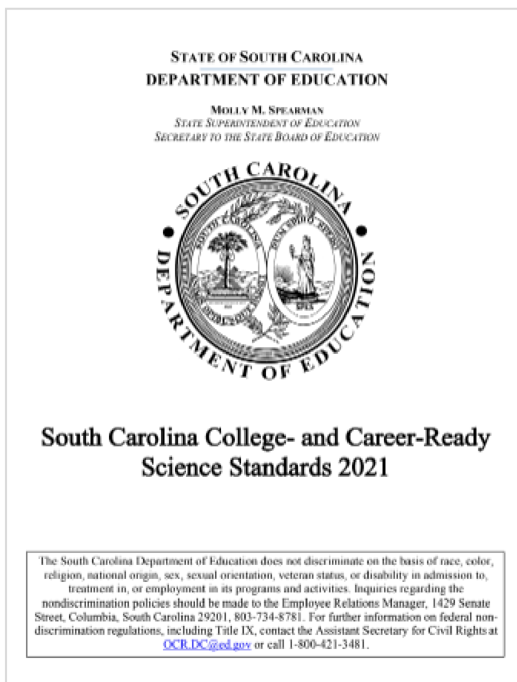
Physics I

Rock Hill Schools Science



STATE OF SOUTH CAROLINA
DEPARTMENT OF EDUCATION

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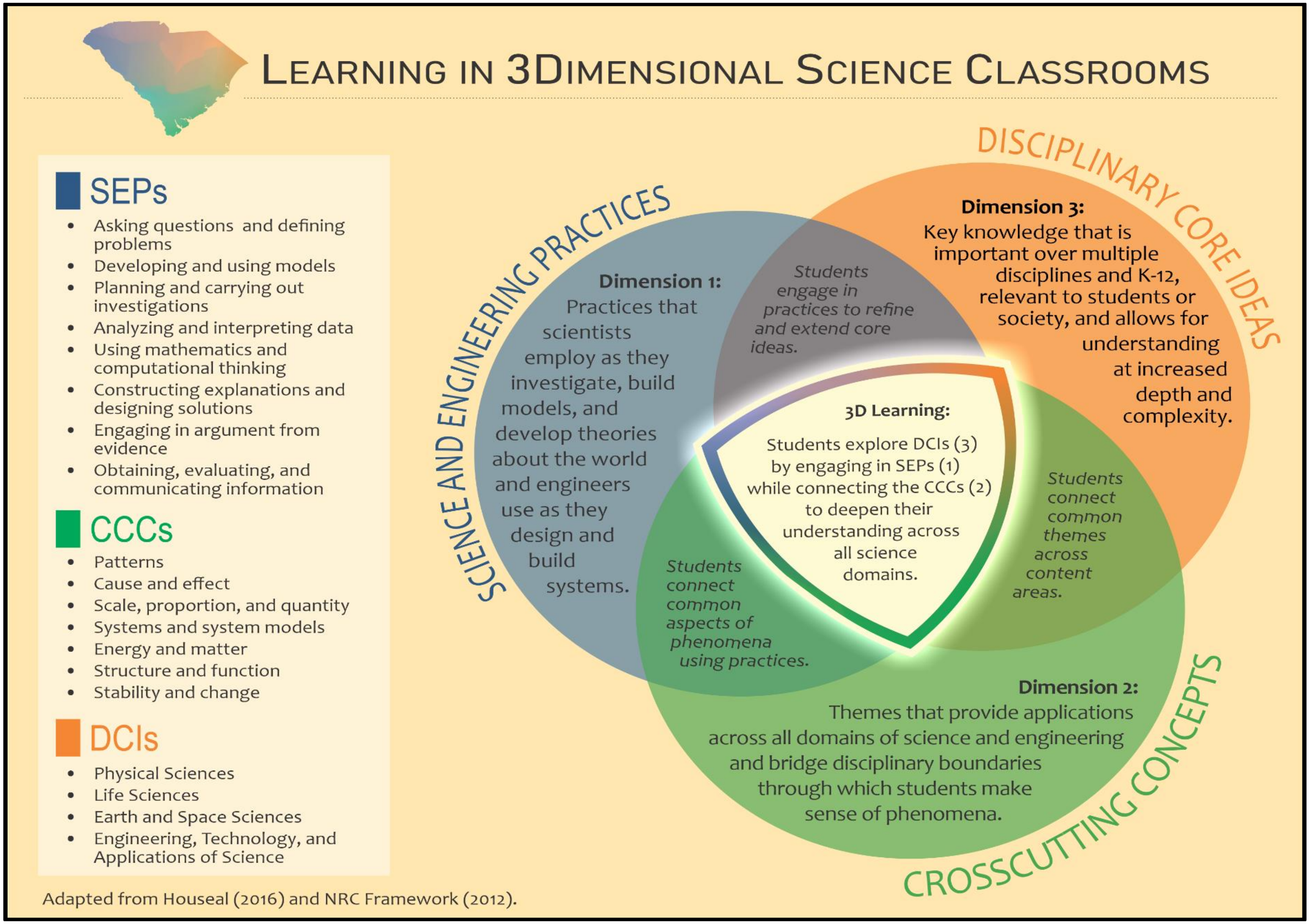
South Carolina College- and Career-Ready
Science Standards 2021

