PHYSICAL SCIENCE Curriculum Map & Pacing Guide

CONTENT STANDARDS

Structure and Properties of Matter (4 Weeks)	Chemical Reactions (4 Weeks)	Forces and Interactions (5 Weeks)	Energy (3 Weeks)	Waves and Electromagnetic Radiation (5 Weeks)
NGSS PERFORMANCE EXPECTATIONS HS-PS1-1 HS-PS1-3 HS-PS1-8 HS-PS2-6	**NGSS PERFORMANCE EXPECTATIONS** HS-PS1-2: HS-PS1-4 HS-PS1-5 HS-PS1-6 HS-PS1-7	**NGSS PERFORMANCE EXPECTATIONS** HS-PS2-1 HS-PS2-2 HS-PS2-3 HS-PS2-4 HS-PS2-5	**NGSS PERFORMANCE EXPECTATIONS** HS-PS3-1 HS-PS3-2 HS-PS3-3 HS-PS3-4 HS-PS3-5	**NGSS PERFORMANCE EXPECTATIONS** HS-PS4-1 HS-PS4-2 HS-PS4-3 HS-PS4-4 HS-PS4-5
CCSS ELA/LITERACY ANCHOR STANDARDS INTEGRATION **RST.9-10.7** *(HS-PS1-1)* **RST.11-12.1** (HS-PS1-3) **WHST.9-12.7** (HS-PS1-3) **WHST.11-12.8** (HS-PS1-3) **WHST.9-12.9** *(HS-PS1-3)* **RST.11-12.1** *(HS-PS2-6)* **WHST.11-12.2** *(HS-PS2-6)*	**CCSS ELA/LITERACY ANCHOR STANDARDS INTEGRATION** **WHST.9-12.2** (HS-PS1-2) **WHST.9-12.5** (HS-PS1-2) **SL.11-12.5** *(HS-PS1-4)* **RST.11-12.1** (HS-PS1-5) **WHST.9-12.2** *(HS-PS1-5)* **WHST.9-12.7** *(HS-PS1-6)*	**CCSS ELA/LITERACY ANCHOR STANDARDS INTEGRATION** **RST.11-12.1** *(HS-PS2-1)* **RST.11-12.7** (HS-PS2-1) **WHST.11-12.9** *(HS-PS2-1)* **WHST.11-12.7** (HS-PS2-3) **WHST.11-12.7** (HS-PS2-5) **WHST.11-12.8** *(HS-PS2-5)* **WHST.11-12.9** *(HS-PS2-5)*	**CCSS ELA/LITERACY ANCHOR STANDARDS INTEGRATION** **SL.11-12.5** *(HS-PS3-1)* **SL.11-12.5** *(HS-PS3-2)* **WHST.9-12.7** *(HS-PS3-3)* **RST.11-12.1** *(HS-PS3-4)* **WHST.9-12.7** (HS-PS3-4) **WHST.11-12.8** (HS-PS3-4) **WHST.9-12.9** *(HS-PS3-4)* **WHST.9-12.7** *(HS-PS3-5)* **WHST.11-12.8** (HS-PS3-5) **WHST.9-12.9** *(HS-PS3-5)* **SL.11-12.5** *(HS-PS3-5)*	**CCSS ELA/LITERACY ANCHOR STANDARDS INTEGRATION** **RST.11-12.7** *(HS-PS4-1)* **RST.9-10.8** (HS-PS4-2) **RST.11-12.1** *(HS-PS4-2)* **RST.11-12.8** (HS-PS4-2) **RST.9-10.8** (HS-PS4-3) **RST.11-12.1** *(HS-PS4-3)* **RST.11-12.8** (HS-PS4-3) **RST.9-10.8** (HS-PS4-4) **RST.11-12.1** *(HS-PS4-4)* **RST.11-12.7** (HS-PS4-4) **RST.11-12.8** (HS-PS4-4) **WHST.11-12.8** (HS-PS4-4) **WHST.9-12.2** *(HS-PS4-5)*
CCSS MATHEMATICS STANDARDS INTEGRATION **HSN-Q.A.1** *(HS-PS1-3)* **HSN-Q.A.3** *(HS-PS1-3)* **MP.4** *(HS-PS1-8)* **HSN-Q.A.1** (HS-PS1-8) **HSN-Q.A.2** (HS-PS1-8) **HSN-Q.A.3** *(HS-PS1-8)* **HSN.Q.A.1** *(HS-PS2-6)* **HSN.Q.A.2** *(HS-PS2-6)* **HSN.Q.A.3** *(HS-PS2-6)*	**CCSS MATHEMATICS STANDARDS INTEGRATION** **HSN-Q.A.1** (HS-PS1-2) **HSN-Q.A.3** *(HS-PS1-2)* **MP.4** *(HS-PS1-4)* **HSN-Q.A.1** *(HS-PS1-4)* **HSN-Q.A.2** (HS-PS1-4) **HSN-Q.A.3** *(HS-PS1-4)* **MP.2** (HS-PS1-5) **HSN-Q.A.1** *(HS-PS1-5)* **HSN-Q.A.3** *(HS-PS1-5)* **MP.2** (HS-PS1-7) **HSN-Q.A.1** (HS-PS1-7) **HSN-Q.A.2** *(HS-PS1-7)* **HSN-Q.A.3** *(HS-PS1-7)*	**CCSS MATHEMATICS STANDARDS INTEGRATION** **MP.2** (HS-PS2-1) **MP.4** (HS-PS2-1) **HSN.Q.A.1** (HS-PS2-1) **HSN.Q.A.2** *(HS-PS2-1)* **HSN.Q.A.3** (HS-PS2-1) **HSA.SSE.A.1** **HSA.SSE.B.3** (HS-PS2-1) **HSA.CED.A.1** (HS-PS2-1) **HSA.CED.A.2** *(HS-PS2-1)* **HSA.CED.A.4** *(HS-PS2-1)* **HSF-IF.C.7** *(HS-PS2-1)* **HSS-IS.A.1** *(HS-PS2-1)* **MP.2** (HS-PS2-2) **MP.4** (HS-PS2-2)	**CCSS MATHEMATICS STANDARDS INTEGRATION** **MP.2** (HS-PS3-1) **MP.4** (HS-PS3-1) **HSN.Q.A.1** (HS-PS3-1) **HSN.Q.A.2** (HS-PS3-1) **HSN.Q.A.3** (HS-PS3-1) **MP.2** (HS-PS3-2) **MP.4** (HS-PS3-2) **MP.2** (HS-PS3-3) **MP.4** (HS-PS3-3) **HSN.Q.A.1** (HS-PS3-3) **HSN.Q.A.2** (HS-PS3-3) **HSN.Q.A.3** (HS-PS3-3) **MP.2** (HS-PS3-4) **MP.4** *(HS-PS3-4)*	**CCSS MATHEMATICS STANDARDS INTEGRATION** **MP.2** (HS-PS4-1) **MP.4** (HS-PS4-1) **HSA-SSE.A.1** (HS-PS4-1) **HSA-SSE.B.3** *(HS-PS4-1)* **HSA.CED.A.4** *(HS-PS4-1)* **MP.2** (HS-PS4-3) **HSA-SSE.A.1** *(HS-PS4-3)* **HSA-SSE.B.3** *(HS-PS4-3)* **HSA.CED.A.4** *(HS-PS4-3)*

