KANSAS SCIENCE STANDARDS

High School Physics

Unpacked Standards

KANSAS STATE DEPARTMENT OF EDUCATION

Kansas leads the world in the success of each student.

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Overview

Purpose of the Tool

The science unpacked standards serve as a tool for teachers and school leaders to provide clarity and consistency around implementing the Kansas State Science Standards.

This tool removes the need for teachers to individually "unpack" each standard, and instead provides key experiences, ideas, and concepts to support the work of standards alignment. This tool intentionally breaks down each standard into the three dimensions of science and engineering practices, disciplinary core ideas, and cross cutting concepts to promote three dimensional instruction and assessment.

There is a need for teachers to intentionally work with and make sense of standards. for each standard, it is encouraged to use the "Student-Standard Alignment Tool" on page 10 to intentionally plan for how the standards can be aligned to the students in each unique class. This tool was developed as a way to incorporate analysis of the students' interests and abilities.[1]

The organization of this document follows the recommended scope and sequence that may be found in the Science Graduation Guidance High School Science Scope and Sequence.[2]

The information for this document came from three locations:

- Disciplinary Core Idea Appendix[1]
- Cross Cutting Concepts Appendix[3]
- Science and Engineering Appendix[3]

Kansas Science Standards

The Kansas State standards reflect what students should know and be able to do at each grade level. We do not recommend prioritizing standards at the exclusion of other standards. High quality instruction includes teaching **all standards for all students** at the appropriate depth and rigor and includes reteaching standards that students have not mastered.[4]

The Next Generation Science Standards (NGSS) standards document and its appendices are the board adopted standards and should supersede this tool. This tool is intended to provide an outline of the vertical alignment of all three dimensions of each standard in this course and to provide clarity in expectations of each standard to ensure appropriate rigor of content.

Kansas NGSS are three-dimensional standards. The Performance Expectation (PE) and its supporting elements are considered the standard. Each standard consists of a Science and Engineering Practice (SEP), a Disciplinary Core Idea (DCI), and a Cross Cutting Concept (CCC). Science is a multi-dimensional discipline and all three dimensions must be considered and taught. Throughout this document, the vertical alignment, K-12, of each

1 Guidance to Leveraging Student Identity and Interests. https://docs.google.com/document/d/1N2ciKuxcglyEhD4s1RwmO_GBvjsLv2dAwrqFFI8JFTY/edit

2 2023 Science HS Scope and Sequence Guidance. https://community.ksde.gov/LinkClick.aspx?fileticket=wmQyOpyeCBs%3d&tabid=5675&mid=13857

3 APPENDIX F – Science and Engineering Practices in the NGSS – April 2013 (nextgenscience.org). https://www.nextgenscience.org/sites/default/files/Appendix%20F%20%20Science%20and%20Engineering%20Practices%20in%20the%20NGSS%20-%20FINAL%20060513.pdf

4 Addressing the Prioritization of Standards, Fact Sheet https://www.ksde.gov/LinkClick.aspx?fileticket=Z5tBLSYTR9k%3D&tabid=472&portalid=0&mid=4744

dimension is provided for every single standard. The full appendix for the SEPs, DCIs[5], and CCCs were used to create this document.

Unpacked Science Standards

The KSDE science team has unpacked each standard for the 3-dimensions of content. There should not be an expectation for an individual teacher to do the work of unpacking standards in science, but instead to engage deeply with the unpacked science standards to consider how to best plan instruction and assessment of the students in their classrooms. Below is an overview of the process used to systematically identify the key ideas, experiences, and concepts a student needs to show mastery of a standard.

1. Identify the Standards
    - Performance Expectation (PE) and its supporting elements are considered the standard.
        - Each standard consists of a Science and Engineering Practice (SEP), a Disciplinary Core Idea (DCI), and a Cross Cutting Concept (CCC).
        - Students need access to each of the three dimensions of the standard to be successful
    - The standards have been arranged into Standards Bundles that are aligned to KSDE's 2023 Science HS Scope and Sequence Guidance
2. Closely examine **vertical alignment** of the elements of the standard.
    - For each dimension of the standard (DCI, SEP, CCC) the elements from grades K-8 that specifically build towards each specific high school standard have been included in this document.
        - For the DCI elements, the foundational concepts that bridge the gap between prior grade level standards and the grade 9-12 standard were identified as the key information that must be taught before reaching the intent of the standard.
        - For the SEP and CCC dimensions, the differences between prior grade level elements and the 9-12 elements were identified.
3. Determine the key experiences, ideas, and concepts necessary to show mastery
    - Only content that is explicitly indicated in the standard (in the performance expectation and/or defined elements) is included and expected of students.
    - Each standard has key experiences, ideas, and concepts that are necessary to meet the full standard.
        - The key experiences are aligned to the Science and Engineering Practices (SEPs).
        - The key ideas are aligned to the Disciplinary Core Ideas (DCIs).
        - The key concepts are aligned to the Cross Cutting Concepts (CCCs).
4. Identify any additional information needed to understand the unpacked standard
    - This could include decisions that were made about what to include and/or not include in the key experiences, ideas, or concepts.
    - This could include clarification around the intention of the standard as determined during the unpacking process
    - This could include clarification needed

Note: Engineering and Technology Standards (ETS)

ETS are included in NGSS, however each is explicitly tied to an additional performance expectation aligned to either life, physical, or earth and space science and are not intended to be taught in isolation.

The ETS standards were not unpacked in this document. However, components of engineering design were considered when unpacking standards that are linked to ETS and are included in multiple SEPs.

5 Disciplinary Core Ideas in the Next Generation Science Standards (NGSS) Final Release https://www.nextgenscience.org/sites/default/files/Handout%2004%20-%20NSTA%20DCIs%20Matrix.pdf

Recommended High School Physics Standards Alignment

The graduation requirements outlined by the Kansas Department of Education state that students should earn three credits in the areas of science that include concepts of Life Science (LS), Physical Science (PS) and Earth/ Space Science (ESS). The intent is that all the standards in these areas are mapped to courses at the local level and KSDE does not dictate which courses are required and we recognize that the scope and sequence of courses vary greatly across the state.

Historically across the nation a sequence including the Physics, Biology, and Chemistry has been identified as the most common. for this reason we have bundled the high school standards to align to these three courses and incorporated the Earth and Space standards into discipline courses where it best aligns. The standards included in this document would be most commonly associated with the introductory course called "Physics" with course code 03151.

> Note: This recommendation for physics is aligned to the NGSS physical science standards and the standards include clear assessment boundaries that support physics for all students. For example, most standards are limited to 1-dimensional motion, basic algebraic expressions, computations, and manipulations, and simple systems. Many school systems use "physics" as an advanced science course that goes beyond the expectations of the NGSS standards. If physics is considered an advanced science course and goes beyond the expectations of the NGSS the scope and sequence below could be used in a "physical science" class

We recognize that student choice and agency is important and as such intend for the recommended standards' bundles to only serve as guidance while making decisions at the local level.

The shaded area below shows an overview of the recommended physics standards bundles.

Physics (03151) or Physical Science (03159)

ONE DIMENSIONAL MOTION

HS-PS2-1

HS-PS2-2

HS-PS2-3

GRAVITY AND ORBITS

HS-PS2-4

HS-ESS1-4

HS-ESS1-6

EARTH'S SURFACE AND INTERIOR PROCESSES

HS-ESS2-3

HS-ESS2-1

HS-ESS1-5

ENERGY CONVERSION

HS-PS3-2

HS-PS3-3

ELECTRICITY AND MAGNETISM

HS-PS2-5

HS-PS3-5

CLIMATE CHANGE

HS-PS3-1

HS-ESS2-4

HS-ESS3-1

HS-ESS3-4

HS-ESS3-5

HS-ESS3-6

ELECTROMAGNETIC RADIATION AND TECHNOLOGY

HS-PS4-1

HS-PS4-2

HS-PS4-3

HS-PS4-4

HS-PS4-5

Student Standard Alignment Process

(Analyze Students' Interests and Identities.[6])

The standards are the expectation for every student in the state of Kansas. However, we acknowledge that Kansas students are a diverse population. Teachers should think intentionally about how the ideas and experiences that students bring to the classroom relate to the science standards in order to plan for the unique students in your classroom.

Question	Ideas and Experiences
What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?	
Where are students using and experiencing these ideas, practices, and concepts outside of the classroom?	
What questions may students have related to these ideas about how the world works?	
What scaffolding might my students need to fully understand this particular standard?	
What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?	

6 https://docs.google.com/document/d/1N2ciKuxcglyEhD4s1RwmO_GBvjsLv2dAwrqFFI8JFTY/edit

Kansas Standards for Science

BUNDLE: One Dimensional Motion

Standards included:

HS-PS2-1
HS-PS2-2
HS-PS2-3

FOCUS SEPs:

Analyzing And Interpreting Data
Constructing Explanations and Designing Solutions
Using Mathematics and Computational Thinking

FOCUS DCIs:

PS2.A	Forces and Motion
PS3.A	Definitions of Energy
ETS1.A	Defining and Delimiting an Engineering Problem
ETS1.C	Optimizing the Design Solution

FOCUS CCCs:

Cause and Effect
Systems and System Models

HS-PS2-1

Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. *[Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object sliding down a ramp, or a moving object being pulled by a constant force.*] [**Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.**]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Analyzing and Interpreting Data

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships. • Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships. • Distinguish between causal and correlational relationships in data. • Analyze and interpret data to provide evidence for phenomena. • Consider limitations of data analysis (e.g., measurement error), and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials). • Analyze and interpret data to determine similarities and differences in findings.
Grades 3-5	• Represent data in tables and/or various graphical displays (bar graphs, pictographs and/or pie charts) to reveal patterns that indicate relationships. • Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics, and/or computation. • Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings.
Grades K-2	• Record information (observations, thoughts, and ideas). • Use and share pictures, drawings, and/or writings of observations. • Use observations (firsthand or from media) to describe patterns and/or relationships in the natural and designed world(s) in order to answer scientific questions and solve problems. • Compare predictions (based on prior experiences) to what occurred (observable events).

