Physics Curriculum Map & Pacing Guide

CONTENT STANDARDS

	1- Forces and Motion	*2- Forces at a Distance*	*3- Energy Conversions*	*4- Waves and Electromagnetic Radiation*	5- Planetary Physics	6- Stars and the Origin of the Universe
NGSS	*HS-PS2-1* *HS-PS2-2* *HS-PS2-3* *HS-ETS1-1* *HS-ETS1-4*	*HS-PS2-4* *HS-PS2-5* *HS-PS2-6* *HS-PS3-5* *HS-ESS1-4* *HS-ETS1-1*	*HS-PS3-1* *HS-PS3-2* *HS-PS3-3* *HS-PS3-5* *HS-ETS1-1* *HS-ETS1-2* *HS-ETS1-3* *HS-ETS1-4*	*HS-PS4-1* *HS-PS4-2* *HS-PS4-3* *HS-PS4-4* *HS-PS4-5* *HS-ETS1-1*	*HS-PS1-8* *HS-ESS1-5* *HS-ESS1-6* *HS-ESS2-1* *HS-ESS2-3*	*HS-ESS1-1* *HS-ESS1-2* *HS-ESS1-3*
CCSS Anchor ELA/Literacy						
CCSS Mathematics						
Vision of a Graduate						

VISION OF A GRADUATE STANDARDS

V.1: Critical & Innovative Thinker	V.2: Communicator	V.3: Collaborator	V.4: Culturally Competent Citizen
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.	**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.	**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.	**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

• V.1c: Are proactive in problem solving by locating and identifying resources independently in order to take ownership of their learning. • 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.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.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.	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	CONTENT	ASSURED EXPERIENCES & ASSESSMENTS	INSTRUCTIONAL STRATEGIES & PATHWAYS
Forces and Motion *HS-PS2-1* *HS-PS2-2* *HS-PS2-3* *HS-ETS1-1* *HS-ETS1-4* .	**Observable features of the student performance by the end of the course: HS-PS1-1** 1 Components of the model 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; **iii.** Electrons in the outermost energy level of atoms (i.e., valence electrons); and **iv.** The number of protons in each element. 2 Relationships 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.	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 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		**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 9–12 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. **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

	<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-PS1-8** <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>	patterns of this table reflect patterns of outer electron states. HS-PS1-8 **Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.** *[Clarification Statement: Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations.] [Assessment Boundary: Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.]* **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-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.		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. **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. **Developing and Using Models** Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). • Develop a model

	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. 3 Connections 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.	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. HS-ESS1-1 **Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy in the form of radiation.** *[Clarification Statement: Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun's core to reach Earth. Examples of evidence for the model include*		based on evidence to illustrate the relationships between systems or between components of a system. **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. **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 •** 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. **Scale, Proportion, and Quantity •** The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.

	Observable features of the student performance by the end of the course: HS-PS4-1 1 Representation 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. 2 Mathematical modeling 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). 3 Analysis a Using the mathematical relationship $v = f\lambda$, students assess claims about any of the three quantities when the 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_PS4-3** 1 Identifying the given explanation and associated claims, evidence, and reasoning	*observations of the masses and lifetimes of other stars, as well as the ways that the sun's radiation varies due to sudden solar flares ("space weather"), the 11-year sunspot cycle, and non-cyclic variations over centuries.] [Assessment Boundary: Assessment does not include details of the atomic and sub-atomic processes involved with the sun's nuclear fusion.]* **ESS1.A: The Universe and Its Stars •** The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. **PS3.D: Energy in Chemical Processes and Everyday Life •** Nuclear fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. (secondary)		