For Science curriculum questions, email kmassey@rhmail.org

Learning in 3 Dimensional Science Classrooms



Dimension 1: Science and Engineering Practices

The **Science and Engineering Practices (SEPs)** are the major practices that scientists apply as they investigate and build models and theories about the world, and that engineers use as they design and build systems. Students should not learn about these practices secondhand, in an isolated unit, or apart from the other two dimensions. While one **SEP** is identified to be assessable and represents the student performance goal for the end of instruction, other **SEPs** should be applied by students to support their progress leading up to the end of instruction. This is vital, as the fields of science and engineering are related and mutually supportive through the eight **SEPs** that students **DO** (NRC Framework, 2012, p. 50-53).

Asking Questions and Defining Problems

Scientists ask and refine questions about phenomena that lead to explanations of how the natural and designed world(s) works.
Engineers ask questions to define the problems, identify constraints, and determine criteria for an effective solution.

Use Mathematical and Computational Thinking

Scientists use mathematics and computation as tools for representing physical variables and their relationships.
Engineers use mathematical and computational representations of established relationships and principles as an integral part of design.

Developing and Using Models

Scientists construct and use models to help develop and understand explanations about natural phenomena.
Engineers use models as helpful tools to test proposed systems and to recognize strengths and limitations of new designs.

Constructing Explanations and Designing Solutions

Scientists construct logically coherent explanations of phenomena that are consistent with the available evidence.
Engineers' designs are based on scientific knowledge and models of the material world.

Planning and Carrying out Scientific Investigations

Scientists use observations and data collected to test existing theories and explanations or to revise and develop new ones.
Engineers use investigations to gain data to specify design criteria and to test their designs.

Engaging in Argument from Evidence

Scientists identify the strengths and weaknesses of a line of reasoning to engage in argument for finding the best explanation of a natural phenomenon.
Engineers engage in argument from evidence to find the best possible solution to a problem.

Analyzing and Interpreting Data

Scientists use a range of tools to identify the significant features and patterns in data.
Engineers use a range of tools and analyze data collected in the tests of their designs and investigations.

Obtaining, Evaluating, and Communicating Information

Scientists derive meaning from texts and evaluate the validity of information to then communicate ideas.
Engineers derive meaning from other's work and texts and evaluate the information, to apply it usefully to express their ideas.

Link to the grounding research for the **SEPs** from the NRC Framework.

Dimension 2: Crosscutting Concepts

The **Crosscutting Concepts (CCCs)** represent seven themes that span across science domains (Physical, Life, Earth and Space, and Engineering, Technology, and Applications of Science) and have value to both scientists and engineers as they identify and connect universal properties and processes found in all domains. Students should not learn about these concepts secondhand, in an isolated unit, or apart from the other two dimensions. While one **CCC** is identified to be assessable and represents the student performance goal for the end of instruction, other **CCCs** could be applied by students to support their progress leading up to the end of instruction. The **CCCs** give students an organizational framework for connecting knowledge from the various disciplines into a coherent and scientific based view of the world (NRC Framework, 2012, 83-102).