		HSN.Q.A.1 (HS-PS2-2) **HSN.Q.A.2** *(HS-PS2-2)* **HSN.Q.A.3** (HS-PS2-2) **HSA.CED.A.1** (HS-PS2-2) **HSA.CED.A.2** *(HS-PS2-2)* **HSA.CED.A.4** *(HS-PS2-2)* **MP.2** (HS-PS2-4) **MP.4** (HS-PS2-4) **HSN.Q.A.1** (HS-PS2-4) **HSN.Q.A.2** *(HS-PS2-4)* **HSN.Q.A.3** (HS-PS2-4) **HSA.SSE.A.1** **HSA.SSE.B.3** (HS-PS2-4) **HSN.Q.A.1** *(HS-PS2-5)* **HSN.Q.A.2** *(HS-PS2-5)* **HSN.Q.A.3** *(HS-PS2-5)*	**MP.2** (HS-PS3-5) **MP.4** (HS-PS3-5)	
VISION OF THE GRADUATE STANDARDS	**VISION OF THE GRADUATE STANDARDS**	**VISION OF THE GRADUATE STANDARDS**	**VISION OF THE GRADUATE STANDARDS**	**VISION OF THE GRADUATE STANDARDS**

VISION OF A GRADUATE STANDARDS

V.1: Critical & Innovative Thinker

Student is able to:

- V.1a: Demonstrate authenticity and inventiveness in their work, generating original ideas and selecting the best, most effective, imaginative ones.
- V.1b: Effectively analyze and evaluate evidence, arguments, claims and beliefs, and alternative points of view.
- V.1c: Are proactive in problem solving by locating and identifying resources independently in order to take ownership of their learning.
- [00
- V.1d: Apply knowledge in new contexts and across disciplines to further their understanding and see that learning can be transferred to other situations and content areas.

V.2: Communicator

Student is able to:

- V.2a: Speak and listen effectively for a variety of purposes.
- V.2b: Use language effectively to enhance meaning and impact in order to accomplish goals.
- V.2c: Use a variety of modes of expression (visual, spoken, written, performing arts, etc.) including the effective use of technology, to create and share ideas.
- V.2d: Demonstrate an awareness of audience and adjust style and tone accordingly.

V.3: Collaborator

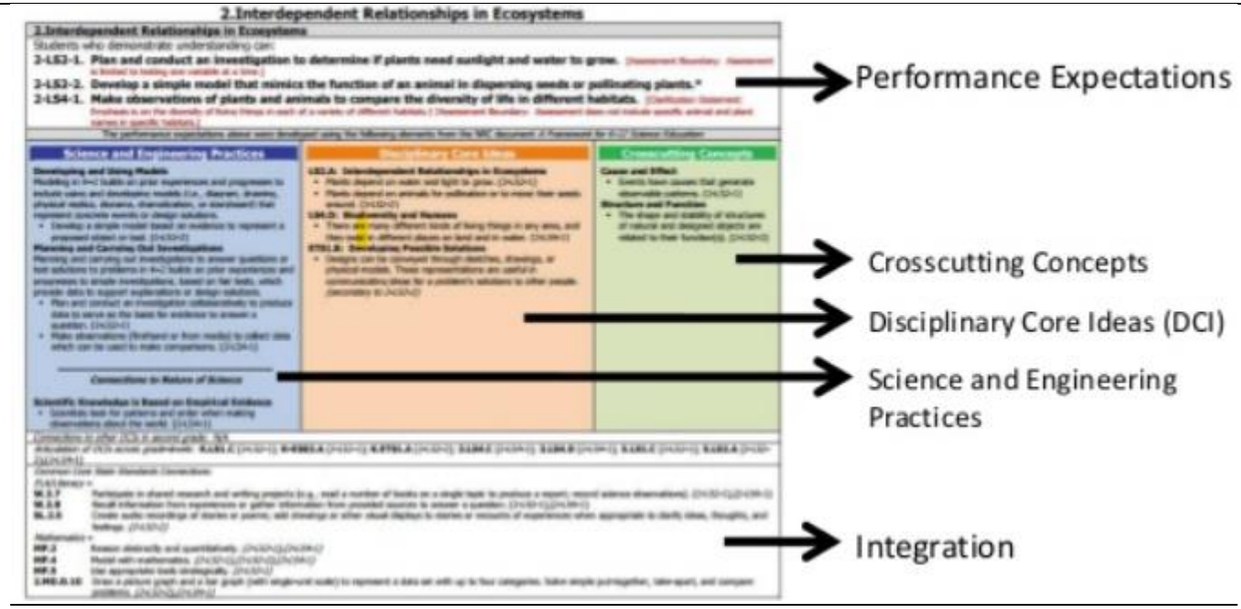
Student is able to:

- V.3a: Collaborate with others to complete a task, or problem solve, by generating new and unique solutions.
- V.3b: Use intrapersonal skills (examples: self-discipline, self-management, self-motivation, and self-reflection) to become better collaborators.
- V.3c: Use interpersonal skills (examples: active listening, dependability, flexibility, and patience) to learn and work with individuals from diverse backgrounds.
- V.3d: Receive and apply constructive criticism from peers and adults to improve their own work.

V.4: Culturally Competent Citizen

Student is able to:

- V.4a: Demonstrate increasing comfort and skills in working with difference and diversity in its many forms: race/ethnicity, nationality, class, gender, sexual orientation/preference, age and ability.
- V.4b: Demonstrate cultural awareness by taking the opportunity to learn about other people's languages, religions, governments, histories, homes, families or daily lives.
- V.4c: Demonstrate empathy for all human beings and have an open mind towards others' situations by treating all with respect, kindness, and dignity.
- V. 4d: Understand how to identify their own emotions and those of others to foster understanding and deeper connections within our community.



