [Clarification Statement: Examples of objects in different field positions include a roller coaster cart at varying positions on a hill, objects at varying heights on shelves, an iron nail being moved closer to a magnet, and a balloon with static electrical charge being brought closer to a classmate's hair.] [*Assessment Boundary: Qualitative- not quantitative.*]

c. **Plan and carry out investigations to show that in some chemical reactions energy is released or absorbed.** [Clarification Statement: Examples of chemical reactions can include baking soda reacting with vinegar, and calcium chloride reacting with baking soda.] [*Assessment Boundary: Qualitative, not quantitative.*]

d. **Use and/or construct models to communicate the means by which thermal energy is transferred during conduction, convection, and radiation.** [Clarification Statement: Examples of models can include a diagram depicting thermal energy transfer through a pan to its handle or warmer water in a pan rising as cooler water sinks; and a model using a heat lamp for the sun and a globe for the earth.]

e. **Collect data and generate evidence to examine the relationship between the change in the temperature of a sample and the nature of the matter, the size of the sample, and the environment.** [Clarification Statement: Examples of data collection could include comparing final water temperatures after different masses of ice melted in the same volume of water with the same initial temperature.]

f. **Compare, evaluate, and design a device that maximizes or minimizes thermal energy transfer, and defend the selection of materials chosen to construct the device.** [*Assessment Boundary: Excludes semiconductors and heat sinks.*]

g. **Design and evaluate solutions that minimize and/or maximize friction and energy transfer in everyday machines.** [Clarification Statement: Solutions can include use of oil as a lubricant on a skateboard, bicycle, or in a lawnmower engine, and wax on skis. Energy transfer can include the transfer of energy from motion to thermal energy due to friction. Everyday machines can include skateboards, bicycles, lawnmowers, skis, and toy cars.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to explain, explore, and predict more abstract phenomena and design systems.
- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (d)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.
- Plan and carry out investigations individually and collaboratively, identifying independent and dependent variables and controls. (c)
- Collect data and generate evidence to answer scientific questions or test design solutions under a range of conditions. (e)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.
- Use qualitative and quantitative relationships between variables to construct explanations for phenomena. (a)
- Construct explanations from models or representations. (b)

Disciplinary Core Ideas

PS3.A: Definitions of Energy
- 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)
- 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. (b)
- Stored energy is decreased in some chemical reactions and increased in others. (c)
- 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. (d),(e)

PS3.B: Conservation of Energy and Energy Transfer
- 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 battery) processes. (f),(g)

Crosscutting Concepts

Scale, Proportion, and Quantity
Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. The observed function of natural and designed systems may change with scale.

Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes. Scientific relationships can be represented through the use of algebraic expressions and equations. (a),(b)

Energy and Matter
Matter is conserved because atoms are conserved in physical and chemical processes. Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. (c)

Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). The transfer of energy can be tracked as energy flows through a designed or natural system. (d),(e)

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World
All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. The uses of technologies are

• Undertake design projects, engaging in the design cycle, to construct and implement a solution that meets specific design criteria and constraints. (f),(g) **Engaging in Argument from Evidence** Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world. • Use oral and written arguments supported by empirical evidence and reasoning to support or refute an argument for a phenomenon or a solution to a problem. (f)	• 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. (e) • Energy is transferred out of hotter regions or objects and into colder ones by the processes of conduction, convection, and radiation. (d) **PS3.D: Energy in Chemical Processes and Everyday Life** • 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. (f),(g)	driven by people's needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Technology use varies over time and from region to region. (f),(g)

Connections to other DCIs in this grade-level: **MS.ESS-SS, MS.LS-MEOE, MS.ETS-ED**

Articulation of DCIs across grade-levels: **4.E, HS.PS-E, HS.PS-FE**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA

W.6.1	Write arguments to support claims with clear reasons and relevant evidence.
W.7.1	Write arguments to support claims with clear reasons and relevant evidence.
W.8.1	Write arguments to support claims with clear reasons and relevant evidence.
WHST.7	Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

Mathematics

MP.2	Reason abstractly and quantitatively.
MP.4	Model with mathematics.
5.MD	Represent and interpret data.
6.RP	Understand ratio concepts and use ratio reasoning to solve problems.
6.EE	Apply and extend previous understandings of arithmetic to algebraic expressions.
	Represent and analyze quantitative relationships between dependent and independent variables.
7.RP	Analyze proportional relationship and use them to solve real-world and mathematical problems.
7.EE	Solve real-life and mathematical problems using numerical and algebraic expressions and equations.

