MS-PS1-1 Matter and its Interactions

Students who demonstrate understanding can:

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 all individual atoms in a complex molecule or extended structure is not required.*]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to describe, test, and predict more abstract phenomena and design systems. • Develop a model to predict and/or describe phenomena.	**PS1.A: Structure and Properties of Matter** • Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. • Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).	**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.

Observable features of the student performance by the end of the course:			
1	Components of the model		
	a	Students develop models of atomic composition of simple molecules and extended structures that vary in complexity. In the models, students identify the relevant components, including:	
		i.	Individual atoms.
		ii.	Molecules.
		iii.	Extended structures with repeating subunits.
		iv.	Substances (e.g., solids, liquids, and gases at the macro level).
2	Relationships		
	a	In the model, students describe* relationships between components, including:	
		i.	Individual atoms, from two to thousands, combine to form molecules, which can be made up of the same type or different types of atom.
		ii.	Some molecules can connect to each other.
		iii.	In some molecules, the same atoms of different elements repeat; in other molecules, the same atom of a single element repeats.
3	Connections		
	a	Students use models to describe* that:	
		i.	Pure substances are made up of a bulk quantity of individual atoms or molecules. Each pure substance is made up of one of the following:
			1. Individual atoms of the same type that are connected to form extended structures.
			2. Individual atoms of different types that repeat to form extended structures (e.g., sodium chloride).
			3. Individual atoms that are not attracted to each other (e.g., helium).
			4. Molecules of different types of atoms that are not attracted to each other (e.g., carbon dioxide).
			5. Molecules of different types of atoms that are attracted to each other to form extended structures (e.g., sugar, nylon).
			6. Molecules of the same type of atom that are not attracted to each other (e.g., oxygen).
		ii.	Students use the models to describe* how the behavior of bulk substances depends on their structures at atomic and molecular levels, which are too small to see.

MS-PS1-2 Matter and its Interactions

Students who demonstrate understanding can:

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.*]

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

Science and Engineering Practices

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.

- Analyze and interpret data to determine similarities and differences in findings.

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Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence

- Science knowledge is based upon logical and conceptual connections between evidence and explanations.

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter

- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.

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.

Crosscutting Concepts

Patterns

- Macroscopic patterns are related to the nature of microscopic and atomic-level structure.

Observable features of the student performance by the end of the course:		
1	Organizing data	
	a	Students organize given data about the characteristic physical and chemical properties (e.g., density, melting point, boiling point, solubility, flammability, odor) of pure substances before and after they interact.
	b	Students organize the given data in a way that facilitates analysis and interpretation.
2	Identifying relationships	
	a	Students analyze the data to identify patterns (i.e., similarities and differences), including the changes in physical and chemical properties of each substance before and after the interaction (e.g., before the interaction, a substance burns, while after the interaction, the resulting substance does not burn).
3	Interpreting data	
	a	Students use the analyzed data to determine whether a chemical reaction has occurred.
	b	Students support their interpretation of the data by describing* that the change in properties of substances is related to the rearrangement of atoms in the reactants and products in a chemical reaction (e.g., when a reaction has occurred, atoms from the substances present before the interaction must have been rearranged into new configurations, resulting in the properties of new substances).

MS-PS1-3 Matter and its Interactions

Students who demonstrate understanding can:

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.*]

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

Science and Engineering Practices

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 6–8 builds on K–5 and progresses to evaluating the merit and validity of ideas and methods.

- Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or now supported by evidence.

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter

- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.

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.

Crosscutting Concepts

Structure and 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.

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Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

- Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems.

Influence of Science, Engineering and Technology on Society and the Natural World

- The uses of technologies and any limitation on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time.

Observable features of the student performance by the end of the course:			
1	Obtaining information		
	a	Students obtain information from published, grade-level appropriate material from at least two sources (e.g., text, media, visual displays, data) about:	
		i.	Synthetic materials and the natural resources from which they are derived.
		ii.	Chemical processes used to create synthetic materials from natural resources (e.g., burning of limestone for the production of concrete).
		iii.	The societal need for the synthetic material (e.g., the need for concrete as a building material).
2	Evaluating information		
	a	Students determine and describe* whether the gathered information is relevant for determining:	
		i.	That synthetic materials, via chemical reactions, come from natural resources.
		ii.	The effects of the production and use of synthetic resources on society.
	b	Students determine the credibility, accuracy, and possible bias of each source of information, including the ideas included and methods described.	
	c	Students synthesize information that is presented in various modes (e.g., graphs, diagrams, photographs, text, mathematical, verbal) to describe*:	

		i.	How synthetic materials are formed, including the natural resources and chemical processes used.
		ii.	The properties of the synthetic material(s) that make it different from the natural resource(s) from which it was derived.
		iii.	How those physical and chemical properties contribute to the function of the synthetic material.
		iv.	How the synthetic material satisfies a societal need or desire through the properties of its structure and function.
		v.	The effects of making and using synthetic materials on natural resources and society.

