NEXT GENERATION SCIENCE STANDARDS

The following documents show the May 2012 Draft NGSS performance expectations grouped by topics.

HS.ESS-SS Space Systems

HS.ESS-SS Space Systems

Students who demonstrate understanding can:

- **a. Construct explanations from evidence about how the stability and structure of the sun change over its lifetime at time scales that are short (solar flares), medium (the hot spot cycle), and long (changes over its 10-billion-year lifetime).** [Clarification Statement: Evidence for long-term changes includes the Hertzsprung-Russell Diagram.]
- **b. Use mathematical, graphical, or computational models to represent the distribution and patterns of galaxies and galaxy clusters in the Universe to describe the Sun's place in space.**
- **c. Construct explanations for how the Big Bang theory accounts for all observable astronomical data including the red shift of starlight from galaxies, cosmic microwave background, and composition of stars and nonstellar gases.**
- **d. Obtain, evaluate, and communicate information about the process by which stars produce all elements except those elements formed during the Big Bang.** [Clarification Statement: Nuclear fusion within certain stars produce atomic nuclei lighter than and including iron; heavier elements are produced when certain massive stars achieve a supernova stage and explode.]
- **e. Use mathematical representations of the positions of objects in the Solar System to predict their motions and gravitational effects on each other.** [Assessment Boundary: Mathematical representations, which include Kepler's Laws, should not deal with more than 2 bodies.]
- **f. Analyze evidence to show how changes in Earth's orbital parameters affect the intensity and distribution of sunlight on Earth's surface, causing cyclical climate changes that include past Ice Ages.** [Assessment Boundary: Orbital parameters are limited to change in orbital shape and orientation of the planetary axis.]
- **g. Construct explanations for how differences in orbital parameters, combined with the object's size and composition, control the surface conditions of other planets and moons within the solar system.**

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

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.

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. (f)

Using Mathematical 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 statistical and mathematical techniques and structure data (e.g., displays, tables, graphs) to find regularities, patterns (e.g., fitting mathematical curves to data), and relationships in data. (b)
- Use simple limit cases to test mathematical expressions, computer programs or algorithms, or simulations to see if a model "makes sense" by comparing the outcomes with what is known about the real world. (e)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Construct and revise explanations and arguments based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories) and peer review. (a),(c),(g)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9–12 builds on 6–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.

- Critically read scientific literature adapted for classroom use to identify key ideas and major points and to evaluate the validity and reliability of the claims, methods, and designs. (d)

Disciplinary Core Ideas

ESS1.A: The Universe and Its Stars

- The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. (a)
- The sun is one of more than 200 billion stars in the Milky Way galaxy, and the Milky Way is just one of hundreds of billions of galaxies in the universe. (b)
- The spectra and brightness of stars are used to identify their compositional elements, movements, and distances from Earth and to develop explanations about the formation, age, and composition of the universe. The Big Bang theory is supported by the fact that it provides an explanation of observations of distant galaxies receding from our own, of the measured composition of stars and nonstellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. (c)
- Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode. (c),(d)

ESS1.B: Earth and the Solar System

- Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. (e)
- Cyclic changes in the shape of Earth's orbit around the sun, together with changes in the orientation of the planet's axis of rotation, have altered the intensity and distribution of sunlight falling on Earth. These changes, both occurring over tens to hundreds of thousands of years, cause cycles of ice ages and other gradual climate changes. (f),(g)

Crosscutting Concepts

Systems and System Models

Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (b)

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. (e),(g)

Energy and Matter

The total amount of energy and matter in closed systems is conserved. Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. Energy drives the cycling of matter within and between systems. In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (a),(c),(d),(f)

HS.ESS-SS Space Systems

Connections to other DCIs in this grade-level: **HS.PS-NP, HS.PS-ER, HS.PS-E, HS.PS-FM, HS.PS-FE, HS.PS-IF**

Articulation to DCIs across grade-levels: **1.PC, 5.SSS, MS.ESS-SS**

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

ELA –

W.9-10.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

RI.9-10.1 Cite strong and thorough textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text.

W.9-10.9(b) Draw evidence from literary or informational texts to support analysis, reflection, and research.

W.11-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

SL.11-12.2 Integrate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data.

W.11-12.9(b) Draw evidence from literary or informational texts to support analysis, reflection, and research.

RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

Mathematics –

MP.2 Reason abstractly and quantitatively

MP.4 Model with mathematics

MP.5 Use appropriate tools strategically

S.ID Summarize, represent, and interpret data on a single count or measurement variable; Summarize, represent, and interpret data on two categorical and quantitative variables

S.IC Make inferences and justify conclusions from sample surveys, experiments, and observational studies

G.MG Apply geometric concepts in modeling situations

F.IF Interpret functions that arise in applications in terms of the context

F.BF Build a function that models a relationship between two quantities

F.LE Construct and compare linear, quadratic, and exponential models and solve problems

HS.PS-SPM Structure and Properties of Matter

HS.PS-SPM Structure and Properties of Matter

Students who demonstrate understanding can:

a. Construct models showing that stable forms of matter are those with minimum magnetic and electrical field energy. [Clarification Statement: Examples of stable forms of matter can include noble gas atoms, simple molecules, and simple ionic substances.] [Assessment Boundary: Only for common substances- for example, water, carbon dioxide, common hydrocarbons, sodium chloride.]

b. Construct various types of models showing that energy is needed to take molecules apart and that energy is released when the atoms come together to form new molecules. [Assessment Boundary: Only for common substances (e.g., water, carbon dioxide, common hydrocarbons, sodium chloride]

c. Develop explanations about how the patterns of electrons in the outer level of atoms, as represented in the periodic table, reflect and can predict properties of elements. [Clarification Statement: An example of a pattern that predicts element properties is the first column of the periodic table: These elements all have one electron in the outer most energy level and as such are all highly reactive metals.] [Assessment Boundary: Only for main group elements (not transition metals or elements beyond the third row).]

d. Construct arguments for which type of atomic and molecular representation best explains a given property of matter. [Clarification Statement: Types of atomic and molecular representations can include computer-based, simulations, physical, ball and stick, and symbolic. Properties of matter can include reactivity, and polar vs. non-polar.] [Assessment Boundary: Not theoretical models]

e. Analyze and interpret data obtained from measuring the bulk properties of various substances to explain the relative strength of the interactions among particles in the substance. [Clarification Statement: Bulk properties of substances can include melting point and boiling point.] [Assessment Boundary: Comparisons between ionic and molecular species or network and molecular species are included, but those that require understanding of different intermolecular forces are not included. Only the following types of particles are included in data and explanations: atoms, ions, and molecules.]

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

Science and Engineering Practices

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.

- Use multiple types of models to represent and explain phenomena and move flexibly between model types based on merits and limitations. (b)
- Construct, revise, and use models to predict and explain relationships between systems and their components. (a)

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.

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. (e)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Construct and revise explanations and arguments based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories) and peer review. (c)

Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world. Arguments may also come from current scientific or historical episodes in science.

- Evaluate the merits of competing arguments, design solutions and/or models. (d)
- Evaluate the claims, evidence, and reasoning of currently accepted explanations or solutions as a basis for the merits of the arguments. (d)

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter

- Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. (c),(d)
- The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. (c)
- The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (e)
- Stable forms of matter are those in which the electric and magnetic field energy is minimized. A stable molecule has less energy, by an amount known as the binding energy, than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. (a),(b)

PS2.B: Types of Interactions

- Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. (d),(e)

Crosscutting Concepts

Cause and Effect

Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects. (a),(b),(c),

- [Clarification Statement for a: Stability is caused by minimization of energy.]
- [Clarification Statement for c: The likelihood of interactions between elements is caused by the number of electrons in their valence shell, and thus the arrangement of the periodic table.]

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. (d)

Structure and Function

Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. (e)

- [Clarification Statement for e: The relative strength of interactions among particles causes different bulk properties.]

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

Articulation to DCIs across grade-levels: **MS.PS-SPM**

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

ELA –

RST.8 Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.

SL.9-10.2 Integrate multiple sources of information presented in diverse media or formats (e.g., visually, quantitatively, orally) evaluating the credibility and accuracy of each source.

RST.9-10.9 Compare and contrast findings presented in a text to those from other sources (including their own experiments), nothing when the findings support or contradict previous explanations or accounts.

SL.11-12.2 Integrate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data.

RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

Mathematics –

MP.4 Model with mathematics.

8.F Use functions to model relationships between quantities

S.ID Summarize, represent, and interpret data on two categorical and quantitative variables

S.IC Make inferences and justify conclusions from sample surveys, experiments, and observational studies

HS.PS-E Energy

HS.PS-E Energy

Students who demonstrate understanding can:

- **a. Construct and defend models and mathematical representations that show that over time the total energy within an isolated system is constant, including the motion and interactions of matter and radiation within the system.** [Assessment Boundary: Computational accounting for energy in a system limited to systems of two or three components.]
- **b. Identify problems and suggest design solutions to optimize the energy transfer into and out of a system.** [Clarification Statement: Design solution examples can include insulation, microchip temperature control, cooking electronics, and roller coaster design.] [Assessment Boundary: Limited to mechanical and thermal systems.]
- **c. Analyze data to support claims that closed systems move toward more uniform energy distribution.**
- **d. Design a solution to minimize or slow a system's inclination to degrade to identify the effects on the flow of the energy in the system.** [Clarification Statement: Examples of system degradation can include wearing down due to friction, increase in disorder, and radioactive decay.]
- **e. Construct models to show that energy is transformed and transferred within and between living organisms.** [Assessment Boundary: Does not mean particular biological processes such as Krebs cycle.]
- **f. Construct models to represent and explain that all forms of energy can be viewed as either the movement of particles or energy stored in fields.** [Assessment Boundary: Models representing field energies need not be mathematical.]
- **g. Construct representations that show that some forms of energy may be best understood at the molecular or atomic scale.** [Clarification Statement: Forms of energy represented can include thermal, electromagnetic, and sound.] Assessment Boundary: Limited to conceptual understanding; quantitative representations are not required.]
- **h. Design, build, and evaluate devices that convert one form of energy into another form of energy.** [Clarification Statement: Examples of devices can include roller coasters, Rube Goldberg devices, wind turbines, and generators.]

