HS-PS1-3

Students who demonstrate understanding can:

Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

[Clarification Statement: Emphasis is on understanding the strengths of forces between particles, not on naming specific intermolecular forces (such as dipole-dipole). Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite). Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.] *[Assessment Boundary: Assessment does not include Raoult's law calculations of vapor pressure.]*

Continue to the next page for the Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. • Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.	**PS1.A: Structure and Properties of Matter** 15. The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.	**Patterns** • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Assessment Targets

Assessment targets describe the focal knowledge, skills, and abilities for a given three-dimensional Performance Expectation. Please refer to the Introduction for a complete description of assessment targets.

Science and Engineering Subpractice(s)

Please refer to appendix A for a complete list of Science and Engineering Practices (SEP) subpractices. Note that the list in this section is not exhaustive.

3.1 Ability to clarify the goal of the investigation and identify the evidence needed to address the purpose of the investigation

3.2 Ability to develop, evaluate, and refine a plan for the investigation

Science and Engineering Subpractice Assessment Targets

Please refer to appendix A for a complete list of SEP subpractice assessment targets. Note that the list in this section is not exhaustive.

3.1.2 Ability to identify relevant independent and dependent variables and to consider possible confounding variables or effects

3.1.3 Ability to describe what and how much data need to be collected to provide sufficient evidence to the purpose of the investigation

3.2.2 Ability to describe detailed experimental procedure, including how the data will be collected, the number of trials, the experimental setup, and the equipment and tools required

3.2.3 Ability to compare and evaluate alternative methods to determine which design provides the evidence necessary to address the purpose of the investigation

Disciplinary Core Idea Assessment Targets

PS1.A.15a Identify bulk properties that are related to the strength of electrical forces of attraction between particles of a substance

PS1.A.15b Use the periodic table to predict the properties of elements based on the patterns of valence electrons

PS1.A.15c Describe atomic structure and the electrical interactions among subatomic particles

PS1.A.15d Recognize that the strength of electrical forces of attraction between particles of a substance is related to the magnitude of and distance between the electrical charges

PS1.A.15e Describe how the input of thermal energy affects the spacing between particles of a substance, in particular, during changes of state

PS1.A.15f Infer the strength of the electrical forces of attractions based on the spacing between particles in the different states of matter

PS1.A.15g Distinguish between intramolecular and intermolecular forces

Crosscutting Concept Assessment Target(s)

CCC1 Identify different patterns at each of the scales at which a system is studied and provide evidence for causality in explanations of phenomena

Examples of Integration of Assessment Targets and Evidence

Note that the list in this section is not exhaustive.

Task provides a scenario involving an investigation of a bulk property related to the strength of electrical forces between particles in a substance or substances to investigate:

- Identify variables that need to be controlled to produce reliable data (3.1.2, PS1.A.15, and CCC1)

Task provides a scenario involving an investigation of a bulk property related to the strength of electrical forces between particles in a substance or substances to investigate and a list of variables:

- Identifies the independent and dependent variables (3.1.2, PS1.A.15, and CCC1)

Task provides a scenario that involves determining the relative strengths of electrical forces between particles for a set of substances:

- Identifies what data to collect in an investigation (3.1.3, PS1.A.15, and CCC1)

Task provides a scenario involving a bulk property to investigate and determine the strength of electrical forces between particles of a substance or substances and a list of experimental procedures:

- Identifies the procedure that will produce the most relevant and reliable data (3.2.2, PS1.A.15, and CCC1)

Task provides a flawed experimental plan and/or data generated from an investigation involving the measurement of bulk properties to determine the strength of electrical forces between particles of a substance or substances:

- Identifies the flaws and refines the plan to better address the purpose of the investigation (3.2.3, PS1.A.15, and CCC1)

- Uses the data to evaluate and refine the experimental plan (3.2.3, PS1.A.15, and CCC1)

Possible Phenomena or Contexts

Note that the list in this section is not exhaustive.

- Specific type of interaction (e.g., ionic, hydrogen bonding, dipole-dipole, London forces)
- Relative strength of an interaction in a set of related compounds
- Factors to consider when planning or evaluating an investigation
- Relevance of collected data
- Appropriateness of measuring tools and instruments
- Properties due to intermolecular forces
- Similarities/differences in compounds due to intermolecular forces
- Phase transition dependence on the magnitude of charges on ions of a compound

Common Misconceptions

Note that the list in this section is not exhaustive.