9-12 GRADE LEVEL ELEMENT(S)

- Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.

What ideas or skills are truly unique to this grade band?

- Make a valid and reliable claim based on data analysis
- Using computational or mathematical models to analyze data

Key experiences students need access to in order to be successful:

- Organize data based on net force, mass, and acceleration
  - Data organization can include: tables, graphs, charts, vector drawings, etc.

- Analyze data to identify patterns
- Use the analyzed data as evidence to make a scientific claim about the relationship between force, mass, and acceleration
- Use reasoning to explain how the analyzed data supports the causal relationships between force, mass, and acceleration for a single object
- Use reasoning to explain how the analyzed data supports a correlational relationship between objects of different masses.
    - i.e., the same force on the two objects will result in different accelerations
- Explain how the data supports the law that all macroscopic objects will follow Fnet =m*a

TARGET DISCIPLINARY CORE IDEA PROGRESSION

PS2.A: Forces and Motion

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. [MS-PS2-2] • All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared. [MS-PS2-2]
Grades 3-5	• Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object's speed or direction of motion. (Boundary: Qualitative and conceptual, but not quantitative addition of forces are used at this level.) [3-PS2-1] • The patterns of an object's motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it. (Boundary: Technical terms, such as magnitude, velocity, momentum, and vector quantity, are not introduced at this level, but the concept that some quantities need both size and direction to be described is developed.) [3-PS2-2]
Grades K-2	• Pushes and pulls can have different strengths and directions. [KPS2-1], [K-PS2-2] • Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. [K-PS2-1], [K-PS2- 2

9-12 GRADE LEVEL ELEMENT(S)

- Newton's second law accurately predicts changes in the motion of macroscopic objects.

Foundational concepts necessary for success that are not covered in previous grade bands:

- Change in motion of an object is always in the direction of the net force
- Using Newton's second law, F_{net}= m*a, to calculate the net force on an object
- Acceleration is a rate of change in velocity over time.
- Newton's laws of motion are only applicable to macroscopic objects
- Newton's laws of motions are only applicable at speeds much slower than the speed of light.

Key ideas that students need to apply in order to be successful:

- Use Newton's second law to calculate for each of the variables
- Describe the relationship between force, mass, and acceleration in Newton's second law

- Identify how changing the net force on an object will change the acceleration of the object
- Identify that objects with a larger mass will require more force to accelerate at the same rate as an object with less mass
- Identify that gravity is a constant acceleration because the ratio of force to mass remains constant for all objects.

TARGET CROSS CUTTING CONCEPT PROGRESSION

Cause and Effect

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.
Grades 3-5	• Cause and effect relationships are routinely identified, tested, and used to explain change. • Events that occur together with regularity might or might not be a cause and effect relationship.
Grades K-2	• Events have causes that generate observable patterns. • Simple tests can be designed to gather evidence to support or refute student ideas about causes.

9-12 GRADE LEVEL ELEMENT(S)

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

What ideas or concepts are truly unique to this grade band?

- Empirical evidence
  - Empirical evidence is information gathered directly from observation or experimentation
- Distinguishing between a correlational relationship or a specific cause and effect based on the evidence.

Key concepts students need access to in order to be successful:

- Gather and analyze empirical evidence from investigations relating to force, mass, and acceleration
- Have opportunities to analyze provided evidence relating to net force, mass, and acceleration
- Use the evidence to make a claim about at least one of the relationships based on Fnet=ma
  - Changing net force will change the acceleration of an object
  - Changing the acceleration of an object will change the net force
  - Two objects with different masses at the same acceleration will have different amounts of net force
- Use reasoning to explain how the analyzed data supports the causal relationships between force, mass, and acceleration for a single object
- Use reasoning to explain how the analyzed data supports a correlational relationship between objects of different masses.
  - i.e., the same net force on the two objects will result in different rates of acceleration

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

HS-PS2-2

Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. [*Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.*] [**Assessment Boundary: Assessment is limited to systems of two macroscopic bodies moving in one dimension.**]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Using Mathematics and Computational Thinking

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends. • Use mathematical representations to describe and/or support scientific conclusions and design solutions. • Create algorithms (a series of ordered steps) to solve a problem. • Apply mathematical concepts and/or processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific and engineering questions and problems.
Grades 3-5	• Organize simple data sets to reveal patterns that suggest relationships.
Grades K-2	• Decide when to use qualitative vs. quantitative data. • Use counting and numbers to identify and describe patterns in the natural and designed world(s). • Describe, measure, and/or compare quantitative attributes of different objects and display the data using simple graphs.

9-12 GRADE LEVEL ELEMENT(S)

- Use mathematical representations of phenomena to describe explanations.

What ideas or skills are truly unique to this grade band?

- Using mathematical representations of phenomena.

Key experiences students need access to in order to be successful:

- Use p=mv as a mathematical representation of the momentum of an object.
- Use the sum of initial or final momentum of the objects in a system to define the total momentum of the system
- Mathematically describe the change in momentum of each object in a system after interacting.
- Use the initial and final momentum of the system (before and after interacting) to support the claim that total momentum is constant without outside force.

TARGET DISCIPLINARY CORE IDEA PROGRESSION

PS2.A: Forces and Motion

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law). [MS-PS2-1] • The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. [MS-PS2-2] • All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared. [MSPS2-2]
Grades 3-5	• Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object's speed or direction of motion. (Boundary: Qualitative and conceptual, but not quantitative addition of forces are used at this level.) [3-PS2-1] • The patterns of an object's motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it. (Boundary: Technical terms, such as magnitude, velocity, momentum, and vector quantity, are not introduced at this level, but the concept that some quantities need both size and direction to be described is developed.) [3-PS2-2]
Grades K-2	• Pushes and pulls can have different strengths and directions. [KPS2-1], [K-PS2-2] • Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. [K-PS2-1], [K-PS2- 2]

9-12 GRADE LEVEL ELEMENT(S)

- Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object.
- If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system.

Foundational concepts necessary for success that are not covered in previous grade bands:

- Momentum (p) is mass in motion (p = m*v) in one dimension only.
- A massive object with a small magnitude of velocity can have the same momentum as a less massive object with a larger magnitude of velocity.
- The total momentum of a system is the sum of the momentum of the objects in the system
- In a collision both objects apply a force of equal magnitude for an equal of time on each other
- When observing a system of two interacting objects you need to define the system vs. surroundings and identify components and initial and final conditions.
- With no external forces acting on a system, there is no change in momentum.
- When defining a one-dimensional system, the observer needs to define a frame of reference for all measurements.
- Interactions within the system are defined as internal, interactions with objects outside of the system are defined as external.

Key ideas that students need to apply in order to be successful:

- If there is no outside force acting on the system then total momentum of the system will remain constant.
- When defining the system, the boundaries of the system should include that two objects in constant motion have no net force acting on them.
- Describe that within the system of two interacting objects, in order to maintain a constant total momentum, if one object's momentum changes there must be an equal and opposite change in the other.
- If an outside force acts on the system changing the total momentum of the objects, then there must be an equal and opposite change in momentum in an object outside of the system

TARGET CROSS CUTTING CONCEPT PROGRESSION

Systems and System Models

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. • Models can be used to represent systems and their interactions - such as inputs, processes and outputs - and energy, matter, and information flows within systems. • Models are limited in that they only represent certain aspects of the system under study.
Grades 3-5	• A system is a group of related parts that make up a whole and can carry out functions its individual parts cannot. • A system can be described in terms of its components and their interactions.
Grades K-2	• Objects and organisms can be described in terms of their parts. • Systems in the natural and designed world have parts that work together.

9-12 GRADE LEVEL ELEMENT(S)

- When investigating or describing a system, the boundaries and initial conditions of the system need to be defined.

What ideas or concepts are truly unique to this grade band?

- Defining boundaries and initial conditions of the system
- Identify objects as a part of the surroundings that may interact with the system
- Analyzing initial and final conditions of the system
- Investigation of systems

Key concepts students need access to in order to be successful:

- Describe a system of interacting objects in motion
- Identify the initial momentum of each object in the system (initial condition)
- Identify the initial total momentum of the system
- Analyze the final momentum of the system to determine if an outside force acted on the system
- Identify what change in momentum exists in the surroundings if there is a change in momentum within the system

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

HS-PS2-3

Apply science and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.* [*Clarification Statement: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.*] [**Assessment Boundary: Assessment is limited to qualitative evaluations and/or algebraic manipulations.**]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Constructing Explanations and Designing Solutions

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real world phenomena, examples, or events. • Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion. • Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process or system. • Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints. • Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and retesting.
Grades 3-5	• Use evidence (e.g., measurements, observations, Patterns) to construct or support an explanation or design a solution to a problem. • Apply scientific ideas to solve design problems. • Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution.
Grades K-2	• Use tools and/or materials to design and/or build a device that solves a specific problem or a solution to a specific problem. • Generate and/or compare multiple solutions to a problem.