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

Science and Engineering Practices

Asking Questions and Defining Problems

Asking questions and defining problems in grades 9–12 builds from grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and explanatory models and simulations.

- Ask questions that challenge the premise of an argument, the interpretation of a data set, or the suitability of a design. (b)

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.

- Use multiple types of models to represent and explain phenomena and move flexibly between model types based on merits and limitations. (a),(f)
- Construct, revise, and use models to predict and explain relationships between systems and their components. (e),(g)

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.

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. (c)

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 or algorithmic representations of phenomena or design solutions to create explanation, computational models, or simulations. (a)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.

- Apply scientific knowledge to solve design problems by taking into account possible unanticipated effects. (b),(d),(h)

Disciplinary Core Ideas

PS3.A: Definitions of Energy

- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. (a)
- 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. (a),(e),(h)
- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. "Mechanical energy" generally refers to some combination of motion and stored energy in an operating machine. (h)
- These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as either motions of particles or energy stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. (f),(g)

PS3.B: Conservation of Energy and Energy Transfer

- 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. (a),(h)
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (b),(c),(e),(h)
- 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. (a),(c)
- The availability of energy limits what can occur in any system. (d)
- Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). (c),(d),(e)
- Any object or system that can degrade with no added energy is unstable. Eventually it will do so, but if the energy releases throughout the transition are small, the process duration can be very long (e.g., long-lived radioactive isotopes). (d)

PS3.D: Energy in Chemical Processes

- The main way in which that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. (e)
- Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy. (h)
- A variety of multistage physical and chemical processes in living organisms, particularly within their cells, account for the transport and transfer (release or uptake) of energy needed for life functions. (e)
- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. Machines are judged as efficient or inefficient based on the amount of energy input needed to perform a particular useful task. Inefficient machines are those that produce more waste heat while performing the task and thus require more energy input. It is therefore important to design for high efficiency so as to reduce costs, waste materials, and many environmental impacts. (b),(h)

Crosscutting Concepts

Systems and System Models

Systems can be designed to do specific tasks. When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows— within and between systems at different scales.

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. (a),(c),(d),(e),(f), (g), (h)

- [Clarification Statement for all PEs: Energy transfer cannot be directly studied- a model must be used. In design for maximal or minimal energy transfer, the boundaries of a system must be defined]

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Connections to Engineering, Technology, and Applications of Science

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

Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. Engineers continuously modify these systems to increase benefits while decreasing costs and risks. New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (b)

HS.PS-ECT Energy *(continued)*
Connections to other DCIs in this grade-level: **HS.LS-SFIP, HS.LS-MEOE, HS.ESS-CC, HS.ESS-HS, HS.ESS-ES, HS.ESS-SS, HS.ETS-ED, HS.ETS-ETSS**
Articulation to DCIs across grade-levels: **MS.PS-E, MS.PS-CR**
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases] *ELA –* **SL.1.c** Propel conversations by posing and responding to questions that probe reasoning and evidence; ensure a hearing for a full range of positions on a topic or issue; clarify, verify, or challenge ideas and conclusions; and promote divergent and creative perspectives. **SL.9-10.2** Integrate multiple sources of information presented in diverse media or formats (e.g., visually, quantitatively, orally) evaluating the credibility and accuracy of each source. **RST.9-10.3** Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text. **SL.11-12.2** Integrate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data. **RST.11-12.3** Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text. *Mathematics –* **MP.2** Reason abstractly and quantitatively. **MP.3** Construct viable arguments and critique the reasoning of others **MP.4** Model with Mathematics **MP.6** Attend to precision **A-REI.10** Represent and solve equations and inequalities graphically. **A.SSE** Interpret the structure of expressions. **A.CED** Create equations that describe numbers or relationships.

HS.PS-FM Forces and Motion

HS.PS-FM Forces and Motion

Students who demonstrate understanding can:

a. **Plan and carry out investigations to show that the algebraic formulation of Newton's second law of motion accurately predicts the relationship between the net force on macroscopic objects, their mass, and acceleration and the resulting change in motion.** [Assessment Boundary: Restricted to one- and two-dimensional motion and does not include rotational motion. Does not apply in the case of subatomic scales or for speeds close to the speed of light. Calculations restricted to macroscopic objects moving at non-relativistic speeds.]

b. **Generate and analyze data to support the claim that the total momentum of a closed system of objects before an interaction is the same as the total momentum of the system of objects after an interaction.** [Clarification Statement: Conservation of momentum is the focus.]

c. **Use algebraic equations to predict the velocities of objects after an interaction when the masses and velocities of objects before the interaction are known.** [Assessment Boundary: Restricted to macroscopic interactions and only two objects moving in one or two dimensions.]

d. **Design and evaluate devices that minimize the force on a macroscopic object during a collision.**

e. **Construct a scientific argument supporting the claim that the predictability of changes within systems can be understood by defining the forces and changes in momentum both inside and outside the system.** [Assessment Boundary: Restricted to macroscopic interactions.]

f. **Communicate arguments to support claims that Newton's laws of motion apply to macroscopic objects but not to objects at the subatomic scales or speeds close to the speed of light.** [Assessment Boundary: No details of quantum physics or relativity are included.]