	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-ESS1-1** <u>1 Components of the model</u> a Students use evidence to develop a model in which they identify and describe* the relevant components, including: i. Hydrogen as the sun's fuel; **ii.** Helium and energy as the products of fusion processes in the sun; and			

	iii. That the sun, like all stars, has a life span based primarily on its initial mass, and that the sun's lifespan is about 10 billion years. 2 Relationships a In the model, students describe* relationships between the components, including a description* of the process of radiation, and how energy released by the sun reaches Earth's system. 3 Connections a Students use the model to predict how the relative proportions of hydrogen to helium change as the sun ages. b Students use the model to qualitatively describe* the scale of the energy released by the fusion process as being much larger than the scale of the energy released by chemical processes. c Students use the model to explicitly identify that chemical processes are unable to produce the amount of energy flowing out of the sun over long periods of time, thus requiring fusion processes as the mechanism for energy release in the sun. **Observable features of the student performance by the end of the course: HS-ESS1-3** 1 Communication style and format a Students use at least two different formats (e.g., oral, graphical, textual, and mathematical) to communicate scientific information, and cite the origin of the information as appropriate. 2 Connecting the DCIs and the CCCs a Students identify and communicate the relationships between the life cycle of the stars, the production of elements, and the conservation of the number of protons plus neutrons in stars. Students identify that atoms are not conserved in nuclear fusion, but the total number of protons plus neutrons is conserved. b Students describe* that: i. Helium and a small amount of other light nuclei (i.e., up to lithium) were formed from high-energy collisions starting from protons			

	and neutrons in the early universe before any stars existed. **ii.** More massive elements, up to iron, are produced in the cores of stars by a chain of processes of nuclear fusion, which also releases energy. **iii.** Supernova explosions of massive stars are the mechanism by which elements more massive than iron are produced. **iv.** There is a correlation between a star's mass and stage of development and the types of elements it can create during its lifetime. **v.** Electromagnetic emission and absorption spectra are used to determine a star's composition, motion and distance to Earth.			
Concepts:				
UNIT 2	**ENDURING UNDERSTANDINGS / ESSENTIAL QUESTIONS**	**CONTENT**	**ASSURED EXPERIENCES & ASSESSMENTS**	**INSTRUCTIONAL STRATEGIES & PATHWAYS**
Forces at a Distance *HS-PS2-4* *HS-PS2-5* *HS-PS2-6* *HS-PS3-5* *HS-ESS1-4* *HS-ETS1-1*	**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	**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		**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.

	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 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	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-PS1-5 **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 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*		**Constructing Explanations and Designing Solutions** Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. **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.

	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-PS1-5** 1 Articulating the explanation of phenomena 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	*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 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*		**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. **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

	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 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. 2 Describing criteria and constraints, including quantification when appropriate	*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.		

	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. 3 Evaluating potential solutions 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). 4 Refining and/or optimizing the design solution 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** 1 Representation 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. 2 Mathematical modeling			

	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:				
UNIT 3	**ENDURING UNDERSTANDINGS / ESSENTIAL QUESTIONS**	**CONTENT**	**ASSURED EXPERIENCES & ASSESSMENTS**	**INSTRUCTIONAL STRATEGIES & PATHWAYS**
Energy Conversions *HS-PS3-1* *HS-PS3-2* *HS-PS3-3* *HS-PS3-5* *HS-ETS1-1*	**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	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*		**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,

HS-ETS1-2 *HS-ETS1-3* *HS-ETS1-4*	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> 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	*(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-PS1-4 Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.** *[Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.] [Assessment Boundary: Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.]* **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		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. **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. **Obtaining, Evaluating, and Communicating Information** Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs. • Communicate scientific and technical information (e.g., about the process of development and the design and performance of a proposed process or system) in multiple formats (including oral, graphical, textual and mathematical). **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.

	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. 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-PS1-4** <u>1 Components of the model</u> 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;	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-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. **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.]*		**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. **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. **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. **Structure and Function** • Investigating or designing new systems or structures requires a detailed examination of the properties of

	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 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. 3 Connections 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	**PS3.A: Definitions of Energy** • Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. **PS3.B: Conservation of Energy and Energy Transfer** • Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. • Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. • Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. • The availability of energy limits what can occur in any system. **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*		different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. **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. **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. **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.

	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. 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-PS2-6** 1 Communication style and format 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. 2 Connecting the DCIs and the CCCs 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.,	*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 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-PS3-4 **Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).** *[Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of*		

	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. **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	*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.		