Patterns

Students observe patterns of forms and events to guide organization and classification. Patterns prompt student questions about the factors that influence cause-and-effect relationships and are useful as evidence to support student explanations and arguments.

Systems and System Models

Students define the system(s) under study by specifying its boundaries and making explicit a model of the system(s). By doing so, the students are provided tools for understanding and testing ideas that are applicable throughout science and engineering.

Cause and Effect

Students investigate and explain causal relationships and the mechanisms by which they are mediated. Events have causes, some simple, some multifaceted and complex. Students can test such mechanisms across given contexts and the mechanisms can be used to predict and explain events in new contexts.

Energy and Matter

Students understand the system's possibilities and limitations by tracking fluxes of energy and matter into, out of, and within systems.

Scale, Proportion, Quantity

Students, while considering phenomena, come to recognize what is relevant at different measures of size, time, and energy, and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.

Structure and Function

Students observe an object or living thing's structure and shape to determine many of its properties and functions. The functioning of natural and built systems both depend on the shapes and relationships of certain key parts and on the properties of the materials from which they are made.

Stability and Change

Students recognize the conditions of stability and rates of change for natural and built systems to develop an understanding of how the system operates and causes for changes in systems.

Link to the grounding research for the **CCCs** from the [NRC Framework.]

Dimension 3: Disciplinary Core Ideas

Disciplinary Core Ideas (**DCIs**) are a set of four science and engineering domains for K–12 science that have broad importance across multiple science and engineering disciplines. The **DCIs** provide a tool for understanding or investigating more complex ideas and solving problems, relate to the interests and life experiences of students, and are learnable over multiple grades at increasing levels of depth and sophistication. Students should not memorize or learn isolated facts about the **DCIs** secondhand or apart from the other two dimensions (NRC Framework, 2012, p. 31).

Physical Science (PS)

PS1: Matter and its interactions
PS2: Motion and stability: Forces and interactions
PS3: Energy
PS4: Waves and their applications in technologies for information transfer

Students gain awareness of the structure of matter, interactions occurring in terms of the forces between objects, related energy transfers, and their consequences to understand the physical and chemical basis of a system. Chemistry and physics underlie all natural and human-created phenomena and helps students see the mechanisms of cause and effect in all systems and processes that are understood through a common set of physical and chemical principles.

Life Science (LS)

LS1: From molecules to organisms: Structures and processes
LS2: Ecosystems: Interactions, energy, and dynamics
LS3: Heredity: Inheritance and variation of traits
LS4: Biological evolution: Unity and diversity

Students focus on patterns, processes, and relationships of living organisms. The study of life ranges over scales from single molecules, organisms, and ecosystems, to the biosphere. A core principle of the life sciences is that organisms are related through common ancestry and that processes of natural selection have led to the tremendous diversity on Earth. Students in life science courses explore all aspects of living things and the environments they live in.

Earth and Space Science (ESS)

ESS1: Earth's place in the universe
ESS2: Earth's systems
ESS3: Earth and human activity

Students investigate processes that operate on Earth and address Earth's place in the universe. Earth and space science involve phenomena that range in scale from unimaginably large to invisibly small. Earth and space sciences also provide students opportunities to understand how the atmosphere, geosphere, and biosphere are interconnected.

