AFK12SE/NGSS Strand Disciplinary Core Idea	**Conceptual Understanding for Teachers at 9-12**
PS1. Matter and Its Interactions	***How can one explain the structure, properties, and interactions of matter?***
PS1.C: NUCLEAR PROCESSES *What forces hold nuclei together and mediate nuclear processes?* ● Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve changes in nuclear binding energies. ● The total number of neutrons plus protons does not change in any nuclear process. ● Strong and weak nuclear interactions determine nuclear stability and processes. ● Spontaneous radioactive decays follow a characteristic exponential decay law. ● Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials from the isotope ratios present. ● Normal stars cease producing light after having converted all of the material in their cores to carbon or, for more massive stars, to iron. ● Elements more massive than iron are formed by fusion processes but only in the extreme conditions of supernova explosions, which explains why they are relatively rare.	● What forces hold nuclei together and mediate nuclear processes? ● How do the number of protons, electrons, and neutrons change during nuclear decay? ● How does the amount of radioactive materials change over the course of a nuclear decay reaction? ● How is half-life used to determine the age of rocks and other natural materials? ● What different star life cycles exist? What properties of stars dictate their end of life states?
PS2: Motion and Stability: Forces and Interactions	● How can one explain and predict interactions between objects and within systems of objects?
PS2.A: FORCES AND MOTION How can one predict an object's continued motion, changes in motion, or stability? ● Newton's second law accurately predicts changes in the motion of macroscopic objects, but it requires revision for subatomic scales or for speeds close to the speed of light. ● Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. In any system, total momentum is always conserved.	● How can one predict an object's continued motion, changes in motion, or stability? ● What are the relationships among mass, velocity, acceleration, force, and momentum for macroscopic objects? ● How do Newton's Laws of Motion apply to macroscopic objects in a system? ● How can one predict an object's continued motion, changes in motion, or stability? ● How can models help explain the variety of interactions observed for forces? ● What are the conceptual and mathematical relationships among velocity and mass for objects in a closed system? ● How are the conservation of momentum and energy related? ● Why are some physical systems more stable than others?
PS2.B: TYPES OF INTERACTIONS	● What underlying forces explain the variety of interactions

What underlying forces explain the variety of interactions observed? • Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. • Forces at a distance are explained by fields permeating space that can transfer energy through space. • Magnets or changing electric fields cause magnetic fields; electric charges or changing magnetic fields cause electric fields. • The strong and weak nuclear interactions are important inside atomic nuclei.	observed? • What is the nature of the gravitational relationship between two masses? • What is the nature of the electrostatic relationship between two electrical charges? What are the mathematical representations of Newton's Law of Gravitation and Coulomb's Law of Electrostatic Forces? • How are electric currents and magnetic fields related? • What are the practical applications of the relationship between electric currents and magnetic fields? • How do strong and weak nuclear forces in an atomic nucleus function?
PS2.C: STABILITY AND INSTABILITY IN PHYSICAL SYSTEMS Why are some physical systems more stable than others? • Systems often change in predictable ways; understanding the forces that drive the transformations and cycles within a system, as well as the forces imposed on the system from the outside, helps predict its behavior under a variety of conditions. • When a system has a great number of component pieces, one may not be able to predict much about its precise future.	• Why are some physical systems more stable than others? • How do feedback mechanisms maintain stability in closed systems? • How is the Second Law of Thermodynamics applied to two components in a closed system?
PS3: Energy	***How is energy transferred and conserved?***
PS3.A: DEFINITIONS OF ENERGY *What is energy?* • Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. • At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. • "Mechanical energy" generally refers to some combination of motion and stored energy in an operating machine. • "Chemical energy" generally is used to mean the energy that can be released or stored in chemical processes, and "electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. Historically, different units and names were used for the energy present in these different phenomena, and it took some time before the relationships between them were recognized. • These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as either motions of particles or energy stored in fields (which mediate interactions between particles). • This last concept includes radiation, a phenomenon in which energy stored	• What is energy and how do we measure it? • How is energy manifested? • What are the conceptual and mathematical relationships among energy, work, and power? • How is energy transferred between objects? • How are efficiency and conservation of energy related? • How do we model energy and energy changes at the particulate level? • What is relationship between thermal energy and temperature? • How is energy harnessed?