MS-PS1-4 Matter and its Interactions

Students who demonstrate understanding can:

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.]

The performance expectation above was 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 describe, test, and predict more abstract phenomena and design systems.

- Develop a model to predict and/or describe phenomena.

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter

- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.

PS3.A: Definitions of Energy

- The term “heat” as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects. *(secondary)*
- The temperature of a system is proportional to the average internal kinetic energy and potential energy per atom or molecule (whichever is the appropriate building block for the system’s material). The details of that relationship depend on the type of atom or molecule and the interactions among the atoms in the material. Temperature is not a direct measure of a system's total thermal energy. The total thermal energy (sometimes called the total internal energy) of a system depends jointly on the temperature, the total number of atoms in the system, and the state of the material. *(secondary)*

Crosscutting Concepts

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Observable features of the student performance by the end of the course:

1	Components of the model		
	a	To make sense of a given phenomenon, students develop a model in which they identify the relevant components, including:	
		i.	Particles, including their motion.
		ii.	The system within which the particles are contained.
		iii.	The average kinetic energy of particles in the system.
		iv.	Thermal energy of the system.

		v. Temperature of the system.
		vi. A pure substance in one of the states of matter (e.g., solid, liquid, gas at the macro scale).
2	Relationships	
	a	In the model, students describe* relationships between components, including:
		i. The relationships between:
		1. The motion of molecules in a system and the kinetic energy of the particles in the system.
		2. The average kinetic energy of the particles and the temperature of the system.
		3. The transfer of thermal energy from one system to another and:
		A. A change in kinetic energy of the particles in that new system, or
		B. A change in state of matter of the pure substance.
		4. The state of matter of the pure substance (gas, liquid, solid) and the particle motion (freely moving and not in contact with other particles, freely moving and in loose contact with other particles, vibrating in fixed positions relative to other particles).
3	Connections	
	a	Students use their model to provide a causal account of the relationship between the addition or removal of thermal energy from a substance and the change in the average kinetic energy of the particles in the substance.
	b	Students use their model to provide a causal account of the relationship between:
		i. The temperature of the system.
		ii. Motions of molecules in the gaseous phase.
		iii. The collisions of those molecules with other materials, which exerts a force called pressure.
	c	Students use their model to provide a causal account of what happens when thermal energy is transferred into a system, including that:
		i. An increase in kinetic energy of the particles can cause:
		1. An increase in the temperature of the system as the motion of the particles relative to each other increases, or
		2. A substance to change state from a solid to a liquid or from a liquid to a gas.
		ii. The motion of molecules in a gaseous state increases, causing the moving molecules in the gas to have greater kinetic energy, thereby colliding with molecules in surrounding materials with greater force (i.e., the pressure of the system increases).
	d	Students use their model to provide a causal account of what happens when thermal energy is transferred from a substance, including that:
		i. Decreased kinetic energy of the particles can cause:
		1. A decrease in the temperature of the system as the motion of the particles relative to each other decreases, or
		2. A substance to change state from a gas to a liquid or from a liquid to a solid.
		ii. The pressure that a gas exerts decreases because the kinetic energy of the gas molecules decreases, and the slower molecules exert less force in collisions with other molecules in surrounding materials.
	e	Students use their model to provide a causal account for the relationship between changes in pressure of a system and changes of the states of materials in the system.
		i. With a decrease in pressure, a smaller addition of thermal energy is required for particles of a liquid to change to gas because particles in the gaseous state are colliding with the surface of the liquid less frequently and exerting less force on the particles in the liquid, thereby allowing the particles in the liquid to break away and move into the gaseous state with the addition of less energy.
		ii. With an increase in pressure, a greater addition of thermal energy is required for particles of a liquid to change to gas because particles in the gaseous state are colliding with the surface of the liquid more frequently and exerting greater force on the particles in the liquid, thereby limiting the movement of particles from the liquid to gaseous state.