	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 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). 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-PS3-4** <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). <u>2 Identifying the evidence to answer this question</u> 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). <u>3 Planning for the investigation</u> 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. <u>4 Collecting the data</u> 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. <u>5 Refining the design</u> 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. 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.			

Concepts:

UNIT 4	ENDURING UNDERSTANDINGS / ESSENTIAL QUESTIONS	CONTENT	ASSURED EXPERIENCES & ASSESSMENTS	INSTRUCTIONAL STRATEGIES & PATHWAYS
Waves and Electromagnetic Radiation *HS-PS4-1* *HS-PS4-2* *HS-PS4-3* *HS-PS4-4* *HS-PS4-5* *HS-ETS1-1*	**Observable features of the student performance by the end of the course: HS-LS1-7** 1 Components of the model a From a given model, students identify and describe* the components of the model relevant for their illustration of cellular respiration, including: i. Matter in the form of food molecules, oxygen, and the products of their reaction (e.g., water and CO_2); **ii.** The breaking and formation of chemical bonds; and **iii.** Energy from the chemical reactions. 2 Relationships a From the given model, students describe* the relationships between components, including: i. Carbon dioxide and water are produced from sugar and oxygen by the process of cellular respiration; and **ii.** The process of cellular respiration releases energy because the energy released when the bonds that are formed in CO_2 and water is greater than the energy required to break the bonds of sugar and oxygen. 3 Connections a Students use the given model to illustrate that: i. The chemical reaction of oxygen and food molecules releases energy as the matter is rearranged, existing chemical bonds are broken, and new chemical bonds are formed, but matter and energy are neither created nor destroyed. **ii.** Food molecules and oxygen transfer energy to the cell to sustain life's processes, including the maintenance of body	HS-LS1-7 **Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.***[Clarification Statement: Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.] [Assessment Boundary: Assessment should not include identification of the steps or specific processes involved in cellular respiration.]* **LS1.C: Organization for Matter and Energy Flow in Organisms** • As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. • As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment. HS-LS2-5 **Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.** *[Clarification Statement: Examples of models could include simulations and*		**Developing and Using Models** Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. • Use 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 **Developing and Using Models** Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). • Develop a model based on evidence to illustrate the relationships between systems or components of a system.

	temperature despite ongoing energy transfer to the surrounding environment. **Observable features of the student performance by the end of the course: HS-ESS2-5** 1 Identifying the phenomenon to be investigated a Students describe* the phenomenon under investigation, which includes the following idea: a connection between the properties of water and its effects on Earth materials and surface processes. 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. Properties of water, including: a) The heat capacity of water; b) The density of water in its solid and liquid states; and c) The polar nature of the water molecule due to its molecular structure. ii. The effect of the properties of water on energy transfer that causes the patterns of temperature, the movement of air, and the movement and availability of water at Earth's surface. iii. Mechanical effects of water on Earth materials that can be used to infer the effect of water on Earth's surface processes. Examples can include: a) Stream transportation and deposition using a stream table, which can be used to infer the ability of water to transport and deposit materials; b) Erosion using variations in soil moisture content, which can be used to infer the ability of water to prevent or facilitate movement of Earth materials; and c) The expansion of water as it freezes, which can be used to infer the ability of water to break rocks into smaller pieces. iv. Chemical effects of water on Earth materials that can be used to infer the effect of water	*mathematical models.] [Assessment Boundary: Assessment does not include the specific chemical steps of photosynthesis and respiration.]* **LS2.B: Cycles of Matter and Energy Transfer in Ecosystems** • Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes. **PS3.D: Energy in Chemical Processes** • The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. (secondary) **HS-ESS2-5 Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.** *[Clarification Statement: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).]* **ESS2.C: The Roles of Water in Earth's Surface Processes** • The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include		**Asking Questions and Defining Problems** Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. • Analyze complex real-world problems by specifying criteria and constraints for successful solutions. **Structure and Function** • The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. **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. **Systems and System Models** • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions — including energy, matter and information flows — within and between systems at different scales. **Connections to Engineering, Technology, and Applications of Science Influence of Science, Engineering, and Technology on Society and the Natural World** • New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.