- There is no empty space between particles in a solid.
- State changes of matter involve chemical changes.
- Attractive and repulsive forces exist between particles of a gas.
- Ionic compounds have a molecular structure like covalent compounds.
- Breaking bonds releases energy and forming bonds requires energy.

Additional Assessment Boundaries

None listed at this time.

Additional References

HS-PS1-3 Evidence Statement https://www.nextgenscience.org/sites/default/files/evidence_statement/black_white/HS-PS1-3%20Evidence%20Statements%20June%202015%20asterisks.pdf

The *2016 Science Framework for California Public Schools Kindergarten through Grade 12 Appendix 1: Progression of the Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts in Kindergarten through Grade 12* https://www.cde.ca.gov/ci/sc/cf/documents/scifwappendix1.pdf

HS-PS1-7

Students who demonstrate understanding can:

Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

[Clarification Statement: Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem-solving techniques.] *[Assessment Boundary: Assessment does not include complex chemical reactions.]*

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Use mathematical representations of phenomena to support claims.	**PS1.B: Chemical Reactions** 9. The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.	**Energy and Matter** • The total amount of energy and matter in closed systems is conserved. -- ***Connections to Nature of Science*** **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** • Science assumes the universe is a vast single system in which basic laws are consistent.

Assessment Targets

Assessment targets describe the focal knowledge, skills, and abilities for a given three-dimensional Performance Expectation. Please refer to the Introduction for a complete description of assessment targets.

Science and Engineering Subpractice(s)

Please refer to appendix A for a complete list of Science and Engineering Practices (SEP) subpractices. Note that the list in this section is not exhaustive.

5.1 Ability to develop mathematical and/or computational models

5.2 Ability to conduct mathematical and/or computational analyses

Science and Engineering Subpractice Assessment Targets

Please refer to appendix A for a complete list of SEP subpractice assessment targets. Note that the list in this section is not exhaustive.

5.1.1 Ability to generate mathematical measurement and representations to describe characteristics and patterns of a scientific phenomenon and/or a design solution

5.2.1 Ability to use the results of computational models (e.g., graphical representation in a simulation) to identify the mathematical and/or computational representations to support a scientific explanation or a design solution

5.2.2 Ability to use computational models (e.g., simulations) to make predictions of a scientific phenomenon

Disciplinary Core Idea Assessment Targets

PS1.B.9a Identify the components of a chemical reaction (i.e., reactants and products) represented in a chemical equation

PS1.B.9b Calculate the molar masses of the components of a chemical reaction based on their chemical formulas

PS1.B.9c Use the molar masses of the components of a chemical reaction to calculate their molar quantities

PS1.B.9d Use Avogadro’s number to calculate the numbers of molecules and/or atoms in the components of a chemical reaction given their mole quantities or masses

PS1.B.9e	Describe the stoichiometric relationships represented by the coefficients in a balanced chemical equation on an atomic/molecular scale and a macroscopic scale
PS1.B.9f	Use stoichiometric relationships to calculate the mass of any component of a reaction given the mass of another component
PS1.B.9g	Use mathematical representations based on the stoichiometric relationships in a balanced chemical equation to show that atoms, and therefore mass, are conserved during a chemical reaction

Crosscutting Concept Assessment Target(s)

CCC5	Identify that the total amount of energy and matter in closed systems is conserved

Examples of Integration of Assessment Targets and Evidence

Note that the list in this section is not exhaustive.

Task provides a balanced chemical equation and the masses of the components of a reaction:

- Selects the mathematical relationships that best demonstrate that atoms are conserved in the chemical reaction (5.1.1, PS1.B.9, and CCC5)

Task provides data or graphical representations of the mass or the number of particles generated from a simulation of a reaction:

- Uses data and/or graphical representations of data to determine the mathematical relationship(s) between the reactant(s) and product(s) (5.2.1, PS1.B.9, and CCC5)

Task provides a balanced chemical equation, the mass of one of the components of the chemical reaction, and a prompt to predict the mass of another component:

- Selects the mathematical representation that predicts the mass of the other component (5.2.2, PS1.B.9, and CCC5)

Possible Phenomena or Contexts

Note that the list in this section is not exhaustive.

- Conservation of atoms/mass
- Amount of excess reactant consumed/needed
- Amount of product predicted

- Stoichiometry
  - Making caramel (hydrolysis of sucrose)
  - Making soap from fats and NaOH
  - Synthesis of compounds used for perfumes, or responsible for aroma in food
  - Simple acid/base, precipitation, and redox reactions for items that focus on balancing chemical equations or limiting reactant calculations

Common Misconceptions

Note that the list in this section is not exhaustive.

