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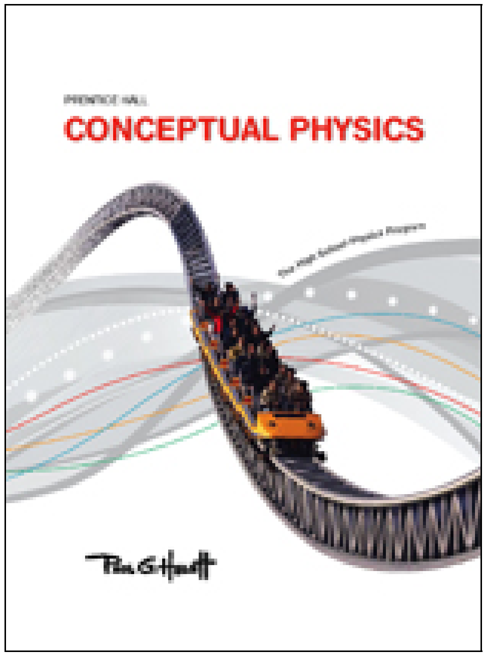

To the

Next Generation Science Standards

Physical Science Standards
Earth and Space Science Standards

Grades 9-12

ALWAYS LEARNING PEARSON

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to the Next Generation Science Standards
Grades 9-12

Dear Educator,

As we embark upon a new and exciting science journey, Pearson is committed to offering its complete support as classrooms transition to the new Next Generation Science Standards (NGSS). Ready-to-use solutions for today and a forward-thinking plan for tomorrow connect teacher education and development, curriculum content and instruction, assessment, and information and school design and improvement. We'll be here every step of the way to provide the easiest possible transition to the NGSS with a coherent, phased approach to implementation.

Pearson has long-standing relationships with contributors and authors who have been involved with the development and review of the Next Generation Science Frameworks and subsequent Next Generation Science Standards. As such, the spirit and pedagogical approach of the NGSS initiative is embedded in all of our programs, such as ***Conceptual Physics.***

The planning and development of ***Prentice-Hall Conceptual Physics*** was informed by the same foundational research as the NGSS Framework. Specifically, our development teams used Project 2061, the National Science Education Standards (1996) developed by the National Research Council, as well as the Science Anchors Project 2009 developed by the National Science Teachers Association to inform the development of this program. As a result, students make connections throughout the program to concepts that cross disciplines, practice science and engineering skills, and build on their foundational knowledge of key science ideas.

With ***Prentice Hall Conceptual Physics****,* students learn physics by doing physics. Author Paul Hewitt, the pioneer of the enormously successful "concepts before computation" approach, continues to set the standard for clear, accessible writing and a *three-step approach to physics* that will stimulate students at every learning level. This program has even more problem-solving opportunities, robust technology, and hands-on materials.

1. *Exploration* - Ignite interest with meaningful examples and hands-on activities.
2. *Concept Development* - Expand understanding with engaging narrative and visuals, multimedia presentations, and a wide range of concept-development questions and exercises.
3. *Application* - Reinforce and apply key concepts with hands-on laboratory work, critical thinking, and problem solving.

Point-of-use STEM activities and teaching strategies in the Teacher's Edition support the implementation of the engineering and design process in an engaging and hands-on fashion.

The following document demonstrates how ***Prentice Hall Conceptual Physics*** supports the Next Generation Science Standards (NGSS). Correlation references are to the Student Edition, Teacher Edition, and Teacher Lab Resources.

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HS-PS1 Matter and Its Interactions

HS-PS1 Matter and Its Interactions

Students who demonstrate understanding can:

HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms. [Clarification Statement: Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen.] [Assessment Boundary: Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.]

The periodic table is introduced in Lesson 17.8: Electrons in the Atom on SE/TE pages 334-336.

HS-PS1-2. Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. [Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.] [Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.]

HS-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles. [Clarification Statement: Emphasis is on understanding the strengths of forces between particles, not on naming specific intermolecular forces (such as dipole-dipole). Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite). Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.] [Assessment Boundary: Assessment does not include Raoult's law calculations of vapor pressure.]

HS-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy. [Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.] [Assessment Boundary: Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.]

HS-PS1-5. Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs. [Clarification Statement: Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules.] [Assessment Boundary: Assessment is limited to simple reactions in which there are only two reactants; evidence from temperature, concentration, and rate data; and qualitative relationships between rate and temperature.]

HS-PS1-6. Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.* [Clarification Statement: Emphasis is on the application of Le Chatlier's Principle and on refining designs of chemical reaction systems, including descriptions of the connection between changes made at the macroscopic level and what happens at the molecular level. Examples of designs could include different ways to increase product formation including adding reactants or removing products.] [Assessment Boundary: Assessment is limited to specifying the change in only one variable at a time. Assessment does not include calculating equilibrium constants and concentrations.]

HS-PS1-7. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. [Clarification Statement: Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem-solving techniques.] [Assessment Boundary: Assessment does not include complex chemical reactions.]

HS-PS1-8. Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay. [Clarification Statement: Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations.] [Assessment Boundary: Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.]

Prentice Hall Conceptual Physics: Students **learn** the changes in the composition of the nucleus of the atom in Lesson 39.2: Radioactive Decay on SE/TE pages 785-786, Lesson 39.6: Natural Transmutation of Elements on SE/TE pages 792-794, and Lesson 39.7: Artificial Transmutation of Elements on page 795. Students **gain understanding** of nuclear fission in Lesson 40.1: Nuclear Fission on pages 809-811, and about nuclear fusion in Lesson 40.7, pages 821-822.

Students **develop models** in discover!: How Can You Model Nuclear Reactions? on SE/TE page 808. Students **model** the concept of half-life in Activity 103, Half Life, on Laboratory Manual pages 363-364. Students **model** a nuclear fission chain reaction in Activity 104, Chain Reaction, on Laboratory Manual pages 365-366.

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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 a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS1-4),(HS-PS1-8)

SE/TE:
discover!: How Can You Model Nuclear Reactions?, p. 808
Laboratory Manual:
Activity 103, Half Life, on Laboratory Manual pp. 363-364
Activity 104, Chain Reaction, pp. 365-366.

- Use a model to predict the relationships between systems or between components of a system. (HS-PS1-1)

Planning and Carrying Out Investigations

Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.

- Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS1-3)

Using Mathematics and Computational Thinking

Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Use mathematical representations of phenomena to support claims. (HS-PS1-7)

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 principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. (HS-PS1-5)
- Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-PS1-2)
- Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-PS1-6)

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. (HS-PS1-1)

SE/TE:
Lesson 17.8: Electrons in the Atom, pp. 334-336

- 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. (HS-PS1-1),(HS-PS1-2)

SE/TE:
Lesson 17.8: Electrons in the Atom, pp. 334-336

- The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (HS-PS1-3),(secondary to HS-PS2-6)
- A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. (HS-PS1-4)

PS1.B: Chemical Reactions

- Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. (HS-PS1-4),(HS-PS1-5)
- In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. (HS-PS1-6)

- The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. (HS-PS1-2),(HS-PS1-7)

PS1.A: Structure and Properties of Matter

- 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. (Secondary to HS-PS1-1, Secondary to HS-PS1-3)

SE/TE:
Lesson 17.8: Electrons in the Atom, pp. 334-336

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. (HS-PS1-1),(HS-PS1-2),(HS-PS-3),(HS-PS1-5)

Energy and Matter

- In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HS-PS1-8)

SE/TE:
Lesson 39.2: Radioactive Decay, pp. 785-786
Lesson 39.6: Natural Transmutation of Elements on SE/TE pages 792-794

- The total amount of energy and matter in closed systems is conserved. (HS-PS1-7)
- 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. (HS-PS1-4)

Stability and Change

- Much of science deals with constructing explanations of how things change and how they remain stable.(HS-PS1-6)

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. (HS-PS1-7)

	PS1.C: Nuclear Processes · Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process. (HS-PS1-8) **SE/TE:** Lesson 39.2: Radioactive Decay, pp. 785-786 Lesson 40.1: Nuclear Fission, pp. 809-811 Lesson 40.7: Nuclear Fusion, pp. 821-822 **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 to HS-PS1-6)	

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

HS-PS2 Motion and Stability: Forces and Interactions

HS-PS2 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.] Newton's Second Law is presented in Lesson 6.3: Newton's Second Law, SE/TE pages 88-89. Students **analyze data** in "do the math" on page 89 and in Appendix F, Chapter 6, pages 850-52. Students **analyze data** in Activity 18, Getting Pushy, Laboratory Manual pages 67-69, Activity 19, Constant Force and Changing Mass on Laboratory Manual pages 71-73, and Activity 20, Constant Mass and Changing Force on Laboratory Manual pages 75-77. **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.] Students **learn** about conservation of momentum in the following lessons: Lesson 7.2: Newton's Third Law on SE/TE page 108 Lesson 7.3: Identifying Action and Reaction on SE/TE pages 108-109 Lesson 7.4: Action and Reaction on Different Masses on SE/TE pages 110-111 Lesson 7.5: Defining Systems on SE/TE pages 112-113 Lesson 7.6: The Horse-Cart Problem on SE/TE pages 114-115 Lesson 7.7: Action Equals Reaction on SE/TE pages 116 More information is provided in Lesson 8.1: Momentum on SE/TE page 125, Lesson 8.2: Impulse Changes Momentum on SE/TE pages 125-129, Lesson 8.3: Bouncing on SE/TE pages 129-130, Lesson 8.4: Conservation of Momentum on SE/TE pages 130-131, and Lesson 8.5: Collisions on SE/TE pages 132-134. Students **use mathematical representations** to solve problems relating to momentum in Think and Solve on SE/TE page 123, do the math! page 135, Appendix F, Chapters 7 and 8, SE/TE pages 853-857, and Activity 24, Conserving Your Momentum in the Laboratory Manual, pages 91-96. **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.] Students are presented with information that would prove useful in creating a devise that minimizes the force on an object in the following lessons: Lesson 7.2: Newton's Third Law on SE/TE page 108 Lesson 7.3: Identifying Action and Reaction on SE/TE pages 108-109 Lesson 7.5: Defining Systems on SE/TE pages 112-113 Lesson 7.6: The Horse-Cart Problem on SE/TE pages 114-115 Lesson 7.7: Action Equals Reaction on SE/TE page 116 Lesson 8.1: Momentum on SE/TE page 125 Lesson 8.2: Impulse Changes Momentum on SE/TE pages 125-129 Lesson 8.3: Bouncing on SE/TE pages 129-130 Lesson 8.4: Conservation of Momentum on pages 130-131 Lesson 8.5: Collisions on SE/TE pages 132-134 Activity 23, Egg Toss on Laboratory Manual pages 87-90

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.]

Newton's Law of Gravitation is introduced in Lesson 13.4: Newton's Law of Universal Gravitation on SE/TE pages 237-239. Further information on gravitation is located in Lesson 13.5: Gravity and Distance: The Inverse-Square Law on SE/TE pages 240-241 and Lesson 13.6: Gravitational Field on SE/TE pages 242-243. Students learn about Coulomb's Law in Lesson 32.3: Coulomb's Law on SE/TE pages 648-650. Information about electric fields is presented in Lesson 33.1: Electric Fields on SE/TE pages 665-666 and Lesson 33.2: Electric Field Lines on SE/TE pages 666-667.

Students **use mathematical** representations to describe and predict gravitational forces in Chapter 13 Assess: Think and Solve on SE/TE pages 260-261 and Appendix F, Chapter 13 on SE/TE pages 867-868. Students **use mathematical** representations to describe and predict electrical forces in do the math! on SE/TE pages 650 and Appendix F, Chapter 32 on SE/TE page 883.

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.]

Information that is relevant to planning and conducting an investigation of the relationship between electric currents and magnetism is located in the following lessons:
Lesson 36.2: Magnetic Fields on SE/TE pages 722-723
Lesson 36.3: The Nature of a Magnetic Field on SE/TE pages 723-724
Lesson 36.5: Electric Currents and Magnetic Fields on SE/TE pages 726-727
Lesson 37.2: Electromagnetic Induction on SE/TE pages 741-742
Lesson 37.3: Faraday's Law on SE/TE page 742
Lesson 37.3: Generator's and Alternating Current on SE/TE pages 742-745
Lesson 37.4: Motor and Generator Comparison on SE/TE page 746
Lesson 37.5: Transformers on SE/TE pages 747-749
Lesson 37.7: Induction of Electric and Magnetic Fields on SE/TE page 751

Examples of investigations are shown in Laboratory Manual, Activity 98: You're Repulsive, pages 341-343 and Activity 99, Motors and Generators, pages 345-350.