	on Earth's surface processes. Examples can include: a) The solubility of different materials in water, which can be used to infer chemical weathering and recrystallization; b) The reaction of iron to rust in water, which can be used to infer the role of water in chemical weathering; c) Data illustrating that water lowers the melting temperature of most solids, which can be used to infer melt generation; and d) Data illustrating that water decreases the viscosity of melted rock, affecting the movement of magma and volcanic eruptions. b In their investigation plan, students describe* how the data collected will be relevant to determining the effect of water on Earth materials and surface processes. 3 Planning for the Investigation a In their investigation plan, students include a means to indicate or measure the predicted effect of water on Earth's materials or surface processes. Examples include: i. The role of the heat capacity of water to affect the temperature, movement of air and movement of water at the Earth's surface; ii. The role of flowing water to pick up, move and deposit sediment; iii. The role of the polarity of water (through cohesion) to prevent or facilitate erosion; iv. The role of the changing density of water (depending on physical state) to facilitate the breakdown of rock; v. The role of the polarity of water in facilitating the dissolution of Earth materials; vi. Water as a component in chemical reactions that change Earth materials; and vii. The role of the polarity of water in changing the melting temperature and viscosity of rocks.	water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks. **HS-ETS1-1 Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.** **ETS1.A: Defining and Delimiting Engineering Problems** • Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. • Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.		

	b In the plan, students state whether the investigation will be conducted individually or collaboratively. 4 Collecting the data a Students collect and record measurements or indications of the predicted effect of a property of water on Earth's materials or surface. 5 Refining the design a Students evaluate the accuracy and precision of the collected data. b Students evaluate whether the data can be used to infer the effect of water on processes in the natural world. c If necessary, students refine the plan to produce more accurate and precise data. **Observable features of the student performance by the end of the course: HS-ETS1-1** 1 Identifying the problem to be solved a Students analyze a major global problem. In their analysis, students: i. Describe* the challenge with a rationale for why it is a major global challenge; ii. Describe*, qualitatively and quantitatively, the extent and depth of the problem and its major consequences to society and/or the natural world on both global and local scales if it remains unsolved; and iii. Document background research on the problem from two or more sources, including research journals. 2 Defining the process or system boundaries, and the components of the process or system a In their analysis, students identify the physical system in which the problem is embedded, including the major elements and relationships in the system and boundaries so as to clarify what is and is not part of the problem. b In their analysis, students describe* societal needs and wants that are relative to the problem (e.g., for controlling CO_2 emissions, societal needs include the need for cheap energy).			

	<u>3 Defining the criteria and constraints</u> a Students specify qualitative and quantitative criteria and constraints for acceptable solutions to the problem.			
Concepts:				
UNIT 5	**ENDURING UNDERSTANDINGS / ESSENTIAL QUESTIONS**	**CONTENT**	**ASSURED EXPERIENCES & ASSESSMENTS**	**INSTRUCTIONAL STRATEGIES & PATHWAYS**
Planetary Physics *HS-PS1-8* *HS-ESS1-5* *HS-ESS1-6* *HS-ESS2-1* *HS-ESS2-3*	**Observable features of the student performance by the end of the course: HS-LS1-7** <u>1 Components of the model</u> a From a given model, students identify and describe* the components of the model relevant for their illustration of cellular respiration, including: iv. Matter in the form of food molecules, oxygen, and the products of their reaction (e.g., water and CO_2); **v.** The breaking and formation of chemical bonds; and **vi.** Energy from the chemical reactions. <u>2 Relationships</u> a From the given model, students describe* the relationships between components, including: iii. Carbon dioxide and water are produced from sugar and oxygen by the process of cellular respiration; and **iv.** The process of cellular respiration releases energy because the energy released when the bonds that are formed in CO_2 and water is greater than the energy required to break the bonds of sugar and oxygen. <u>3 Connections</u> a Students use the given model to illustrate that: iii. The chemical reaction of oxygen and food molecules releases energy as the matter is rearranged, existing chemical bonds are broken, and new chemical bonds are	HS-LS1-7 **Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.***[Clarification Statement: Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.] [Assessment Boundary: Assessment should not include identification of the steps or specific processes involved in cellular respiration.]* **LS1.C: Organization for Matter and Energy Flow in Organisms** • As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. • As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment.		**Developing and Using Models** Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. • Use 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 **Developing and Using Models** Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the