- In a reaction, atoms can be gained or lost depending on whether a reaction is exothermic or endothermic.

Additional Assessment Boundaries

None listed at this time.

Additional References

HS-PS1-7 Evidence Statement https://www.nextgenscience.org/sites/default/files/evidence_statement/black_white/HS-PS1-7%20Evidence%20Statements%20June%202015%20asterisks.pdf

The *2016 Science Framework for California Public Schools Kindergarten through Grade 12 Appendix 1: Progression of the Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts in Kindergarten through Grade 12* *https://www.cde.ca.gov/ci/sc/cf/documents/scifwappendix1.pdf*

HS-PS2-1

Students who demonstrate understanding can:

Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

[Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.] *[Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.]*

Continue to the next page for the Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. -- ***Connections to Nature of Science*** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • Theories and laws provide explanations in science. • Laws are statements or descriptions of the relationships among observable phenomena.	**PS2.A: Forces and Motion** 8. Newton's second law accurately predicts changes in the motion of macroscopic objects.	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Assessment Targets

Assessment targets describe the focal knowledge, skills, and abilities for a given three-dimensional Performance Expectation. Please refer to the Introduction for a complete description of assessment targets.

Science and Engineering Subpractice(s)

Please refer to appendix A for a complete list of Science and Engineering Practices (SEP) subpractices. Note that the list in this section is not exhaustive.

4.1 Ability to record and organize data

4.2 Ability to analyze data to identify relationships

Science and Engineering Subpractice Assessment Targets

Please refer to appendix A for a complete list of SEP subpractice assessment targets. Note that the list in this section is not exhaustive.

4.1.1 Ability to record information and represent data in tables and graphical displays

4.1.3 Ability to organize data in a way that facilitates analysis and interpretation

4.2.1 Ability to use observational and/or empirical data to describe patterns and relationships

4.2.2 Ability to identify patterns (qualitative or quantitative) among variables represented in data

Disciplinary Core Idea Assessment Targets

PS2.A.8a Organize data, graphs, charts, or vector drawings representing the net force and acceleration for an object with constant mass

PS2.A.8b Recognize that, for the same net force, objects with a larger mass experience a smaller acceleration

PS2.A.8c Recognize that, for an object with a constant mass, a larger net force exerted onto the object results in a larger acceleration

PS2.A.8d Identify that the force of gravity exerted onto a free-falling object produces a constant acceleration because the net force/mass ratio is the same for all objects in a specific local gravitational field

PS2.A.8e Analyze data as empirical evidence describing the relationship between net force, acceleration, and mass

PS2.A.8f Recognize the cause-effect relationship in that the net force exerted onto an object causes the object to experience accelerated motion using the expression $F_{net} = ma$

Crosscutting Concept Assessment Target(s)

CCC2 Identify empirical evidence to differentiate between cause and correlation and make claims about specific causes and effects

Examples of Integration of Assessment Targets and Evidence

Note that the list in this section is not exhaustive.

Task provides a description of a physical situation involving an object being accelerated:

- Identifies from a list the correct information and data corresponding to the physical situation (4.1.1, PS2.A.8, and CCC2)

Task provides a simulation of a physical situation involving an object being accelerated. As the object accelerates, the simulation provides information/data of time, position, and velocity:

- Identifies the free-body diagrams and/or motion diagrams corresponding to the presented physical situation (4.1.3, PS2.A.8, and CCC2)

Task provides graphs or a data table of position, velocity, and force as a function of time:

- Describes the relationship between net force and acceleration, and/or net force and mass, and/or mass and acceleration (4.2.1, PS2.A.8, and CCC2)

Task provides a data set of acceleration, mass, and net force:

- Identifies the relationship between net force and acceleration, and/or net force and mass, and/or mass and acceleration (4.2.2, PS2.A.8, and CCC2)

Possible Phenomena or Contexts

Note that the list in this section is not exhaustive.

- Motion diagrams
- Motion graphs (e.g., position-time, velocity-time, and acceleration-time graphs)
- Data regarding changes in position, time, instantaneous velocities, and/or acceleration
- Freely-falling objects in gravitational fields
- Data regarding mass and acceleration of a two-cart system

Common Misconceptions

Note that the list in this section is not exhaustive.

- The forces exerted on an object are unbalanced when the object moves with constant velocity.