9-12 GRADE LEVEL ELEMENT(S)

- Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects.

What ideas or skills are truly unique to this grade band?

- Accounting for possible unanticipated effects.

Key experiences students need access to in order to be successful:

- Identify the need of the device to minimize the net force on an object during a collision, including criteria and constraints.
- Apply scientific reasoning to design a device that will minimize the net force on an object during a collision
- Justify design choices based on the criteria and constraints, including the trade-offs considered
  - i.e., cost, mass, maximum allowable net force during collision, needs set by user for ease of use
- Test the designed device
- Evaluate the efficacy of designed device using either qualitative or quantitative methods

- Refine device to improve performance.
- Explain why the device works or doesn't work including unanticipated results and why the refinements were made.

TARGET DISCIPLINARY CORE IDEA PROGRESSION

PS2.A: Definitions of Energy, **ETS1.A**: Defining and Delimiting an Engineering Problem, and **ETS1.C**: Optimizing the Design Solution

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law). [MS-PS2-1] • The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. [MS-PS2-2] • All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared. [MS-PS2-2]
Grades 3-5	• Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object's speed or direction of motion. (Boundary: Qualitative and conceptual, but not quantitative addition of forces are used at this level.) [3-PS2-1] • The patterns of an object's motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it. (Boundary: Technical terms, such as magnitude, velocity, momentum, and vector quantity, are not introduced at this level, but the concept that some quantities need both size and direction to be described is developed.) [3-PS2-2]
Grades K-2	• Pushes and pulls can have different strengths and directions. [KPS2-1], [K-PS2-2] • Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. [K-PS2-1], [K-PS2- 2]

9-12 GRADE LEVEL ELEMENT(S)

PS2.A: Definitions of Energy

- If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system.

ETS1.A: Defining and Delimiting an Engineering Problem

- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary)

ETS1.C: Optimizing the Design Solution

- Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (secondary)

Foundational concepts necessary for success that are not covered in previous grade bands:

- Acceleration is the change in velocity over time (a = Δv/t)
- Momentum is mass times velocity (p = m*v) in one dimensional systems.
- The total momentum of a system is the sum of the momentum of the objects in the system
- Net forces cause masses to accelerate. (a = Fnet/m)
- When observing a system of two interacting objects you need to define the system vs. surroundings and identify components and initial conditions.
- When defining a one-dimensional system, the observer needs to define the perspective being applied.
- Net forces acting on an object for a time change an object's momentum (Fnet *Δt=Δp)
- In a collision both objects apply a force of equal magnitude for an equal of time on each other

Key ideas that students need to apply in order to be successful:

- If two objects have the same mass, the object with the smaller magnitude of velocity has less momentum.
- To lessen a force, the change in velocity, and therefore momentum, needs to happen over a larger collision time period.
- To lessen the force during a collision, an object needs to reduce its magnitude of velocity prior to the collision, requiring a smaller change in momentum to stop the object.
- Reducing the mass of an object (or device) can also lessen the force from collision

Additional Information:

- This standard needs to be taught after HS-PS2-1 and HS-PS2-2.
- The ETS elements were not specifically unpacked in the DCI because the critical content of these ETS elements is covered through the SEP for this standard.

TARGET CROSS CUTTING CONCEPT PROGRESSION

Cause and Effect

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. • Cause and effect relationships may be used to predict phenomena in natural or designed systems.
Grades 3-5	• Cause and effect relationships are routinely identified, tested, and used to explain change. • Events that occur together with regularity might or might not be a cause and effect relationship.
Grades K-2	• Events have causes that generate observable patterns. • Simple tests can be designed to gather evidence to support or refute student ideas about causes.

9-12 GRADE LEVEL ELEMENT(S)

- Systems can be designed to cause a desired effect.

What ideas or concepts are truly unique to this grade band?

- Purposeful design of a system to cause a desired effect

Key concepts students need access to in order to be successful:

- Determine the desired effect
- Identify the causational relationships that could lead to the desired effect
- Design a system based on the identified relationships intended to produce the desired effect
- Test the design to determine if the results support the cause and effect relationship student identified

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

BUNDLE: Gravity and Orbits

Standards included:

HS-PS2-4
HS-ESS1-4

FOCUS SEPs:

Using Mathematics and Computational Thinking

FOCUS DCIs:

ESS1.B Earth and The Solar System
PS2.B Types of Interactions

FOCUS CCCs:

Patterns
Scale, Proportion, and Quantity

HS-PS2-4

Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects. [*Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.*] [**Assessment Boundary: Assessment is limited to systems with two objects**.]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Using Mathematics and Computational Thinking

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Use mathematical representations to describe and/or support scientific conclusions and design solutions. • Create algorithms (a series of ordered steps) to solve a problem. • Apply mathematical concepts and/or processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific and engineering questions and problems.
Grades 3-5	• Organize simple data sets to reveal patterns that suggest relationships. • Describe, measure, estimate, and/or graph quantities (e.g., area, volume, weight, time) to address scientific and engineering questions and problems.
Grades K-2	• Decide when to use qualitative vs. quantitative data. • Use counting and numbers to identify and describe patterns in the natural and designed world(s). • Describe, measure, and/or compare quantitative attributes of different objects and display the data using simple graphs.

9-12 GRADE LEVEL ELEMENT(S)

- Use mathematical representations of phenomena to describe explanations.

What ideas or skills are truly unique to this grade band?

- Mathematical representations are used to explain phenomena
- Mathematical representations can be used for explanations

Key experiences students need access to in order to be successful:

- Mathematical models (Newton's Law and Coulomb's Law) are used to represent and predict the forces between distant objects
- Students identify which mathematical formula would be best to apply to the given situation to explain the phenomena
- Students correctly use the given mathematical formulas to predict the relevant force (gravitational or electrostatic) between two objects.
- Students use the results of mathematical calculations to describe the strength of the force and if it is repulsive or attractive.
- Students use mathematical representations to predict how the force would change if one component of the system changed (mass, charge, or distance)

TARGET DISCIPLINARY CORE IDEA PROGRESSION

PS2.B: Types of Interactions

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. [MS-PS2-3] • Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass - e.g., Earth and the sun. [MS-PS2-4] • Forces that act at a distance (electric and magnetic) can be explained by fields that extend through space and can be mapped by their effect on a test object (a ball, a charged object, or a magnet, respectively). [MS-PS2-5]
Grades 3-5	• Objects in contact exert forces on each other. [3-PS2-1] • Electric, and magnetic forces between a pair of objects do not require that the objects be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other. [3-PS2- 3], [3-PS2-4] • The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center. [5-PS2-1]
Grades K-2	• When objects touch or collide, they push on one another and can change motion. [K-PS2-1]

9-12 GRADE LEVEL ELEMENT(S)

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

Foundational concepts necessary for success that are not covered in previous grade bands:

- Gravity is a force dependent on distance.
- Fields allow energy to be transferred through space.
- Magnetic fields can be caused by magnets or by electric currents.
- Electric fields can be caused by electric charges or by changing magnetic fields.
- The fields exist all around the mass (gravitational fields) or charge (electrostatic fields).

Key ideas that students need to apply in order to be successful:

- Define and describe the objects that are interacting at a distance.
- Identify the type of force (gravitational or electrostatic) existing between these objects.
- Mathematical models (Newton's Law and Coulomb's Law) are used to represent and predict the forces between distant objects.
- Gravity is dependent on distance and mass, however changing distance has a larger impact on gravitational forces.
- Coulomb's law is dependent on distance and charge, however changing distance has a larger impact on electrostatic forces.
- Differentiate that gravitational forces are always attractive, but that electrostatic forces can be described as attractive or repulsive.
- Changing distance between objects would change the energy that can be transferred through space (i.e., gravitational potential, electrical potential).

TARGET CROSS CUTTING CONCEPT PROGRESSION

Patterns

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Macroscopic patterns are related to the nature of microscopic and atomic-level structure. • Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems. • Patterns can be used to identify cause and effect relationships.
Grades 3-5	• Patterns of change can be used to make predictions. • Patterns can be used as evidence to support an explanation.
Grades K-2	• Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence.

9-12 GRADE LEVEL ELEMENT(S)

- 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.

What ideas or concepts are truly unique to this grade band?

- Patterns might be different at different scales

Key concepts students need access to in order to be successful:

- Students use mathematical modeling with enough data sets related to gravity at the macro scale to identify the pattern that the masses of the objects have a direct impact on force.
- Students use mathematical modeling with enough data sets related to electrostatics at the atomic scale to identify the pattern that the charges of two objects have a direct impact on force.
- Students use mathematical modeling for both electrostatics and gravity to identify that relative changes in distance have the same impact in both situations.
- Students use models of gravitational and electrostatic fields to predict the direction of the force that an object placed in the field would experience.