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

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that build, test, and revise conceptual, mathematical, physical and empirical models.

- Plan and carry out investigations individually and collaboratively and test designs as part of building and revising models, explaining phenomena, or testing solutions to problems. Consider possible confounding variables or effects, and ensure that the investigation's design has controlled for them. (a)

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.

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims. (b)

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 expressions to represent phenomena or design solutions in order to solve algebraically for desired quantities. (c)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Apply scientific knowledge to solve design problems by taking into account possible unanticipated effects. (d)
- Evaluate the claims, evidence, and reasoning of currently accepted explanations or solutions as a basis for the merits of the arguments. (d)

Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world. Arguments may also come from current scientific or historical episodes in science.

- Evaluate the claims, evidence, and reasoning of currently accepted explanations or solutions as a basis for the merits of the arguments. (e),(f)

Disciplinary Core Ideas

PS2.A: Forces and Motion

- Newton's second law accurately predicts changes in the motion of macroscopic objects, but it requires revision for subatomic scales or for speeds close to the speed of light. (a),(e),(f)
- Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (b)
- In any system, total momentum is always conserved. (b),(c)
- 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. (c),(d),(e)

PS2.C: Stability and Instability in Physical Systems

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

Crosscutting Concepts

Cause and Effect

Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects. (a),(c),(d)

Systems and System Models

When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (b),(e)

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Connections to Engineering, Technology, and Applications of Science

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

Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. Engineers continuously modify these systems to increase benefits while decreasing costs and risks. New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (d)

HS.PS-FM Forces and Motion *(continued)*	
Connections to other DCIs in this grade-level: **HS.ETS-ED, HS.ESS-SS, HS.ESS-ES**	
Articulation to DCIs across grade-levels: **MS.PS-FM, MS.PS-WER**	
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]	
ELA –	
RST.6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks
RST.9-10.7	Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.
RST.11-12.7	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.
RST.11-12.8	Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
WHST.9	Draw evidence from informational texts to support analysis, reflection, and research.
Mathematics –	
MP.2	Reason abstractly and quantitatively
MP.4	Model with Mathematics
MP.5	Use appropriate tools strategically
8.F	Define, evaluate, and compare functions.
S.ID	Summarize, represent, and interpret data on a single count or measurement variable
F.BF	Build a function that models a relationship between two quantities
N-Q	Reason quantitatively and use units to solve problems

HS.PS-FE Forces and Energy

HS.PS-FE Forces and Energy

Students who demonstrate understanding can:

a. Plan and carry out investigations in which a force field is mapped to provide evidence that forces can transmit energy across a distance. [Assessment Boundary: Mapping limited to the direction of the force field.]

b. Develop arguments to support the claim that when objects interact at a distance, the energy stored in the field changes as the objects change relative position. [Clarification Statement: An example of this phenomenon could include repelling magnets moving apart, reducing the repelling force and the strength of the field between them.] [Assessment Boundary: Qualitative comparisons only.]

c. Evaluate natural and designed systems where there is an exchange of energy between objects and fields and characterize how the energy is exchanged. [Clarification Statement: Examples of these systems could include motors, generators, speakers, microphones, planets orbiting a start.] [Assessment Boundary: Characterizations limited to qualitative descriptors.]

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

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that build, test, and revise conceptual, mathematical, physical and empirical models.

- Plan and carry out investigations individually and collaboratively and test designs as part of building and revising models, explaining phenomena, or testing solutions to problems. Consider possible confounding variables or effects, and ensure that the investigation's design has controlled for them. (a)

Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world. Arguments may also come from current scientific or historical episodes in science.

- Evaluate the claims, evidence, and reasoning of currently accepted explanations or solutions as a basis for the merits of the arguments. (b)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9–12 builds on 6–8 and progresses to evaluate the validity and reliability of the claims, methods, and designs.

- Generate, synthesize, communicate, and critique claims, methods, and designs that appear in scientific and technical texts or media reports. (c)

Disciplinary Core Ideas

PS3.C: Relationship Between Energy and Forces

- Force fields (gravitational, electric, and magnetic) contain energy and can transmit energy across space from one object to another. (a)
- When two objects interacting through a force field change relative position, the energy stored in the force field is changed. (b),(c)
- Each force between the two interacting objects acts in the direction such that motion in that direction would reduce the energy in the force field between the objects. However, prior motion and other forces also affect the actual direction of motion. (c)

Crosscutting Concepts

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. Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus requiring improved investigations and experiments. Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system. Mathematical representations are needed to identity some patterns. (a),(b)

- [Clarification Statement for a: Mapping force fields requires evidence of the pattern of the field lines]
- [Clarification Statement for b: Coulomb's law: Proportion is a pattern.]
- [Clarification Statement for c: A pattern of energy transfer will be apparent.]