HS-PS2-6. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.* [Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.] [Assessment Boundary: Assessment is limited to provided molecular structures of specific designed materials.]

Students **gain understanding** of how atomic-level interactions contribute to the conductivity of metals in Lesson 32.4: Conductors and Insulators, SE/TE page 651, and the flow of current through a wire, located in Lesson 34.2: Electric Current, SE/TE page 682; and Lesson 34.9; The Speed of Electrons in a Circuit, SE/TE pages 691-692.

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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. (HS-PS2-5)

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. (HS-PS2-1)

SE/TE:
do the math!, p. 89
Appendix F, Chapter 6, pp. 850-852

Laboratory Manual:
Activity 18, Getting Pushy, pp. 67-69
Activity 19, Constant Force and Changing Mass, pp. 71-73
Activity 20, Constant Mass and Changing Force, pp. 75-77

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. (HS-PS2-2),(HS-PS2-4)

SE/TE:
Think and solve, p. 123
Do the math! p. 135
Chapter 13 Assess: Think and Solve pp. 260-261
do the math! p. 650
Appendix F, Chapter 7, pp. 853-854
Appendix F, Chapter 8, pp. 855-857
Appendix F, Chapter 13, pp. 867-868
Appendix F, Chapter 32, p. 883

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter

- The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (Secondary to HS-PS2-6)

PS2.A: Forces and Motion

- Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1)

SE/TE:
Lesson 6.3: Newton's Second Law, pp. 88-89

- Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (HS-PS2-2)

SE/TE:
Lesson 8.1: Momentum, pp. 125
Lesson 8.2: Impulse Changes Momentum, pp. 125-129

- 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. (HS-PS2-2),(HS-PS2-3)

SE/TE:
Lesson 8.1: pp. 125
Lesson 8.2: Impulse Changes Momentum, pp. 125-129

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. (HS-PS2-4)

SE/TE:
Lesson 13.5: Gravity and Distance: The Inverse-Square Law, pp. 240-241
Lesson 13.6: Gravitational Field, pp. 242-243
Lesson 32.3: Coulomb's Law, pp. 648-650
Lesson 33.1: Electric Fields, pp. 665-666
Lesson 33.2: Electric Field Lines, pp. 666-667

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. (HS-PS2-4)

SE/TE:
Lesson 13.4: Newton's Law of Universal , pp. 237-239
Lesson 13.5: Gravity and Distance: The Inverse-Square Law, pp. 240-241

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS2-1),(HS-PS2-5)

SE/TE:

Laboratory Manual:
Activity 18, Getting Pushy, pp. 67-69
Activity 19, Constant Force and Changing Mass, pp. 71-73
Activity 20, Constant Mass and Changing Force, pp. 75-77
Lesson 36.2: Magnetic Fields , pp. 722-723
Lesson 36.3: The Nature of a Magnetic Field, pp. 723-724
Lesson 36.5: Electric Currents and Magnetic Fields, pp. 726-727

- Systems can be designed to cause a desired effect. (HS-PS2-3)

Systems and System Models

- When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (HS-PS2-2)

SE/TE:
Lesson 7.5: Defining Systems, pp.
Lesson 7.6: The Horse-Cart Problem, pp. 114-115

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. (HS-PS2-6)

Laboratory Manual: Activity 24, Conserving Your Momentum on Laboratory Manual pp. 91-96 **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. (HS-PS2-3) **Obtaining, Evaluating, and Communicating Information** 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. · Communicate scientific and technical information (e.g. about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-PS2-6) --- **Connections to Nature of Science** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** · Theories and laws provide explanations in science. (HS-PS2-1),(HS-PS2-4) **SE/TE:** Lesson 6.3: Newton's Second Law, pp. 88-89 · Laws are statements or descriptions of the relationships among observable phenomena. (HS-PS2-1),(HS-PS2-4) **SE/TE:** Lesson 6.3: Newton's Second Law, pp. 88-89	· 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. (HS-PS2-4),(HS-PS2-5) **SE/TE:** Lesson 13.5: Gravity and Distance: The Inverse-Square Law, pp. 240-241 Lesson 13.6: Gravitational Field, pp. 242-243 Lesson 32.3: Coulomb's Law, pp. 648-650 Lesson 33.1: Electric Fields, pp. 665-666 Lesson 33.2: Electric Field Lines, pp. 666-667 Lesson 36.2: Magnetic Fields, pp. 722-723 Lesson 36.3: The Nature of a Magnetic Field, pp. 723-724 · 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. (HS-PS2-6),(secondary to HS-PS1-1),(secondary to HS-PS1-3) **PS3.A: Definitions of Energy** ·"Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. (secondary to HS-PS2-5) **SE/TE:** Lesson 36.5: Electric Currents and Magnetic Fields on SE/TE pages 726-727 **ETS1.A: Defining and Delimiting Engineering Problems** · 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 to HS-PS2-3) **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 to HS-PS2-3)	

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

HS-PS3 Energy

HS-PS3 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.]

Program coverage of energy in systems can be found in the following locations:
Lesson 7.5: Defining Systems on SE/TE pages 112-113
Lesson 7.6: The Horse-Cart Problem on SE/TE pages 114-115
Lesson 9.4: Potential Energy on SE/TE pages 148-149
Lesson 9.5: Kinetic Energy on SE/TE page 150
Lesson 9.6: Work-Energy Theorem on SE/TE pages 151-152
Lesson 9.7: Conservation of Energy on SE/TE pages 153-154
Lesson 9.8: Machines on SE/TE pages 155-157
Lesson 9.9: Efficiency on SE/TE pages 158-160
Lesson 13.4: Newton's Law of Universal Gravitation on SE/TE pages 237-239
Lesson 13.5: Gravity and Distance: The Inverse Square Law on SE/TE pages 240-241

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 position 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.]