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

HS-ESS1-4

Use mathematical or computational representations to predict the motion of orbiting objects in the solar system. [*Clarification Statement: Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets and moons.*] [**Assessment Boundary: Mathematical representations for the gravitational attraction of bodies and Kepler's Laws of orbital motions should not deal with more than two bodies, nor involve calculus.**]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Using Mathematics and Computational Thinking

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Use mathematical representations to describe and/or support scientific conclusions and design solutions. • Create algorithms (a series of ordered steps) to solve a problem. • Apply mathematical concepts and/or processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific and engineering questions and problems.
Grades 3-5	• Organize simple data sets to reveal patterns that suggest relationships. • Describe, measure, estimate, and/or graph quantities (e.g., area, volume, weight, time) to address scientific and engineering questions and problems.
Grades K-2	• Decide when to use qualitative vs. quantitative data. • Use counting and numbers to identify and describe patterns in the natural and designed world(s). • Describe, measure, and/or compare quantitative attributes of different objects and display the data using simple graphs.

9-12 GRADE LEVEL ELEMENT(S)

- Use mathematical representations of phenomena to describe explanations.

What ideas or skills are truly unique to this grade band?

- Mathematical representations are used to explain phenomena
- Mathematical representations can be used for explanations

Key experiences students need access to in order to be successful:

- Describe that Newton's laws are mathematical models used to describe the gravitational forces between objects in the solar system

$$F_g = -\frac{Gm_1m_2}{d^2}$$

  - There is an equal and opposite pull between the two objects
- Identify that Kepler's laws help to explain the elliptical nature of orbiting objects in our solar system
  - Eccentricity Equation: eccentricity e = f/d, where f is the distance between foci of an ellipse, and d is the ellipse's major axis length
  - Kepler's third law: (T^2 is directly proportional to R^3, or $T^2 \propto R^3$, where T is the orbital period and R is the semi-major axis of the orbit)

- Use the mathematical models to make predictions (qualitative or quantitative) on what happens when the quantities are changed
- Describe how to determine the orbital distance based on the orbital period

Additional Information:

- The relationships found in Newton's Law of Gravity and Newton's 2nd Law can lead to Kepler's Laws

TARGET DISCIPLINARY CORE IDEA PROGRESSION

ESS1.B: Earth and The Solar System

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. [MS-ESS1-2], [MS-ESS1-3] • The solar system appears to have formed from a disk of dust and gas, drawn together by gravity. [MS-ESS1-2]
Grades 3-5	• The orbits of Earth around the sun and of the moon around Earth, together with the rotation of Earth about an axis between its North and South poles, cause observable Patterns. These include day and night; daily changes in the length and direction of shadows; and different positions of the sun, moon, and stars at different times of the day, month, and year. [5-ESS1-2]
Grades K-2	• 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.

9-12 GRADE LEVEL ELEMENT(S)

- 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.

Foundational concepts necessary for success that are not covered in previous grade bands:

- Objects orbit in elliptical Patterns
- The amount of eccentricity (how elliptical) is based on how far apart the two foci (sun and other foci) are, closer together means less eccentricity (Kepler's 1st law)
- Objects in an elliptical orbit speed up as they get closer to the sun during their orbit and slow down as they get farther away (Kepler's 2nd law)
- The amount of time an orbit of an object around the sun or other body (satellites around earth) takes is proportional to how far away the object is from the sun or other body. (Kepler's 3rd law)
- Orbits can change due to interaction with other objects
- Gravity is a force dependent on distance
- Two objects interacting will exert an equal and opposite force on each other (i.e., the sun pulls on a planet due to gravity, the planet is also pulling on the sun in the opposite direction).

Key ideas that students need to apply in order to be successful:

- Describe how relative speed can be predicted if you know an object's position on its orbital path
- Describe how changing orbital distance will change the orbital period
- Describe how changing the orbital period will change the orbital distance
- Gravity is dependent on distance and mass, however changing distance has a larger impact on

gravitational forces.
- Describe how objects with a more eccentric orbit will have greater variation in the object's speed at different locations on the path of orbit
- Explain why the smaller object orbits around the larger object even though both objects are exerting a force (pulling) on each other (Newton's 3rd law)
- Explain how both Newton's law of gravitation and Kepler's second law both support each other in the idea that planets and other bodies travel faster the closer they are to the sun

Additional Information:

- Students should not be required to identify the specific laws by name or number.

TARGET CROSS CUTTING CONCEPT PROGRESSION

Scale, Proportion, and Quantity

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. • Proportional relationships (e.g., speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes. • Scientific relationships can be represented through the use of algebraic expressions and equations.
Grades 3-5	• Natural objects and/or observable phenomena exist from the very small to the immensely large or from very short to very long time periods. • Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume.
Grades K-2	• Relative scales allow objects and events to be compared and described (e.g., bigger and smaller; hotter and colder; faster and slower). • Standard units are used to measure length.

9-12 GRADE LEVEL ELEMENT(S)

- Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).

What ideas or concepts are truly unique to this grade band?

- Predict the effect of changing a variable
- Using scientific data in calculation

Key concepts students need access to in order to be successful:

- Students use the mathematical equations to make a prediction about one variable of an orbiting object based on given known information about another variable.
- Students compare their mathematical prediction to known information about an orbiting object.
- Students use mathematical reasoning to predict relative information about an orbiting object given data for other orbiting objects.
- Example: given information about an orbiting object (distance or period) students predict its relative period or distance as compared to earth.

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

BUNDLE: Physical Earth Processes

Standards included:

HS-ESS1-5
HS-ESS1-6
HS-ESS2-1
HS-ESS2-3

FOCUS SEPs:

Constructing Explanations and Designing Solutions
Developing and Using Models
Engaging in Argument from Evidence

FOCUS DCIs:

ESS1.C	The History of Planet Earth
ESS2.A	Earth Materials and Systems
ESS2.B	Plate Tectonics and Large-Scale System Interactions
PS1.C	Nuclear Processes
PS4.A	Wave Properties

FOCUS CCCs:

Energy and Matter
Patterns
Stability and Change

HS-ESS1-5

Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks. [*Clarification Statement: Emphasis is on the ability of plate tectonics to explain the ages of crustal rocks. Examples include evidence of the ages oceanic crust increasing with distance from mid-ocean ridges (a result of plate spreading) and the ages of North American continental crust decreasing with distance away from a central ancient core of the continental plate (a result of past plate interactions).*]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Engaging in Argument from Evidence

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Compare and critique two arguments on the same topic and analyze whether they emphasize similar or different evidence and/or interpretations of facts. • Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.
Grades 3-5	• Compare and refine arguments based on an evaluation of the evidence presented. • Distinguish among facts, reasoned judgment based on research findings, and speculation in an explanation. • Construct and/or support an argument with evidence, data, and/or a model. • Use data to evaluate claims about cause and effect.
Grades K-2	• Identify arguments that are supported by evidence. • Distinguish between explanations that account for all gathered evidence and those that do not. • Analyze why some evidence is relevant to a scientific question and some is not. • Distinguish between opinions and evidence in one's own explanations.

9-12 GRADE LEVEL ELEMENT(S)

- Evaluate evidence behind currently accepted explanations or solutions to determine the merits of arguments.

What ideas or skills are truly unique to this grade band?

- Use of currently accepted explanations
- Evaluate evidence to determine if it supports or refutes a currently accepted explanation.
- Some arguments have more merit than others.

Key experiences students need access to in order to be successful:

- Need exposure to currently accepted scientific explanations related to plate tectonics.
- Analyze multiple sources of evidence to determine value to support or refute an explanation.
- Determine merits of arguments about the ages of crustal rocks based on evidentiary support for or against it.

TARGET DISCIPLINARY CORE IDEA PROGRESSION

ESS1.C: The History of Planet Earth, **ESS2.B**: Plate Tectonics and Large-Scale System Interactions, and **PS1.C**: Nuclear Processes

ESS1.C: The History of Planet Earth

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• The geologic time scale interpreted from rock strata provides a way to organize Earth's history. Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale. [MS-ESS1-4] • Tectonic processes continually generate new ocean sea floor at ridges and destroy old sea floor at trenches. [HS.ESS1.C GBE] [secondary to MS-ESS2-3].
Grades 3-5	• Local, regional, and global patterns of rock formations reveal changes over time due to earth forces, such as earthquakes. The presence and location of certain fossil types indicate the order in which rock layers were formed. [4- ESS1-1]
Grades K-2	• Some events happen very quickly; others occur very slowly, over a time period much longer than one can observe. [2-ESS1-1]

9-12 GRADE LEVEL ELEMENT(S)

- Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old.

ESS2.B: Plate Tectonics and Large-Scale System Interactions

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Maps of ancient land and water Patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided, and spread apart. [MS-ESS2-3]
Grades 3-5	• The locations of mountain ranges, deep ocean trenches, ocean floor structures, earthquakes, and volcanoes occur in Patterns. Most earthquakes and volcanoes occur in bands that are often along the boundaries between continents and oceans. Major mountain chains form inside continents or near their edges. Maps can help locate the different land and water features areas of Earth. [4-ESS2-2]
Grades K-2	• Maps show where things are located. One can map the shapes and kinds of land and water in any area. [2-ESS2-2]

9-12 GRADE LEVEL ELEMENT(S)

- Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust. [ESS2.B Grade 8 GBE] (secondary)

PS1.C: Nuclear Processes

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• N/A
Grades 3-5	• N/A
Grades K-2	• N/A

9-12 GRADE LEVEL ELEMENT(S)

- Spontaneous radioactive decay follows a characteristic exponential decay law. Nuclear lifetime s allow radiometric dating to be used to determine the ages of rocks and other materials. (secondary)

Foundational concepts necessary for success that are not covered in previous grade bands:

- Rocks have been formed over billions of years. Some rocks are much older (continental rocks, closer to the center of the plate) and some rocks are much younger (oceanic crust) Note: continental rocks further from the center of the plate are younger than central rocks but older than oceanic crust.
- The location of crustal rocks can be used to predict relative ages of crust.
- Radioactive isotopes decay at a predictable rate called half life.
- Half life can be used to predict ages of objects such as rocks due to the ratio of atoms currently in a sample (note: no need to do half life calculations).
- The oceanic crust is spreading out from the ridges in the ocean floor, creating new rock at the site of the ridge.