Additional Assessment Boundaries

None listed at this time.

Additional References

HS-PS2-1 Evidence Statement https://www.nextgenscience.org/sites/default/files/evidence_statement/black_white/HS-PS2-1%20Evidence%20Statements%20June%202015%20asterisks.pdf

The *2016 Science Framework for California Public Schools Kindergarten through Grade 12 Appendix 1: Progression of the Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts in Kindergarten through Grade 12* *https://www.cde.ca.gov/ci/sc/cf/documents/scifwappendix1.pdf*

HS-PS2-2

Students who demonstrate understanding can:

Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.

[Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.] *[Assessment Boundary: Assessment is limited to systems of two macroscopic bodies moving in one dimension.]*

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis; a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms; and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Use mathematical representations of phenomena to describe explanations.	**PS2.A: Forces and Motion** 9. Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. 10. If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system.	**Systems and System Models** • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined.

Assessment Targets

Assessment targets describe the focal knowledge, skills, and abilities for a given three-dimensional Performance Expectation. Please refer to the Introduction for a complete description of assessment targets.

Science and Engineering Subpractice(s)

Please refer to appendix A for a complete list of Science and Engineering Practices (SEP) subpractices. Note that the list in this section is not exhaustive.

5.2 Ability to conduct mathematical and/or computational analyses

Science and Engineering Subpractice Assessment Targets

Please refer to appendix A for a complete list of SEP subpractice assessment targets. Note that the list in this section is not exhaustive.

5.2.2 Ability to use computational models (e.g., simulations) to make predictions of a scientific phenomenon

5.2.3 Ability to use the results of computational models (e.g., simulations) to identify patterns in natural and/or design worlds

Disciplinary Core Idea Assessment Targets

PS2.A.9a Clearly define the reference frame and identify the objects that define the system

PS2.A.9b Define momentum *p* as the product of the object's mass *m* and velocity *v* and mathematically model the net momentum and/or individual momenta of a system of objects based on either the system's initial or final conditions

PS2.A.10a Recognize, through the analysis of the motion of the objects, that the net momentum of a system remains constant before and after any interactions from the objects within the system

PS2.A.10b Balance the losses and gains of momentum across objects in a closed system using mathematical representations

PS2.A.10c Attribute changes in the net momentum of a system to the openness of the system (objects in the system are able to interact with objects external to the system)

Crosscutting Concept Assessment Target(s)

CCC4 Identify that the boundaries and initial conditions of the system need to be defined when investigation or describing a system

Examples of Integration of Assessment Targets and Evidence

Note that the list in this section is not exhaustive.

Task provides values for the physical properties of the system and options to complete any missing values or to determine/predict the values before/after the collision:

- Mathematically determines the properties of the system using the conservation of momentum of objects in the system (5.2.2, PS2.A.9, and CCC4)

Task provides a simplified computational model for the collision of two objects that produces an inaccurate prediction. Task also provides data from the actual collision:

- Identifies which ways a model was simplified (e.g., it assumed conservation of momentum, but an outside force was actually applied) and how it contributed to the difference between predicted and experimental values (5.2.3, PS2.A.10, and CCC4)

Possible Phenomena or Contexts

Note that the list in this section is not exhaustive.

- Two objects traveling in the same direction (but at different velocities) collide and stick together.
- Two objects travelling toward each other collide and stick together.
- A single moving object breaks apart into two separate objects, each with their own mass and velocity.
- An open system of continuous, successive collisions seems to decay due to losses to the environment.

Common Misconceptions

Note that the list in this section is not exhaustive.

- Momentum is a scalar physical quantity.
- Momentum is conserved for an individual object, rather than a system.
- Momentum is like a force.

Additional Assessment Boundaries

None listed at this time.

Additional References

HS-PS2-2 Evidence Statement https://www.nextgenscience.org/sites/default/files/evidence_statement/black_white/HS-PS2-2%20Evidence%20Statements%20June%202015%20asterisks.pdf

The *2016 Science Framework for California Public Schools Kindergarten through Grade 12*

Appendix 1: Progression of the Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts in Kindergarten through Grade 12 https://www.cde.ca.gov/ci/sc/cf/documents/scifwappendix1.pdf

HS-PS3-1

Students who demonstrate understanding can:

Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.

[Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] *[Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.]*

Continue to the next page for the Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis; a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms; and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Create a computational model or simulation of a phenomenon, designed device, process, or system.	**PS3.A: Definitions of Energy** 9. Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. **PS3.B: Conservation of Energy and Energy Transfer** 8. Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. 9. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. 10. Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. 11. The availability of energy limits what can occur in any system.	**Systems and System Models** • Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. --------------------------- ***Connections to Nature of Science*** **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** • Science assumes the universe is a vast single system in which basic laws are consistent.

Assessment Targets

Assessment targets describe the focal knowledge, skills, and abilities for a given three-dimensional Performance Expectation. Please refer to the Introduction for a complete description of assessment targets.

Science and Engineering Subpractice(s)

Please refer to appendix A for a complete list of Science and Engineering Practices (SEP) subpractices. Note that the list in this section is not exhaustive.

5.1 Ability to develop mathematical and/or computational models

Science and Engineering Subpractice Assessment Targets

Please refer to appendix A for a complete list of SEP subpractice assessment targets. Note that the list in this section is not exhaustive.

5.1.1 Ability to generate mathematical measurement and representations to describe characteristics and patterns of a scientific phenomenon and/or a design solution

5.1.2 Ability to use mathematical units, diagrams, and graphs to record and organize first-hand or given data from scientific investigations

Disciplinary Core Idea Assessment Targets

PS3.A.9a Identify the boundaries and initial energy configuration of a system to be modeled

PS3.A.9b Identify the components of the total energy in a system

PS3.A.9c Describe the energy flow into and out of the system and the conversion of energy within the system

PS3.B.8a Create a computational model in which total energy is conserved

PS3.B.9a Create a computational model for the transfer of energy within a system

PS3.B.10a Use algebraic descriptions of the initial and final energy states of a system based on the principle of conservation of energy

PS3.B.10b Use a computational model to predict the maximum possible change in the energy of one component of the system for a given set of energy flows

PS3.B.10c Identify and describe the limitations of a computational model describing energy flows in a system

PS3.B.11a Explain that the availability of energy impacts a system

Crosscutting Concept Assessment Target(s)

CCC4 Use models to predict the behavior of a system, taking into consideration that predictions have limited precision and reliability due to the assumptions and approximations inherent in models

Examples of Integration of Assessment Targets and Evidence

Note that the list in this section is not exhaustive.

Task provides a qualitative description of a system of interacting objects:

- Creates a correct mathematical representation to determine the components of energy in a system (5.1.1, PS3A.9, and CCC4)

Task provides a system in which total energy is conserved and can be transferred between components within the system:

- Provides a mathematical description of the interactions between components to correctly model the energy configuration of the system (5.1.1, PS3.B.10, and CCC4)

Task provides a description of a closed system in which energy is conserved:

- Creates graphs or tables that correctly compare initial and final energy states of the system (5.1.2, PS3.B.8, and CCC4)

Possible Phenomena or Contexts

Note that the list in this section is not exhaustive.

- An Earth-object system
- A planetary system
- A thermodynamic system
- A device that converts electric energy to mechanical energy
- A power plant the converts various forms of energy to electric energy

Common Misconceptions

Note that the list in this section is not exhaustive.

- Mathematical models are only used to calculate values, not to describe relationships.

Additional Assessment Boundaries

None listed at this time.

Additional References

HS-PS3-1 Evidence Statement https://www.nextgenscience.org/sites/default/files/evidence_statement/black_white/HS-PS3-1%20Evidence%20Statements%20June%202015%20asterisks.pdf

The *2016 Science Framework for California Public Schools Kindergarten through Grade 12 Appendix 1: Progression of the Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts in Kindergarten through Grade 12* *https://www.cde.ca.gov/ci/sc/cf/documents/scifwappendix1.pdf*

HS-PS4-1

Students who demonstrate understanding can:

Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.

[Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.] *[Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.]*

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking Mathematical and computational thinking at the 9-12 level builds on K-8 and progresses to using algebraic thinking and analysis; a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms; and computational tools for statistical analysis to analyze, represent and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations.	**PS4.A: Wave Properties** 7. The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing.	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Assessment Targets

Assessment targets describe the focal knowledge, skills, and abilities for a given three-dimensional Performance Expectation. Please refer to the Introduction for a complete description of assessment targets.

Science and Engineering Subpractice(s)

Please refer to appendix A for a complete list of Science and Engineering Practices (SEP) subpractices. Note that the list in this section is not exhaustive.

5.1 Ability to develop mathematical and/or computational models

Science and Engineering Subpractice Assessment Targets

Please refer to appendix A for a complete list of SEP subpractice assessment targets. Note that the list in this section is not exhaustive.