UNIT 1	ENDURING UNDERSTANDINGS / ESSENTIAL QUESTIONS **EVIDENCE STATEMENTS**	CONTENT **PERFORMANCE EXPECTATIONS** **DISCIPLINARY CORE IDEAS (DCIs)**	ASSURED EXPERIENCES & ASSESSMENTS	INSTRUCTIONAL STRATEGIES & PATHWAYS **SCIENCE & ENGINNERING PRACTICES (SEPs)** **CROSSCUTTING CONCEPTS (CCCs)**
Structure and Properties of Matter HS-PS1-1 HS-PS1-3 HS-PS1-8 HS-PS2-6 .	**Observable features of the student performance by the end of the course: HS-PS1-1** <u>1 Components of the model</u> a From the given model, students identify and describe* the components of the model that are relevant for their predictions, including: i. Elements and their arrangement in the periodic table; **ii.** A positively-charged nucleus composed of both protons and neutrons, surrounded by negatively-charged electrons;	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.]* **PS1.A: Structure and Properties of Matter** • Each atom has a charged substructure consisting of a		**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 world(s). • Use a model to predict the relationships between systems or between components of a system. **Developing and Using Models** Modeling in 9–

	iii. Electrons in the outermost energy level of atoms (i.e., valence electrons); and **iv.** The number of protons in each element. <u>2 Relationships</u> a Students identify and describe* the following relationships between components in the given model, including: i. The arrangement of the main groups of the periodic table reflects the patterns of outermost electrons. **ii.** Elements in the periodic table are arranged by the numbers of protons in atoms. <u>3 Connections</u> a Students use the periodic table to predict the patterns of behavior of the elements based on the attraction and repulsion between electrically charged particles and the patterns of outermost electrons that determine the typical reactivity of an atom. b Students predict the following patterns of properties: i. The number and types of bonds formed (i.e. ionic, covalent, metallic) by an element and between elements; **ii.** The number and charges in stable ions that form from atoms in a group of the periodic table; **iii.** The trend in reactivity and electronegativity of atoms down a group, and across a row in the periodic table, based on attractions of outermost (valence) electrons to the nucleus; and **iv.** The relative sizes of atoms both across a row and down a group in the periodic table. **Observable features of the student performance by the end of the course: HS-PS1-3** <u>1 Identifying the phenomenon to be investigated</u> a Students describe* the phenomenon under investigation, which includes the following idea: the relationship between the measurable properties (e.g., melting point, boiling point, vapor pressure, surface tension) of a substance and the strength of the electrical forces between the particles of the substance. <u>2 Identifying the evidence to answer this question</u>	nucleus, which is made of protons and neutrons, surrounded by electrons. • 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 pattern 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.]* **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. 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*		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. **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. **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

	a Students develop an investigation plan and describe* the data that will be collected and the evidence to be derived from the data, including bulk properties of a substance (e.g., melting point and boiling point, volatility, surface tension) that would allow inferences to be made about the strength of electrical forces between particles. b Students describe* why the data about bulk properties would provide information about strength of the electrical forces between the particles of the chosen substances, including the following descriptions*: i. The spacing of the particles of the chosen substances can change as a result of the experimental procedure even if the identity of the particles does not change (e.g., when water is boiled the molecules are still present but further apart). **ii.** Thermal (kinetic) energy has an effect on the ability of the electrical attraction between particles to keep the particles close together. Thus, as more energy is added to the system, the forces of attraction between the particles can no longer keep the particles close together. **iii.** The patterns of interactions between particles at the molecular scale are reflected in the patterns of behavior at the macroscopic scale. **iv.** Together, patterns observed at multiple scales can provide evidence of the causal relationships between the strength of the electrical forces between particles and the structure of substances at the bulk scale. <u>3 Planning for the investigation</u> a In the investigation plan, students include: i. A rationale for the choice of substances to compare and a description* of the composition of those substances at the atomic molecular scale. **ii.** A description* of how the data will be collected, the number of trials, and the experimental set up and equipment required.	*quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.]* **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-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.]* **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.		of a proposed process or system) in multiple formats (including oral, graphical, textual and mathematical). **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. **Energy and Matter** • In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. **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.

	b Students describe* how the data will be collected, the number of trials, the experimental set up, and the equipment required. <u>4 Collecting the data</u> a Students collect and record data — quantitative and/or qualitative — on the bulk properties of substances. <u>5 Refining the design</u> a Students evaluate their investigation, including evaluation of: i. Assessing the accuracy and precision of the data collected, as well as the limitations of the investigation; and **ii.** The ability of the data to provide the evidence required. b If necessary, students refine the plan to produce more accurate, precise, and useful data. **Observable features of the student performance by the end of the course: HS-PS1-8** <u>1 Components of the model</u> a Students develop models in which they identify and describe* the relevant components of the models, including: i. Identification of an element by the number of protons; **ii.** The number of protons and neutrons in the nucleus before and after the decay; **iii.** The identity of the emitted particles (i.e., alpha, beta — both electrons and positrons, and gamma); and iv. The scale of energy changes associated with nuclear processes, relative to the scale of energy changes associated with chemical processes. <u>2 Relationships</u> a Students develop five distinct models to illustrate the relationships between components underlying the nuclear processes of 1) fission, 2) fusion and 3) three distinct types of radioactive decay. b Students include the following features, based on evidence, in all five models: i. The total number of neutrons plus protons is the same both before and after the nuclear process,			

	although the total number of protons and the total number of neutrons may be different before and after. **ii.** The scale of energy changes in a nuclear process is much larger (hundreds of thousands or even millions of times larger) than the scale of energy changes in a chemical process. <u>3 Connections</u> a Students develop a fusion model that illustrates a process in which two nuclei merge to form a single, larger nucleus with a larger number of protons than were in either of the two original nuclei. b Students develop a fission model that illustrates a process in which a nucleus splits into two or more fragments that each have a smaller number of protons than were in the original nucleus. c In both the fission and fusion models, students illustrate that these processes may release energy and may require initial energy for the reaction to take place. d Students develop radioactive decay models that illustrate the differences in type of energy (e.g., kinetic energy, electromagnetic radiation) and type of particle (e.g., alpha particle, beta particle) released during alpha, beta, and gamma radioactive decay, and any change from one element to another that can occur due to the process. e Students develop radioactive decay models that describe* that alpha particle emission is a type of fission reaction, and that beta and gamma emission are not. _____ **Observable features of the student performance by the end of the course: HS-PS2-6** <u>1 Communication style and format</u> a Students use at least two different formats (including oral, graphical, textual and mathematical) to communicate scientific and technical information, including fully describing* the structure, properties, and design of the chosen material(s). Students cite the origin of the information as appropriate. <u>2 Connecting the DCIs and the CCCs</u>			

	a Students identify and communicate the evidence for why molecular level structure is important in the functioning of designed materials, including: i. How the structure and properties of matter and the types of interactions of matter at the atomic scale determine the function of the chosen designed material(s); and **ii.** How the material's properties make it suitable for use in its designed function. b Students explicitly identify the molecular structure of the chosen designed material(s) (using a representation appropriate to the specific type of communication — e.g., geometric shapes for drugs and receptors, ball and stick models for long-chained molecules). c Students describe* the intended function of the chosen designed material(s). d Students describe* the relationship between the material's function and its macroscopic properties (e.g., material strength, conductivity, reactivity, state of matter, durability) and each of the following: i. Molecular level structure of the material; **ii.** Intermolecular forces and polarity of molecules; and **iii.** The ability of electrons to move relatively freely in metals. e Students describe* the effects that attractive and repulsive electrical forces between molecules have on the arrangement (structure) of the chosen designed material(s) of molecules (e.g., solids, liquids, gases, network solid, polymers). f Students describe* that, for all materials, electrostatic forces on the atomic and molecular scale results in contact forces (e.g., friction, normal forces, stickiness) on the macroscopic scale.			
Concepts: Structure & Properties of Matter Periodic Table-predicting properties, Nuclear Phenomenon, Radioactivity, generation of nuclear power, Structure & function of designed materials.				
UNIT 2	ENDURING UNDERSTANDINGS / ESSENTIAL QUESTIONS	CONTENT **PERFORMANCE EXPECTATIONS**	ASSURED EXPERIENCES & ASSESSMENTS	INSTRUCTIONAL STRATEGIES & PATHWAYS **SCIENCE & ENGINNERING PRACTICES (SEPs)**

