NGSS Alignment Guide for High School Physics

This guide outlines how the Khan Academy high school physics course aligns with the Next Generation Science Standards (NGSS). NGSS is built around a three-dimensional approach:

<table>
<tr><td colspan="3">Performance Expectations (PEs)
Each unit is aligned with specific PEs that blend all three dimensions—DCIs, SEPs, and CCCs—into meaningful, assessable learning goals that reflect what students should know and be able to do.</td></tr>
<tr><td>Science and Engineering Practices (SEPs)</td><td>Disciplinary Core Ideas (DCIs)</td><td>Crosscutting Concepts (CCCs)</td></tr>
<tr><td>Describe the behaviors that scientists engage in as they investigate the natural world and that engineers use to design and build solutions. These practices go beyond “skills”—they involve applying content knowledge in purposeful ways.</td><td>Help students make connections across the different domains of science. By making these ideas explicit, instruction helps students build a coherent, transferable understanding of science that they can apply in new and unfamiliar contexts.</td><td>Key ideas that are central to understanding the physical sciences, life sciences, Earth and space sciences, and engineering. These ideas have broad relevance across scientific disciplines and build in complexity across grade levels.</td></tr>
</table>

Quick navigation to unit standards

Unit 1: Motion and forces

Unit 2: Force pairs and momentum

Unit 3: Gravitation

Unit 4: Electrostatics

Unit 5: Energy

Unit 6: Electromagnetics

Unit 7: Electromagnetic radiation

Unit 8: Nuclear physics

NGSS Unit guides

Looking for tools and support for implementing Khan Academy physics in your classroom? Check out our NGSS high school physics unit guides! These guides are designed to support the implementation of Khan Academy as a supplement to your existing science curriculum.

Designed *by* educators *for* educators, these NGSS-aligned guides blend pedagogy with content support for all teachers. Whether you're new to the course or a seasoned educator, you'll find resources to build confidence, inspire new ideas, and enhance classroom implementation.

Unit 1: Motion and forces (link to unit)

Performance expectations (PEs)

- **HS-PS2-1:** Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

Disciplinary core ideas (DCIs)

- **HS-PS2.A.1:** Newton's second law accurately predicts changes in the motion of macroscopic objects.
- **HS-ETS1.A.1:** 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.
  HS-ETS1.C.1: 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.

Science and engineering practices (SEPs)

Asking questions and defining problems: Students progress to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.

Developing and using models: Students progress to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

Using mathematics and computational thinking: Students progress 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.

Constructing explanations and designing solutions: Students progress to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

Crosscutting concepts (CCCs)

Crosscutting concept	Unit implementation
Cause and effect (Mechanism and explanation): Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.	Students examine the cause and effect relationships between forces and motion.

Systems and system models: Defining the system under study—specifying its boundaries and making explicitly a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.	Students use mathematical models to analyze and predict the motion of objects.
Structure and function: The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.	Students use Newton's laws of motion to analyze the structure and function of bridge designs.
Stability and change: For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.	Students apply Newton's laws of motion to understand how forces impact the stability of systems and structures.

Unit 2: Force pairs and momentum (link to unit)

Performance expectations

- **HS-PS2-2**: Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.
- **HS-PS2-3**: Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.

Disciplinary core ideas (DCIs)

- **HS-PS2.A.2:** Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object.
- **HS-PS2.A.3:** If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system.
- **HS-ETS1.B:** When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.

Science and engineering practices (SEPs)

Asking questions and defining problems: Students progress to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.

Developing and using models: Students progress to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

Using mathematics and computational thinking: Students progress 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.

Constructing explanations and designing solutions: Students progress to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

Crosscutting concepts (CCCs)

Crosscutting concept	Unit implementation
Cause and effect (Mechanism and explanation): Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.	Students examine the cause and effect relationship between momentum and forces.
Systems and system models: Defining the system under study—specifying its boundaries and making explicitly a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.	Students apply Newton's third law to construct and evaluate models that depict force pairs.
Structure and function: The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.	Students assess the structure and function of real-world rescue cushions to design and refine a device that minimizes the force on a macroscopic object during a collision
Stability and change: For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.	Students examine how forces contribute to the stability of a system and cause changes in momentum.

Unit 3: Gravitation (link to unit)

Performance expectations

- **HS-PS2-1:** Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.
- **HS-PS2-4:** Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.
- **HS-ESS1-4**: Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.