MS-PS1-5 Matter and its Interactions

Students who demonstrate understanding can:

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, that represent atoms.] [*Assessment Boundary: Assessment does not include the use of atomic masses, balancing symbolic equations, or intermolecular forces.*]

The performance expectation above was 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 describe, test, and predict more abstract phenomena and design systems.

- Develop a model to describe unobservable mechanisms.

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Connections to Nature of Science

Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

- Laws are regularities or mathematical descriptions of natural phenomena.

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.
- The total number of each type of atom is conserved, and thus the mass does not change.

Crosscutting Concepts

Energy and Matter

- Matter is conserved because atoms are conserved in physical and chemical processes.

Observable features of the student performance by the end of the course:		
1	Components of the model	
	a	To make sense of a given phenomenon, students develop a model in which they identify the relevant components for a given chemical reaction, including:
		i. The types and number of molecules that make up the reactants.
		ii. The types and number of molecules that make up the products.
2	Relationships	
	a	In the model, students describe* relationships between the components, including:
		i. Each molecule in each of the reactants is made up of the same type(s) and number of atoms.
		ii. When a chemical reaction occurs, the atoms that make up the molecules of reactants rearrange and form new molecules (i.e., products).
		iii. The number and types of atoms that make up the products are equal to the number and types of atoms that make up the reactants.
		iv. Each type of atom has a specific mass, which is the same for all atoms of that type.
3	Connections	
	a	Students use the model to describe* that the atoms that make up the reactants rearrange and come together in different arrangements to form the products of a reaction.
	b	Students use the model to provide a causal account that mass is conserved during chemical reactions because the number and types of atoms that are in the reactants equal the number and types of atoms that are in the products, and all atoms of the same type have the same mass regardless of the molecule in which they are found.

MS-PS1-6 Matter and its Interactions

Students who demonstrate understanding can:

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 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.*]

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

Science and Engineering Practices

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.

- Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.

Disciplinary Core Ideas

PS1.B: Chemical Reactions

- Some chemical reactions release energy, others store energy.

ETS1.B: Developing Possible Solutions

- A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. *(secondary)*

ETS1.C: Optimizing the Design Solution

- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process - that is, some of the characteristics may be incorporated into the new design. *(secondary)*
- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. *(secondary)*

Crosscutting Concepts

Energy and Matter

- The transfer of energy can be tracked as energy flows through a designed or natural system.

Observable features of the student performance by the end of the course:			
1	Using scientific knowledge to generate design solutions		
	a	Given a problem to solve that requires either heating or cooling, students design and construct a solution (i.e., a device). In their designs, students:	
		i.	Identify the components within the system related to the design solution, including:
			1. The components within the system to or from which energy will be transferred to solve the problem.
			2. The chemical reaction(s) and the substances that will be used to either release or absorb thermal energy via the device.
		ii.	Describe* how the transfer of thermal energy between the device and other components within the system will be tracked and used to solve the given problem.
2	Describing* criteria and constraints, including quantification when appropriate		
	a	Students describe* the given criteria, including:	
		i.	Features of the given problem that are to be solved by the device.
		ii.	The absorption or release of thermal energy by the device via a chemical reaction.
	b	Students describe* the given constraints, which may include:	
		i.	Amount and cost of materials.
		ii.	Safety.
		iii.	Amount of time during which the device must function.
3	Evaluating potential solutions		
	a	Students test the solution for its ability to solve the problem via the release or absorption of thermal energy to or from the system.	

	b	Students use the results of their tests to systematically determine how well the design solution meets the criteria and constraints, and which characteristics of the design solution performed the best.
4	Modifying the design solution	
	a	Students modify the design of the device based on the results of iterative testing, and improve the design relative to the criteria and constraints.

MS-PS2-1 Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

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 vehicle.] [*Assessment Boundary: Assessment is limited to vertical or horizontal interactions in one dimension.*]

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

Science and Engineering Practices

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 ideas, principles, and theories.

- Apply scientific ideas or principles to design an object, tool, process or system.

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).

Crosscutting Concepts

Systems and System Models

- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems.

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Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology on Society and the Natural World

- The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions.