	EVIDENCE STATEMENTS	DISCIPLINARY CORE IDEAS (DCIs)		CROSSCUTTING CONCEPTS (CCCs)
Chemical Reactions HS-PS1-2: HS-PS1-4 HS-PS1-5 HS-PS1-6 HS-PS1-7	**Observable features of the student performance by the end of the course: HS-PS1-2** 1 Articulating the explanation of phenomena a Students construct an explanation of the outcome of the given reaction, including: i. The idea that the total number of atoms of each element in the reactant and products is the same; ii. The numbers and types of bonds (i.e., ionic, covalent) that each atom forms, as determined by the outermost (valence) electron states and the electronegativity; iii. The outermost (valence) electron state of the atoms that make up both the reactants and the products of the reaction is based on their position in the periodic table; and iv. A discussion of how the patterns of attraction allow the prediction of the type of reaction that occurs (e.g., formation of ionic compounds, combustion of hydrocarbons). 2 Evidence a Students identify and describe* the evidence to construct the explanation, including: i. Identification of the products and reactants, including their chemical formulas and the arrangement of their outermost (valence) electrons; ii. Identification that the number and types of atoms are the same both before and after a reaction; iii. Identification of the numbers and types of bonds (i.e., ionic, covalent) in both the reactants and the products; iv. The patterns of reactivity (e.g., the high reactivity of alkali metals) at the macroscopic level as determined by using the periodic table; and v. The outermost (valence) electron configuration and the relative electronegativity of the atoms that	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.]* **PS1.A: Structure and Properties of Matter** • 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. **PS1.B: Chemical Reactions** • 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-PS1-4 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:*		**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 and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, and 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. **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. **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

	make up both the reactants and the products of the reaction based on their position in the periodic table. 3 Reasoning a Students describe* their reasoning that connects the evidence, along with the assumption that theories and laws that describe their natural world operate today as they did in the past and will continue to do so in the future, to construct an explanation for how the patterns of outermost electrons and the electronegativity of elements can be used to predict the number and types of bonds each element forms. b In the explanation, students describe* the causal relationship between the observable macroscopic patterns of reactivity of elements in the periodic table and the patterns of outermost electrons for each atom and its relative electronegativity. 4 Revising the explanation a Given new evidence or context, students construct a revised or expanded explanation about the outcome of a chemical reaction and justify the revision. **Observable features of the student performance by the end of the course: HS-PS1-4** 1 Components of the model a Students use evidence to develop a model in which they identify and describe* the relevant components, including: i. The chemical reaction, the system, and the surroundings under study; ii. The bonds that are broken during the course of the reaction; iii. The bonds that are formed during the course of the reaction; iv. The energy transfer between the systems and their components or the system and surroundings; v. The transformation of potential energy from the chemical system interactions to kinetic energy in the surroundings (or vice versa) by molecular collisions; and vi. The relative potential energies of the reactants and the products. 2 Relationships	*Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.]* **PS1.A: Structure and Properties of Matter** • 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. **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-PS1-5 **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.]* **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		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. **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. • Refine a solution to a complex realworld problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. **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.

	a In the model, students include and describe* the relationships between components, including: i. The net change of energy within the system is the result of bonds that are broken and formed during the reaction (Note: This does not include calculating the total bond energy changes.); ii. The energy transfer between system and surroundings by molecular collisions; iii. The total energy change of the chemical reaction system is matched by an equal but opposite change of energy in the surroundings (Note: This does not include calculating the total bond energy changes.); and iv. The release or absorption of energy depends on whether the relative potential energies of the reactants and products decrease or increase. <u>3 Connections</u> a Students use the developed model to illustrate: i. The energy change within the system is accounted for by the change in the bond energies of the reactants and products. (Note: This does not include calculating the total bond energy changes.) ii. Breaking bonds requires an input of energy from the system or surroundings, and forming bonds releases energy to the system and the surroundings. iii. The energy transfer between systems and surroundings is the difference in energy between the bond energies of the reactants and the products. iv. The overall energy of the system and surroundings is unchanged (conserved) during the reaction. v. Energy transfer occurs during molecular collisions. vi. The relative total potential energies of the reactants and products can be accounted for by the changes in bond energy. **Observable features of the student performance by the end of the course: HS-PS1-5** <u>1 Articulating the explanation of phenomena</u>	in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. 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 Chatelier'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.]* **PS1.B: Chemical Reactions** • 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. **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) 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*		**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. **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. **Stability and Change** • Much of science deals with constructing explanations of how things change and how they remain stable. **Energy and Matter** • The total amount of energy and matter in closed systems is conserved. **Connections to Nature of Science Scientific Knowledge Assumes an Order and Consistency in Natural Systems** • Science assumes the universe is a vast single system in which basic laws are consistent.

	a Students construct an explanation that includes the idea that as the kinetic energy of colliding particles increases and the number of collisions increases, the reaction rate increases. 2 Evidence a Students identify and describe* evidence to construct the explanation, including: i. Evidence (e.g., from a table of data) of a pattern that increases in concentration (e.g., a change in one concentration while the other concentration is held constant) increase the reaction rate, and vice versa; and ii. Evidence of a pattern that increases in temperature usually increase the reaction rate, and vice versa. 3 Reasoning a Students use and describe* the following chain of reasoning that integrates evidence, facts, and scientific principles to construct the explanation: i. Molecules that collide can break bonds and form new bonds, producing new molecules. ii. The probability of bonds breaking in the collision depends on the kinetic energy of the collision being sufficient to break the bond, since bond breaking requires energy. iii. Since temperature is a measure of average kinetic energy, a higher temperature means that molecular collisions will, on average, be more likely to break bonds and form new bonds. iv. At a fixed concentration, molecules that are moving faster also collide more frequently, so molecules with higher kinetic energy are likely to collide more often. v. A high concentration means that there are more molecules in a given volume and thus more particle collisions per unit of time at the same temperature. **Observable features of the student performance by the end of the course: HS-PS1-6** 1 Using scientific knowledge to generate the design solution a Students identify and describe* potential changes in a component of the given chemical reaction system that will	*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.]* **PS1.B: Chemical Reactions** • 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.		