Disciplinary core ideas (DCIs)

- **HS-PS2.A.1:** Newton's second law accurately predicts changes in the motion of macroscopic objects.
- **HS-PS2.B.1:** Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects.
- **HS-ESS1.B.1**: Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system.

Science and engineering practices (SEPs)

Analyzing and interpreting data: Students progress to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

Using mathematics and computational thinking: Students progress 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.

Constructing explanations and designing solutions: Students progress to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

Engaging in argument from evidence: Students progress 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.

Crosscutting concepts (CCCs)

Crosscutting concept	Unit implementation
Patterns: Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.	Students use Kepler's laws to explain the patterns observed in planetary orbits.
Cause and effect (Mechanism and explanation): Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.	Students examine the cause and effect relationship between gravitational force, mass, and distance.
Stability and change: For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.	Students examine how a body can remain in a stable orbit while constantly changing its velocity.

Unit 4: Electrostatics (link to unit)

Performance expectations

- **HS-PS2-4:** Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.

Disciplinary core ideas (DCIs)

- **HS-PS2.B.1:** Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects.
- **HS-PS2.B.2:** Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.
- **HS-PS2.B.3:** 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.

Science and engineering practices (SEPs)

Developing and using models: Students progress to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

Planning and carrying out investigations: Students progress to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.

Using mathematics and computational thinking: Students progress 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.

Constructing explanations and designing solutions: Students progress to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

Engaging in argument from evidence: Students progress 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.

Crosscutting concepts (CCCs)

Crosscutting concept	Unit implementation
Patterns: Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.	Students identify patterns in the behavior of charged objects.
Cause and effect (Mechanism and explanation): Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.	Students analyze the cause and effect relationship behind static electricity and electric charge polarization.
Energy and matter (Flows, cycles, and conservation): Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.	Students explore how electric charge in matter results from an imbalance of protons and electrons.

Unit 5: Energy (link to unit)

Performance expectations (PEs)

- **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.
- **HS-PS3-2:** Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects).
- **HS-PS3-3:** Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.
- **HS-PS3-5:** Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.

Disciplinary core ideas (DCIs)

- **HS-PS3.A.2:** Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.
- **HS-PS3.A.3:** At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.
- **HS-PS3.A.4:** 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.B.1:** Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.
- **HS-PS3.B.2:** Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- **HS-PS3.B.3:** Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
- **HS-PS3.B.4:** The availability of energy limits what can occur in any system.
- **HS-PS3.C.1:** When two objects interacting through a field change relative position, the energy stored in the field is changed.

- **HS-PS3.D.1:** Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.
- **HS-ETS1.A:** 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.

Science and engineering practices (SEPs)

- **Developing and using models**: Students progress to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.
- **Using mathematics and computational thinking:** Students progress 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.
- **Constructing explanations and designing solutions:** Students progress to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.
- **Engaging in argument from evidence:** Students progress 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.

Crosscutting concepts (CCCs)

Crosscutting concept	Unit implementation
Structure and function: The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.	Students design a roller coaster and ensure that the structure and function of the track meets specific requirements and constraints.
Systems and system models: Defining the system under study—specifying its boundaries and making explicitly a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.	Students use models to show the transfer and transformation of energy within systems, and to illustrate energy conservation.
Energy and matter (Flows, cycles, and conservation): Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.	Students evaluate the transfer and transformation of energy in various systems.

Unit 6: Electromagnetics (link to unit)

Performance expectations (PEs)

- **HS-PS2-5:** Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.
- **HS-PS3-3:** Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

Disciplinary core ideas (DCIs)

- **HS-PS2.B.2:** Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.
- **HS-PS3.A.1:** “Electrical energy” may mean energy stored in a battery or energy transmitted by electric currents.
- **HS-PS3.A.3:** At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.
- **HS-ESS3.A.2:** All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors.

Science and engineering practices (SEPs)

- **Developing and using models**: Students progress to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.
- **Constructing explanations and designing solutions:** Students progress to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.
- **Engaging in argument from evidence:** Students progress 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.