	formed, but matter and energy are neither created nor destroyed. **iv.** Food molecules and oxygen transfer energy to the cell to sustain life's processes, including the maintenance of body temperature despite ongoing energy transfer to the surrounding environment. **Observable features of the student performance by the end of the course: HS-ESS2-5** <u>1 Identifying the phenomenon to be investigated</u> a Students describe* the phenomenon under investigation, which includes the following idea: a connection between the properties of water and its effects on Earth materials and surface processes. <u>2 Identifying the evidence to answer this question</u> a Students develop an investigation plan and describe* the data that will be collected and the evidence to be derived from the data, including: v. Properties of water, including: a) The heat capacity of water; b) The density of water in its solid and liquid states; and c) The polar nature of the water molecule due to its molecular structure. vi. The effect of the properties of water on energy transfer that causes the patterns of temperature, the movement of air, and the movement and availability of water at Earth's surface. vii. Mechanical effects of water on Earth materials that can be used to infer the effect of water on Earth's surface processes. Examples can include: a) Stream transportation and deposition using a stream table, which can be used to infer the ability of water to transport and deposit materials; b) Erosion using variations in soil moisture content, which can be used to infer the ability of water to prevent or facilitate movement of Earth materials; and c) The	HS-LS2-5 **Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.** *[Clarification Statement: Examples of models could include simulations and mathematical models.] [Assessment Boundary: Assessment does not include the specific chemical steps of photosynthesis and respiration.]* **LS2.B: Cycles of Matter and Energy Transfer in Ecosystems** • Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes. **PS3.D: Energy in Chemical Processes** • The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. (secondary) **HS-ESS2-5 Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.** *[Clarification Statement: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).]*		natural and designed world(s). • Develop a model based on evidence to illustrate the relationships between systems or components of a system. **Asking Questions and Defining Problems** Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. • Analyze complex real-world problems by specifying criteria and constraints for successful solutions. **Structure and Function** • The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. **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. **Systems and System Models** • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions — including energy, matter and information flows — within and between systems at different scales. **Connections to Engineering, Technology, and Applications of Science Influence of Science, Engineering, and Technology on Society and the Natural World** • New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.

	expansion of water as it freezes, which can be used to infer the ability of water to break rocks into smaller pieces. viii. Chemical effects of water on Earth materials that can be used to infer the effect of water on Earth's surface processes. Examples can include: a) The solubility of different materials in water, which can be used to infer chemical weathering and recrystallization; b) The reaction of iron to rust in water, which can be used to infer the role of water in chemical weathering; c) Data illustrating that water lowers the melting temperature of most solids, which can be used to infer melt generation; and d) Data illustrating that water decreases the viscosity of melted rock, affecting the movement of magma and volcanic eruptions. b In their investigation plan, students describe* how the data collected will be relevant to determining the effect of water on Earth materials and surface processes. 3 Planning for the Investigation a In their investigation plan, students include a means to indicate or measure the predicted effect of water on Earth's materials or surface processes. Examples include: viii. The role of the heat capacity of water to affect the temperature, movement of air and movement of water at the Earth's surface; ix. The role of flowing water to pick up, move and deposit sediment; x. The role of the polarity of water (through cohesion) to prevent or facilitate erosion; xi. The role of the changing density of water (depending on physical state) to facilitate the breakdown of rock; xii. The role of the polarity of water in facilitating the dissolution of Earth materials;	**ESS2.C: The Roles of Water in Earth's Surface Processes** • The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks. **HS-ETS1-1 Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.** **ETS1.A: Defining and Delimiting Engineering Problems** • Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. • Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.		