	increase the amounts of particular species at equilibrium. Students use evidence to describe* the relative quantities of a product before and after changes to a given chemical reaction system (e.g., concentration increases, decreases, or stays the same), and will explicitly use Le Chatelier's principle, including: i. How, at a molecular level, a stress involving a change to one component of an equilibrium system affects other components; ii. That changing the concentration of one of the components of the equilibrium system will change the rate of the reaction (forward or backward) in which it is a reactant, until the forward and backward rates are again equal; and iii. A description* of a system at equilibrium that includes the idea that both the forward and backward reactions are occurring at the same rate, resulting in a system that appears stable at the macroscopic level. <u>2 Describing criteria and constraints, including quantification when appropriate</u> a Students describe* the prioritized criteria and constraints, and quantify each when appropriate. Examples of constraints to be considered are cost, energy required to produce a product, hazardous nature and chemical properties of reactants and products, and availability of resources. <u>3 Evaluating potential solutions</u> a Students systematically evaluate the proposed refinements to the design of the given chemical system. The potential refinements are evaluated by comparing the redesign to the list of criteria (i.e., increased product) and constraints (e.g., energy required, availability of resources). <u>4 Refining and/or optimizing the design solution</u> a Students refine the given designed system by making tradeoffs that would optimize the designed system to increase the amount of product, and describe* the reasoning behind design decisions. **Observable features of the student performance by the end of the course: HS-PS1-7** <u>1 Representation</u>			

	a Students identify and describe* the relevant components in the mathematical representations: i. Quantities of reactants and products of a chemical reaction in terms of atoms, moles, and mass; ii. Molar mass of all components of the reaction; iii. Use of balanced chemical equation(s); and iv. Identification of the claim that atoms, and therefore mass, are conserved during a chemical reaction. b The mathematical representations may include numerical calculations, graphs, or other pictorial depictions of quantitative information. c Students identify the claim to be supported: that atoms, and therefore mass, are conserved during a chemical reaction. <u>2 Mathematical modeling</u> a Students use the mole to convert between the atomic and macroscopic scale in the analysis. b Given a chemical reaction, students use the mathematical representations to i. Predict the relative number of atoms in the reactants versus the products at the atomic molecular scale; and ii. Calculate the mass of any component of a reaction, given any other component. <u>3 Analysis</u> a Students describe* how the mathematical representations (e.g., stoichiometric calculations to show that the number of atoms or number of moles is unchanged after a chemical reaction where a specific mass of reactant is converted to product) support the claim that atoms, and therefore mass, are conserved during a chemical reaction. b Students describe* how the mass of a substance can be used to determine the number of atoms, molecules, or ions using moles and mole relationships (e.g., macroscopic to atomic molecular scale conversion using the number of moles and Avogadro's number).			
Concepts: Simple Chemical reactions, trends in the periodic table, Endo/ExoThermic Reactions & rearrangement of atoms, explain bio-geo phenomena, manipulating chemical reaction rates, shifting equilibrium reactions, conservation of mass				

UNIT 3	ENDURING UNDERSTANDINGS / ESSENTIAL QUESTIONS **EVIDENCE STATEMENTS**	CONTENT **PERFORMANCE EXPECTATIONS** **DISCIPLINARY CORE IDEAS (DCIs)**	ASSURED EXPERIENCES & ASSESSMENTS	INSTRUCTIONAL STRATEGIES & PATHWAYS **SCIENCE & ENGINNERING PRACTICES (SEPs)** **CROSSCUTTING CONCEPTS (CCCs)**
Forces and Interactions HS-PS2-1 HS-PS2-2 HS-PS2-3 HS-PS2-4 HS-PS2-5	**Observable features of the student performance by the end of the course: HS-PS2-1** <u>1 Organizing data</u> a Students organize data that represent the net force on a macroscopic object, its mass (which is held constant), and its acceleration (e.g., via tables, graphs, charts, vector drawings). <u>2 Identifying relationships</u> a Students use tools, technologies, and/or models to analyze the data and identify relationships within the datasets, including: i. A more massive object experiencing the same net force as a less massive object has a smaller acceleration, and a larger net force on a given object produces a correspondingly larger acceleration; and **ii.** The result of gravitation is a constant acceleration on macroscopic objects as evidenced by the fact that the ratio of net force to mass remains constant. <u>3 Interpreting data</u> a Students use the analyzed data as evidence to describe* that the relationship between the observed quantities is accurately modeled across the range of data by the formula a = Fnet/m (e.g., double force yields double acceleration, etc.). b Students use the data as empirical evidence to distinguish between causal and correlational relationships linking force, mass, and acceleration. c Students express the relationship Fnet=ma in terms of causality, namely that a net force on an object causes the object to accelerate. **Observable features of the student performance by the end of the course: HS-PS2-2**	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 onedimensional motion and to macroscopic objects moving at non-relativistic speeds.]* **PS2.A: Forces and Motion** • Newton's second law accurately predicts changes in the motion of macroscopic objects. 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.]* **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;		**Analyzing and Interpreting Data** Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. **Connections to Nature of Science Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • Theories and laws provide explanations in science. • Laws are statements or descriptions of the relationships among observable phenomena. **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

	1 Representation a Students clearly define the system of the two interacting objects that is represented mathematically, including boundaries and initial conditions. b Students identify and describe* the momentum of each object in the system as the product of its mass and its velocity, p = mv (p and v are restricted to one-dimensional vectors), using the mathematical representations. c Students identify the claim, indicating that the total momentum of a system of two interacting objects is constant if there is no net force on the system. 2 Mathematical modeling a Students use the mathematical representations to model and describe* the physical interaction of the two objects in terms of the change in the momentum of each object as a result of the interaction. b Students use the mathematical representations to model and describe* the total momentum of the system by calculating the vector sum of momenta of the two objects in the system. 3 Analysis a Students use the analysis of the motion of the objects before the interaction to identify a system with essentially no net force on it. b Based on the analysis of the total momentum of the system, students support the claim that the momentum of the system is the same before and after the interaction between the objects in the system, so that momentum of the system is constant. c Students identify that the analysis of the momentum of each object in the system indicates that any change in momentum of one object is balanced by a change in the momentum of the other object, so that the total momentum is constant. **Observable features of the student performance by the end of the course: HS-PS2-3** 1 Using scientific knowledge to generate the design solution a Students design a device that minimizes the force on a macroscopic object during a collision. In the design, students: i. Incorporate the concept that for a given change in momentum, force in the direction of the change in momentum is decreased by increasing the time interval of the collision (FΔt = mΔv); and	however, any such change is balanced by changes in the momentum of objects outside the system. 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.]* **PS2.A: Forces and Motion** • If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. **ETS1.A: Defining and Delimiting an Engineering Problem** • Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary) **ETS1.C: Optimizing the Design Solution** • Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed. (secondary) 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:*		used based on mathematical models of basic assumptions. • Use mathematical representations of phenomena to describe explanations **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. **Using Mathematics and Computational Thinking** Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis; a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms; and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Use mathematical representations of phenomena to describe explanations. **Connections to Nature of Science Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena**