Information about energy associated with the relative position of particles or objects is located in the following lessons:
Lesson 9.4: Potential Energy, SE/TE page 148-149
Lesson 13.6: Gravitational Field, SE/TE pages 242-243
Lesson 13.7: Gravitational Field Inside a Planet, SE/TE page 244
Lesson 13.9: Ocean Tides, SE/TE pages 246-248
Lesson 33.1: Electric Fields, SE/TE pages 665-666
Lesson 33.2: Electrical Field Lines SE/TE pages 666-667
Lesson 33.4: Electrical Potential Energy, SE/TE pages 669-670
Lesson 33.5: Electrical Potential, SE/TE pages 670-671
Lesson 33.6: Electrical Energy Storage, SE/TE pages 672-673
Lesson 36.2: Magnetic Fields, SE/TE pages 722-723
Lesson 36.3: The Nature of a Magnetic Field, SE/TE pages 723-724
Lesson 36.4: Magnetic Domains, SE/TE pages 724-725
Lesson 36.5: Electric Currents and Magnetic Fields, SE/TE pages 726-727
Lesson 36.6: Magnetic Forces on Moving Charged Particles, SE/TE page 728
Lesson 36.7: Magnetic Forces on Current-Carrying Wires, SE/TE page 729

Information about energy associated with the motions of particles or objects is located in the following lessons:
Lesson 9.4: Potential Energy, SE/TE page 148-149
Lesson 21.1: Temperature, SE/TE pages 407-408
Lesson 21.2: Heat, SE/TE page 409
Lesson 21.4: Internal Energy, SE/TE page 411
Lesson 21.8: Thermal Expansion, SE/TE pages 416-419
Lesson 21.9: Expansion of Water, SE/TE pages 419-422
Lesson 22.2: Cooling Air, SE/TE page 435

Lesson 23.1: Condensation, SE/TE pages 452-453
Lesson 23.5: Freezing, SE/TE page 456
Lesson 24.1: Absolute Motion, SE/TE page 469
Lesson 25.2: Wave Description: SE/TE pages 491-492
Lesson 23.1: The Origin of Sound, SE/TE page 515

Models are **developed and used** in the following program locations:
Illustration of the tides on Earth, 13.20-22 on SE/TE page 247
Graph of the volume of water vs. temperature on SE/TE page 420
Diagram of air molecules on SE/TE page 435
Drawing of water molecules in water vapor on SE/TE page 453
Diagram of an ice crystal on SE/TE page 456
Model of compression and rarefaction on SE/TE page 517
Diagrams of electric fields on SE/TE page 666
Illustration of the even distribution of static charges on objects on SE/TE page 668
Model of a magnetic field on SE/TE page 722
Model of magnetism in an iron bar on SE/TE page 725
Diagrams of the magnetic field of wire with and without electric current on SE/TE page 726

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.]

Information related to devices that convert energy into different forms is discussed in Lesson 9.11: Sources of Energy on SE/TE pages 161-162; Science, Technology, and Society: Power Production on SE/TE page 248; and discover!, Can You Create an Electric Current Without a Battery? on SE/TE page 740.

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.]

Program coverage of transfer of thermal energy is located in Lesson 21.1: Temperature on SE/TE pages 407-408; Lesson 21.2: Heat on SE/TE page 409; Lesson 21.3: Thermal Equilibrium on SE/TE page 410; Lesson 21.4: Internal Energy on SE/TE page 411; Lesson 2.2: First Law of Thermodynamics on SE/TE pages 470-471; and Lesson 24.4: Second and Third Law of Thermodynamics on SE/TE pages 474-475.

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, including an explanation of how the change in energy of the objects is related to the change in energy of the field.] [Assessment Boundary: Assessment is limited to systems containing two objects.]

Program content about objects interacting in electric and magnetic fields is located in the following lessons: in
Lesson 33.1: Electric Fields on SE/TE pages 665-666
Lesson 33.2: Electric Field Lines on SE/TE pages 666-667
Lesson 33.4: Electrical Potential Energy on SE/TE pages 669-670
Lesson 33.5: Electrical Potential on SE/TE pages 670-671
Lesson 36.2: Magnetic Fields on SE/TE pages
Lesson 36.3: The Nature of a Magnetic Field on SE/TE pages 723-724
Lesson 36.5: Electric Currents and Magnetic Fields on SE/TE pages 726-727
Lesson 37.3: Generator's and Alternating Current on SE/TE pages 743-745.
Students **use models** in diagrams of electric fields on SE/TE page 666, in a model of a magnetic field on SE/TE page 722, and in a model of magnetism in an iron bar on SE/TE page 725. Models are also provided for diagrams of the magnetic field of wire with and without electric current on SE/TE page 726 and in a diagram of induced voltage and current in a simple generator.

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Grades 9-12

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. (HS-PS3-2),(HS-PS3-5)

SE/TE:
Figure 13.20-13.22, p. 247
Figure 21.13, p. 420
Figure 22.8-22.9, p. 435
Figure 23.4, p. 453
Figure 23.8, p. 456
Figure 26.5, p. 517
Figure 33.3-33.4, p. 666
Figure 33.8, p. 668
Figure 36.4, p. 722
Figure 36.10, p. 725
Figure 36.12, p. 726

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. (HS-PS3-4)

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. (HS-PS3-1)

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. (HS-PS3-3)

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. (HS-PS3-1),(HS-PS3-2)

SE/TE:
Lesson 9.4: Potential Energy, pp. 148-149
Lesson 9.6: Work-Energy Theorem, pp. 151-152
Lesson 9.7: Conservation of Energy, pp. 153-154
Lesson 21.1: Temperature, pp. 407-408
Lesson 21.2: Heat, p. 409
Lesson 21.4: Internal Energy, p. 411
Lesson 33.4: Electrical Potential Energy, pp. 669-670

· At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HS-PS3-2) (HS-PS3-3)

SE/TE:
Lesson 9.4: Potential Energy, pp. 148-149
Lesson 9.6: Work-Energy Theorem, pp. 151-152
Lesson 9.7: Conservation of Energy, pp. 153-154
Lesson 21.1: Temperature, pp. 407-408
Lesson 21.2: Heat, p. 409
Lesson 21.4: Internal Energy, p. 411
Lesson 33.4: Electrical Potential Energy, pp. 669-670

· 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. (HS-PS3-2)

SE/TE:
Lesson 9.7: Conservation of Energy, pp. 153-154

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. (HS-PS3-5)