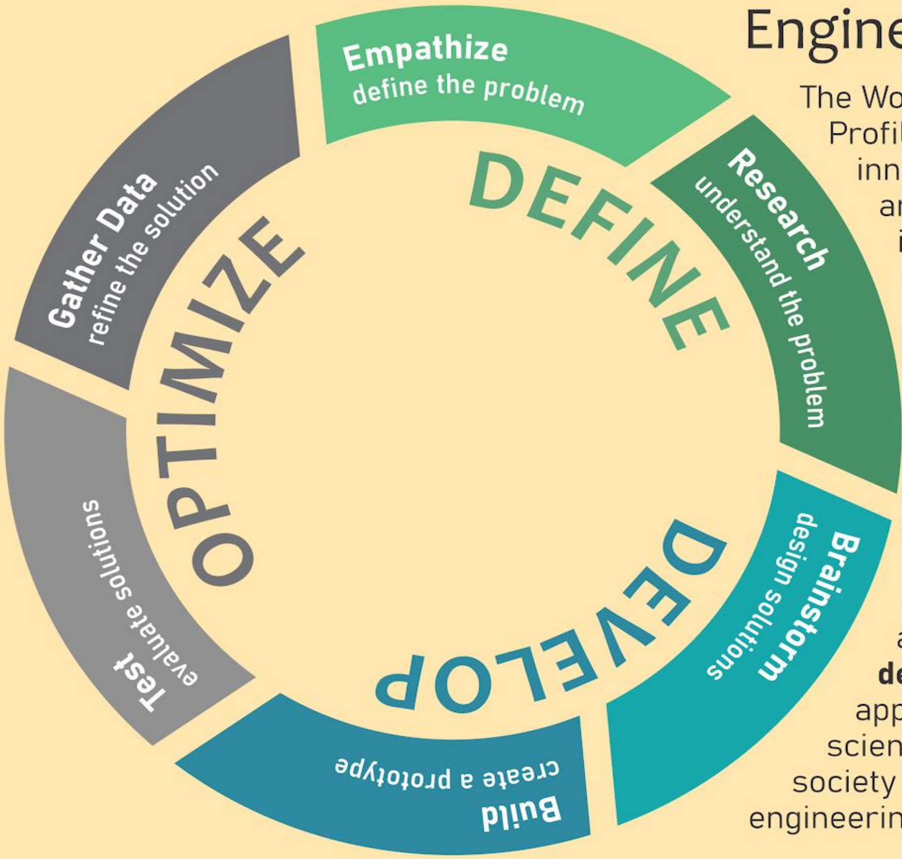
Engineering, Technology, and Applications of Science (ETS)

ETS1: Engineering design
ETS2: Links among engineering, technology, science, and society

Students learn how science is utilized, through the engineering design process, and have the opportunity to appreciate the distinctions and relationships between engineering, technology, and applications of science alongside the physical, life, and Earth and space sciences of other science domains. Science-based designs of technologies and systems affect the ways in which people interact with each other and with the environment, indicating how these designs deeply influence society.

Link to the grounding research for the **DCIs** from the NRC Framework: PS, LS, ESS, and ETS.

Engineering, Technology, and Applications of Science: Engineering Design Process



Engineering Design Process:

The World Class Skills as articulated in the Profile of the SC Graduate: creativity and innovation, critical thinking, collaboration and teamwork, and communication are infused in the **engineering design process** to support student development of both individual and cooperative engineering practices. During the iterative process, students **define** problems to **develop** and **optimize** solutions to local, national, and global issues. The fields of science and engineering are related and mutually supportive and by engaging students in the knowledge and practices related to the **engineering design process**, students establish an appreciation for the interdependence of science, engineering, and technology within society and the natural world and view engineering as a possible career path.

ETS1: This icon found within the PE aligns to ETS1 and notes where students engage directly in the engineering design process.

ETS2: This icon found within the DCI box shows learning connections to ETS2 - Links Among Engineering, Technology, and Society.

Link to the grounding research for the **ETS** from the NRC Framework.

Physics

South Carolina physics students engage in thinking and solving problems the way scientists and engineers do to help them better see how science is relevant to their lives. To capitalize on the natural curiosity all students have about the world around them, learning experiences are built around the three dimensions of science: **Science and Engineering Practices (SEPs)**, **Crosscutting Concepts (CCCs)**, and **Disciplinary Core Ideas (DCIs)**. This three-dimensional approach to teaching and learning helps educators provide meaningful learning experiences that offer varied entry points for students from diverse backgrounds.