	ii. Explicitly make use of the principle above so that the device has the desired effect of reducing the net force applied to the object by extending the time the force is applied to the object during the collision. b In the design plan, students describe* the scientific rationale for their choice of materials and for the structure of the device. <u>2 Describing criteria and constraints, including quantification when appropriate</u> a Students describe* and quantify (when appropriate) the criteria and constraints, along with the tradeoffs implicit in these design solutions. Examples of constraints to be considered are cost, mass, the maximum force applied to the object, and requirements set by society for widely used collision-mitigation devices (e.g., seatbelts, football helmets). <u>3 Evaluating potential solutions</u> a Students systematically evaluate the proposed device design or design solution, including describing* the rationales for the design and comparing the design to the list of criteria and constraints. b Students test and evaluate the device based on its ability to minimize the force on the test object during a collision. Students identify any unanticipated effects or design performance issues that the device exhibits. <u>4 Refining and/or optimizing the design solution</u> a Students use the test results to improve the device performance by extending the impact time, reducing the device mass, and/or considering cost-benefit analysis. **Observable features of the student performance by the end of the course: HS-PS2-4** <u>1 Representation</u> a Students clearly define the system of the interacting objects that is mathematically represented. b Using the given mathematical representations, students identify and describe* the gravitational attraction between two objects as the product of their masses divided by the separation distance squared (Fg = −G m1m2 d2), where a negative force is understood to be attractive.	*Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.] [Assessment Boundary: Assessment is limited to systems with two objects.]* **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. 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.]* **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) • Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. **PS3.A: Definitions of Energy**		• Theories and laws provide explanations in science. • Laws are statements or descriptions of the relationships among observable phenomena. **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 **Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. **Systems and System Models** • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined **Cause and Effect** • Systems can be designed to cause a desired effect. **Patterns** • Different patterns may be observed at each of the scales at which a system is

	c Using the given mathematical representations, students identify and describe* the electrostatic force between two objects as the product of their individual charges divided by the separation distance squared (Fe = k q1q2 d2), where a negative force is understood to be attractive. 2 Mathematical modeling a Students correctly use the given mathematical formulas to predict the gravitational force between objects or predict the electrostatic force between charged objects. 3 Analysis a Based on the given mathematical models, students describe* that the ratio between gravitational and electric forces between objects with a given charge and mass is a pattern that is independent of distance. b Students describe* that the mathematical representation of the gravitational field (Fg = −G m1m2 d2) only predicts an attractive force because mass is always positive. c Students describe* that the mathematical representation of the electric field (Fe = k q1q2 d2) predicts both attraction and repulsion because electric charge can be either positive or negative. d Students use the given formulas for the forces as evidence to describe* that the change in the energy of objects interacting through electric or gravitational forces depends on the distance between the objects. **Observable features of the student performance by the end of the course: HS-PS2-5** 1 Identifying the phenomenon to be investigated a Students describe* the phenomenon under investigation, which includes the following idea: that an electric current produces a magnetic field and that a changing magnetic field produces an electric current. 2 Identifying the evidence to answer this question a Students develop an investigation plan and describe* the data that will be collected and the evidence to be derived from the data about 1) an observable effect of a magnetic field that is uniquely related to the presence of an electric current in the circuit, and 2) an electric current in the circuit that is uniquely related to the presence of a changing magnetic field near the	• "Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. (secondary)		studied and can provide evidence for causality in explanations of phenomena. **Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

	circuit. Students describe* why these effects seen must be causal and not correlational, citing specific cause-effect relationships. <u>3 Planning for the investigation</u> a In the investigation plan, students include: i. The use of an electric circuit through which electric current can flow, a source of electrical energy that can be placed in the circuit, the shape and orientation of the wire, and the types and positions of detectors; **ii.** A means to indicate or measure when electric current is flowing through the circuit; **iii.** A means to indicate or measure the presence of a local magnetic field near the circuit; and **iv.** A design of a system to change the magnetic field in a nearby circuit and a means to indicate or measure when the magnetic field is changing. b In the plan, students state whether the investigation will be conducted individually or collaboratively. <u>4 Collecting the data</u> a Students measure and record electric currents and magnetic fields. <u>5 Refining the design</u> a Students evaluate their investigation, including an evaluation of: i. The accuracy and precision of the data collected, as well as limitations of the investigation; and **ii.** The ability of the data to provide the evidence required. b If necessary, students refine the investigation plan to produce more accurate, precise, and useful data such that the measurements or indicators of the presence of an electric current in the circuit and a magnetic field near the circuit can provide the required evidence.			
Concepts: Newton's 2nd law, Gravitational and Electrostatic Forces, Collision & force manipulation				

UNIT 4	ENDURING UNDERSTANDINGS / ESSENTIAL QUESTIONS **EVIDENCE STATEMENTS**	CONTENT **PERFORMANCE EXPECTATIONS** **DISCIPLINARY CORE IDEAS (DCIs)**	ASSURED EXPERIENCES & ASSESSMENTS	INSTRUCTIONAL STRATEGIES & PATHWAYS **SCIENCE & ENGINNERING PRACTICES (SEPs)** **CROSSCUTTING CONCEPTS (CCCs)**
Energy HS-PS3-1 HS-PS3-2 HS-PS3-3 HS-PS3-4 HS-PS3-5	**Observable features of the student performance by the end of the course: HS-PS3-1** 1 Representation a Students identify and describe* the components to be computationally modeled, including: i. The boundaries of the system and that the reference level for potential energy = 0 (the potential energy of the initial or final state does not have to be zero); ii. The initial energies of the system's components (e.g., energy in fields, thermal energy, kinetic energy, energy stored in springs — all expressed as a total amount of Joules in each component), including a quantification in an algebraic description to calculate the total initial energy of the system; iii. The energy flows in or out of the system, including a quantification in an algebraic description with flow into the system defined as positive; and iv. The final energies of the system components, including a quantification in an algebraic description to calculate the total final energy of the system. 2 Computational Modeling a Students use the algebraic descriptions of the initial and final energy state of the system, along with the energy flows to create a computational model (e.g., simple computer program, spreadsheet, simulation software package application) that is based on the principle of the conservation of energy. b Students use the computational model to calculate changes in the energy of one component of the system when changes in	**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.]* **PS3.A: Definitions of Energy** • Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. **PS3.B: Conservation of Energy and Energy Transfer** • Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. • Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. • Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged		**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. **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 **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

	the energy of the other components and the energy flows are known. 3 Analysis a Students use the computational model to predict the maximum possible change in the energy of one component of the system for a given set of energy flows. b Students identify and describe* the limitations of the computational model, based on the assumptions that were made in creating the algebraic descriptions of energy changes and flows in the system. **Observable features of the student performance by the end of the course: HS-PS3-2** 1 Components of the model a Students develop models in which they identify and describe* the relevant components, including: i. All the components of the system and the surroundings, as well as energy flows between the system and the surroundings; ii. Clearly depicting both a macroscopic and a molecular/atomic-level representation of the system; and iii. Depicting the forms in which energy is manifested at two different scales: a) Macroscopic , such as motion, sound, light, thermal energy, potential energy or energy in fields; and b) Molecular/ atomic, such as motions (kinetic energy) of particles (e.g., nuclei and electrons), the relative positions of particles in fields (potential energy), and energy in fields. 2 Relationships a Students describe* the relationships between components in their models, including: i. Changes in the relative position of objects in gravitational, magnetic or electrostatic fields can affect the energy of the fields (e.g., charged objects moving away from each other change the field energy).	particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. • The availability of energy limits what can occur in any system. **HS-PS3-2 Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects).** *[Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically-charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.]* **PS3.A: Definitions of Energy** • Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. • At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. • These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position		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. **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 **Systems and System Models** • Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. **Connections to Nature of Science Scientific Knowledge Assumes an Order and Consistency in Natural Systems** • Science assumes the universe is a vast single system in which basic laws are consistent.