SE/TE:
Lesson 36.5: Electric Currents and Magnetic Fields, pp. 726-727
Lesson 37.3: Generator's and Alternating Current, pp. 743-745

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. (HS-PS3-4)

SE/TE:
Lesson 21.3: Thermal Equilibrium, pp. 410
Lesson 2.2: First Law of Thermodynamics, pp. 470-471
Lesson 24.4: Second and Third Law of Thermodynamics, pp. 474-475

· 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. (HS-PS3-1)

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. (HS-PS3-3)
· Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems. (HS-PS3-2)

SE/TE:
Lesson 9.4: Potential Energy, pp. 148-149
Lesson 9.6: Work-Energy Theorem, pp. 151-152
Lesson 9.7: Conservation of Energy, pp. 153-154
Lesson 21.1: Temperature, pp. 407-408
Lesson 21.2: Heat, p. 409
Lesson 21.4: Internal Energy, p. 411
Lesson 33.4: Electrical Potential Energy, pp. 669-670

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

	Lesson 13.6: Gravitational Field, pp. 242-243 Lesson 21.1: Temperature, pp. 407-408 Lesson 21.2: Heat, p. 409 Lesson 21.4: Internal Energy, p. 411 Lesson 33.1: Electric Fields, pp. 665-666 Lesson 33.4: Electrical Potential Energy, pp. 669-670 Lesson 36.2: Magnetic Fields, pp. 722-723 **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. (HS-PS3-1) **SE/TE:** Lesson 9.7: Conservation of Energy, pp. 153-154 · Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-1),(HS-PS3-4) **SE/TE:** Lesson 9.7: Conservation of Energy, pp. 153-154 Lesson 21.3: Thermal Equilibrium, pp. 410 Lesson 2.2: First Law of Thermodynamics, pp. 470-471 Lesson 24.4: Second and Third Law of Thermodynamics, pp. 474-475 · 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. (HS-PS3-1) **SE/TE:** Lesson 9.4: Potential Energy, pp. 148-149 Lesson 9.5: Kinetic Energy, p. 150 · The availability of energy limits what can occur in any system. (HS-PS3-1) **SE/TE:** Lesson 7.5: Defining, pp. 112-113 Lesson 7.6: The Horse-Cart Problem, pp. 114-115 Lesson 9.6: Work-Energy Theorem, pp. 151-152 Lesson 9.7: Conservation of	technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HS-PS3-3) --- **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. (HS-PS3-1) **SE/TE:** Lesson 13.4: Newton's Law of Universal, pp. 237-239

	Energy, pp. 153-154 Lesson 9.9: Efficiency, pp. 158-160 · 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). (HS-PS3-4) **SE/TE:** Lesson 21.3: Thermal Equilibrium, p. 410 Lesson 24.4: Second and Third Law of Thermodynamics, pp. 474-475 **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. (HS-PS3-5) **SE/TE:** Lesson 33.1: Electric Fields, pp. 665-666 Lesson 33.2: Electric Field Lines, pp. 666-667 Lesson 33.4: Electrical Potential Energy, pp. 669-670 Lesson 33.5: Electrical Potential, pp. 670-671 Lesson 36.2: Magnetic Fields, pp. 722-723 Lesson 36.3: The Nature of a Magnetic Field, pp. 723-724 Lesson 36.5: Electric Currents and Magnetic Fields, pp. 726-727 Lesson 37.3: Generator's and Alternating Current, pp. 743-745 **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. (HS-PS3-3),(HS-PS3-4) **SE/TE:** Lesson 21.3: Thermal Equilibrium, p. 410 Lesson 2.2: First Law of Thermodynamics, pp. 470-471 Lesson 24.4: Second and Third Law of Thermodynamics, pp. 474-475 **ETS1.A: Defining and Delimiting Engineering Problems** · 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 to HS-PS3-3)	

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

HS-PS4 Waves and Their Applications in Technologies for Information Transfer

HS-PS4 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.]

Program coverage on waves is located in Lesson 25.2: Wave Description on SE/TE pages 491-490; Lesson 25.4: Wave Speed on SE/TE pages 495-496; Lesson 25.7: Interference on SE/TE page 498; Appendix F, Chapter 25, on SE/TE pages 878-879; Appendix F, Chapter 26 on SE/TE pages 879; and in the Laboratory Manual, Activity 70: Catch a Wave, pages 261-264.

Students **use mathematical representations** in "do the math!" on SE/TE page 496, "Think and solve" on SE/TE pages 512-513, "Think and Solve" on SE/TE pages 530-531, Appendix F, Chapter 25, on SE/TE pages 878-879, and Appendix F, Chapter 26 on SE/TE pages 879.

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.]

Students **gain understanding** of digital transmission use and storage of information in Link to Technology: The Digital Camera on SE/TE page 611 and in Link to Technology: Magnetic Storage on SE/TE page 751.

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.]

Electromagnetic radiation duality is discussed in Lesson 37.8: Electromagnetic Waves on SE/TE pages 753-755; Lesson 38.2: Light Quanta on SE/TE page 768; Lesson 38.3: The Photoelectric Effect on SE/TE pages 769-770; Lesson 38.5: Waves as Particles on SE/TE pages 770; and Lesson 38.6: Particles as Waves on SE/TE pages 771.

Students **evaluate** electromagnetic radiation duality in Concept Check on SE/TE page 770, Check Concepts on SE/TE page 779, and Think and Explain on SE/TE pages 780-781.

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 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.]

Information on the effects that different frequencies of electromagnetic radiation have on matter are presented in Lesson 39.11: Radiation and You, pp. 800-801. In Activity, SE/TE page 807, students **summarize** benefits and dangers of radioactivity.

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.]

Program coverage of using waves to transmit and capture information or energy is located in Lesson 31.7, The Hologram, on SE/TE pages 635-636. Students **communicate** technical information about a technological device in Concept Check on SE/TE page 636.

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Science and Engineering Practices

Asking Questions and Defining Problems
Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.
- Evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design. (HS-PS4-2).

