

PHYSICAL SCIENCE CURRICULUM

Unit 1: Motion and Forces

OVERVIEW

Summary

Students will explore and define Newton's second law of motion, momentum, and Newton's law of gravitation. They will apply mathematics to test conservation of energy in systems and explore system limits. Using mathematical formulas they will predict changes in variables within a system and test theories.

Content to Be Learned

- Define momentum as the mass times velocity of an object.
- Understand interactions of objects and the impact on momentum and total momentum.
- 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.
- Forces at a distance are explained by fields (gravitational) permeating space that can transfer energy through space.
- Calculate the change of one component in a system when the change in the energy of the other component and energy flows in and out of a system are known.
- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system.
- 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 a system (conservation of energy).
- Energy can not be created or destroyed, but it can be transported from one place to another and can be transferred between systems.
- Stored energy in a system depends on its configuration and how kinetic energy depends on mass and speed.
- Allow the conservation of energy to be used, predict, and describe system behavior.
- The availability of energy limits what can occur in any system.

Practices

- Analyze data to support a claim.
- Use mathematical representations to support a claim or predict a relationship between variables.
- Apply science and engineering ideas to design, evaluate, and refine a device.
- Create a computational model to calculate.

Crosscutting Concepts

- Cause and effect.
- Systems and system models.
- Patterns.

Essential Questions

- What is the relationship between force, mass, and acceleration?
- How can Newton's second law be used to predict the change in motion of an object?
- How can changing the energy of one part of a system affect the energy of other parts of that system?
- How can the properties of objects and the the distance between them be used to describe the relationship between electric and magnetic fields?
- How can a model demonstrate conservation of energy?

Next Generation Science Standards

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

Students who demonstrate understanding can:

- HS-PS2-1.** Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. [Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.] [Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.]

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

Science and Engineering Practices

Analyzing and Interpreting Data

Analyzing data in 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.

Disciplinary Core Ideas

PS2.A: Forces and Motion

- Newton's second law accurately predicts changes in the motion of macroscopic objects.

Crosscutting Concepts

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Connections to other DCIs in this grade-level:

HS.PS3.C ; HS.ESS1.A ; HS.ESS1.C ; H.ESS2.C

Articulation of DCIs across grade-bands:

MS.PS2.A ; MS.PS3.C

Common Core State Standards Connections:

ELA/Literacy -

RST.11-12.1

Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS2-1)

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. (HS-PS2-1)

WHST.11-

12.9

Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS2-1)

Mathematics -

MP.2

Reason abstractly and quantitatively. (HS-PS2-1)

MP.4

Model with mathematics. (HS-PS2-1)

HSN.Q.A.1

Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS2-1)

HSN.Q.A.2

Define appropriate quantities for the purpose of descriptive modeling. (HS-PS2-1)

HSN.Q.A.3

Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS2-1)

HSA.SSE.A.1

Interpret expressions that represent a quantity in terms of its context. (HS-PS2-1)

HSA.SSE.B.3

Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS2-1)

HSA.CED.A.1

Create equations and inequalities in one variable and use them to solve problems. (HS-PS2-1)

HSA.CED.A.2

Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. (HS-PS2-1)

HSA.CED.A.4

Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-PS2-1)

HSF-IF.C.7

Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases. (HS-PS2-1)

HSS-IS.A.1

Represent data with plots on the real number line (dot plots, histograms, and box plots). (HS-PS2-1)

* The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

The section entitled "Disciplinary Core Ideas" is reproduced verbatim from *A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas*. Integrated and reprinted with permission from the National Academy of Sciences.

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

Students who demonstrate understanding can:

HS-PS2-2. Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on 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.]

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

Science and Engineering Practices

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.

Disciplinary Core Ideas

PS2.A: Forces and Motion

- Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object.
- 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.

Crosscutting Concepts

Systems and System Models

- When investigating or describing a system, the boundaries and initial conditions of the system need to be defined.