	ii. Thermal energy includes both the kinetic and potential energy of particle vibrations in solids or molecules and the kinetic energy of freely moving particles (e.g., inert gas atoms, molecules) in liquids and gases. iii. The total energy of the system and surroundings is conserved at a macroscopic and molecular/atomic level. iv. Chemical energy can be considered in terms of systems of nuclei and electrons in electrostatic fields (bonds). v. As one form of energy increases, others must decrease by the same amount as energy is transferred among and between objects and fields. 3 Connections a Students use their models to show that in closed systems the energy is conserved on both the macroscopic and molecular/atomic scales so that as one form of energy changes, the total system energy remains constant, as evidenced by the other forms of energy changing by the same amount or changes only by the amount of energy that is transferred into or out of the system. b Students use their models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles/objects and energy associated with the relative positions of particles/objects on both the macroscopic and microscopic scales. **Observable features of the student performance by the end of the course: HS-PS3-3** 1 Using scientific knowledge to generate the design solution a Students design a device that converts one form of energy into another form of energy. b Students develop a plan for the device in which they: i. Identify what scientific principles provide the basis for the energy conversion design;	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-PS3-3 **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.]* **PS3.A: Definitions of Energy** • At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. **PS3.D: Energy in Chemical Processes** • Although energy cannot be destroyed, it can be converted to less useful forms — for example, to thermal energy in the surrounding environment. **ETS1.A: Defining and Delimiting an Engineering Problem** • Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary) 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**		**Energy and Matter** • Energy cannot be created or destroyed; it only moves between one place and another place, between objects and/or fields, or between systems **Energy and Matter** • Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. **Connections to Engineering, Technology, and Applications of Science Influence of Science, Engineering and Technology on Society and the Natural World** • Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. **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. **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.

	ii. Identify the forms of energy that will be converted from one form to another in the designed system; iii. Identify losses of energy by the design system to the surrounding environment; iv. Describe* the scientific rationale for choices of materials and structure of the device, including how student-generated evidence influenced the design; and v. Describe* that this device is an example of how the application of scientific knowledge and engineering design can increase benefits for modern civilization while decreasing costs and risk. <u>2 Describing criteria and constraints, including quantification when appropriate</u> a Students describe* and quantify (when appropriate) prioritized criteria and constraints for the design of the device, along with the tradeoffs implicit in these design solutions. Examples of constraints to be considered are cost and efficiency of energy conversion. <u>3 Evaluating potential solutions</u> a Students build and test the device according to the plan. b Students systematically and quantitatively evaluate the performance of the device against the criteria and constraints. <u>4 Refining and/or optimizing the design solution</u> a Students use the results of the tests to improve the device performance by increasing the efficiency of energy conversion, keeping in mind the criteria and constraints, and noting any modifications in tradeoffs. **Observable features of the student performance by the end of the course: HS-PS3-4** <u>1 Identifying the phenomenon to be investigated</u> a Students describe* the purpose of the investigation, which includes the following idea, 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.]* **PS3.B: Conservation of Energy and Energy Transfer** • Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. • Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down**).** **PS3.D: Energy in Chemical Processes** • Although energy cannot be destroyed, it can be converted to less useful forms — for example, to thermal energy in the surrounding environment. HS-PS3-5 **Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.** *[Clarification Statement: Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.] [Assessment Boundary: Assessment is limited to systems containing two objects.]* **PS3.C: Relationship Between Energy and Forces**		

	distribution among the components in the system (second law of thermodynamics). 2 Identifying the evidence to answer this question a Students develop an investigation plan and describe* the data that will be collected and the evidence to be derived from the data, including: i. The measurement of the reduction of temperature of the hot object and the increase in temperature of the cold object to show that the thermal energy lost by the hot object is equal to the thermal energy gained by the cold object and that the distribution of thermal energy is more uniform after the interaction of the hot and cold components; and ii. The heat capacity of the components in the system (obtained from scientific literature). 3 Planning for the investigation a In the investigation plan, students describe*: i. How a nearly closed system will be constructed, including the boundaries and initial conditions of the system; ii. The data that will be collected, including masses of components and initial and final temperatures; and iii. The experimental procedure, including how the data will be collected, the number of trials, the experimental set up, and equipment required. 4 Collecting the data a Students collect and record data that can be used to calculate the change in thermal energy of each of the two components of the system. 5 Refining the design a Students evaluate their investigation, including: i. The accuracy and precision of the data collected, as well as the limitations of the investigation; and ii. The ability of the data to provide the evidence required.	• When two objects interacting through a field change relative position, the energy stored in the field is changed.		

	b If necessary, students refine the plan to produce more accurate, precise, and useful data that address the experimental question. c Students identify potential causes of the apparent loss of energy from a closed system (which should be zero in an ideal system) and adjust the design of the experiment accordingly. **Observable features of the student performance by the end of the course: HS-PS3-5** <u>1 Components of the model</u> a Students develop a model in which they identify and describe* the relevant components to illustrate the forces and changes in energy involved when two objects interact, including: i. The two objects in the system, including their initial positions and velocities (limited to one dimension). **ii.** The nature of the interaction (electric or magnetic) between the two objects. **iii.** The relative magnitude and the direction of the net force on each of the objects. **iv.** Representation of a field as a quantity that has a magnitude and direction at all points in space and which contains energy. <u>2 Relationships</u> a In the model, students describe* the relationships between components, including the change in the energy of the objects, given the initial and final positions and velocities of the objects. <u>3 Connections</u> a Students use the model to determine whether the energy stored in the field increased, decreased, or remained the same when the objects interacted. b Students use the model to support the claim that the change in the energy stored in the field (which is qualitatively determined to be either positive, negative, or zero) is consistent with the change in energy of the objects. c Using the model, students describe* the cause and effect relationships on a qualitative level between forces produced by electric or magnetic fields and the change of energy of the objects in the system.			
Concepts: Model energy, conservation, types of energy, energy transfer & conversion, energy transformations				