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (c)

Connections to other DCIs in this grade-level: **HS.ESS-SS, HS.ESS-ES, HS.ESS-CC, HS.ETS-ETSS**

Articulation to DCIs across grade-levels: **MS.PS-E**

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

ELA –

RST.9-10.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

RST.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

RST.11-12.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.

WHST.9 Draw evidence from informational texts to support analysis, reflection, and research.

Mathematics –

MP.2 Reason abstractly and quantitatively.

MP.4 Model with Mathematics.

F.BF Build a function that models a relationship between two quantities.

A.CED Create equations that describe numbers or relationships.

HS.PS-IF Interactions of Forces

HS.PS-IF Interactions of Forces

Students who demonstrate understanding can:

a. Use mathematical expressions to determine the relationship between the variables in Newton's Law of Gravitation and Coulomb's Law, and use these to predict the electrostatic and gravitational forces between objects. [Assessment Boundary: Only situations with two objects are predicted.]

b. Use models to demonstrate that electric forces at the atomic scale affect and determine the structure, properties (including contact forces), and transformations of matter. [Clarification statement: Models can include graphical and computer models. Examples of properties and transformations of matter can include intermolecular forces, chemical bonding, and enzyme substrate interaction.] [Assessment Boundary: Only a qualitative understanding is expected.]

c. Plan and carry out investigations to demonstrate the claim that magnets, electric currents, or changing electric fields cause magnetic fields and electric charges or changing magnetic fields cause electric fields. [Assessment Boundary: Qualitative observations only.]

d. Obtain, evaluate, and communicate information to show that strong and weak nuclear interactions inside atomic nuclei determine which nuclear isotopes are stable, and that the pattern of decay of an unstable nucleus can often be predicted. [Clarification Statement: Types of decay in unstable nuclei can include alpha or beta radiation.] [Assessment Boundary: Only a qualitative understanding of nuclear interactions is expected.]

e. Obtain, evaluate, and communicate information to show how scientists and engineers take advantage of the effects of electrical and magnetic forces in materials to design new devices and materials through a process of research and development. [Clarification Statement: Designed devices can include magnetic strips on credit cards, laser printers, and photo copiers.]

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

Science and Engineering Practices

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.

- Construct, revise, and use models to predict and explain relationships between systems and their components. (b)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that build, test, and revise conceptual, mathematical, physical and empirical models.

- Plan and carry out investigations individually and collaboratively and test designs as part of building and revising models, explaining phenomena, or testing solutions to problems. Consider possible confounding variables or effects and ensure the investigation's design has controlled for them. (c)

Using Mathematical 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 expressions to represent phenomena or design solutions in order to solve algebraically for desired quantities. (a)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9–12 builds on 6–8 and progresses to evaluate the validity and reliability of the claims, methods, and designs.

- Generate, synthesize, communicate, and critique claims, methods and designs that appear in scientific and technical texts or media reports. (d),(e)

Disciplinary Core Ideas

PS2.B: Types of Interactions

- Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (a)
- Forces at a distance are explained by fields permeating space that can transfer energy through space. Magnets or changing electric fields cause magnetic fields; electric charges or changing magnetic fields cause electric fields. (c)
- Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. (b),(e)
- The strong and weak nuclear interactions are important inside atomic nuclei—for example, they determine the patterns of which nuclear isotopes are stable and what kind of decays occur for unstable ones. (d)

Crosscutting Concepts

Cause and Effect

Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects. (a),(b),(c),(d)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (e)

Connections to other DCIs in this grade-level: **HS.ETS-ETSS, HS.ESS-SS, HS.ESS-ES**

Articulation to DCIs across grade-levels: **MS.PS-IF, MS.PS-FM**

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

ELA –

RST.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

WHST.9 Draw evidence from informational texts to support analysis, reflection, and research.

Mathematics –

MP.2 Reason abstractly and quantitatively

MP.4 Model with Mathematics

8.F Define, evaluate, and compare functions.

S.ID Summarize, represent, and interpret data on a single count or measurement variable

F.BF Build a function that models a relationship between two quantities

HS.PS-W Waves

HS.PS-W Waves

Students who demonstrate understanding can:

a. Plan and carry out investigations to determine the mathematical relationships among wave speed, frequency, and wavelength and how they are affected by the medium through which the wave travels. [Assessment Boundary: Algebraic calculations only.]

b. Carry out an investigation to describe a boundary between two media that affects the reflection, refraction, and transmission of waves crossing the boundary. [Clarification Statement: Descriptions should include mathematical relationships.] [Assessment Boundary: Descriptions requiring trigonometric functions are excluded.]

c. Investigate the patterns created when waves of different frequencies combine and explain how these patterns are used to encode and transmit information. [Assessment Boundary: Qualitative only.]

d. Use drawings, physical replicas, or computer simulation models to explain that resonance occurs when waves add up in phase in a structure, and that structures have a unique frequency at which resonance occurs. [Clarification Statement: Constructive and destructive interference of waves results in a standing wave pattern (resonance).] [Assessment Boundary: Qualitative explanations only.]