Observable features of the student performance by the end of the course:			
1	Using scientific knowledge to generate design solutions		
	a	Given a problem to solve involving a collision of two objects, students design a solution (e.g., an object, tool, process, or system). In their designs, students identify and describe*:	
		i.	The components within the system that are involved in the collision.
		ii.	The force that will be exerted by the first object on the second object.
		iii.	How Newton's third law will be applied to design the solution to the problem.
		iv.	The technologies (i.e., any human-made material or device) that will be used in the solution.
2	Describing* criteria and constraints, including quantification when appropriate		
	a	Students describe* the given criteria and constraints, including how they will be taken into account when designing the solution.	
		i.	Students describe* how the criteria are appropriate to solve the given problem.
		ii.	Students describe* the constraints, which may include:
			1. Cost.
			2. Mass and speed of objects.
			3. Time.
			4. Materials.
3	Evaluating potential solutions		
	a	Students use their knowledge of Newton's third law to systematically determine how well the design solution meets the criteria and constraints.	
	b	Students identify the value of the device for society.	
	c	Students determine how the choice of technologies that are used in the design is affected by the constraints of the problem and the limits of technological advances.	

MS-PS2-2 Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

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.*]

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

Science and Engineering Practices

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 an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.

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Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence

- Science knowledge is based upon logical and conceptual connections between evidence and explanations.

Disciplinary Core Ideas

PS2.A: Forces and Motion

- 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.
- 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.

Crosscutting Concepts

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.

Observable features of the student performance by the end of the course:				
1	Identifying the phenomenon to be investigated			
	a	Students identify the phenomenon under investigation, which includes the change in motion of an object.		
	b	Students identify the purpose of the investigation, which includes providing evidence that the change in an object's motion is due to the following factors:		
		i.	Balanced or unbalanced forces acting on the object.	
		ii.	The mass of the object.	
2	Identifying the evidence to address the purpose of the investigation			
	a	Students develop a plan for the investigation individually or collaboratively. In the plan, students describe*:		
		i.	That the following data will be collected:	
			1.	Data on the motion of the object.
			2.	Data on the total forces acting on the object.
			3.	Data on the mass of the object.
		ii.	Which data are needed to provide evidence for each of the following:	
			1.	An object subjected to balanced forces does not change its motion (sum of F=0).
			2.	An object subjected to unbalanced forces changes its motion over time (sum of F≠0).

		3. The change in the motion of an object subjected to unbalanced forces depends on the mass of the object.
3	Planning the investigation	
	a	In the investigation plan, students describe*:
		i. How the following factors will be determined and measured:
		1. The motion of the object, including a specified reference frame and appropriate units for distance and time.
		2. The mass of the object, including appropriate units.
		3. The forces acting on the object, including balanced and unbalanced forces.
		ii. Which factors will serve as independent and dependent variables in the investigation (e.g., mass is an independent variable, forces and motion can be independent or dependent).
		iii. The controls for each experimental condition.
		iv. The number of trials for each experimental condition.

MS-PS2-3 Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

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.*]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions and Defining Problems Asking questions and defining problems in grades 6–8 builds from grades K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models. • Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles.	**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.	**Cause and Effect** • Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Observable features of the student performance by the end of the course:

1	Addressing phenomena of the natural world or scientific theories			
	a	Students formulate questions that arise from examining given data of objects (which can include particles) interacting through electric and magnetic forces, the answers to which would clarify:		
		i.	The cause-and-effect relationships that affect magnetic forces due to:	
			1.	The magnitude of any electric current present in the interaction, or other factors related to the effect of the electric current (e.g., number of turns of wire in a coil).
			2.	The distance between the interacting objects.
			3.	The relative orientation of the interacting objects.
			4.	The magnitude of the magnetic strength of the interacting objects.
		ii.	The cause-and-effect relationship that affect electric forces due to:	
			1.	The magnitude and signs of the electric charges on the interacting objects.
			2.	The distances between the interacting objects.
			3.	Magnetic forces.
	b	Based on scientific principles and given data, students frame hypotheses that:		
		i.	Can be used to predict the strength of electric and magnetic forces due to cause-and-effect relationships.	
		ii.	Can be used to distinguish between possible outcomes, based on an understanding of the cause-and-effect relationships driving the system.	
2	Identifying the scientific nature of the question			
	a	Students' questions can be investigated scientifically within the scope of a classroom, outdoor environment, museum, or other public facility.		

MS-PS2-4 Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

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.*]

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

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.

- Construct and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.

- -

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence

- Science knowledge is based upon logical and conceptual connections between evidence and explanations.

Disciplinary Core Ideas

PS2.B: Types of Interactions

- 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.