Key ideas that students need to apply in order to be successful:

- Use location of crustal rocks to predict the relative age of the rocks and therefore describe the likely movement of those rocks over time.
- Use data about the radioactive age of rocks as evidence of plate movement and the cycling of rock matter at plate boundaries
- Describe how a given continental or ocean-floor landform can be used as evidence of the interaction between tectonic plates.
- Use the location of earthquake and volcanic activity as evidence of on-going plate interactions.

TARGET CROSS CUTTING CONCEPT PROGRESSION

Patterns

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems. • Patterns can be used to identify cause and effect relationships. • Graphs, charts, and images can be used to identify patterns in data.
Grades 3-5	• Similarities and differences in patterns can be used to sort, classify, communicate and analyze simple rates of change for natural phenomena and designed products. • Patterns can be used as evidence to support an explanation.
Grades K-2	• Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence.

9-12 GRADE LEVEL ELEMENT(S)

- Empirical evidence is needed to identify Patterns.

What ideas or concepts are truly unique to this grade band?

- Empirical evidence
  - Empirical evidence is information gathered directly from observation or experimentation
- Empirical evidence is necessary to determine the relevance of the pattern in explaining a phenomenon

Key concepts students need access to in order to be successful:

- Access to data about crust at plate boundaries, mid ocean ridges, and the middle of continental plates.
- Work with data about the age of crust at different locations to identify patterns in location of young vs older crust.
- Work with data about the age of crust at different locations to identify observable landform structures at each location to help explain the pattern of age.

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

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. [*Clarification Statement: Emphasis is on using available evidence within the solar system to reconstruct the early history of Earth, which formed along with the rest of the solar system 4.6 billion years ago. Examples of evidence include the absolute ages of ancient materials (obtained by radiometric dating of meteorites, moon rocks, and Earth's oldest minerals), the sizes and compositions of solar system objects, and the impact cratering record of planetary surfaces.*]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Constructing Explanations and Designing Solutions

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena. • Construct an explanation using models or representations. • Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) 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. • Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real world phenomena, examples, or events. • Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion.
Grades 3-5	• Construct an explanation of observed relationships (e.g., the distribution of plants in the backyard). • Use evidence (e.g., measurements, observations, Patterns) to construct or support an explanation or design a solution to a problem. • Identify the evidence that supports particular points in an explanation.
Grades K-2	• Make observations (firsthand or from media) to construct an evidence-based account for natural phenomena.

9-12 GRADE LEVEL ELEMENT(S)

- Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.

What ideas or skills are truly unique to this grade band?

- Use reasoning to link evidence to the claim
- Assessing the data and reasoning for the extent of support of an explanation or conclusion

Key experiences students need access to in order to be successful:

- Experience gathering different pieces of evidence from ancient earth's materials and meteorites and sorting them into useful and not useful in support of the age of the earth.
- Experience gathering different pieces of evidence from other bodies in the solar system and sorting them into useful and not useful in support of early earth's history.
- Write an explanation or claim of earth's formation and early history .
- Use reasoning to explain how each piece of chosen evidence supports the claim.

TARGET DISCIPLINARY CORE IDEA PROGRESSION

ESS1.C: The History of Planet Earth and **PS1.C**: Nuclear Processes

ESS1.C: The History of Planet Earth

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• The geologic time scale interpreted from rock strata provides a way to organize Earth's history. Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale. [MS-ESS1-4] • Tectonic processes continually generate new ocean sea floor at ridges and destroy old sea floor at trenches. [HS.ESS1.C GBE] [secondary to MS-ESS2-3].
Grades 3-5	• Local, regional, and global patterns of rock formations reveal changes over time due to earth forces, such as earthquakes. The presence and location of certain fossil types indicate the order in which rock layers were formed. [4- ESS1-1]
Grades K-2	• Some events happen very quickly; others occur very slowly, over a time period much longer than one can observe. [2-ESS1-1]

9-12 GRADE LEVEL ELEMENT(S)

- Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history.

PS1.C: Nuclear Processes

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• N/A
Grades 3-5	• N/A
Grades K-2	• N/A

9-12 GRADE LEVEL ELEMENT(S)

- Spontaneous radioactive decay follows a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials. (secondary)

Foundational concepts necessary for success that are not covered in previous grade bands:

- There is no (or limited) remaining rock record of earth's earliest history due to earth's active geologic processes.
- Other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years.
- The moon does not have active geologic processes, therefore the rocks on the surface are either from the moon's early history or have been added to the surface through impacts.
- Radioactive decay follows a predictable pattern

Key ideas that students need to apply in order to be successful:

- Radiometric dating can be used on rocks from earth, the moon, asteroids, and meteorites to determine the age of the rocks.
- Radiometric dating of rocks from various solar system sources has indicated that the age of the solar system is 4.6 billion years old.
- Earth is a terrestrial planet because it formed close enough to the sun for its core to remain hot metal.
- The oldest rocks found on Earth have been dated 4.4 billions years old, which indicates the age of Earth's solid crust.
- Most of earth's surface rocks are younger than the earth itself.
- Material from the asteroid belt may be used as evidence of earth's formation if samples can provide information about planetary core materials.
- Samples of moon rock indicate that the composition of the lunar maria is similar to igneous (lava) rocks from earth which is evidence that the moon was formed from early earth's materials.
- The rocks from the moon's craters have been studied and used as evidence that some of earth's craters are the result of objects colliding with earth's surface
- The evidence of craters on the moon and other terrestrial planets can be used to infer that Earth would also have had many impact craters in its early history
- The active geologic processes (such as volcanism, plate tectonics, and erosion) of earth have erased evidence of many of these craters.

TARGET CROSS CUTTING CONCEPT PROGRESSION

Stability and Change

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale. • Small changes in one part of a system might cause large changes in another part. • Stability might be disturbed either by sudden events or gradual changes that accumulate over time.
Grades 3-5	• Change is measured in terms of differences over time and may occur at different rates. • Some systems appear stable, but over long periods of time will eventually change.
Grades K-2	• Some things stay the same while other things change. • Things may change slowly or rapidly.

9-12 GRADE LEVEL ELEMENT(S)

- Much of science deals with constructing explanations of how things change and how they remain stable.

What ideas or concepts are truly unique to this grade band?

- N/A

Key concepts students need access to in order to be successful:

- Identify how earth's surface can change gradually or rapidly due to weathering and geologic activity.
- Identify how earth's history can be inferred through studying the surface of other planetary bodies that have not changed due to lack of weather and geologic activity.
- Explain how one can use ideas about nuclear decay to determine the age of a sample
- Identify how radiometric data from a rock sample can indicate how much the rock has changed and over what time period based on what is known about nuclear decay.
- Write an explanation or claim of earth's formation and early history using reasoning to explain how chosen evidence supports the claim.

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

HS-ESS2-1

Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features. [*Clarification Statement: Emphasis is on how the appearance of land features (such as mountains, valleys, and plateaus) and sea-floor features (such as trenches, ridges, and seamounts) are a result of both constructive forces (such as volcanism, tectonic uplift, and orogeny) and destructive mechanisms (such as weathering, mass wasting, and coastal erosion).*] [**Assessment Boundary: Assessment does not include memorization of the details of the formation of specific geographic features of Earth's surface.**]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Developing and Using Models

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Develop or modify a model - based on evidence – to match what happens if a variable or component of a system is changed. • Use and/or develop a model of simple systems with uncertain and less predictable factors. • Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena. • Develop and/or use a model to predict and/or describe phenomena. • Develop a model to describe unobservable mechanisms.
Grades 3-5	• Collaboratively develop and/or revise a model based on evidence that shows the relationships among variables for frequent and regular occurring events. • Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution. • Develop and/or use models to describe and/or predict phenomena.
Grades K-2	• Develop and/or use a model to represent amounts, relationships, relative scales (bigger, smaller), and/or patterns in the natural and designed world(s).

9-12 GRADE LEVEL ELEMENT(S)

- Develop a model based on evidence to illustrate the relationships between systems or between components of a system.

What ideas or skills are truly unique to this grade band?

- Use of models to show relationships between systems and components of systems, not just variables or phenomena.
- Multiple systems represented.