5.1.1 Ability to generate mathematical measurement and representations to describe characteristics and patterns of a scientific phenomenon and/or a design solution

5.1.4 Ability to recognize that science computational models such as simulations are built on mathematical models that incorporate underlying science principles being studied

Disciplinary Core Idea Assessment Targets

PS4.A7a Identify and describe the mathematical values for frequency, wavelength, and speed of waves traveling in various media

PS4.A7b Show that the product of the frequency and the wavelength of a particular type of wave in a given medium is constant, and identify this relationship as the wave speed according to the mathematical relationship $v = f\lambda$

PS4.A7c Use data to show that the wave speed for a particular type of wave changes as the medium through which the wave travels changes

PS4.A7d Predict the relative change in wavelength of a wave when it moves from one medium to another using the terms cause and effect

PS4.A7e Use the mathematical relationship $v = f\lambda$ to assess claims about any of the three quantities when the other two quantities are known for waves traveling in various specified media

PS4.A7f Use mathematical relationships to distinguish between cause and correlation with respect to the supported claims

Crosscutting Concept Assessment Target(s)

CCC2 Identify empirical evidence to differentiate between cause and correlation and make claims about specific causes and effects

Examples of Integration of Assessment Targets and Evidence

Note that the list in this section is not exhaustive.

Task provides a computer simulation that generates waves travelling at different speeds, presenting the speed, frequency, and wavelength for each generated wave in a table:

- Selects the mathematical model that is best supported by the data (5.1.1, PS4.A.7, and CCC2)

Task provides students with different statements that describe the mathematical model $v = f\lambda$:

- Identifies the statement that correctly explains the model (5.1.1, PS4.A.7, and CCC2)

Task provides graphs of different waves traveling through the same medium. The graphs provide information on wavelength, frequency, and amplitude:

- Describes the relationship between these three wave characteristics when the medium remains constant (5.1.4, PS4.A.7, and CCC2)

Task provides graphs of different waves traveling through different mediums. The graphs provide information on wavelength, frequency, and amplitude:

- Describes how wavelength and frequency are related to the change in the medium (5.1.4, PS4.A.7, and CCC2)

Task provides a simulation of a wave pulse traveling along a thin rope that will eventually travel into a thicker and heavier section of rope. Wavelength, frequency, amplitude, and wave speed are provided for each simulation before and after the pulse reaches the thicker and heavier section of rope:

- Selects the simulation modeling mathematically and visually the specific scientific phenomenon for the pulse traveling along the varied mediums (5.1.4, PS4.A.7, and CCC2)

Task provides a simulation of two waves that are traveling towards each other. The waves combine with constructive interference, but the amplitude of the combined wave is incorrect:

- Cites the scientific principle demonstrated when the waves interact and can interact and adjust the simulation to produce the correct amplitude (5.1.4, PS4.A.7, and CCC2)

Task provides data from an earthquake study, with certain data about the seismic waves missing. Student is provided a simulation where they can change the speed, frequency, and wavelength of a traveling sound wave as well as the medium through which the wave is traveling:

- Uses the simulation to fill in missing data points for either frequency, wavelength, or speed in order to evaluate whether the missing data follows the mathematical model of $v = f\lambda$ (5.1.4, PS4.A.7, and CCC2)

Possible Phenomena or Contexts

Note that the list in this section is not exhaustive.

- Electromagnetic radiation traveling through glass and a vacuum
- Sound waves traveling through air and water
- Seismic waves traveling through the Earth
- A transverse wave of a slinky oscillating in the plane of the ground
- A water wave moving through water of different salinity

Common Misconceptions

Note that the list in this section is not exhaustive.

- Waves act as if they are solid objects in a collision, bouncing off each other.
- Constructive interference can only be applied if the peaks of the waves interact.
- Waves stop traveling when encountering an object or media.
- The speed of a wave is dependent upon its frequency and/or its wavelength.

Additional Assessment Boundaries

None listed at this time.

Additional References

HS-PS4-1 Evidence Statement https://www.nextgenscience.org/sites/default/files/evidence_statement/black_white/HS-PS4-1%20Evidence%20Statements%20June%202015%20asterisks.pdf

The *2016 Science Framework for California Public Schools Kindergarten through Grade 12 Appendix 1: Progression of the Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts in Kindergarten through Grade 12* *https://www.cde.ca.gov/ci/sc/cf/documents/scifwappendix1.pdf*