The **performance expectations** in physics help students engage in inquiry questions such as, **but not limited to:**

How can one explain and predict interactions between objects and within systems of objects?
Students build an understanding of forces and interactions, as well as total momentum of a system of objects. Students also predict the gravitational and electrostatic forces between objects. Students apply scientific and engineering ideas to design, evaluate as well as investigate the relationship between electric current and magnetic fields.

How is energy transferred and conserved?
Students illustrate that energy at the macroscopic level can be explained by motion of particles or energy associated with the configuration (relative positions) of particles at the atomic scale. Students apply scientific and engineering ideas to design, build, and refine a device that converts one form of energy into another.

How are waves/particles used to transfer energy and send and store information?
Students support a claim that wave/particle properties are related and evaluate the interactions of electromagnetic radiation with matter in transmission and capture of information and energy.

***The PEs should be bundled to design classroom experiences. There are multiple ways to bundle the PEs to help students lead inquiry and see connections between ideas, and help teachers facilitate phenomenon-driven learning with efficient use of instructional time.**

Physics

Through the physics performance expectations, students demonstrate grade-appropriate proficiency in each of three dimensions. When students explore **Disciplinary Core Ideas** (Dimension 3), they will do so by engaging in **Science and Engineering Practices** (Dimension 1) and should be supported in making connections to the **Crosscutting Concepts** (Dimension 2) to link their understanding across the four disciplinary core domains.

Each performance expectation contains one **SEP** and one **CCC** to be assessable and represents the student performance goal for the end of instruction; however, other **SEPs** and **CCCs** should be applied by students to support their progress leading up to the end of instruction. In physics, these **end-of-instruction** **SEPs**, **DCIs**, and **CCCs** include:

SEPs	DCIs	CCCs
• Developing and Using Models • Planning and Carrying Out Investigations • Analyzing and Interpreting Data • Using Mathematics and Computational Thinking • Constructing Explanations and Designing Solutions • Engaging in Argument from Evidence • Obtaining, Evaluating, and Communicating Information	• Physical Science (PS2, PS3, PS4) • Engineering, Technology, and Applications of Science (ETS1, ETS2)	• Patterns • Cause and Effect • Systems and System Models • Energy and Matter • Structure and Function • Stability and Change

Hyperlinks within the Standards Document

SC Conceptual Vertical Articulation links: Hover over the above underlined and hyperlinked titles to view links for all SEPs, DCIs, and CCCs.
A Framework for K-12 Science Education links: Hover over titles found within the foundation boxes under each PE to link the guiding research for all SEPs, DCIs, and CCCs.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data Analyzing data in K-2 builds on prior experiences and progresses to collecting, recording, and sharing observations. Use observations (firsthand or from media) to describe patterns in the natural world in order to answer scientific questions. NRC Framework Link	**LS1.C: Organization for Matter and Energy Flow in Organisms** All animals need food in order to live and grow. They obtain their food from plants or from other animals. Plants need water and light to live and grow. NRC Framework Link	**Patterns** Patterns in the natural and human designed world can be observed and used as evidence. NRC Framework Link

*Equity in science education requires that all students are provided with equitable opportunities to learn science and become engaged in science and engineering practices; with access to quality space, equipment, and teachers to support and motivate that learning and engagement; and adequate time spent on science. In addition, the issue of connecting to students' interests and experiences is particularly important for broadening participation in science (NRC Framework, p. 28).

Motion and Stability: Forces and Interactions (PS2)		
P-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 of an object as a function of time. Examples of objects subjected to a net force could include objects in free-fall, objects sliding down a ramp, or moving objects pulled by a constant force.* ***State Assessment Boundary:*** *Assessment is limited to macroscopic objects moving in one-dimensional motion, at non-relativistic speeds.*		
Science and Engineering Practices	**Disciplinary Core Ideas**	**Crosscutting Concepts**
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. NRC Framework Link	**PS2.A: Forces and Motion** Newton's second law accurately predicts changes in the motion of macroscopic objects (Fnet=ma). NRC Framework Link	**Cause and Effect** Empirical evidence is required to differentiate between cause and correlations and make claims about specific causes and effects. NRC Framework Link