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 to support claims and /or explanations. (HS-PS4-1)

SE/TE:
Lesson 25.2: Wave, pp. 490-491
Lesson 25.4: Wave Speed, pp. 495-496
Appendix F, Chapter 25, pp. 878-879
Appendix F, Chapter 26, pp. 879
Laboratory Manual:
Activity 70: Catch a Wave, pp. 261-264

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 the natural and designed world(s). 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. (HS-PS4-3)

Obtaining, Evaluating, and Communicating Information
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.
- Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible. (HS-PS4-4)
- 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). (HS-PS4-5)

SE/TE:
Concept Check, p. 636

Disciplinary Core Ideas

PS3.D: Energy in Chemical Processes
- Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy. (secondary to HS-PS4-5)

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. (HS-PS4-1)

SE/TE:
Lesson 25.2: Wave, pp. 491-490
Lesson 25.4: Wave Speed, pp. 495-496

- 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. (HS-PS4-2),(HS-PS4-5)

SE/TE:
Lesson 25.7: Interference, p.498

[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.) (HS-PS4-3)

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. (HS-PS4-3)
- 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. (HS-PS4-4)

SE/TE:
Lesson 39.11: Radiation and You, pp. 800-801

- Photoelectric materials emit electrons when they absorb light of a high-enough frequency. (HS-PS4-5)

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. (HS-PS4-5)

Crosscutting Concepts

Cause and Effect
- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS4-1)
- 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. (HS-PS4-4)
- Systems can be designed to cause a desired effect. (HS-PS4-5)

SE/TE:
The Hologram, pp. 635-636

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. (HS-PS4-3)

SE/TE:
Lesson 37.8: Electromagnetic Waves, pp. 753-755
Lesson 38.2: Light Quanta, p. 768
Lesson 38.3: The Photoelectric Effect, pp. 769-770
Lesson 38.5: Waves as Particles, pp. 770
Lesson 38.6: Particles as Waves, pp. 771

Stability and Change
- Systems can be designed for greater or lesser stability. (HS-PS4-2)

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). (HS-PS4-5)

Influence of Engineering, Technology, and Science on Society and the Natural World
- Modern civilization depends on major technological systems. (HS-PS4-2),(HS-PS4-5)
- Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HS-PS4-2)

--- **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. (HS-PS4-3) Lesson 37.8: Electromagnetic Waves, pp. 753-755 Lesson 38.2: Light Quanta, p. 768 Lesson 38.3: The Photoelectric Effect, pp. 769-770 Lesson 38.5: Waves as Particles, pp. 770 Lesson 38.6: Particles as Waves, pp. 771		

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

HS-ESS1 Earth's Place in the Universe

HS-ESS1 Earth's Place in the Universe

Students who demonstrate understanding can:

HS-ESS1-1. Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation. [Clarification Statement: Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun's core to reach Earth. Examples of evidence for the model include observations of the masses and lifetimes of other stars, as well as the ways that the sun's radiation varies due to sudden solar flares ("space weather"), the 11-year sunspot cycle, and non-cyclic variations over centuries.] [Assessment Boundary: Assessment does not include details of the atomic and sub-atomic processes involved with the sun's nuclear fusion.]

Students **gain understanding** about the life span of the sun and stars in Lesson 13.10: Black Holes on SE/TE pages 249-250.

HS-ESS1-2. Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe. [Clarification Statement: Emphasis is on the astronomical evidence of the red shift of light from galaxies as an indication that the universe is currently expanding, the cosmic microwave background as the remnant radiation from the Big Bang, and the observed composition of ordinary matter of the universe, primarily found in stars and interstellar gases (from the spectra of electromagnetic radiation from stars), which matches that predicted by the Big Bang theory (3/4 hydrogen and 1/4 helium).]

Program content on the Big Bang Theory is located in "The Expanding Universe" section of Lesson 13.11: Universal Gravitation on SE/TE pages 251-254.

HS-ESS1-3. Communicate scientific ideas about the way stars, over their life cycle, produce elements. [Clarification Statement: Emphasis is on the way nucleosynthesis, and therefore the different elements created, varies as a function of the mass of a star and the stage of its lifetime.] [Assessment Boundary: Details of the many different nucleosynthesis pathways for stars of differing masses are not assessed.]

The production of elements within stars is covered in Lesson 17.1: Elements on SE/TE pages 325-326.

HS-ESS1-4. Use mathematical or computational representations to predict the motion of orbiting objects in the solar system. [Clarification Statement: Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets and moons.] [Assessment Boundary: Mathematical representations for the gravitational attraction of bodies and Kepler's Laws of orbital motions should not deal with more than two bodies, nor involve calculus.]

Students **gain knowledge** about the motion of orbiting objects in the solar system in Lesson 14.2: Circular Orbits on SE/TE pages 265-267; Lesson 14.3: Elliptical Orbits on SE/TE pages 267-268; and Lesson 14.4: Energy Conservation and Satellite Motion on SE/TE pages 269-270.

Students **use computational representations** in Activity 46 on Laboratory Manual pages 171-172.

HS-ESS1-5. Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks. [Clarification Statement: Emphasis is on the ability of plate tectonics to explain the ages of crustal rocks. Examples include evidence of the ages oceanic crust increasing with distance from mid-ocean ridges (a result of plate spreading) and the ages of North American continental crust increasing with distance away from a central ancient core (a result of past plate interactions).]

HS-ESS1-6. Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history. [Clarification Statement: Emphasis is on using available evidence within the solar system to reconstruct the early history of Earth, which formed along with the rest of the solar system 4.6 billion years ago. Examples of evidence include the absolute ages of ancient materials (obtained by radiometric dating of meteorites, moon rocks, and Earth's oldest minerals), the sizes and compositions of solar system objects, and the impact cratering record of planetary surfaces.]

Students **gain understanding** of how the radioactive decay of uranium is used to date rocks and minerals on Earth (and its moon) in Lesson 39.9: Uranium Dating, SE/TE page 798.