Crosscutting concepts (CCCs)

Crosscutting concept	Unit implementation
Cause and effect (Mechanism and explanation): Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.	Students analyze how voltage leads to current, how magnetic fields exert forces on currents, and how changing magnetic fields induce electricity.
Energy and matter (Flows, cycles, and conservation): Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.	Students examine energy conservation, including electrical potential energy, energy conversion in motors, and the transformation of kinetic energy into electricity.
Structure and function: The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.	Students examine how the design of solenoids, coils, motors, and generators influences the behavior of electric and magnetic fields and their applications.

Unit 7: Electromagnetic radiation (link to unit)

Performance expectations (PEs)

- **HS-PS4-1:** Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.
- **HS-PS4-2:** Evaluate questions about the advantages of using digital transmission and storage of information.
- **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.
- **HS-PS4-4:** Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.
- **HS-PS4-5:** Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.
- **HS-ESS2-2**: Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.
- **HS-ESS2-4:** Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.
- **HS-ESS3-6:** Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.

Disciplinary core ideas (DCIs)

- **HS-PS3.D.2:** Solar cells are human-made devices that likewise capture the Sun's energy and produce electrical energy
- **HS-PS4.A.1:** The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing.
- **HS-PS4.A.2:** Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.
- **HS-PS4.A.3:** 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.
- **HS-PS4.B.1:** Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features.
- **HS-PS4.B.2:** When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells.

- **HS-PS4.B.3:** Photoelectric materials emit electrons when they absorb light of a high-enough frequency.
- **HS-PS4.B.4:** Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities.
- **HS-PS4.C.1:** Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them.
- **HS-ESS1.A.2:** The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.
- **HS-ESS2.A.1:** Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.
- **HS-ESS2.D.1:** The foundation for Earth's global climate systems is the electromagnetic radiation from the Sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.
- **HS-ESS2.D.3:** Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.

Science and engineering practices (SEPs)

Asking questions and defining problems: Students progress to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.

Developing and using models: Students progress to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

Planning and carrying out investigations: Students progress to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.

Analyzing and interpreting data: Students progress to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

Constructing explanations and designing solutions: Students progress to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

Engaging in argument from evidence: Students progress 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.

Crosscutting concepts (CCCs)

Crosscutting concept	Unit implementation
Patterns: Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.	Students identify patterns among properties of the different types of EM radiation.
Cause and effect (Mechanism and explanation): Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.	Students examine how human activities can disrupt feedback loops that keep Earth's systems stable. For example, increased carbon emissions enhance the greenhouse effect.
Systems and system models: Defining the system under study—specifying its boundaries and making explicitly a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.	Students utilize models to illustrate how EM radiation interacts with various Earth systems.
Energy and matter (Flows, cycles, and conservation): Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.	Students investigate how EM radiation interacts with matter in processes such as blackbody radiation, atmospheric scattering, and the photoelectric effect.
Structure and function: The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.	Students evaluate the function of various technologies that enable the use of EM radiation for electricity generation, communication, and space exploration.
Stability and change: For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.	Students analyze how the energy transferred by EM radiation drives stability and change in Earth systems.

Unit 8: Nuclear physics (link to unit)

Performance expectations

- **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.
- **HS-ESS1-1:** Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation.
- **HS-ESS1-3:** Communicate scientific ideas about the way stars, over their life cycle, produce elements.
- **HS-ESS1-6:** Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history.

Disciplinary core ideas (DCIs)

- **HS-PS1.C.1:** Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process.
- **HS-PS1.C.2:** 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.
- **HS-ESS1.A.1:** The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years.
- **HS-ESS1.A.4:** Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.
- **HS-PS3.D.4:** Nuclear fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation.

Science and engineering practices (SEPs)

Developing and using models: Students progress to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

Using mathematics and computational thinking: Students progress 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.

Analyzing and interpreting data: Students progress to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

Constructing explanations and designing solutions: Students progress to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

Crosscutting concepts (CCCs)

Crosscutting concept	Unit implementation
Systems and system models: Defining the system under study—specifying its boundaries and making explicitly a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.	Students utilize models of nuclear changes to explain what happens during nuclear decay and nuclear reactions.
Energy and matter: Flows, cycles, and conservation. Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.	Students evaluate the mass loss that occurs during nuclear reactions to explain why fission and fusion release large amounts of energy.
Stability and change: For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.	Students investigate how radioisotopes undergo nuclear changes to become stable.
Patterns: Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.	Students recognize patterns in the decay rates of radioisotopes and use the concept of half-life to make predictions about the remaining quantity of a substance over time, the age of geological and archaeological samples, and the stability of different isotopes.