Crosscutting Concepts

Systems and System Models

- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems.

Observable features of the student performance by the end of the course:			
1	Supported claims		
	a	Students make a claim to be supported about a given phenomenon. In their claim, students include the following idea: Gravitational interactions are attractive and depend on the masses of interacting objects.	
2	Identifying scientific evidence		
	a	Students identify and describe* the given evidence that supports the claim, including:	
		i.	The masses of objects in the relevant system(s).
		ii.	The relative magnitude and direction of the forces between objects in the relevant system(s).
3	Evaluating and critiquing the evidence		
	a	Students evaluate the evidence and identify its strengths and weaknesses, including:	
		i.	Types of sources.
		ii.	Sufficiency, including validity and reliability, of the evidence to make and defend the claim.
		iii.	Any alternative interpretations of the evidence, and why the evidence supports the given claim as opposed to any other claims.
4	Reasoning and synthesis		
	a	Students use reasoning to connect the appropriate evidence about the forces on objects and construct the argument that gravitational forces are attractive and mass dependent. Students describe* the following chain of reasoning:	
		i.	Systems of objects can be modeled as a set of masses interacting via gravitational forces.
		ii.	In systems of objects, larger masses experience and exert proportionally larger gravitational forces.

		iii. In every case for which evidence exists, gravitational force is attractive.
	b	To support the claim, students present their oral or written argument concerning the direction of gravitational forces and the role of the mass of the interacting objects.

MS-PS2-5 Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

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 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.*]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
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. • Conduct an investigation and evaluate the experimental design to produce data to serve as the basis for evidence that can meet the goals of the investigation.	**PS2.B: Types of Interactions** • Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively).	**Cause and Effect** • Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Observable features of the student performance by the end of the course:			
1	Identifying the phenomenon to be investigated		
	a	From the given investigation plan, students identify the phenomenon under investigation, which includes the idea that objects can interact at a distance.	
	b	Students identify the purpose of the investigation, which includes providing evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.	
2	Identifying evidence to address the purpose of the investigation		
	a	From the given plan, students identify and describe* the data that will be collected to provide evidence for each of the following:	
		i.	Evidence that two interacting objects can exert forces on each other even though the two interacting objects are not in contact with each other.
		ii.	Evidence that distinguishes between electric and magnetic forces.
		iii.	Evidence that the cause of a force on one object is the interaction with the second object (e.g., evidence for the presence of force disappears when the second object is removed from the vicinity of the first).
3	Planning the investigation		
	a	Students describe* the rationale for why the given investigation plan includes:	
		i.	Changing the distance between objects.
		ii.	Changing the charge or magnetic orientation of objects.
		iii.	Changing the magnitude of the charge on an object or the strength of the magnetic field.
		iv.	A means to indicate or measure the presence of electric or magnetic forces.
4	Collecting the data		
	a	Students make and record observations according to the given plan. The data recorded may include observations of:	
		i.	Motion of objects.
		ii.	Suspension of objects.
		iii.	Simulations of objects that produce either electric or magnetic fields through space and the effects of moving those objects closer to or farther away from each other.
		iv.	A push or pull exerted on the hand of an observer holding an object.

5	Evaluation of the design	
	a	Students evaluate the experimental design by assessing whether or not the data produced by the investigation can provide evidence that fields exist between objects that act on each other even though the objects are not in contact.

MS-PS3-1 Energy

Students who demonstrate understanding can:

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.]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
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. • Construct and interpret graphical displays of data to identify linear and nonlinear relationships.	**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.	**Scale, Proportion, and Quantity** • 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.

Observable features of the student performance by the end of the course:			
1	Organizing data		
	a	Students use graphical displays to organize the following given data:	
		i.	Mass of the object.
		ii.	Speed of the object.
		iii.	Kinetic energy of the object.
	b	Students organize the data in a way that facilitates analysis and interpretation.	
2	Identifying relationships		
	a	Using the graphical display, students identify that kinetic energy:	
		i.	Increases if either the mass or the speed of the object increases or if both increase.
		ii.	Decreases if either the mass or the speed of the object decreases or if both decrease.
3	Interpreting data		
	a	Using the analyzed data, students describe*:	
		i.	The relationship between kinetic energy and mass as a linear proportional relationship ($KE \propto m$) in which:
			1. The kinetic energy doubles as the mass of the object doubles.
			2. The kinetic energy halves as the mass of the object halves.
		ii.	The relationship between kinetic energy and speed as a nonlinear (square) proportional relationship ($KE \propto v2$) in which:
			1. The kinetic energy quadruples as the speed of the object doubles.
			2. The kinetic energy decreases by a factor of four as the speed of the object is cut in half.