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

Science and Engineering Practices

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.

- Use models (including mathematical and computational) to generate data to explain and predict phenomena, analyze systems, and solve problems. (d)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that build, test, and revise conceptual, mathematical, physical and empirical models.

- Plan and carry out investigations individually and collaboratively and test designs as part of building and revising models, explaining phenomena, or testing solutions to problems. Consider possible confounding variables or effects, and ensure that the investigation's design has controlled for them. (a),(b),(c)

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 expressions to represent phenomena or design solutions in order to solve algebraically for desired quantities. (b)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Construct and revise explanations and arguments based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories) and peer review. (c)

Disciplinary Core Ideas

PS4.A: Wave Properties

- The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing. The reflection, refraction, and transmission of waves at an interface between two media can be modeled on the basis of these properties. (a),(b)
- Combining waves of different frequencies can make a wide variety of patterns and thereby encode and transmit information. (c)
- Resonance is a phenomenon in which waves add up in phase in a structure, growing in amplitude due to energy input near the natural vibration frequency. Structures have particular frequencies at which they resonate. This phenomenon (e.g., waves in a stretched string, vibrating air in a pipe) is used in speech and in the design of all musical instruments. (d)

Crosscutting Concepts

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. Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus requiring improved investigations and experiments. Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system. Mathematical representations are needed to identity some patterns. (a),(c),(d)

- [Clarification Statement for d: Constructive and destructive interference of waves results in a standing wave pattern, i.e. resonance.]

Cause and Effect

Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects. (b)

Connections to other DCIs in this grade-level: **HS-ETS-ETSS, HS-ETS-ED, HS.ESS-ES**

Articulation to DCIs across grade-levels: **MS.PS-WER**

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

ELA –

W.9-10.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

RST.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

W.11-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

Mathematics –

MP.2 Reason abstractly and quantitatively.

MP.4 Model with Mathematics.

F.LE Construct and compare linear, quadratic, and exponential models and solve problems.

A-REI.10 Represent and solve equations and inequalities graphically.

A.CED Create equations that describe numbers or relationships.

HS.PS-ER Electromagnetic Radiation

HS.PS-ER Electromagnetic Radiation

Students who demonstrate understanding can:

a. Use arguments to support the claim that electromagnetic radiation can be described using both a wave model and a particle model, and determine which model provides a better explanation of phenomena. [Assessment Boundary: Limited to understanding that the quantum theory relates the two models, but students do not need to know the specifics of the quantum theory.]

b. Obtain, evaluate, and communicate scientific literature to show that all electromagnetic radiation travels through a vacuum at the same speed (called the speed of light).

c. Obtain, evaluate, and communicate scientific literature about the effects different wavelengths of electromagnetic radiation have on matter when the matter absorbs it. [Assessment Boundary: Only IR, UV, and gamma radiation are intended; qualitative descriptions only.]

d. Analyze and interpret data of both atomic emission and absorption spectra of different samples to make claims about the presence of certain elements in the sample. [Assessment Boundary: Identification of elements to be based on comparison of spectral lines.]

e. Construct an explanation of how photovoltaic materials work using the particle model of light, and describe their application in everyday devices. [Clarification Statement: Everyday devices can include solar cells and barcodes.] [Assessment Boundary: Qualitative descriptors only]

f. Obtain, evaluate, and communicate scientific literature about the differences and similarities between analog and digital representations of information to describe the relative advantages and disadvantages. [Assessment Boundary: Qualitative explanations only.]

g. Construct explanations for why the wavelength of an electromagnetic wave determines its use for certain applications. [Clarification Statement: Examples of wavelength determining applications can include visible light not being used to observe atoms, and x-rays being used for bone imaging.] [Assessment Boundary: Only qualitative descriptors in the explanation are intended.]

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

Science and Engineering Practices

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.

- Use tools, technologies, and models (e.g. computational and mathematical) to plan, gather, and analyze data to make valid and reliable scientific claims or justify an optimal solution. (d)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Construct and revise explanations and arguments based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories) and peer review. (e),(g)

Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about natural and designed world. Arguments may also come from current scientific or historical episodes in science.

- Construct a counter-argument that is based in data and evidence that challenges another proposed argument. (a)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9–12 builds on 6–8 and progresses to evaluate the validity and reliability of the claims, methods, and designs.