Motion and Stability: Forces and Interactions (PS2)		
P-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.* ***State Assessment Boundary:*** *Assessment is limited to systems of two macroscopic bodies moving in one dimension.*		
Science and Engineering Practices	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Using Mathematics and Computational Thinking Mathematical and computational thinking in 9-12 builds on K-8 and 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, computational, and/or algorithmic representations of phenomena to describe and/or support claims and/or explanations. NRC Framework Link	**PS2.A: Forces and Motion** Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. NRC Framework Link	**Systems and System Models** When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. NRC Framework Link

Motion and Stability: Forces and Interactions (PS2)

P-PS2-3. Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the effect of a force on a macroscopic object during a collision.

Clarification Statement: *An example of evaluation could include determining the success of the device at protecting an object from damage. Examples of devices could include football helmets, parachutes, and car restraint systems, such as seatbelts and airbags. Refinement of the device could include modifying one or more parts or all of the device to improve performance of the device.*
State Assessment Boundary: *Assessment is limited to qualitative evaluations, algebraic manipulations, or both.*

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
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 refine a solution to a complex real-world problem, based on scientific knowledge, student generated sources of evidence, prioritized criteria, and trade off considerations. NRC Framework Link	**PS2.A: Forces and Motion** If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. NRC Framework Link **ETS1.A: Defining and Delimiting Engineering Problems** Criteria may include satisfying cost, safety, reliability, aesthetics requirements and taking into account constraints regarding social, cultural, and environmental impacts. NRC Framework Link **ETS1.B: Developing Possible Solutions** The aim of engineering is to design the best solution under clearly defined constraints and criteria, but there is often no one best solution. NRC Framework Link (continued on next page)	**Cause and Effect** Systems can be designed to cause a desired effect. NRC Framework Link

	ETS1.C: Optimizing the Design Solution Criteria may need to be broken down into simpler ones that can be approached systematically. Trade-offs among the criteria will need to be analyzed, and certain criteria may need to be prioritized over others. NRC Framework Link	

Motion and Stability: Forces and Interactions (PS2)

P-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 interactions between masses in gravitational fields and electrical charges in electric fields.*
State Assessment Boundary: *Assessment is limited to systems with two objects.*

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking Mathematical and computational thinking in 9-12 builds on K-8 and 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, computational, and/or algorithmic representations of phenomena to describe and/or support claims and/or explanations. NRC Framework Link	**PS2.B: Types of Interactions** Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. NRC Framework Link	**Patterns** Different patterns may be observed at each of the scales at which a system is studied and can provide for causality in explanations of phenomena. NRC Framework Link

Motion and Stability: Forces and Interactions (PS2)

P

P-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.

Clarification Statement: *Examples could include current carrying wires and electromagnets/solenoids in motors, anti-shoplifting devices, junkyard magnets, metal detectors, and magnetic levitation in high-speed trains.*
State Assessment Boundary: *Assessment is limited to planning and conducting investigations with provided materials and tools.*

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying out Investigations Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence. During the planning process: decide on types, how much, and accuracy of data needed to produce reliable measurements, consider limitations on the precision of the data (such as number of trials, cost, risk, time), and refine the design accordingly. NRC Framework Link	**PS2.B: Types of Interactions** 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. NRC Framework Link **PS3.A: Definitions of Energy** "Electrical Energy" may mean energy stored in battery or energy transmitted by electric current. NRC Framework Link	**Cause and Effect** Empirical evidence is required to differentiate between cause and correlations and make claims about specific causes and effects. NRC Framework Link

Motion and Stability: Forces and Interactions (PS2)

P-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, and transfer of electric charge. Examples of designed conductive materials could include wiring in phone chargers, wiring in car speakers, or computer chips. Examples of designed insulating materials could include polystyrene and fiberglass.*
State Assessment Boundary: *Assessment is limited to molecular structures that are given or provided to students during instruction.*

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
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 and/or technical information about phenomena and performance of a proposed process or system. Communication can be in multiple formats including orally, graphically, textually, and mathematically. NRC Framework Link	**PS2.B: Types of Interactions** Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. NRC Framework Link **ETS2.A: Interdependence of Science, Engineering, and Technology** Engineers continuously modify these technological systems by applying scientific knowledge. *(secondary)* NRC Framework Link	**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. NRC Framework Link