Connections to other DCIs in this grade-level:

HS.ESS1.A : HS.ESS1.C

Articulation of DCIs across grade-bands:

MS.PS2.A : MS.PS3.C

Common Core State Standards Connections:

Mathematics -

- MP.2** Reason abstractly and quantitatively. (HS-PS2-2)
MP.4 Model with mathematics. (HS-PS2-2)
HSN.Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS2-2)
HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-PS2-2)
HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS2-2)
HSA.CED.A.1 Create equations and inequalities in one variable and use them to solve problems. (HS-PS2-2)
HSA.CED.A.2 Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. (HS-PS2-2)
HSA.CED.A.4 Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-PS2-2)

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

Students who demonstrate understanding can:

- HS-PS2-3.** Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.* [Clarification Statement: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.] [Assessment Boundary: Assessment is limited to qualitative evaluations and/or algebraic manipulations.]

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

Science and Engineering Practices

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 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 ideas, principles, and theories.

- Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects.

Disciplinary Core Ideas

PS2.A: Forces and Motion

- 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.

ETS1.A: Defining and Delimiting an Engineering Problem

- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary)

ETS1.C: Optimizing the Design Solution

- Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (secondary)

Crosscutting Concepts

Cause and Effect

- Systems can be designed to cause a desired effect.

Connections to other DCIs in this grade-level: N/A

Articulation of DCIs across grade-bands:

MS.PS2.A ; MS.PS3.C

Common Core State Standards Connections:

ELA/Literacy -

WHST.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. (HS-PS2-3)

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

Students who demonstrate understanding can:

HS-PS2-4. Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects. [Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.] [Assessment Boundary: Assessment is limited to systems with two objects.]

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

Science and Engineering Practices

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.

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.

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.
- Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.

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.

Connections to other DCIs in this grade-level:

HS.PS3.A ; HS.ESS1.B

Articulation of DCIs across grade-bands:

MS.PS2.B ; MS.ESS1.B

Common Core State Standards Connections:

Mathematics -

MP.2

Reason abstractly and quantitatively. (HS-PS2-4)

MP.4

Model with mathematics. (HS-PS2-4)

HSN.Q.A.1

Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS2-4)

HSN.Q.A.2

Define appropriate quantities for the purpose of descriptive modeling. (HS-PS2-4)

HSN.Q.A.3

Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS2-4)

HSA.SSE.A.1

Interpret expressions that represent a quantity in terms of its context. (HS-PS2-4)

HSA.SSE.B.3

Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS2-4)

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

Students who demonstrate understanding can:

HS-PS2-5. Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current. *[Assessment Boundary: Assessment is limited to designing and conducting investigations with provided materials and tools.]*

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

Science and Engineering Practices

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 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.

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.
- Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.

PS3.A: Definitions of Energy

- "Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. (secondary)

Crosscutting Concepts

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Connections to other DCIs in this grade-level:

HS.PS3.A ; HS.PS4.B ; HS.ESS2.A

Articulation of DCIs across grade-bands:

MS.PS1.A ; MS.PS2.B ; MS.ESS1.B

Common Core State Standards Connections:

ELA/Literacy -

WHST.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. (HS-PS2-5)

WHST.11-

12.8

Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS2-5)

WHST.11-

12.9

Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS2-5)

Mathematics -

HSN.Q.A.1

Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS2-5)

HSN.Q.A.2

Define appropriate quantities for the purpose of descriptive modeling. (HS-PS2-5)

HSN.Q.A.3

Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS2-5)

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Unit 2: Energy and Electricity

OVERVIEW

Summary

Students will be introduced to the mathematics behind Coulomb's law. They will use this law and mathematical models to explain electrostatic forces between objects. Students will explore how energy is stored in fields (electrical and magnetic) and how objects interact in those fields. Small experiments will allow students to explore the fact that energies can be converted into different forms such as motion, sound, light, and heat and they will create devices to transform energy into different forms.