MS-PS3-2 Energy

Students who demonstrate understanding can:

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.*]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to describe, test, and predict more abstract phenomena and design systems. • Develop a model to describe unobservable mechanisms.	**PS3.A: Definitions of Energy** • A system of objects may also contain stored (potential) energy, depending on their relative positions. **PS3.C: Relationship Between Energy and Forces** • When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.	**Systems and System Models** • Models can be used to represent systems and their interactions – such as inputs, processes, and outputs – and energy and matter flows within systems.

Observable features of the student performance by the end of the course:			
1	Components of the model		
	a	To make sense of a given phenomenon involving two objects interacting at a distance, students develop a model in which they identify the relevant components, including:	
		i.	A system of two stationary objects that interact.
		ii.	Forces (electric, magnetic, or gravitational) through which the two objects interact.
		iii.	Distance between the two objects.
		iv.	Potential energy.
2	Relationships		
	a	In the model, students identify and describe* relationships between components, including:	
		i.	When two objects interact at a distance, each one exerts a force on the other that can cause energy to be transferred to or from an object.
		ii.	As the relative position of two objects (neutral, charged, magnetic) changes, the potential energy of the system (associated with interactions via electric, magnetic, and gravitational forces) changes (e.g., when a ball is raised, energy is stored in the gravitational interaction between the Earth and the ball).
3	Connections		
	a	Students use the model to provide a causal account for the idea that the amount of potential energy in a system of objects changes when the distance between stationary objects interacting in the system changes because:	
		i.	A force has to be applied to move two attracting objects farther apart, transferring energy to the system.
		ii.	A force has to be applied to move two repelling objects closer together, transferring energy to the system.

MS-PS3-3 Energy

Students who demonstrate understanding can:

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.*]

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

Science and Engineering Practices

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 ideas, principles, and theories.

- Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process or system.

Disciplinary Core Ideas

PS3.A: Definitions of Energy

- 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.

PS3.B: Conservation of Energy and Energy Transfer

- Energy is spontaneously transferred out of hotter regions or objects and into colder ones.

ETS1.A: Defining and Delimiting an Engineering Problem

- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions.*(secondary)*

ETS1.B: Developing Possible Solutions

- A solution needs to be tested, and then modified on the basis of the test results in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem. *(secondary)*

Crosscutting Concepts

Energy and Matter

- The transfer of energy can be tracked as energy flows through a designed or natural system.

Observable features of the student performance by the end of the course:			
1	Using scientific knowledge to generate design solutions		
	a	Given a problem to solve that requires either minimizing or maximizing thermal energy transfer, students design and build a solution to the problem. In the designs, students:	
		i.	Identify that thermal energy is transferred from hotter objects to colder objects.
		ii.	Describe* different types of materials used in the design solution and their properties (e.g., thickness, heat conductivity, reflectivity) and how these materials will be used to minimize or maximize thermal energy transfer.
		iii.	Specify how the device will solve the problem.
2	Describing* criteria and constraints, including quantification when appropriate		
	a	Students describe* the given criteria and constraints that will be taken into account in the design solution:	
		i.	Students describe* criteria, including:

		1. The minimum or maximum temperature difference that the device is required to maintain.
		2. The amount of time that the device is required to maintain this difference.
		3. Whether the device is intended to maximize or minimize the transfer of thermal energy.
		ii. Students describe* constraints, which may include:
		1. Materials.
		2. Safety.
		3. Time.
		4. Cost.
3	Evaluating potential solutions	
	a	Students test the device to determine its ability to maximize or minimize the flow of thermal energy, using the rate of temperature change as a measure of success.
	b	Students use their knowledge of thermal energy transfer and the results of the testing to evaluate the design systematically against the criteria and constraints.

MS-PS3-4 Energy

Students who demonstrate understanding can:

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.*]

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

Science and Engineering Practices

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 an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.

- -

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence

- Science knowledge is based upon logical and conceptual connections between evidence and explanations

Disciplinary Core Ideas

PS3.A: Definitions of Energy

- 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.

PS3.B: Conservation of Energy and Energy Transfer

- 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.