(continued on next page)

	ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World Modern civilization depends on major technological systems which can have deep impacts on society and the environment. *(secondary)* NRC Framework Link	

Energy (PS3)		
P-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the following are known: 1) the change in energy of the other component(s) and 2) the energy flowing in and out of the system. ***Clarification Statement:*** *Emphasis is on explaining the calculations in the computational model. Examples of computational models could include diagrams, drawings, descriptions, mathematical equations, and computer simulations.* ***State Assessment Boundary:*** *Assessment is limited to basic algebraic equations, to systems of two or three components, and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.*		
Science and Engineering Practices	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Using Mathematics and Computational Thinking Mathematical and computational thinking in 9-12 builds on K-8 and 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. NRC Framework Link	**PS3.A: Definitions of Energy** Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. A system's total energy is 1) conserved as energy is transferred within the system from one object to another and between its various possible forms and 2) always equal to the energy transferred into or out of the system. NRC Framework Link **PS3.B: Conservation of Energy and Energy Transfer** Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (continued on next page)	**Systems and System Models** Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. NRC Framework Link

	PS3.B: Conservation of Energy and Energy Transfer (Cont.) Mathematical expressions allow the concept of conservation of energy to be used to predict and describe system behavior. Mathematical expressions quantify how the stored energy in a system depends on its configurations (such as relative positions of charged particles or compression of a spring) and how kinetic energy depends on mass and speed. The availability of energy limits what can occur in any system. NRC Framework Link	

Energy (PS3)

P-PS3-2. Develop and use models to illustrate that energy can be explained by the combination of motion and position of objects at the macroscopic scale and the motion and position of particles at the microscopic scale

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 (as stored in fields), and the energy stored between two electrically charged plates. Examples of models could include diagrams, drawings, descriptions, or computer simulations.*
State Assessment Boundary: *Assessment does not include quantitative calculations.*

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, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components. NRC Framework Link	**PS3.A: Definitions of Energy** Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. Energy at the macroscopic level can be better understood, 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 (continued on next page)	**Energy and Matter** Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems. NRC Framework Link

	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. [NRC Framework Link]	

Energy (PS3)

P-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, speakers, or generators. Examples of constraints placed on a device could include the cost of materials, types of materials available, having to use renewable energy, an efficiency threshold, and time to build and/or operate the device.*
State 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.*

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
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 refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations. NRC Framework Link	**PS3.A: Definitions of Energy** At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. NRC Framework Link **PS3.D: Energy in Chemical Processes and Everyday Life** Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. NRC Framework Link **ETS1.A: Defining and Delimiting an Engineering Problem** Criteria may include satisfying cost, safety, reliability, aesthetics requirements and taking into account constraints regarding social, cultural, and environmental impacts. NRC Framework Link (continued on next page)	**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. NRC Framework Link

	ETS1.B: Developing Possible Solutions The aim of engineering is to design the best solution under clearly defined constraints and criteria, but there is often no one best solution. NRC Framework Link **ETS1.C: Optimizing the Design Solution** Criteria may need to be broken down into simpler ones that can be approached systematically. Trade-offs among the criteria will need to be analyzed, and certain criteria may need to be prioritized over others. NRC Framework Link ETS2 **ETS2.A: Interdependence of Science, Engineering, and Technology.** Engineers continuously modify these technological systems by applying scientific knowledge. NRC Framework Link **ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World** Modern civilization depends on major technological systems which can have deep impacts on society and the environment. *(secondary)* NRC Framework Link	

Energy (PS3)		
P-PS3-5. **Develop and use a model to illustrate the forces between two objects and the changes in energy of the objects due to their interaction through electric or magnetic fields.** ***Clarification Statement:*** *Examples of models could include drawings, diagrams, descriptions, or computer simulations.* ***State Assessment Boundary:*** *Assessment is limited to systems containing two objects.*		
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, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components. NRC Framework Link	**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. Each force between the two interacting objects acts in the direction such that the motion in that direction would reduce the energy in the force field between the objects. NRC Framework Link	**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. NRC Framework Link