Key experiences students need access to in order to be successful:

- Identify the interacting components of earth's systems that can change earth's surface. These include:
  - Earth's Interior
  - Earth's surface structure (geosphere)
  - Atmosphere (wind)
  - Hydrosphere (rain, rivers, coastlines, glaciers)
- Identify the processes that change earth's surface structure
  - Build up earth's surface: plate tectonics, volcanic eruptions,
  - Wear down earth's surface: weathering, erosion, mass wasting (landslides), earthquakes
- Identify the timescale that change occurs
  - Relatively shorter timescale changes (earthquakes, volcanoes, landslides)
  - Relatively longer timescale (weathering, erosion, plate tectonics)
- Identify the spatial scale that the change occurs
  - Mountain ranges span large areas, individual volcanoes cover relatively small areas
  - Erosion can span large areas, mass wasting (landslides) cover relatively small areas
- Describe the relationships between the processes and the way these processes can create feedbacks to continue to change earth's surface.
- Describe that slower processes will have a larger spatial impact on earth's surface and faster processes will have a smaller spatial impact on earth's surfaces.

TARGET DISCIPLINARY CORE IDEA PROGRESSION

ESS2.A: Earth Materials and Systems and **ESS2.B**: Plate Tectonics and Large-Scale System Interactions

ESS2.A: Earth Materials and Systems

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms. [MS-ESS2-1] • The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future. [MS-ESS2-2]
Grades 3-5	• Rainfall helps to shape the land and affects the types of living things found in a region. Water, ice, wind, living organisms, and gravity break rocks, soils, and sediments into smaller particles and move them around. [4-ESS2-1] • Earth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth's surface materials and processes. The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather. [5-ESS2-1]
Grades K-2	• Wind and water change the shape of the land. [2-ESS2-1]

9-12 GRADE LEVEL ELEMENT(S)

- Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.

ESS2.B: Plate Tectonics and Large-Scale System Interactions

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Maps of ancient land and water Patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided, and spread apart. [MS-ESS2-3]
Grades 3-5	• The locations of mountain ranges, deep ocean trenches, ocean floor structures, earthquakes, and volcanoes occur in Patterns. Most earthquakes and volcanoes occur in bands that are often along the boundaries between continents and oceans. Major mountain chains form inside continents or near their edges. Maps can help locate the different land and water features areas of Earth. [4-ESS2-2]
Grades K-2	• Maps show where things are located. One can map the shapes and kinds of land and water in any area. [2-ESS2-2]

9-12 GRADE LEVEL ELEMENT(S)

- Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust. [ESS2.B Grade 8 GBE]

Foundational concepts necessary for success that are not covered in previous grade bands:

- Feedback effects in an ecosystem happen when changing one component of the system leads to a chain of events that cycle back to the original component causing an amplification or inhibition of the system functions.
- The oceanic crust is spreading out from the ridges in the ocean floor, creating new rock at the site of the ridge.
- Weathering is the process of the breaking down or dissolving of rocks and minerals on the surface of the Earth.
- Erosion is the geological process in which earthen materials are worn away and transported by natural forces such as wind or water.

Key ideas that students need to apply in order to be successful:

- Internal processes (i.e., volcanism, mountain building or tectonic uplift) build up Earth's surface over time.
- Surface processes (i.e., weathering and erosion) wear down Earth's surface over time.
- The creations on Earth's surface from internal processes impact surface processes, some possible examples include:
    - Mountain ranges impact weather, which impacts erosion.
    - Glaciers can cause erosion.
    - Volcanic eruptions change the area (topography) around them.
    - Earthquakes can open large crevices in surface changing erosions patterns.
    - Mass wasting (landslides) are influenced by location and weather.
- Changes to earth's surface happen at different time scales.
    - Tectonic plate movement and erosion occur over long periods of time.
    - Volcanic eruptions and earthquake changes occur rapidly.
    - Mass wasting (landslides) occurs rapidly.
- Ocean floor features only change due to internal processes such as plate tectonics and volcanic eruptions.

TARGET CROSS CUTTING CONCEPT PROGRESSION

Stability and Change

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale. • Small changes in one part of a system might cause large changes in another part. • Stability might be disturbed either by sudden events or gradual changes that accumulate over time.
Grades 3-5	• Change is measured in terms of differences over time and may occur at different rates. • Some systems appear stable, but over long periods of time will eventually change.
Grades K-2	• Some things stay the same while other things change. • Things may change slowly or rapidly.

9-12 GRADE LEVEL ELEMENT(S)

- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

What ideas or concepts are truly unique to this grade band?

- Scale of time: very short or very long
- Some system changes are irreversible

Key concepts students need access to in order to be successful:

- Data, including maps, showing time scale of different earth surface changes
- Data, including maps, showing area scale of different earth surface changes
- Maps and source documents showing or describing before and after sudden surface changes
- Sudden changes to earth's surface will seem irreversible on a human time scale

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

HS-ESS2-3

Develop a model based on evidence of Earth's interior here to describe the cycling of matter by thermal convection. [*Clarification Statement: Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Examples of evidence include maps of Earth's three-dimensional structure obtained from seismic waves, records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth's layers from high-pressure laboratory experiments.*]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Developing and Using Models

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Develop or modify a model - based on evidence – to match what happens if a variable or component of a system is changed. • Use and/or develop a model of simple systems with uncertain and less predictable factors. • Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena. • Develop and/or use a model to predict and/or describe phenomena. • Develop a model to describe unobservable mechanisms.
Grades 3-5	• Collaboratively develop and/or revise a model based on evidence that shows the relationships among variables for frequent and regular occurring events. • Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution. • Develop and/or use models to describe and/or predict phenomena.
Grades K-2	• Develop and/or use a model to represent amounts, relationships, relative scales (bigger, smaller), and/or patterns in the natural and designed world(s).

9-12 GRADE LEVEL ELEMENT(S)

- Develop a model based on evidence to illustrate the relationships between systems or between components of a system.

What ideas or skills are truly unique to this grade band?

- Use of models to show relationships between systems and components of systems, not just variables or phenomena.
- Multiple systems represented.

Key experiences students need access to in order to be successful:

- Identify the interacting components of earth's layers that can change earth's surface. These include:
  - Solid inner core
  - Liquid outer core
  - Solid (but fluid) mantle
  - Crust
- Identify the processes in earth's interior that cause the cycling of matter.
  - Thermal convection fueled by radioactive decay.
  - Changing density due to changing temperature (gravity).

    - Magnetic field caused by movement in liquid outer core.
- Describe the interactions between the layers of earth's geosphere (i.e., mantle movement causes crust movement through plate tectonics).

TARGET DISCIPLINARY CORE IDEA PROGRESSION

ESS2.A: Earth Materials and Systems, **ESS2.B**: Plate Tectonics and Large-Scale System Interactions and **PS4.A**: Wave Properties

ESS2.A: Earth Materials and Systems

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms. [MS-ESS2-1]
Grades 3-5	• Earth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth's surface materials and processes. The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather. [5-ESS2-1]
Grades K-2	• N/A

9-12 GRADE LEVEL ELEMENT(S)

- Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior.

ESS2.B: Plate Tectonics and Large-Scale System Interactions

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Maps of ancient land and water Patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided, and spread apart. [MS-ESS2-3]
Grades 3-5	• The locations of mountain ranges, deep ocean trenches, ocean floor structures, earthquakes, and volcanoes occur in Patterns. Most earthquakes and volcanoes occur in bands that are often along the boundaries between continents and oceans. Major mountain chains form inside continents or near their edges. Maps can help locate the different land and water features areas of Earth. [4-ESS2-2]
Grades K-2	• Maps show where things are located. One can map the shapes and kinds of land and water in any area. [2-ESS2-2]

9-12 GRADE LEVEL ELEMENT(S)

- The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle, providing the primary source of the heat that drives mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection.

PS4.A: Wave Properties

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. [MS-PS4-1]
Grades 3-5	• Waves of the same type can differ in amplitude (height of the wave) and wavelength (spacing between wave peaks). [4-PS4-1]
Grades K-2	• N/A

9-12 GRADE LEVEL ELEMENT(S)

- Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet. [secondary to HS-ESS2-3]

Foundational concepts necessary for success that are not covered in previous grade bands:

- Thermal convection is the transfer of heat from one place to another due to the movement of fluid.
- Earth's structure includes a hot but solid inner core, a liquid outer core, a solid mantle and crust.
- Radioactive decay produces energy
- Seismic waves are waves that travel through or over earth wave speed changes when the medium it travels through changes
- Earth has a magnetic field, the magnetic field can change polarity
- Density is temperature and pressure dependent

Key ideas that students need to apply in order to be successful:

- Identify the relative density of each layer of earth's geosphere.
- Identify the relative temperature of each layer of earth's geosphere.
- Heat in the Earth's crust and mantle comes from energy released from radioactive decay of isotopes.
- Describe how denser materials move towards the interior due to gravity.
- Describe how energy flows outward from earth's core towards earth's surface (thermal convection).
- Describe how matter can be pushed towards earth's surface as heat rises from earth's interior and when that matter cools at or near the surface.
- Matter can be cycled through the geosphere as the matter is heated (rises) and cools (sinks).
- Describe how the movement of earth's liquid outer core around the solid inner core creates a magnetic field.
- Identify how polar reversals measured at the ocean floor can be used as evidence of a changing magnetic field.
- Identify how the movement of plate tectonics can be used as evidence of thermal convection under earth's surface.
- Identify how evidence from laboratory based high pressure experiments can be used to simulate the conditions deep in earth's interior.
- Identify how seismic waves can be used to identify the composition of each layer of earth's geosphere.
- Identify how evidence from deep probe investigations can be be used to develop a model of earth's geosphere.
- Identify how historical reconstructions of earth's surface can be used to infer plate movement and therefore be used as evidence of earth's structure and mantle convection.