	xiii. Water as a component in chemical reactions that change Earth materials; and xiv. The role of the polarity of water in changing the melting temperature and viscosity of rocks. b In the plan, students state whether the investigation will be conducted individually or collaboratively. 4 Collecting the data a Students collect and record measurements or indications of the predicted effect of a property of water on Earth's materials or surface. 5 Refining the design a Students evaluate the accuracy and precision of the collected data. b Students evaluate whether the data can be used to infer the effect of water on processes in the natural world. c If necessary, students refine the plan to produce more accurate and precise data. **Observable features of the student performance by the end of the course: HS-ETS1-1** 1 Identifying the problem to be solved a Students analyze a major global problem. In their analysis, students: iv. Describe* the challenge with a rationale for why it is a major global challenge; v. Describe*, qualitatively and quantitatively, the extent and depth of the problem and its major consequences to society and/or the natural world on both global and local scales if it remains unsolved; and vi. Document background research on the problem from two or more sources, including research journals. 2 Defining the process or system boundaries, and the components of the process or system a In their analysis, students identify the physical system in which the problem is embedded, including the major			

	elements and relationships in the system and boundaries so as to clarify what is and is not part of the problem. b In their analysis, students describe* societal needs and wants that are relative to the problem (e.g., for controlling CO2 emissions, societal needs include the need for cheap energy). <u>3 Defining the criteria and constraints</u> a Students specify qualitative and quantitative criteria and constraints for acceptable solutions to the problem.			
Concepts:				

UNIT 6	ENDURING UNDERSTANDINGS / ESSENTIAL QUESTIONS	CONTENT	ASSURED EXPERIENCES & ASSESSMENTS	INSTRUCTIONAL STRATEGIES & PATHWAYS
Stars and the Origin of the Universe *HS-ESS1-1* *HS-ESS1-2* *HS-ESS1-3*	**Observable features of the student performance by the end of the course: HS-LS1-7** <u>1 Components of the model</u> a From a given model, students identify and describe* the components of the model relevant for their illustration of cellular respiration, including: vii. Matter in the form of food molecules, oxygen, and the products of their reaction (e.g., water and CO2); **viii.** The breaking and formation of chemical bonds; and **ix.** Energy from the chemical reactions. <u>2 Relationships</u> a From the given model, students describe* the relationships between components, including: v. Carbon dioxide and water are produced from sugar and oxygen by the process of cellular respiration; and **vi.** The process of cellular respiration releases energy because the energy released when the bonds that are formed in CO2 and water	HS-LS1-7 **Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.***[Clarification Statement: Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.] [Assessment Boundary: Assessment should not include identification of the steps or specific processes involved in cellular respiration.]* **LS1.C: Organization for Matter and Energy Flow in Organisms** • As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. • As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can		**Developing and Using Models** Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. • Use 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

	is greater than the energy required to break the bonds of sugar and oxygen. 3 Connections a Students use the given model to illustrate that: v. The chemical reaction of oxygen and food molecules releases energy as the matter is rearranged, existing chemical bonds are broken, and new chemical bonds are formed, but matter and energy are neither created nor destroyed. **vi.** Food molecules and oxygen transfer energy to the cell to sustain life's processes, including the maintenance of body temperature despite ongoing energy transfer to the surrounding environment. **Observable features of the student performance by the end of the course: HS-ESS2-5** 1 Identifying the phenomenon to be investigated a Students describe* the phenomenon under investigation, which includes the following idea: a connection between the properties of water and its effects on Earth materials and surface processes. 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: ix. Properties of water, including: a) The heat capacity of water; b) The density of water in its solid and liquid states; and c) The polar nature of the water molecule due to its molecular structure. x. The effect of the properties of water on energy transfer that causes the patterns of temperature, the movement of air, and the movement and availability of water at Earth's surface. xi. Mechanical effects of water on Earth materials that can be used to infer the effect of water on Earth's surface processes.	transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment. HS-LS2-5 **Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.** *[Clarification Statement: Examples of models could include simulations and mathematical models.] [Assessment Boundary: Assessment does not include the specific chemical steps of photosynthesis and respiration.]* **LS2.B: Cycles of Matter and Energy Transfer in Ecosystems** • Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes. **PS3.D: Energy in Chemical Processes** • The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. (secondary) **HS-ESS2-5 Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.** *[Clarification Statement: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as*		precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly **Developing and Using Models** Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). • Develop a model based on evidence to illustrate the relationships between systems or components of a system. **Asking Questions and Defining Problems** Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. • Analyze complex real-world problems by specifying criteria and constraints for successful solutions. **Structure and Function** • The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. **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. **Systems and System Models** • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions — including energy, matter and information flows — within and between systems at different scales.