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Science and Engineering Practices

Developing and Using Models
Modeling in 9–12 builds on K–8 experiences 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 world(s).
- Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-ESS1-1)

Using Mathematical and Computational Thinking
Mathematical and computational thinking in 9–12 builds on K–8 experiences 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 computational representations of phenomena to describe explanations. (HS-ESS1-4)

SE/TE:
Lesson 14.2: Circular, pp. 265-267
Lesson 14.3: Elliptical, pp. 267-268
Laboratory Manual:
Activity 46, pp. 171-172

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.
- Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-ESS1-2)
- Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. (MS-ESS1-6)

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 the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.
- Evaluate evidence behind currently accepted explanations or solutions to determine the merits of arguments. (HS-ESS1-5)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs.
- Communicate scientific 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). (HS-ESS1-3)

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. (HS-ESS1-1)

SE/TE:
Lesson 13.10: Black Holes, pp. 249-250

- The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. (HS-ESS1-2),(HS-ESS1-3)
- The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. (HS-ESS1-2)

SE/TE:
Lesson 13.11: Universal Gravitation, pp. 251-254

- 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. (HS-ESS1-2),(HS-ESS1-3)

SE/TE:
Lesson 17.1: Elements, pp. 325-326

ESS1.B: Earth and the Solar System
- Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. (HS-ESS1-4)

SE/TE:
Lesson 14.2: Circular, pp. 265-267
Lesson 14.3: Elliptical, pp. 267-268

ESS1.C: The History of Planet Earth
- Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old. (HS-ESS1-5)
- Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history. (HS-ESS1-6)

ESS2.B: Plate Tectonics and Large-Scale System Interactions
- Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. (ESS2.B Grade 8 GBE) (secondary to HS-ESS1-5)

Crosscutting Concepts

Patterns
- Empirical evidence is needed to identify patterns. (HS-ESS1-5)

Scale, Proportion, and Quantity
- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. (HS-ESS1-1)

SE/TE:
Lesson 13.10: Black Holes, pp. 249-250

- Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). (HS-ESS1-4)

Laboratory Manual:
Activity 46, pp. 171-172

Energy and Matter
- Energy cannot be created or destroyed–only moved between one place and another place, between objects and/or fields, or between systems. (HS-ESS1-2)
- In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HS-ESS1-3)

Stability and Change
- Much of science deals with constructing explanations of how things change and how they remain stable. (HS-ESS1-6)

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. (HS-ESS1-2),(HS-ESS1-4)

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems
- Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. (HS-ESS1-2)

SE/TE:
Lesson 13.11: Universal Gravitation on SE/TE page 251-254

- Science assumes the universe is a vast single system in which basic laws are consistent. (HS-ESS1-2)

SE/TE:
Lesson 13.11: Universal Gravitation on SE/TE page 251-254

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. (HS-ESS1-2),(HS-ESS1-6) **SE/TE:** Lesson 13.11: Universal Gravitation on SE/TE page 251-254 · Models, mechanisms, and explanations collectively serve as tools in the development of a scientific theory. (HS-ESS1-6)	**PS1.C: Nuclear Processes** · 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. (secondary to HS-ESS1-5),(secondary to HS-ESS1-6) **PS3.D: Energy in Chemical Processes and Everyday Life** · Nuclear Fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. (secondary to HS-ESS1-1) **SE/TE:** Lesson 13.10: Black Holes, pp. 249-250 **PS4.B Electromagnetic Radiation** · Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities. (secondary to HS-ESS1-2)	

HS-ESS2 Earth's Systems

HS-ESS2 Earth's Systems

Students who demonstrate understanding can:

HS-ESS2-1. Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features. [Clarification Statement: Emphasis is on how the appearance of land features (such as mountains, valleys, and plateaus) and sea-floor features (such as trenches, ridges, and seamounts) are a result of both constructive forces (such as volcanism, tectonic uplift, and orogeny) and destructive mechanisms (such as weathering, mass wasting, and coastal erosion).] [Assessment Boundary: Assessment does not include memorization of the details of the formation of specific geographic features of Earth's surface.]

HS-ESS2-2. Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth's systems. [Clarification Statement: Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.]

HS-ESS2-3. Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection. [Clarification Statement: Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Examples of evidence include maps of Earth's three-dimensional structure obtained from seismic waves, records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth's layers from high-pressure laboratory experiments.]

HS-ESS2-4. Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate. [Clarification Statement: Examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years: long-term changes in atmospheric composition.] [Assessment Boundary: Assessment of the results of changes in climate is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.]

Students **gain understanding** about the effect of the high heat capacity of water on climate areas in Lesson 21.7: The High Specific Heat Capacity of Water on SE/TE pages 415-416. The effects of changes in energy flows on climate is covered in Lesson 22.7: Global Warming and the Greenhouse Effect on SE/TE pages 441-442. Students **use models** in Figures 22.17, 22.18, and 22.19 on SE/TE pages 442-443.

HS-ESS2-5. Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes. [Clarification Statement: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).]

HS-ESS2-6. Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere. [Clarification Statement: Emphasis is on modeling biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere (including humans), providing the foundation for living organisms.]

HS-ESS2-7. Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth. [Clarification Statement: Emphasis is on the dynamic causes, effects, and feedbacks between the biosphere and Earth's other systems, whereby geoscience factors control the evolution of life, which in turn continuously alters Earth's surface. Examples of include how photosynthetic life altered the atmosphere through the production of oxygen, which in turn increased weathering rates and allowed for the evolution of animal life; how microbial life on land increased the formation of soil, which in turn allowed for the evolution of land plants; or how the evolution of corals created reefs that altered patterns of erosion and deposition along coastlines and provided habitats for the evolution of new life forms.] [Assessment Boundary: Assessment does not include a comprehensive understanding of the mechanisms of how the biosphere interacts with all of Earth's other systems.]

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 9–12 builds on K–8 experiences 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 world(s). ▪ Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-ESS2-1),(HS-ESS2-3),(HS-ESS2-6) ▪ Use a model to provide mechanistic accounts of phenomena. (HS-ESS2-3)	**ESS1.B: Earth and the Solar System** ▪Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes. (secondary to HS-ESS2-4) **ESS2.A: Earth Materials and Systems** ▪ Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. (HS-ESS2-1),(HS-ESS2-2) ▪ Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical	**Cause and Effect** ▪Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-ESS2-4) **SE/TE:** Lesson 22.7: Global Warming and the Greenhouse, pp. 441-442 **Energy and Matter** ▪ The total amount of energy and matter in closed systems is conserved. (HS-ESS2-6) ▪ Energy drives the cycling of matter within and between systems. (HS-ESS2-3)