TARGET CROSS CUTTING CONCEPT PROGRESSION

Energy and Matter

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. • Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). • The transfer of energy can be tracked as energy flows through a designed or natural system.
Grades 3-5	• Matter flows and cycles can be tracked in terms of the weight of the substances before and after a process occurs. The total weight of the substances does not change. This is what is meant by conservation of matter. Matter is transported into, out of, and within systems. • Energy can be transferred in various ways and between objects.
Grades K-2	• Objects may break into smaller pieces, be put together into larger pieces, or change shapes.

9-12 GRADE LEVEL ELEMENT(S)

- Energy drives the cycling of matter within and between systems.

What ideas or concepts are truly unique to this grade band?

- Energy can be transferred between systems

Key concepts students need access to in order to be successful:

- Identify the forms of energy involved in cycling matter in the earth.
- Energy from radioactive decay is transferred as thermal energy to the mantle.
- Thermal energy in the mantle is used to cycle matter upwards as it is heated.
- Gravitational potential energy causes matter to cycle towards the core as it cools and becomes more dense.
- Thermal energy is transferred to mechanical energy as tectonic plates move.
- Describe how matter moves through earth's layers due to the energy transfers that are involved in earth's interior processes.

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

BUNDLE: Energy Conversion

Standards included:

HS-PS2-5
HS-PS3-2
HS-PS3-3
HS-PS3-5

FOCUS SEPs:

Constructing Explanations and Designing Solutions
Developing and Using Models
Plan and Conduct an Investigation

FOCUS DCIs:

PS2.B	Types of Interactions
PS3.A	Definitions of Energy
PS3.C	Relationship Between Energy and Forces
PS3.D	Energy in Chemical Processes
ETS1.A	Defining and Delimiting an Engineering Problem

FOCUS CCCs:

Cause and Effect
Energy and Matter

HS-PS2-5

Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current. [**Assessment Boundary: Assessment is limited to designing and conducting investigations with provided materials and tools.**]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Plan and Conduct an Investigation

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim. • Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation.
Grades 3-5	• Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered.
Grades K-2	• With guidance, plan and conduct an investigation in collaboration with peers (for K). • Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence to answer a question.

9-12 GRADE LEVEL ELEMENT(S)

- 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.

What ideas or skills are truly unique to this grade band?

- Planning design to account for:
  - Accuracy of data.
  - Reliability of measurements.
  - Limitations on precision of data.
- Refining experimental design as needed.

Key experiences students need access to in order to be successful:

- Identify the purpose of the investigation in order to effectively plan.
- Experience planning an investigation where the procedure is justified gather appropriate evidence.
- Writing procedures/directions for activities that use only the provided materials and that can be followed by anyone, not just partners or themselves.
- Experience with laboratory investigations specifically related to the DCI so that they have an idea of types of things that can reasonably be done in their specific classroom situation.
  - Investigation(s) of using electric fields to produce magnetic fields:
    - Sources of electrical energy can be placed in the circuit to create currents.
    - The shape and orientation of a wire can affect the magnetic field.
    - Detectors used to measure magnetic fields and electrical current.

- Investigation(s) of using magnetic fields to produce electrical currents.
  - The impact of the size and orientation of a magnet on strength of magnetic fields.
  - Varying amounts and shapes of wire to conduct electricity.
  - Detectors used to measure magnetic fields and electrical current.

TARGET DISCIPLINARY CORE IDEA PROGRESSION

PS2.B: Types of Interactions, **PS3.A**: Definitions of Energy

PS2.B: Types of Interactions

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. [MS-PS2-3] • Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass - e.g., Earth and the sun. [MS-PS2-4] • Forces that act at a distance (electric and magnetic) can be explained by fields that extend through space and can be mapped by their effect on a test object (a ball, a charged object, or a magnet, respectively). [MS-PS2-5]
Grades 3-5	• Objects in contact exert forces on each other. [3-PS2-1] • Electric, and magnetic forces between a pair of objects do not require that the objects be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other. [3-PS2- 3], [3-PS2-4] • The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center. [5-PS2-1]
Grades K-2	• When objects touch or collide, they push on one another and can change motion. [K-PS2-1].

9-12 GRADE LEVEL ELEMENT(S)

- Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.

PS3.A: Definitions of Energy

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed. [MS-PS3-1] • A system of objects may also contain stored (potential) energy, depending on their relative positions. [MS-PS3-2] • Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. [MS-PS3-3],[MS-PS3-4] • The term "heat" as used in everyday language refers both to thermal motion (the motion of atoms or molecules within a substance) and radiation (particularly infrared and light). In science, heat is used only for this second meaning; it refers to energy transferred when two objects or systems are at different temperatures. [secondary to MS-PS1-4] • Temperature is not a measure of energy; the relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. [secondary to MS-PS1-4]
Grades 3-5	• The faster a given object is moving, the more energy it possesses. [4-PS3-1] • Energy can be moved from place to place by moving objects or through sound, light, or electric currents. [4-PS3-2],[4-PS3-3]
Grades K-2	• N/A

9-12 GRADE LEVEL ELEMENT(S)

- "Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. (secondary)

Foundational concepts necessary for success that are not covered in previous grade bands:

- Interactions between objects that can exert a force on each other without touching can be modeled as a field
- Larger magnitude fields equate to a larger force experienced by objects within the field
- Fields can be changed by changing the position or strength of the object(s) creating the field
- Magnets and electric currents (moving charges) cause magnetic fields.
- The strength of the magnetic fields is dependent upon several factors like distance from the magnet or current carrier and the motion and size of charges.
- An electrically charged object or changing magnetic fields cause electric fields.
- "Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents.

Key ideas that students need to apply in order to be successful:

- Explain the relationship between electric current and magnetic fields.
  - An electric current creates a magnetic field.
  - Manipulating a magnetic field can create an electric current.
  - A changing electric field creates a magnetic field and a changing magnetic field creates an electric current (or changing electric field).

TARGET CROSS CUTTING CONCEPT PROGRESSION

Cause and Effect

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. • Cause and effect relationships may be used to predict phenomena in natural or designed systems. • Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.
Grades 3-5	• Cause and effect relationships are routinely identified, tested, and used to explain change. • Events that occur together with regularity might or might not be a cause and effect relationship.
Grades K-2	• Events have causes that generate observable patterns. • Simple tests can be designed to gather evidence to support or refute student ideas about causes.

9-12 GRADE LEVEL ELEMENT(S)

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

What ideas or concepts are truly unique to this grade band?

- Empirical evidence.
  - Empirical evidence is information gathered directly from observation or experimentation.
- Distinguishing between a correlational relationship or a specific cause and effect based on the evidence.

Key concepts students need access to in order to be successful:

- Gather evidence to show the cause and effect relationship between magnetic fields and electrical currents
- Make a claim that electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

HS-PS3-2

Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects). [*Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically-charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.*]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Developing and Using Models

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Develop or modify a model - based on evidence – to match what happens if a variable or component of a system is changed. • Use and/or develop a model of simple systems with uncertain and less predictable factors. • Develop and/or use a model to predict and/or describe phenomena. • Develop a model to describe unobservable mechanisms.
Grades 3-5	• Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution. • Develop and/or use models to describe and/or predict phenomena.
Grades K-2	• Develop and/or use a model to represent amounts, relationships, relative scales (bigger, smaller), and/or patterns in the natural and designed world(s).

9-12 GRADE LEVEL ELEMENT(S)

- Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.

What ideas or skills are truly unique to this grade band?

- Use of models to show relationships between systems and components of systems, not just variables or phenomena.
- Use of an already developed and accepted model as a source of information.

Key experiences students need access to in order to be successful:

- Define the system and surroundings as chosen for the model.
- Develop a model to show motion of particles and/or objects and the kinetic energy of the system.
- Develop a model to show relative position of particles and/or objects and the potential energy of the system.
- Use model to explain how energy at the macroscale is a sum of energy of motion and energy of relative position.
- Use the model to explain that if the motion or relative position of the object changes, then the energy is transferred (from kinetic to potential or vice versa) but the total energy within the closed system remains the same.

TARGET DISCIPLINARY CORE IDEA PROGRESSION

PS3.A: Definitions of Energy

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Kinetic energy can be distinguished from the various forms of potential energy. Energy changes to and from each type can be tracked through physical or chemical interactions. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter.
Grades 3-5	• Moving objects contain energy. The faster the object moves, the more energy it has. Energy can be moved from place to place by moving objects, or through sound, light, or electrical currents. Energy can be converted from one form to another form.
Grades K-2	• N/A

9-12 GRADE LEVEL ELEMENT(S)

- 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.

Foundational concepts necessary for success that are not covered in previous grade bands:

- The system is an organized group of related objects or components; surroundings would be anything that is not considered part of the system
- Systems and their boundaries must be defined to track energy transfers within a system and to the external environment
- Energy is a quantitative property
- Energy is conserved
- Energy is a single summative quantity of all the motion and radiation in a system
- Radiation is when energy stored in fields moves across space
- Relative position energy can be thought of as stored in fields
- Energy fields mediate interactions between particles
- Energy is continually transferred from one object to another and between its various possible forms
- Interactions between energy types 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).