Crosscutting Concepts

Scale, Proportion, and Quantity

- 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.

Observable features of the student performance by the end of the course:		
1	Identifying the phenomenon under investigation	
	a	Students identify the phenomenon under investigation involving thermal energy transfer.
	b	Students describe* the purpose of the investigation, including determining the relationships among the following factors:
		i. The transfer of thermal energy.
		ii. The type of matter.
		iii. The mass of the matter involved in thermal energy transfer.
		iv. The change in the average kinetic energy of the particles.
2	Identifying the evidence to address the purpose of the investigation	
	a	Individually or collaboratively, students develop an investigation plan that describes* the data to be collected and the evidence to be derived from the data, including:
		i. That the following data are to be collected:
		1. Initial and final temperatures of the materials used in the investigation.
		2. Types of matter used in the investigation.
		3. Mass of matter used in the investigation.
		ii. How the collected data will be used to:

		1. Provide evidence of proportional relationships between changes in temperature of materials and the mass of those materials.
		2. Relate the changes in temperature in the sample to the types of matter and to the change in the average kinetic energy of the particles.
3	Planning the investigation	
	a	In the investigation plan, students describe*:
		i. How the mass of the materials are to be measured and in what units.
		ii. How and when the temperatures of the materials are to be measured and in what units.
		iii. Details of the experimental conditions that will allow the appropriate data to be collected to address the purpose of the investigation (e.g., time between temperature measurements, amounts of sample used, types of materials used), including appropriate independent and dependent variables and controls.

MS-PS3-5 Energy

Students who demonstrate understanding can:

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.*]

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

Science and Engineering Practices

Engaging in Argument from Evidence

Engaging in argument from evidence in 6–8 builds on 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 worlds.

- Construct, use, and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon.

- -

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence

- Science knowledge is based upon logical and conceptual connections between evidence and explanations

Disciplinary Core Ideas

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.

Crosscutting Concepts

Energy and Matter

- Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion).

Observable features of the student performance by the end of the course:			
1	Supported claims		
	a	Students make a claim about a given explanation or model for a phenomenon. In their claim, students include idea that when the kinetic energy of an object changes, energy is transferred to or from that object.	
2	Identifying scientific evidence		
	a	Students identify and describe* the given evidence that supports the claim, including the following when appropriate:	
		i.	The change in observable features (e.g., motion, temperature, sound) of an object before and after the interaction that changes the kinetic energy of the object.
		ii.	The change in observable features of other objects or the surroundings in the defined system.
3	Evaluating and critiquing the evidence		
	a	Students evaluate the evidence and identify its strengths and weaknesses, including:	
		i.	Types of sources.
		ii.	Sufficiency, including validity and reliability, of the evidence to make and defend the claim.
		iii.	Any alternative interpretations of the evidence and why the evidence supports the given claim as opposed to any other claims.
4	Reasoning and synthesis		
	a	Students use reasoning to connect the necessary and sufficient evidence and construct the argument. Students describe* a chain of reasoning that includes:	
		i.	Based on changes in the observable features of the object (e.g., motion, temperature), the kinetic energy of the object changed.
		ii.	When the kinetic energy of the object increases or decreases, the energy (e.g., kinetic, thermal, potential) of other objects or the surroundings within the system increases or decreases, indicating that energy was transferred to or from the object.
	b	Students present oral or written arguments to support or refute the given explanation or model for the phenomenon.	

MS-PS4-1 Waves and Their Applications in Technologies for Information Transfer

Students who demonstrate understanding can:

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.*]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using 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 representations to describe and/or support scientific conclusions and design solutions. - ***Connections to Nature of Science*** **Scientific Knowledge is Based on Empirical Evidence** • Science knowledge is based upon logical and conceptual connections between evidence and explanations.	**PS4.A: Wave Properties** • A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.	**Patterns** • Graphs and charts can be used to identify patterns in data.