in fields moves across space.	
PS3.B: CONSERVATION OF ENERGY AND ENERGY TRANSFER *What is meant by conservation of energy?* *How is energy transferred between objects or systems?* ● 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 allow the concept of conservation of energy to be used to predict and describe system behavior. ● Uncontrolled systems always evolve toward more stable states	● How do the amount and properties of matter affect the energy needed to change the temperature of the sample? ● How do various energy diagrams represent mechanical, light, and electric interactions? ● How is energy (electrical, thermal, and magnetic) transferred from one object to another object in a closed system? ● How does energy (electrical, thermal, and magnetic) change when energy flows in and out of a system? ● How is energy converted from one form to another? ● What are the practical applications of energy conversion for real-world examples? ● What is meant by conservation of energy? ● How can mathematical expressions be used to predict and describe system behavior?
PS3.C RELATIONSHIP BETWEEN ENERGY AND FORCES *How are forces related to energy?* ● Force fields (gravitational, electric, and magnetic) contain energy and can transmit energy across space from one object to another. ● When two objects interacting through a force field change relative position, the energy stored in the force field is changed.	● What are the conceptual and mathematical relationships between two objects interacting through electrical or magnetic fields? ● How are forces related to energy? ● What are the conceptual and mathematical relationships among conservation of mass, momentum, energy, and charge?
PS3.D: ENERGY IN CHEMICAL PROCESSES AND EVERYDAY LIFE *How do food and fuel provide energy?* *If energy is conserved, why do people say it is produced or used?* ● Nuclear fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. ● All forms of electricity generation and transportation fuels have associated economic, social, and environmental costs and benefits, both short and long term. ● Although energy cannot be destroyed, it can be converted to less useful forms ● Machines are judged as efficient or inefficient based on the amount of energy input needed to perform a particular useful task.	● What are the chemical processes in which plants produce sugar? ● How is energy released from complex molecules containing carbon? ● In what ways can a mechanical system be made more energy efficient? ● How does Earth receive seemingly unlimited energy?
Core Idea PS4 Waves and Their Applications in Technologies for Information Transfer	***How are waves used to transfer energy and information?***
PS4.A: WAVE PROPERTIES	

What are the characteristic properties and behaviors of waves? ● The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing. ● The reflection, refraction, and transmission of waves at an interface between two media can be modeled on the basis of these properties. ● Combining waves of different frequencies can make a wide variety of patterns and thereby encode and transmit information. ● Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. ● Resonance is a phenomenon in which waves add up in phase in a structure, growing in amplitude due to energy input near the natural vibration frequency. ● Structures have particular frequencies at which they resonate. This phenomenon (e.g., waves in a stretched string, vibrating air in a pipe) is used in speech and in the design of all musical instruments.	● What are the different types of waves? ● What is the relationship among, frequency, wavelength, and speed of waves traveling in different media? ● What are the characteristic properties and behaviors of waves? ● What happens to light what it interacts with different materials? ● What other forms of electromagnetic radiation are there? ● How can information be digitized and communicated using the electromagnetic spectrum? ● What is resonance and how is the concept applied to everyday events?
PS4.B: ELECTROMAGNETIC RADIATION *What is light?* *How can one explain the varied effects that involve light?* *What other forms of electromagnetic radiation are there?* ● 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. Quantum theory relates the two models. (Boundary: Quantum theory is not explained further at this grade level.) ● Because a wave is not much disturbed by objects that are small compared with its wavelength, visible light cannot be used to see such objects as individual atoms. ● All electromagnetic radiation travels through a vacuum at the same speed, called the speed of light. Its speed in any other given medium depends on its wavelength and the properties of that medium. ● When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). ● Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells. ● Photovoltaic materials emit electrons when they absorb light of a high-enough frequency. ● Atoms of each element emit and absorb characteristic frequencies of light,	● What is light? ● How does light behave given the two models of electromagnetic behavior (e.g., particle versus wave)? ● What forms of electromagnetic radiation exist? ● What are the different models for electromagnetic radiation? ● What are some practical applications of electromagnetic radiation? ● How does electromagnetic radiation affect matter? ● How does electromagnetic radiation influence the emission of energy by an atom?

and nuclear transitions have distinctive gamma ray wavelengths. These characteristics allow identification of the presence of an element, even in microscopic quantities.	
PS4.C: INFORMATION TECHNOLOGIES AND INSTRUMENTATION *How are instruments that transmit and detect waves used to extend human senses?* ● Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them. ● Knowledge of quantum physics enabled the development of semiconductors, computer chips, and lasers, all of which are now essential components of modern imaging, communications, and information technologies. (Boundary: Details of quantum physics are not formally taught at this grade level.)	● How do different technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy? ● How are instruments that transmit and detect waves used to explore the world around us beyond what we can see and hear?
Supporting Competencies	
Mathematics	● How can mathematical and statistical models evaluate the strength of a conclusion? ● How are mathematical models used in physics? ● What are the applications of calculus and differential equations in physics?
Chemistry	● What is matter? ● What trends exist in the Periodic Table and how do those trends reflect atomic structure? ● In what ways do atoms combine to form novel substances? ● What conventions do chemists use for naming chemical compounds and writing chemical formulas? ● How does a balanced chemical reaction represent conservation of mass in a given chemical reaction?
Biology	● How do organisms obtain and use the matter and energy they need to live and grow? ● How do matter and energy move through an ecosystem?
Earth and Space Sciences	● What is the universe, and what goes on in stars? ● What are the predictable patterns caused by Earth's motion in the Solar System?

	• How do the properties and movements of water shape Earth's surface and affect its systems? • How do people model and predict the effects of human activities on Earth's climate?