Content to Be Learned

- Coulomb's Law predicts the electrostatic forces between objects.
- Coulomb's Law provides the mathematical models to describe and predict the effects of electrostatic forces between distant objects.

- Forces at a distance are explained by fields (electrical, magnetic) permeating space that can transfer energy through space.
- Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.
- Provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.
- 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.
- "Electrical energy" may mean energy stored in a battery or energy transmitted by electrical currents.
- Molecular level structure is important in the functioning in designed materials.
- 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 (emphasis on attractive and repulsive forces).
- Calculate the change of one component in a system when the change in the energy of the other component and energy flows in and out of a system are known.
- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system.
- 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 a system.
- Energy can not be created or destroyed, but it can be transported from one place to another and can be transferred between systems.
- Energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles and energy associated with the relative positions of particles.
- At the macroscopic scale, energy manifests itself in multiple ways, such as through motion, sound, light and thermal energy.
- Relationships are better understood at the microscopic scale at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and the energy associated with configuration.
- In some cases, the relative position energy can be thought of as stored in fields (includes radiation).
- Design, build and refine a device that works within given constraints to convert one form of energy into another form of energy (e.g. Rube Goldberg device, wind turbines, solar cells, solar ovens, generators, etc.).
- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light and thermal energy.
- Although energy can not be destroyed, it can be converted into less useful forms.
- Provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components of the system (2nd law of thermodynamics).
- Energy can not be created or destroyed but it can be transported from one place to another and transferred between systems.
- Uncontrolled system always evolve towards more stable states, that is, towards more uniform energy distribution.
- Although energy can not be destroyed, it can be converted into less useful forms.

- Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes of energy of the objects due to the interaction.
- When two objects, interacting through a field, change relative position, the energy stored in the field is changed.

Practices

- Developing and using models.
- Use mathematical representations.
- Planning and carrying out investigations.
- Obtain, evaluate, and communicate information.
- Use computational models to calculate.
- Construct explanations and design solutions.

Crosscutting Concepts

- Patterns.
- Cause and effect.
- Systems and system models.
- Structure and function.
- Energy and matter.

Essential Questions

- What relationship exists between electric current and magnetic fields?
- How can attractive and repulsive forces of materials determine their function in design?
- Using examples, how can a device be used to convert energy from one form to another?
- How can we collect evidence to show that heat energy is transferred between two objects of different temperatures?
- How can a model demonstrate how particle/object motion and position can be used to calculate total energy in a system?

Next Generation Science Standards

HS-PS3-1 Energy

Students who demonstrate understanding can:

HS-PS3-1 Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. [Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] [Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.]

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

Science and Engineering Practices

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.

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. 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

- Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
- The availability of energy limits what can occur in any system.

Crosscutting Concepts

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.

Connections to other DCIs in this grade-band:

HS.PS1.B ; HS.LS2.B ; HS.ESS2.A

Articulation of DCIs across grade-bands:

MS.PS3.A ; MS.PS3.B ; MS.ESS2.A

Common Core State Standards Connections:

ELA/Literacy -

SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-PS3-1)

Mathematics -

MP.2 Reason abstractly and quantitatively. (HS-PS3-1)

MP.4 Model with mathematics. (HS-PS3-1)

HSN.Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS3-1)

HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-PS3-1)

HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS3-1)

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HS-PS3-2 Energy

Students who demonstrate understanding can:

HS-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects). [Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically-charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.]

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

Science and Engineering Practices

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

- Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.

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. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.
- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.
- These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.

Crosscutting Concepts

Energy and Matter

- Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.

Connections to other DCIs in this grade-band:

HS.PS1.A ; HS.PS1.B ; HS.PS2.B

Articulation of DCIs across grade-bands:

MS.PS1.A ; MS.PS2.B ; MS.PS3.A ; MS.PS3.C

Common Core State Standards Connections:

ELA/Literacy -

SL.11- Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-PS3-2)

Mathematics -

MP.2 Reason abstractly and quantitatively. (HS-PS3-2)

MP.4 Model with mathematics. (HS-PS3-2)

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HS-PS3-3 Energy

Students who demonstrate understanding can:

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

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

Science and Engineering Practices

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 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 ideas, principles, and theories.

- Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

Disciplinary Core Ideas

PS3.A: Definitions of Energy

- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.

PS3.D: Energy in Chemical Processes

- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.

ETS1.A: Defining and Delimiting an Engineering Problem

- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary)

Crosscutting Concepts

Energy and Matter

- 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.

Connections to Engineering, Technology, and Applications of Science

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

- Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.

Connections to other DCIs in this grade-band:

HS.ESS3.A

Articulation of DCIs across grade-bands:

MS.PS3.A ; MS.PS3.B ; MS.ESS2.A

Common Core State Standards Connections:

ELA/Literacy -

WHST.9-12.7 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. (HS-PS3-3)

Mathematics -

MP.2 Reason abstractly and quantitatively. (HS-PS3-3)

MP.4 Model with mathematics. (HS-PS3-3)

HSN.Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS3-3)

HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-PS3-3)

HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS3-3)

* The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

The section entitled "Disciplinary Core Ideas" is reproduced verbatim from *A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas*. Integrated and reprinted with permission from the National Academy of Sciences.

HS-PS3-4 Energy

Students who demonstrate understanding can:

HS-PS3-4. Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics). [Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.] [Assessment Boundary: Assessment is limited to investigations based on materials and tools provided to students.]

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

Science and Engineering Practices

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 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.

Disciplinary Core Ideas

PS3.B: Conservation of Energy and Energy Transfer

- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- 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).

PS3.D: Energy in Chemical Processes

- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.

Crosscutting Concepts

Systems and System Models

- 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.

Connections to other DCIs in this grade-band:

HS.ESS2.A

Articulation of DCIs across grade-bands:

MS.PS3.B

Common Core State Standards Connections:

ELA/Literacy -

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS3-4)

WHST.9-12.7 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. (HS-PS3-4)

WHST.11-12.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS3-4)

WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS3-4)

Mathematics -

MP.2 Reason abstractly and quantitatively. (HS-PS3-4)

MP.4 Model with mathematics. (HS-PS3-4)

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HS-PS3-5 Energy

Students who demonstrate understanding can:

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

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

Science and Engineering Practices

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

- Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.

Disciplinary Core Ideas

PS3.C: Relationship Between Energy and Forces

- When two objects interacting through a field change relative position, the energy stored in the field is changed.

Crosscutting Concepts

Cause and Effect

- 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.

Connections to other DCIs in this grade-band:

HS.PS2.B

Articulation of DCIs across grade-bands:

MS.PS2.B ; MS.PS3.C

Common Core State Standards Connections:

ELA/Literacy -

WHST.9-12.7 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. (HS-PS3-5)

WHST.11-12.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS3-5)

WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS3-5)

SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-PS3-5)

Mathematics -

MP.2 Reason abstractly and quantitatively. (HS-PS3-5)

MP.4 Model with mathematics. (HS-PS3-5)

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Unit 3: Waves

OVERVIEW

Summary

Students will be introduced to the relationships between frequency, wavelength, and speed of waves as they travel through various media. They will explore the interactions of waves and how waves are used in digital technologies through transmission and storage of materials. Students will also explore various types of waves and how the wave or particle models help to explain electromagnetic radiation.

Content to Be Learned

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

- Advantages of using a digital transmission and storage of information.
- Information can be digitized. In this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.
- Waves can add or cancel one another as they cross depending on their relative phase but they emerge unaffected by each other.
- Electromagnetic radiation can be modeled as a wave of changing electric and magnetic fields or as particles called photons.
- The wave model is used for explaining many features of electromagnetic radiation and the particle model explains other features.
- When light or longer wavelength electromagnetic radiation is absorbed in matter it is generally converted into thermal energy. Shorter wavelength electromagnetic radiation can ionize atoms and cause damage to living cells.
- Some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.
- Solar cells are human made devices that likewise capture the sun's energy and produce electrical energy.
- Photoelectric materials emit electrons when they absorb light of a high enough frequency.
- Multiple technologies, based on the understanding of waves, and their interactions with matter are part of everyday experiences in the modern world and in scientific research.