- Critically read scientific literature adapted for classroom use to identify key ideas and major points and to evaluate the validity and reliability of the claims, methods, and designs. (b),(c),(f)

Disciplinary Core Ideas

PS4.A: Wave Properties

- Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. (f)

PS4.B: Electromagnetic Radiation

- Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. Quantum theory relates the two models. (Boundary: Quantum theory is not explained further at this grade level.) (a)
- Because a wave is not much disturbed by objects that are small compared with its wavelength, visible light cannot be used to see such objects as individual atoms. (g)
- All electromagnetic radiation travels through a vacuum at the same speed, called the speed of light. Its speed in any other given medium depends on its wavelength and the properties of that medium. (b),(g)
- When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). (c),(g)
- Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells. (c),(g)
- Photovoltaic materials emit electrons when they absorb light of a high-enough frequency. (e)
- Atoms of each element emit and absorb characteristic frequencies of light, and nuclear transitions have distinctive gamma ray wavelengths. These characteristics allow identification of the presence of an element, even in microscopic quantities. (d)

PS4.C: Information Technologies and Instrumentation

- Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them. (e),(f),(g)
- Knowledge of quantum physics enabled the development of semiconductors, computer chips, and lasers, all of which are now essential components of modern imaging, communication, and information technologies. (Boundary: Details of quantum physics are not formally taught at this grade level.) (g)

Crosscutting Concepts

Structure and Function

Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. (a),(b),(d),(e)

- [Clarification Statement for a: The way something functions, e.g. visible light, can be best understood through a particular representation of its structure.]
- [Clarification Statement for d: Rationale is that from the spectra (the way they function) the structure can be inferred.]

Connections to Engineering, Technology, and Applications of Science

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

Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. Engineers continuously modify these systems to increase benefits while decreasing costs and risks. New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (c),(f),(g)

HS.PS-ER Electromagnetic Radiation *(continued)*
Connections to other DCIs in this grade-level: **HS.ETS-ETSS, HS.ESS-SS**
Articulation to DCIs across grade-levels: **MS.PS-WER**
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases] *ELA –* **RI.9-10.8** Delineate and evaluate the argument and specific claims in a text, assessing whether the reasoning is valid and the evidence is relevant and sufficient; identify false statements and fallacious reasoning. **SL.9-10.4** Present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task. **SL.11-12.4** Present information, findings, and supporting evidence, conveying a clear and distinct perspective, such that listeners can follow the line of reasoning, alternative or opposing perspectives are addressed, and the organization, development, substance, and style are appropriate to purpose, audience, and a range of formal and informal tasks. *Mathematics –* **N-Q** Reason quantitatively and use units to solve problems **S.ID** Summarize, represent, and interpret data on a single count or measurement variable **S.IC** Make inferences and justify conclusions from sample surveys, experiments, and observational studies

HS.PS-NP Nuclear Processes

HS.PS-NP Nuclear Processes

Students who demonstrate understanding can:

a. Construct models to explain changes in nuclear energies during the processes of fission, fusion, and radioactive decay and the nuclear interactions that determine nuclear stability. [Assessment Boundary: Models to exclude mathematical representations. Radioactive decays limited to alpha, beta, and gamma.]

b. Analyze and interpret data sets to determine the age of samples (rocks, organic material) using the mathematical model of radioactive decay. [Assessment Boundary: Mathematical model limited to graphical representations.]

c. Ask questions and make claims about the relative merits of nuclear processes compared to other types of energy production. [Clarification Statement: Students are given data about energy production methods, such as burning coal versus using nuclear reactors.] [Assessment Boundary: Students only analyze data provided. Merits only include economic, safety, and environmental]

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

Science and Engineering Practices

Asking Questions and Defining Problems

Asking questions and defining problems in grades 9–12 builds from grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and explanatory models and simulations.

- Ask questions that challenge the premise of an argument, the interpretation of a data set, or the suitability of a design. (c)

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.

- Construct, revise, and use models to predict and explain relationships between systems and their components. (a)

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.

- Use tools, technologies, and models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. (b),(c)

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. Students also use and create simple computational simulations based on mathematical models of basic assumptions.

- Use statistical and mathematical techniques and structure data (e.g., displays, tables, and graphs) to find regularities, patterns (e.g., fitting mathematical curves to data), and relationships in data. (b)

Disciplinary Core Ideas

PS1.C: Nuclear Processes

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

PS3.D: Energy in Chemical Processes and Everyday Life

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

Crosscutting Concepts

Energy and Matter

The total amount of energy and matter in closed systems is conserved. Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems. Energy drives the cycling of matter within and between systems. In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (a)

Stability and Change

Much of science deals with constructing explanations of how things change and how they remain stable. Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. Feedback (negative or positive) can stabilize or destabilize a system. Systems can be designed for greater or lesser stability. (b)

Connections to Engineering, Technology, and Applications of Science

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

Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. Engineers continuously modify these systems to increase benefits while decreasing costs and risks. New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (c)

Connections to other topics in this grade-level: **HS.ESS-SS, HS.ESS-HE, HS.ETS-ETSS**

Articulation across grade-levels: **MS.PS-SPM, MS.LS-NSA**

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

ELA –

SL.1.c Propel conversations by posing and responding to questions that relate the current discussion to broader themes or larger ideas; actively incorporate others into the discussion; and clarify, verify, or challenge ideas and conclusions.

W.1 Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.

W.9 Draw evidence from literary or informational texts to support analysis, reflection, and research.