MS.PS-WER Waves and Electromagnetic Radiation

How to read the standards »

Go to the NGSS Survey

Students who demonstrate understanding can:

a. **Use a drawing or physical representation of simple wave properties to explain brightness and color.** [*Assessment Boundary: Qualitative, not quantitative; mechanical waves only. Restricted to the following wave properties: frequency, wavelength, and amplitude.*]

b. **Plan and carry out investigations of sound traveling through various types of mediums and lack of medium to determine whether a medium is necessary for the transfer of sound waves.** [Clarification Statement: Examples of investigations examining a lack of medium could include using a vacuum bell jar.]

c. **Construct explanations of how waves are reflected, absorbed or transmitted through an object, considering the material the object is made from and the frequency of the wave.** [*Assessment Boundary: Qualitative application to light, sound, and seismic waves only.*]

d. **Use empirical evidence to support the claim that light travels in straight lines except at surfaces between different transparent materials.** [Clarification Statement: Examples of surfaces between transparent materials can include air and water, and air and glass.] [*Assessment Boundary: Only non-computational observations; alterations of the speed of waves is not assessed until high school.*]

e. **Ask questions about certain properties of light that can be explained by a wave model of light.** [Clarification Statement: Examples of properties of light can include brightness, color, and the refracting of light in a prism.]

f. **Apply scientific knowledge to explain the application of waves in common communication designs.** [Clarification Statement: Examples of common communication designs can include cell phones, radios, remote controls, and Bluetooth.] [*Assessment Boundary: Applications limited to ability to transmit, receive, and encode.*]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Asking Questions and Defining Problems
Asking questions and defining problems in grades 6–8 builds from grades K–5 experiences and progresses to formulating and refining empirically testable questions and explanatory models.
- Ask questions that arise from phenomena, models, or unexpected results. (e)

Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to explain, explore, and predict more abstract phenomena and design systems.
- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (a)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.
- Plan and carry out investigations individually and collaboratively, identifying independent and dependent variables, and controls. (b)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.
- Use qualitative and quantitative relationships between variables to construct explanations for phenomena. (c)
- Apply scientific knowledge to explain real-world examples or events. (f)

Engaging in Argument from Evidence
Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.

Disciplinary Core Ideas

PS4.A: Wave Properties
- A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. (a)
- A sound wave needs a medium through which it is transmitted. (b)
- Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet. (c)

PS4.B: Electromagnetic Radiation
- 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. (c)
- 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. (d)
- 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. (a),(e)

PS4.C: Information Technologies and Instrumentation
- 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. (f)
- Many modern communication devices use digitized signals (sent as wave pulses) as a more reliable way to encode and transmit information. (f)

Crosscutting Concepts

Systems and System Models
Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. Models are limited in that they only represent certain aspects of the system under study. (b),(e)

Structure and Function
Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts, therefore complex natural and designed structures/systems can be analyzed to determine how they function. Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (a),(c),(d),(f)

• Use oral and written arguments supported by empirical evidence and reasoning to support or refute an explanation for a phenomenon or a solution to a problem. (d)	

Connections to other DCIs in this grade-level: **MS.ESS-SS, MS.ESS-ESP, MS.ESS-EIP**

Articulation of DCIs across grade-levels: **3.SFS, 4.WAV, 5.SSS, HS.PS-W, HS.PS-ER, HS.PS-FM**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA

SL.5.1	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacherled) with diverse partners on grade 5 topics and texts, building on others' ideas and expressing their own clearly.
SL.6.1	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.
SL.6.3	Delineate a speaker's argument and specific claims, distinguishing claims that are supported by reasons and evidence from claims that are not.
SL.7.3	Delineate a speaker's argument and specific claims, evaluating the soundness of the reasoning and the relevance and sufficiency of the evidence.
SL.8.3	Delineate a speaker's argument and specific claims, evaluating the soundness of the reasoning and relevance and sufficiency of the evidence and identifying when irrelevant evidence is introduced.
RST.6-8	Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.

Mathematics

MP.2	Reason abstractly and quantitatively.
MP.4	Model with mathematics.
MP.6	Attend to precision.
6.EE	Represent and analyze quantitative relationships between dependent and independent variables.