Waves and Their Applications in Technologies for Information Transfer (PS4)		
P-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 different media that could be explored include electromagnetic radiation traveling in a vacuum or glass, sound waves traveling through air or water, or seismic waves traveling through Earth.* ***State Assessment Boundary:*** *Assessment is limited to algebraic relationships and describing relationships qualitatively.*		
Science and Engineering Practices	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Using Mathematics and Computational Thinking Mathematical and computational thinking in 9-12 builds on K-8 and 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 representations of phenomena or design solutions to describe and/or support claims and/or explanations. NRC Framework Link	**PS4.A: Wave Properties** The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing. The reflection, refraction, and transmission of waves at an interface between two media can be modeled on the bases of wave properties. NRC Framework Link	**Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. NRC Framework Link

Waves and Their Applications in Technologies for Information Transfer (PS4)

P-PS4-2. Design, evaluate, and refine a solution for improving how digital devices store and transmit information.

Clarification Statement: *Examples of design problems could include poor signal strength in rural areas with satellite radio or internet connections, lack of security on social media applications (reducing personal data theft), and low quality images (pixelated/fuzzy images, small size). Examples of evaluating the stability of the solution could include determining how successful the solution is at improving signal strength, preventing hacking, and improving image quality.*
State Assessment Boundary: *Assessment is limited to designed solutions with qualitative analysis of wave properties through drawings, diagrams, or computer simulations.*

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
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 refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations. NRC Framework Link	**PS4.A: Wave Properties** Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this stable form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. Combining waves of different frequencies can make a wide variety of patterns and thereby encode and transmit information. NRC Framework Link **ETS1.B: Developing Possible Solutions** The aim of engineering is to design the best solution under clearly defined constraints and criteria, but there is often no one best solution. NRC Framework Link (continued on next page)	**Stability and Change** Systems can be designed for greater or lesser stability. NRC Framework Link

	ETS2.A: Interdependence of Science, Engineering, and Technology Engineers continuously modify these technological systems by applying scientific knowledge. NRC Framework Link **ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World** Modern civilization depends on major technological systems, which can have deep impacts on society and the environment. NRC Framework Link	

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P-PS4-3. **Evaluate the claims, evidence, and reasoning about how electromagnetic radiation can be described either by a wave model or a particle model, and in 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.* ***State Assessment Boundary:*** *Assessment does not include using quantum theory.*		
Science and Engineering Practices	**Disciplinary Core Ideas**	**Crosscutting 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 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. NRC Framework Link	**PS4.A: Wave Properties** 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. NRC Framework Link **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. NRC Framework Link	**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. NRC Framework Link

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P-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:*** *Examples of technology applications could include medical imaging devices, tanning beds, radiation cancer treatments, or potential health concerns related to digital signals. Examples of published materials could include trade books, magazines, web resources, videos, and other passages that may reflect bias.* ***State Assessment Boundary:*** *Assessment is limited to qualitative descriptions.*		
Science and Engineering Practices	**Disciplinary Core Ideas**	**Crosscutting Concepts**
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. Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible. NRC Framework Link	**PS4.B: Electromagnetic Radiation** 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. NRC Framework Link	**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. NRC Framework Link

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P-PS-4-5. 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.*
State Assessment Boundary: *Assessments are limited to qualitative information. Assessments do not include band theory.*

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
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 and/or 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). NRC Framework Link	**PS4.A: Wave Properties** Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. NRC Framework Link **PS4.B: Electromagnetic Radiation** Photoelectric materials emit electrons when they absorb light of a high-enough frequency. NRC Framework Link **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. NRC Framework Link (continued next page)	**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. NRC Framework Link

	ETS2.A: Interdependence of Science, Engineering, and Technology Engineers continuously modify these technological systems by applying scientific knowledge. *(secondary)* NRC Framework Link **ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World** Modern civilization depends on major technological systems which can have deep impacts on society and the environment. *(secondary)* NRC Framework Link	