	Examples can include: a) Stream transportation and deposition using a stream table, which can be used to infer the ability of water to transport and deposit materials; b) Erosion using variations in soil moisture content, which can be used to infer the ability of water to prevent or facilitate movement of Earth materials; and c) The expansion of water as it freezes, which can be used to infer the ability of water to break rocks into smaller pieces. xii. Chemical effects of water on Earth materials that can be used to infer the effect of water on Earth's surface processes. Examples can include: a) The solubility of different materials in water, which can be used to infer chemical weathering and recrystallization; b) The reaction of iron to rust in water, which can be used to infer the role of water in chemical weathering; c) Data illustrating that water lowers the melting temperature of most solids, which can be used to infer melt generation; and d) Data illustrating that water decreases the viscosity of melted rock, affecting the movement of magma and volcanic eruptions. b In their investigation plan, students describe* how the data collected will be relevant to determining the effect of water on Earth materials and surface processes. <u>3 Planning for the Investigation</u> a In their investigation plan, students include a means to indicate or measure the predicted effect of water on Earth's materials or surface processes. Examples include: xv. The role of the heat capacity of water to affect the temperature, movement of air and movement of water at the Earth's surface; xvi. The role of flowing water to pick up, move and deposit sediment;	*it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).]* **ESS2.C: The Roles of Water in Earth's Surface Processes** • The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks. **HS-ETS1-1 Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.** **ETS1.A: Defining and Delimiting Engineering Problems** • Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. • Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.		**Connections to Engineering, Technology, and Applications of Science Influence of Science, Engineering, and Technology on Society and the Natural World** • New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.

	xvii. The role of the polarity of water (through cohesion) to prevent or facilitate erosion; xviii. The role of the changing density of water (depending on physical state) to facilitate the breakdown of rock; xix. The role of the polarity of water in facilitating the dissolution of Earth materials; xx. Water as a component in chemical reactions that change Earth materials; and xxi. The role of the polarity of water in changing the melting temperature and viscosity of rocks. b In the plan, students state whether the investigation will be conducted individually or collaboratively. <u>4 Collecting the data</u> a Students collect and record measurements or indications of the predicted effect of a property of water on Earth's materials or surface. <u>5 Refining the design</u> a Students evaluate the accuracy and precision of the collected data. b Students evaluate whether the data can be used to infer the effect of water on processes in the natural world. c If necessary, students refine the plan to produce more accurate and precise data. **Observable features of the student performance by the end of the course: HS-ETS1-1** <u>1 Identifying the problem to be solved</u> a Students analyze a major global problem. In their analysis, students: vii. Describe* the challenge with a rationale for why it is a major global challenge; viii. Describe*, qualitatively and quantitatively, the extent and depth of the problem and its major consequences to society and/or the natural world on both global and local scales if it remains unsolved; and			

	ix. Document background research on the problem from two or more sources, including research journals. 2 Defining the process or system boundaries, and the components of the process or system a In their analysis, students identify the physical system in which the problem is embedded, including the major elements and relationships in the system and boundaries so as to clarify what is and is not part of the problem. b In their analysis, students describe* societal needs and wants that are relative to the problem (e.g., for controlling CO_2 emissions, societal needs include the need for cheap energy). 3 Defining the criteria and constraints a Students specify qualitative and quantitative criteria and constraints for acceptable solutions to the problem.			
Concepts:				