Practices

- Using mathematics and computational thinking.
- Asking questions and defining problems.
- Engaging in argument from evidence.
- Obtaining, evaluating, and communicating information.

Crosscutting Concepts

- Cause and effect.
- Systems and system models.
- Stability and change.

Essential Questions

- What is the relationship between the frequency, wavelength, and speed of a wave?
- How is wavelength knowledge used to improve storage and transmission of digital data?
- Why can electromagnetic radiation be described as a wave in some scenarios but a particle in others?
- When would the photon model be better than the electromagnetic wave model for explaining features of electromagnetic radiation?
- How do different frequencies of electromagnetic radiation impact living systems.

Next Generation Science Standards

HS-PS4-1 Waves and their Applications in Technologies for Information Transfer

Students who demonstrate understanding can:

HS-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. [Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.] [Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.]

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

Science and Engineering Practices

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.

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.

Crosscutting Concepts

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Connections to other DCIs in this grade-band:

HS.ESS2.A

Articulation of DCIs across grade-bands:

MS.PS4.A ; MS.PS4.B

Common Core State Standards Connections:

ELA/Literacy -

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. (HS-PS4-1)

Mathematics -

MP.2

Reason abstractly and quantitatively. (HS-PS4-1)

MP.4

Model with mathematics. (HS-PS4-1)

HSA-SSE.A.1

Interpret expressions that represent a quantity in terms of its context. (HS-PS4-1)

HSA-SSE.B.3

Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS4-1)

HSA.CED.A.4

Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-PS4-1)

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HS-PS4-2 Waves and their Applications in Technologies for Information Transfer

Students who demonstrate understanding can:

- HS-PS4-2. Evaluate questions about the advantages of using a digital transmission and storage of information.** [Clarification Statement: Examples of advantages could include that digital information is stable because it can be stored reliably in computer memory, transferred easily, and copied and shared rapidly. Disadvantages could include issues of easy deletion, security, and theft.]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>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 design problems using models and simulations.</p> <ul style="list-style-type: none">Evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design.	<p>PS4.A: Wave Properties</p> <ul style="list-style-type: none">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.	<p>Stability and Change</p> <ul style="list-style-type: none">Systems can be designed for greater or lesser stability. <p>-----</p> <p><i>Connections to Engineering, Technology, and Applications of Science</i></p> <p>Influence of Engineering, Technology, and Science on Society and the Natural World</p> <ul style="list-style-type: none">Modern civilization depends on major technological systems.Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.
<p><i>Connections to other DCIs in this grade-band: N/A</i></p>		
<p><i>Articulation of DCIs across grade-bands:</i></p>		
<p>MS.PS4.A ; MS.PS4.B ; MS.PS4.C</p>		
<p><i>Common Core State Standards Connections:</i></p>		
<p><i>ELA/Literacy -</i></p> <p>RST.9-10.8 Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem. (HS-PS4-2)</p> <p>RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS4-2)</p> <p>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. (HS-PS4-2)</p>		

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HS-PS4-3 Waves and their Applications in Technologies for Information Transfer

Students who demonstrate understanding can:

HS-PS4-3. Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.

[Clarification Statement: Emphasis is on how the experimental evidence supports the claim and how a theory is generally modified in light of new evidence. Examples of a phenomenon could include resonance, interference, diffraction, and photoelectric effect.] [Assessment Boundary: Assessment does not include using quantum theory.]

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

Science and Engineering Practices

Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds on 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 worlds. Arguments may also come from current scientific or historical episodes in science.

- Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.

Connections to Nature of Science

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

- A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.