UNIT 5	ENDURING UNDERSTANDINGS / ESSENTIAL QUESTIONS **EVIDENCE STATEMENTS**	CONTENT **PERFORMANCE EXPECTATIONS** **DISCIPLINARY CORE IDEAS (DCIs)**	ASSURED EXPERIENCES & ASSESSMENTS	INSTRUCTIONAL STRATEGIES & PATHWAYS **SCIENCE & ENGINNERING PRACTICES (SEPs)** **CROSSCUTTING CONCEPTS (CCCs)**
Waves and Electromagnetic Radiation HS-PS4-1 HS-PS4-2 HS-PS4-3 HS-PS4-4 HS-PS4-5	**Observable features of the student performance by the end of the course:HS-PS4-1** <u>1 Representation</u> a Students identify and describe* the relevant components in the mathematical representations: i. Mathematical values for frequency, wavelength, and speed of waves traveling in various specified media; and ii. The relationships between frequency, wavelength, and speed of waves traveling in various specified media. <u>2 Mathematical modeling</u> a Students show that the product of the frequency and the wavelength of a particular type of wave in a given medium is constant, and identify this relationship as the wave speed according to the mathematical relationship $v = f\lambda$. b Students use the data to show that the wave speed for a particular type of wave changes as the medium through which the wave travels changes. c Students predict the relative change in the wavelength of a wave when it moves from one medium to another (thus different wave speeds using the mathematical relationship $v = f\lambda$). Students express the relative change in terms of cause (different media) and effect (different wavelengths but same frequency). <u>3 Analysis</u> a Using the mathematical relationship $v = f\lambda$, students assess claims about any of the three quantities when the	**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.]* **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-PS4-2 **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.]* **PS4.A: Wave Properties**		**Using Mathematics and Computational Thinking** Mathematical and computational thinking at the 9-12 level builds on K-8 and progresses to using algebraic thinking and analysis; a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms; and computational tools for statistical analysis to analyze, represent and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations. **Asking Questions and Defining Problems** Asking questions and defining problems in grades 9–12 builds from grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. • Evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set or the suitability of a design.

	other two quantities are known for waves travelling in various specified media. b Students use the mathematical relationships to distinguish between cause and correlation with respect to the supported claims. --- **Observable features of the student performance by the end of the course: HS-PS4-2** <u>1 Addressing phenomena or scientific theories</u> a Students evaluate the given questions in terms of whether or not answers to the questions would: i. Provide examples of features associated with digital transmission and storage of information (e.g., can be stored reliably without degradation over time, transferred easily, and copied and shared rapidly; can be easily deleted; can be stolen easily by making a copy; can be broadly accessed); and b In their evaluation of the given questions, students: i. Describe* the stability and importance of the systems that employ digital information as they relate to the advantages and disadvantages of digital transmission and storage of information; and ii. Discuss the relevance of the answers to the question to real-life examples (e.g., emailing your homework to a teacher, copying music, using the internet for research, social media). <u>2 Evaluating empirical testability</u> Students evaluate the given questions in terms of whether or not answers to the questions would provide means to empirically determine whether given features are advantages or disadvantages. --- **Observable features of the student performance by the end of the course: HS-PS4-3** <u>1 Identifying the given explanation and associated claims, evidence, and reasoning</u>	• 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-PS4-3 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.]* **PS4.A: Wave Properties** • [From the 3–5 grade band endpoints] Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.) **PS4.B: Electromagnetic Radiation** • Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features.		**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. **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. 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. **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

	a Students identify the given explanation that is to be supported by the claims, evidence, and reasoning to be evaluated, and that includes the following idea: Electromagnetic radiation can be described either by a wave model or a particle model, and for some situations one model is more useful than the other. b Students identify the given claims to be evaluated. c Students identify the given evidence to be evaluated, including the following phenomena: i. Interference behavior by electromagnetic radiation; and ii. The photoelectric effect. d Students identify the given reasoning to be evaluated. <u>2 Evaluating given evidence and reasoning</u> a Students evaluate the given evidence for interference behavior of electromagnetic radiation to determine how it supports the argument that electromagnetic radiation can be described by a wave model. b Students evaluate the phenomenon of the photoelectric effect to determine how it supports the argument that electromagnetic radiation can be described by a particle model. c Students evaluate the given claims and reasoning for modeling electromagnetic radiation as both a wave and particle, considering the transfer of energy and information within and between systems, and why for some aspects the wave model is more useful and for other aspects the particle model is more useful to describe the transfer of energy and information. ---------- **Observable features of the student performance by the end of the course: HS-PS4-4** <u>1 Obtaining information</u> a Students obtain at least two claims proposed in published material (using at least two sources per claim) regarding the effect of electromagnetic radiation that is absorbed by matter. One of these claims deals with the effect of electromagnetic radiation on living tissue.	**HS-PS4-4 Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.** *[Clarification Statement: Emphasis is on the idea that photons associated with different frequencies of light have different energies, and the damage to living tissue from electromagnetic radiation depends on the energy of the radiation. Examples of published materials could include trade books, magazines, web resources, videos, and other passages that may reflect bias.] [Assessment Boundary: Assessment is limited to qualitative descriptions.]* **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. **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.]* **PS3.D: Energy in Chemical Processes**		and technical texts or media reports, verifying the data when possible. **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 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). **Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. **Stability and Change** • Systems can be designed for greater or lesser stability **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. • Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.

	2 Evaluating information a Students use reasoning about the data presented, including the energies of the photons involved (i.e., relative wavelengths) and the probability of ionization, to analyze the validity and reliability of each claim. b Students determine the validity and reliability of the sources of the claims. c Students describe* the cause and effect reasoning in each claim, including the extrapolations to larger scales from cause and effect relationships of mechanisms at small scales (e.g., extrapolating from the effect of a particular wavelength of radiation on a single cell to the effect of that wavelength on the entire organism). ---------- **Observable features of the student performance by the end of the course: HS-PS4--5** 1 Communication style and format a Students use at least two different formats (e.g., oral, graphical, textual, and mathematical) to communicate technical information and ideas, including fully describing* at least two devices and the physical principles upon which the devices depend. One of the devices must depend on the photoelectric effect for its operation. Students cite the origin of the information as appropriate. 2 Connecting the DCIs and the CCCs a When describing* how each device operates, students identify the wave behavior utilized by the device or the absorption of photons and production of electrons for devices that rely on the photoelectric effect, and qualitatively describe* how the basic physics principles were utilized in the design through research and development to produce this functionality (e.g., absorbing electromagnetic energy and converting it to thermal energy to heat an object; using the photoelectric effect to produce an electric current). b For each device, students discuss the real-world problem it solves or need it addresses, and how civilization now depends on the device.	• Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy. (secondary) **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. **PS4.B: Electromagnetic Radiation** • Photoelectric materials emit electrons when they absorb light of a high-enough frequency. **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		**Systems and System Models** • Models (e.g., physical, mathematical, and computer models) can be used to simulate systems and interactions — including energy, matter and information flows — within and between systems at different scales. **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. **Cause and Effect** • Systems can be designed to cause a desired effect. **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). **Influence of Engineering, Technology, and Science on Society and the Natural World** • Modern civilization depends on major technological systems.

	c Students identify and communicate the cause and effect relationships that are used to produce the functionality of the device.			
Concepts: Waves & characteristics, digital information, EMS theory, wave interactions, EMR effects on living tissue, tech devices & EMR				

Full link to digital evidence statements and standards from the NGSS Physical Science Evidence Statements