Observable features of the student performance by the end of the course:			
1	Representation		
	a	Students identify the characteristics of a simple mathematical wave model of a phenomenon, including:	
		i.	Waves represent repeating quantities.
		ii.	Frequency, as the number of times the pattern repeats in a given amount of time (e.g., beats per second).
		iii.	Amplitude, as the maximum extent of the repeating quantity from equilibrium (e.g., height or depth of a water wave from average sea level).
		iv.	Wavelength, as a certain distance in which the quantity repeats its value (e.g., the distance between the tops of a series of water waves).
2	Mathematical modeling		
	a	Students apply the simple mathematical wave model to a physical system or phenomenon to identify how the wave model characteristics correspond with physical observations (e.g., frequency corresponds to sound pitch, amplitude corresponds to sound volume).	
3	Analysis		
	a	Given data about a repeating physical phenomenon that can be represented as a wave, and amounts of energy present or transmitted, students use their simple mathematical wave models to identify patterns, including:	
		i.	That the energy of the wave is proportional to the square of the amplitude (e.g., if the height of a water wave is doubled, each wave will have four times the energy).
		ii.	That the amount of energy transferred by waves in a given time is proportional to frequency (e.g., if twice as many water waves hit the shore each minute, then twice as much energy will be transferred to the shore).
	b	Students predict the change in the energy of the wave if any one of the parameters of the wave is changed.	

MS-PS4-2 Waves and Their Applications in Technologies for Information Transfer

Students who demonstrate understanding can:

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.*]

The performance expectation above was 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 describe, test, and predict more abstract phenomena and design systems.

- Develop and use a model to describe phenomena.

Disciplinary Core Ideas

PS4.A: Wave Properties

- A sound wave needs a medium through which it is transmitted.

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

Crosscutting Concepts

Structure and 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.

Observable features of the student performance by the end of the course:			
1	Components of the model		
	a	Students develop a model to make sense of a given phenomenon. In the model, students identify the relevant components, including:	
		i.	Type of wave.
			1. Matter waves (e.g., sound or water waves) and their amplitudes and frequencies.
			2. Light, including brightness (amplitude) and color (frequency).
		ii.	Various materials through which the waves are reflected, absorbed, or transmitted.
		iii.	Relevant characteristics of the wave after it has interacted with a material (e.g., frequency, amplitude, wavelength).
		iv.	Position of the source of the wave.
2	Relationships		
	a	In the model, students identify and describe* the relationships between components, including:	
		i.	Waves interact with materials by being:
			1. Reflected.
			2. Absorbed.
			3. Transmitted.
		ii.	Light travels in straight lines, but the path of light is bent at the interface between materials when it travels from one material to another.
		iii.	Light does not require a material for propagation (e.g., space), but matter waves do require a material for propagation.
3	Connections		
	a	Students use their model to make sense of given phenomena involving reflection, absorption, or transmission properties of different materials for light and matter waves.	

	b	Students use their model about phenomena involving light and/or matter waves to describe* the differences between how light and matter waves interact with different materials.
	c	Students use the model to describe* why materials with certain properties are well-suited for particular functions (e.g., lenses and mirrors, sound absorbers in concert halls, colored light filters, sound barriers next to highways).

MS-PS4-3 Waves and Their Applications in Technologies for Information Transfer

Students who demonstrate understanding can:

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 not include binary counting. Assessment does not include the specific mechanism of any given device.*]

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

Science and Engineering Practices

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 6-8 builds on K-5 and progresses to evaluating the merit and validity of ideas and methods.

- Integrate qualitative scientific and technical information in written text with that contained in media and visual displays to clarify claims and findings.

Disciplinary Core Ideas

PS4.C: Information Technologies and Instrumentation

- Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information.

Crosscutting Concepts

Structure and Function

- Structures can be designed to serve particular functions.

- -

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology on Society and the Natural World

- Technologies extend the measurement, exploration, modeling, and computational capacity of scientific investigations.

- -

Connections to Nature of Science

Science is a Human Endeavor

- Advances in technology influence the progress of science and science has influenced advances in technology.

Observable features of the student performance by the end of the course:			
1	Obtaining information		
	a	Given materials from a variety of different types of sources of information (e.g., texts, graphical, video, digital), students gather evidence sufficient to support a claim about a phenomenon that includes the idea that using waves to carry digital signals is a more reliable way to encode and transmit information than using waves to carry analog signals.	
2	Evaluating information		
	a	Students combine the relevant information (from multiple sources) to support the claim by describing*:	
		i.	Specific features that make digital transmission of signals more reliable than analog transmission of signals, including that, when in digitized form, information can be:
			1. Recorded reliably.
			2. Stored for future recovery.
			3. Transmitted over long distances without significant degradation.
		ii.	At least one technology that uses digital encoding and transmission of information. Students should describe* how the digitization of that technology has advanced science and scientific investigations (e.g., digital probes, including thermometers and pH probes; audio recordings).