Disciplinary Core Ideas

PS4.A: Wave Properties

- [From the 3–5 grade band endpoints] Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.)

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.

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.

Connections to other DCIs in this grade-band:

HS.PS3.D ; HS.ESS1.A ; HS.ESS2.D

Articulation of DCIs across grade-bands:

MS.PS4.B

Common Core State Standards Connections:

ELA/Literacy -

- RST.9-10.8** Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem. (HS-PS4-3)
- RST.11-12.1** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS4-3)
- 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. (HS-PS4-3)

Mathematics -

MP.2

Reason abstractly and quantitatively. (HS-PS4-3)

HSA-SSE.A.1

Interpret expressions that represent a quantity in terms of its context. (HS-PS4-3)

HSA-SSE.B.3

Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS4-3)

HSA.CED.A.4

Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-PS4-3)

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HS-PS4-4 Waves and their Applications in Technologies for Information Transfer

Students who demonstrate understanding can:

HS-PS4-4. Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter. [Clarification Statement: Emphasis is on the idea that photons associated with different frequencies of light have different energies, and the damage to living tissue from electromagnetic radiation depends on the energy of the radiation. Examples of published materials could include trade books, magazines, web resources, videos, and other passages that may reflect bias.] [Assessment Boundary: Assessment is limited to qualitative descriptions.]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Obtaining, Evaluating, and Communicating Information</p> <p>Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.</p> <ul style="list-style-type: none"> Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible. 	<p>PS4.B: Electromagnetic Radiation</p> <ul style="list-style-type: none"> When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells. 	<p>Cause and Effect</p> <ul style="list-style-type: none"> 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.
<p><i>Connections to other DCIs in this grade-band:</i> HS.PS1.C ; HS.PS3.A ; HS.PS3.D ; HS.LS1.C</p>		
<p><i>Articulation of DCIs across grade-bands:</i> MS.PS3.D ; MS.PS4.B ; MS.LS1.C ; MS.ESS2.D</p>		
<p><i>Common Core State Standards Connections:</i> ELA/Literacy -</p> <p>RST.9-10.8 Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem. (HS-PS4-4)</p> <p>RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS4-4)</p> <p>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. (HS-PS4-4)</p> <p>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. (HS-PS4-4)</p> <p>WHST.11-12.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS4-4)</p>		

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HS-PS4-5 Waves and their Applications in Technologies for Information Transfer

Students who demonstrate understanding can:

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

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Obtaining, Evaluating, and Communicating Information</p> <p>Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.</p> <ul style="list-style-type: none"> Communicate technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). 	<p>PS3.D: Energy in Chemical Processes</p> <ul style="list-style-type: none"> Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy. (secondary) <p>PS4.A: Wave Properties</p> <ul style="list-style-type: none"> 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. <p>PS4.B: Electromagnetic Radiation</p> <ul style="list-style-type: none"> Photoelectric materials emit electrons when they absorb light of a high-enough frequency. <p>PS4.C: Information Technologies and Instrumentation</p> <ul style="list-style-type: none"> 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. 	<p>Cause and Effect</p> <ul style="list-style-type: none"> Systems can be designed to cause a desired effect. <p>-----</p> <p style="text-align: center;"><i>Connections to Engineering, Technology, and Applications of Science</i></p> <p>Interdependence of Science, Engineering, and Technology</p> <ul style="list-style-type: none"> Science and engineering complement each other in the cycle known as research and development (R&D). <p>Influence of Engineering, Technology, and Science on Society and the Natural World</p> <ul style="list-style-type: none"> Modern civilization depends on major technological systems.
<p><i>Connections to other DCIs in this grade-band:</i> HS.PS3.A</p>		
<p><i>Articulation of DCIs across grade-bands:</i> MS.PS4.A ; MS.PS4.B ; MS.PS4.C</p>		
<p><i>Common Core State Standards Connections:</i> ELA/Literacy - WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS4-5)</p>		

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