Mathematics –

MP.4 Model with Mathematics

F.LE Construct and compare linear, quadratic, and exponential models and solve problems

A-CED.1 Create equations that describe numbers or relationships

N-Q Reason quantitatively and use units to solve problems

HS-ETS-ETSS Links Among Engineering, Technology, Science, and Society

HS-ETS-ETSS Links Among Engineering, Technology, Science, and Society

Students who demonstrate understanding can:

a. Plan and carry out an investigation to improve a technology and suggest ideas for further related scientific study. [Clarification Statement: For example, a group of students investigate the environmental conditions needed to maintain a healthy aquatic population, apply findings to improving an aquarium, and recommend research that can be done with the improved technology to study aquatic ecosystems.]

b. Gather evidence to evaluate different explanations for the widespread adoption of a modern technology, including the role of societal demands, market forces, evaluations by scientists and engineers, and possible government regulation. [Clarification Statement: For example, students evaluate explanations for the rapid spread of cell phones, LED lighting, or genetically engineered crops for farming.)

c. Analyze data to compare different technologies designed to accomplish the same function regarding their relative environmental impacts, costs, risks, and benefits, and what may need to be done to reduce unanticipated negative effects. [Clarification Statement: Comparisons include paper vs. electronic books, nuclear vs. coal-fired power plants.] [Assessment Boundary: Analysis limited to data available online or provided to students.]

d. Construct or critique arguments based on evidence concerning the costs, risks, and benefits of changes in major technological systems related to agriculture, health, water, energy, transportation, manufacturing, or construction, needed to support a growing world population. [Clarification Statement: For example, students construct arguments concerning the costs and benefits of shifting from centralized to distributed energy generation systems or natural to genetically engineered crops.] [Assessment Boundary: Limited to relative comparison of costs and benefits of different technological changes.]

The performance expectations above were developed using the following elements from the NRC *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 9–12 builds on K–8 experiences and progresses to include investigations that build, test, and revise conceptual, mathematical, physical and empirical models.

- Plan and carry out investigations Individually and collaboratively and test designs as part of building and revising models, explaining phenomena, or testing solutions to problems. Consider possible confounding variables or effects, and ensure the investigation's design has controlled for them. (a)

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.

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. (c)

Engaging in Argument from Evidence
Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world. Arguments may also come from current scientific or historical episodes in science.

- Construct a counter-argument that is based in data and evidence that challenges another proposed argument (d)
- Criticize and evaluate arguments and design solutions in light of new evidence, limitations (e.g., trade-offs), constraints, and ethical issues. (d)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluate the validity and reliability of the claims, methods, and designs.

- Critically read scientific literature adapted for classroom use to identify key ideas and major points and to evaluate the validity and reliability of the claims, methods, and designs. (b)
- Generate, synthesize, communicate, and critique claims, methods, and designs that appear in scientific and technical texts or media reports. (b)

Disciplinary Core Ideas

ETS2.A: Interdependence of Science, Engineering, and Technology

- Science and engineering complement each other in the cycle known as research and development (R&D). (a)
- Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (a)

ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World

- Modern civilization depends on major technological systems, including those related to agriculture, health, water, energy, transportation, manufacturing, construction, and communications. (d)
- Engineers continuously modify these technological systems by applying scientific and engineering knowledge and practices to increase benefits while decreasing costs and risks. (d)
- Widespread adoption of technological innovations often depends on market forces or other societal demands, but it may also be subject to evaluation by scientists and engineers and to eventual government regulation. (b)
- New technologies can have deep impacts on society and the environment, including some that were not anticipated or that may build up over time to a level that requires attention or mitigation. (c)
- Analysis of costs, environmental impacts, risks and benefits, are critical aspects of decisions about technology use. (c)

Crosscutting Concepts

Cause and Effect
Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects. (a),(b)

Stability and Change
Much of science deals with constructing explanations of how things change and how they remain stable. Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. Feedback (negative or positive) can stabilize or destabilize a system. Systems can be designed for greater or lesser stability. (b),(c),(d)

HS-ETS-ETSS Links Among Engineering, Technology, Science, and Society

HS-ETS-ETSS Links Among Engineering, Technology, Science, and Society *(continued)*

Connections to other DCIs in this grade-level: **HS.ESS-CC, HS.ESS-HS, HS.LS.IRE, HS.LS.NSE, HS.PS-ER, HS.PS-NP, HS.ETS-ED**

Articulation to DCIs across grade-levels: **MS.ETS-ETSS**

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

ELA –

W.8.8 Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.

RST.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

WHST.9 Draw evidence from informational texts to support analysis, reflection, and research.

Mathematics –

MP.2 Reason abstractly and quantitatively

MP.4 Model with Mathematics

MP.5 Use appropriate tools strategically

8.F Define, evaluate, and compare functions.

S.ID Summarize, represent, and interpret data on a single count or measurement variable

S.IC Make inferences and justify conclusions from sample surveys, experiments, and observational studies

F.BF Build a function that models a relationship between two quantities

N-Q Reason quantitatively and use units to solve problems

MP.4 Model with Mathematics.

A.CED Create equations that describe numbers or relationships.