Planning and Carrying Out Investigations Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. · Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-ESS2-5) **Analyzing and Interpreting Data** Analyzing data in 9–12 builds on K–8 experiences 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. (HS-ESS2-2) **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 the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. · Construct an oral and written argument or counter-arguments based on data and evidence. (HS-ESS2-7) --- **Connections to Nature of Science** **Scientific Knowledge is Based on Empirical Evidence** · Science knowledge is based on empirical evidence. (HS-ESS2-3) · Science disciplines share common rules of evidence used to evaluate explanations about natural systems. (HS-ESS2-3) · Science includes the process of coordinating patterns of evidence with current theory. (HS-ESS2-3) · Science arguments are strengthened by multiple lines of evidence supporting a single explanation. (HS-ESS2-4) **SE/TE:** Lesson 22.7: Global Warming and the Greenhouse, pp. 441-442	and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior. (HS-ESS2-3) · The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles. (HS-ESS2-4) **ESS2.B: Plate Tectonics and Large-Scale System Interactions** · The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle, providing the primary source of the heat that drives mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection. (HS-ESS2-3) · Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust. (ESS2.B Grade 8 GBE) (HS-ESS2-1) **ESS2.C: The Roles of Water in Earth's Surface Processes** · The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks. (HS-ESS2-5) **ESS2.D: Weather and Climate** · The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. (HS-ESS2-2, HS-ESS2-4) **SE/TE:** Lesson 22.7: Global Warming and the Greenhouse Effect, pp. 441-442 · Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. (HS-ESS2-6),(HS-ESS2-7) · Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (HS-ESS2-6),(HS-ESS2-4) **SE/TE:** Lesson 22.7: Global Warming and the Greenhouse, pp. 441-442 **ESS2.E: Biogeology** · The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it. (HS-ESS2-7) **PS4.A: Wave Properties** · Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet. (secondary to HS-ESS2-3)	**Structure and Function** · 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. (HS-ESS2-5) **Stability and Change** · Much of science deals with constructing explanations of how things change and how they remain stable. (HS-ESS2-7) · Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. (HS-ESS2-1) · Feedback (negative or positive) can stabilize or destabilize a system. (HS-ESS2-2) --- **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. (HS-ESS2-3) **Influence of Engineering, Technology, and Science on Society and the Natural World** · 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. (HS-ESS2-2)

HS-ESS3 Earth and Human Activity

HS-ESS3 Earth and Human Activity

Students who demonstrate understanding can:

HS-ESS3-1. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. [Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.]

HS-ESS3-2. Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.* [Clarification Statement: Emphasis is on the conservation, recycling, and reuse of resources (such as minerals and metals) where possible, and on minimizing impacts where it is not. Examples include developing best practices for agricultural soil use, mining (for coal, tar sands, and oil shales), and pumping (for petroleum and natural gas). Science knowledge indicates what can happen in natural systems—not what should happen.]

HS-ESS3-3. Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity. [Clarification Statement: Examples of factors that affect the management of natural resources include costs of resource extraction and waste management, per-capita consumption, and the development of new technologies. Examples of factors that affect human sustainability include agricultural efficiency, levels of conservation, and urban planning.] [Assessment Boundary: Assessment for computational simulations is limited to using provided multi-parameter programs or constructing simplified spreadsheet calculations.]

HS-ESS3-4. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.* [Clarification Statement: Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).]

HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems. [Clarification Statement: Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature) and their associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition).] [Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.]

HS-ESS3-6. Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. [Clarification Statement: Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere. An example of the far-reaching impacts from a human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations.] [Assessment Boundary: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.]

Science and Engineering Practices

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 experiences 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 computational models in order to make valid and reliable scientific claims. (HS-ESS3-5)

Using Mathematics and Computational Thinking

Mathematical and computational thinking in 9-12 builds on K-8 experiences 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. (HS-ESS3-3)
- Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations. (HS-ESS3-6)

SE/TE:

778-786 Section 24.7, Climate

466 Writing in Science

Disciplinary Core Ideas

ESS2.D: Weather and Climate

- Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere. (secondary to HS-ESS3-6)

ESS3.A: Natural Resources

- Resource availability has guided the development of human society. (HS-ESS3-1)
- All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors. (HS-ESS3-2)

ESS3.B: Natural Hazards

- Natural hazards and other geologic events have shaped the course of human history; [they] have significantly altered the sizes of human populations and have driven human migrations. (HS-ESS3-1)

ESS3.C: Human Impacts on Earth Systems

- The sustainability of human societies and the

Crosscutting Concepts

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-ESS3-1)

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. (HS-ESS3-6)

Stability and Change

- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. (HS-ESS3-3),(HS-ESS3-5)
- Feedback (negative or positive) can stabilize or destabilize a system. (HS-ESS3-4)

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. (HS-ESS3-1),(HS-ESS3-3)
- Engineers continuously modify these technological systems by applying scientific knowledge and engineering

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 an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-ESS3-1) · Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ESS3-4) **SE/TE:** 466 Writing in Science 786 Connecting Concepts **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 world(s). Arguments may also come from current scientific or historical episodes in science. · Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations). (HS-ESS3-2) --- **Connections to Nature of Science** **Scientific Investigations Use a Variety of Methods** · Science investigations use diverse methods and do not always use the same set of procedures to obtain data. (HS-ESS3-5) · New technologies advance scientific knowledge. (HS-ESS3-5) **Scientific Knowledge is Based on Empirical Evidence** · Science knowledge is based on empirical evidence. (HS-ESS3-5) - Science arguments are strengthened by multiple lines of evidence supporting a single explanation. (HS-ESS3-5)	biodiversity that supports them requires responsible management of natural resources. (HS-ESS3-3) · Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (HS-ESS3-4) **ESS3.D: Global Climate Change** · Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. (HS-ESS3-5) · Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities. (HS-ESS3-6) **ETS1.B: Developing Possible Solutions** · When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (secondary to HS-ESS3-2),(secondary HS-ESS3-4)	design practices to increase benefits while decreasing costs and risks. (HS-ESS3-2),(HS-ESS3-4) · New technologies can have deep impacts on society and the environment, including some that were not anticipated. (HS-ESS3-3) · Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ESS3-2) --- **Connections to Nature of Science** **Science is a Human Endeavor** · Science is a result of human endeavors, imagination, and creativity. (HS-ESS3-3) **Science Addresses Questions About the Natural and Material World** · Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions. (HS-ESS3-2) · Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. (HS-ESS3-2) · Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues. (HS-ESS3-2) \

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