Key ideas that students need to apply in order to be successful:

- Total energy of a system and the surroundings is conserved both at the macroscopic and atomic levels.
- Defining system and its boundaries is necessary to track energy transfers within a system and to the external environments
- Because energy is conserved within a closed system, if one form of energy increases, the other forms must decrease by the same amount.
- Chemical energy is the potential energy that can be released upon formation of stable compounds due to interactions in the electrostatic field created by the positive nuclei and negative electrons of atoms involved.
- Thermal energy is the kinetic (and potential energy) of particle vibrations in solids or molecules and (kinetic only) of freely moving particles in liquids and gases.
    - Ex: When energy is added to a solid (or liquid), the particles speed up and move further apart as it turns into a liquid (or gas).
- Energy of fields (gravitational, magnetic, or electrostatic) change due to positioning of objects in the field.
    - Ex: The higher above ground an object is, the more gravitational potential energy it will have. And as the object falls (movement) the kinetic energy will increase and potential will decrease
    - Ex: Farther away two similarly charged electrical or magnetic plates are, the less electrical or magnetic potential energy between them. If the plates are pushed together, the potential energy increases and converts to kinetic as they are forced back apart
    - Ex: Farther away two oppositely charged electrical or magnetic plates are, the higher the potential energy between them. If they are brought close enough to attract the potential energy is converted to kinetic energy as they attract to each other.

Additional Information:

- The system must be defined as a closed system to state that energy is conserved in a system.

TARGET CROSS CUTTING CONCEPT PROGRESSION

Energy and Matter

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. • Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). • The transfer of energy can be tracked as energy flows through a designed or natural system.
Grades 3-5	• Energy can be transferred in various ways and between objects.
Grades K-2	• Objects may break into smaller pieces, be put together into larger pieces, or change shapes.

9-12 GRADE LEVEL ELEMENT(S)

- Energy cannot be created or destroyed - only moves between one place and another place, between objects and/or fields, or between systems.

What ideas or concepts are truly unique to this grade band?

- Energy (and matter) flows into and out of a system
- Energy cannot be destroyed

Key concepts students need access to in order to be successful:

- Identifying the forms of energy in the system
- Tracking changes in energy form when motion or relative position changes to show that energy is conserved, but can change forms.
- Explain that energy is not destroyed, if there is a change in total energy in the system then the surroundings have an equal but opposite change.

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

HS-PS3-3

Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.* [*Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency.*] [**Assessment Boundary: Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students.**]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Constructing Explanations and Designing Solutions

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process or system. • Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints. • Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and retesting.
Grades 3-5	• Apply scientific ideas to solve design problems • Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution.
Grades K-2	• Use tools and/or materials to design and/or build a device that solves a specific problem or a solution to a specific problem . • Generate and/or compare multiple solutions to a problem.

9-12 GRADE LEVEL ELEMENT(S)

- Design, evaluate, and/or refine a solution to a complex real-world problem based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

What ideas or skills are truly unique to this grade band?

- Refining a solution
- Complex real world problem
- Student generated evidence

Key experiences students need access to in order to be successful:

- Be given a problem and design criteria and constraints to design a solution around
- Build and test initial designs
- Refine initial design after evaluating the performance of the device against the criteria and constraints.
- Multiples trials of design challenges where changes are controlled and all variables are measured
- Results of trials are analyzed for efficacy or tradeoffs
- Describe how the design works to meet the needs of the problem (energy conversion, energy loss, etc.).
- Final designs are chosen based on analyzed results and needs and constraints of the challenge and can support the choices made

TARGET DISCIPLINARY CORE IDEA PROGRESSION

PS3.A: Definitions of Energy, PS3.D: Energy in Chemical Processes, and ETS1.A: Defining and Delimiting an Engineering Problem

PS3.A: Definitions of Energy

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed. [MS-PS3-1] • A system of objects may also contain stored (potential) energy, depending on their relative positions. [MS-PS3-2] • Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. [MS-PS3-3],[MS-PS3-4]
Grades 3-5	• The faster a given object is moving, the more energy it possesses. [4-PS3-1] • Energy can be moved from place to place by moving objects or through sound, light, or electric currents. [4-PS3-2],[4-PS3-3]
Grades K-2	• N/A

9-12 GRADE LEVEL ELEMENT(S)

- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.

PS3.D: Energy in Chemical Processes

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen. [secondary to MS-LS1-6] • Cellular respiration in plants and animals involve chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials. [secondary to MS-LS1-7]
Grades 3-5	• The expression “produce energy” typically refers to the conversion of stored energy into a desired form for practical use. [4-PS3-4] • The energy released [from] food was once energy from the sun that was captured by plants in the chemical process that forms plant matter (from air and water). [5-PS3-1]
Grades K-2	• N/A

9-12 GRADE LEVEL ELEMENT(S)

- Although energy cannot be destroyed, it can be converted to less useful forms - for example, to thermal energy in the surrounding environment.

ETS1.A: Defining and Delimiting an Engineering Problem

9-12 GRADE LEVEL ELEMENT(S)

- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary)

Foundational concepts necessary for success that are not covered in previous grade bands:

- There are different forms of energy
- Energy is continually transferred from one object to another and between its various possible forms
- The system is an organized group of related objects or components; surroundings would be anything that is not considered part of the system
- Energy can be transferred within the system, transferred from the surroundings to the system, or transferred from the system to the surroundings
- Energy into a system (from surroundings) increases the energy of the system
- Energy transferred from the system to the surroundings decreases the energy of the system and increase the energy of the surroundings
- Energy cannot be created or destroyed
- Sometimes energy conversion is not 100% efficient because some energy often is converted to unintended energy forms (i.e., thermal energy, light, sound, etc.)

Key ideas that students need to apply in order to be successful:

- Know that chemical energy can be converted to other forms of energy such as light, heat, sound
- Specific chemical reactions are used to produce or absorb thermal energy
- Identify possible ways energy was transferred to the surroundings
- Identify places in a design where the efficiency of energy transfer could be improved to minimize energy transfer to surroundings

Additional Information:

- The ETS element was not specifically unpacked in the DCI because the critical content of this ETS element is covered through the SEP for this standard.

TARGET CROSS CUTTING CONCEPT PROGRESSION

Energy and Matter

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. • Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). • The transfer of energy can be tracked as energy flows through a designed or natural system.
Grades 3-5	• Energy can be transferred in various ways and between objects.
Grades K-2	• N/A

9-12 GRADE LEVEL ELEMENT(S)

- 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.

What ideas or concepts are truly unique to this grade band?

- Energy (and matter) flows into and out of a system
- Energy cannot be destroyed

Key concepts students need access to in order to be successful:

- Identifying the forms of energy in the system
- Tracking changes in energy form to show that energy is conserved, but can change forms.
- Explain that energy is not destroyed, if there is a change in total energy in the system then the surroundings have an equal but opposite change.

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

HS-PS3-5

Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction. [*Clarification Statement: Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.*] [**Assessment Boundary: Assessment is limited to systems containing two objects.**]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Develop and Use Models

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Develop or modify a model - based on evidence – to match what happens if a variable or component of a system is changed. • Use and/or develop a model of simple systems with uncertain and less predictable factors. • Develop and/or use a model to predict and/or describe phenomena. • Develop a model to describe unobservable mechanisms.
Grades 3-5	• Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution. • Develop and/or use models to describe and/or predict phenomena.
Grades K-2	• Develop and/or use a model to represent amounts, relationships, relative scales (bigger, smaller), and/or patterns in the natural and designed world(s).

9-12 GRADE LEVEL ELEMENT(S)

- Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.

What ideas or skills are truly unique to this grade band?

- Use of models to show relationships between systems and components of systems, not just variables or phenomena.
- Use of an already developed and accepted model as a source of information.

Key experiences students need access to in order to be successful:

- Develop a model to show relative position of particles and/or objects in a clearly defined system.
- Develop a model to show a field (electrical or magnetic) caused by the interaction of objects
- Develop a model to show the forces between objects that are interacting in a field (electrical or magnetic) are either attractive or repulsive
- Use the model to explain that if the relative position of two objects interacting in a field are changed then the forces become stronger or weaker
- Use the model to explain that if the relative position of two objects interacting in a field are changed then the energy in the objects changes from potential (field), to kinetic (movement)
- Use the model to explain that if two objects in fields move towards a lower potential energy, the kinetic energy of their movement is converted to potential energy in the field.

TARGET DISCIPLINARY CORE IDEA PROGRESSION

PS3.C: Relationship Between Energy and Forces

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object. [MS-PS3-2]
Grades 3-5	• When objects collide, the contact forces transfer energy so as to change the objects' motions. [4-PS3-3]
Grades K-2	• A bigger push or pull makes things go faster. [secondary to K-PS2-1]

9-12 GRADE LEVEL ELEMENT(S)

- When two objects interacting through a field change relative position, the energy stored in the field is changed.

Foundational concepts necessary for success that are not covered in previous grade bands:

- Objects can interact through fields (non-contact)
- The position of an object within a field changes the force that the object experiences
- Energy can be stored in a field
- Objects in a field experience a force that moves the object towards a lower potential energy
- If an object changes its relative position, the energy in the field is changed

Key ideas that students need to apply in order to be successful:

- When charged particles are close enough to exert force on each other (attractive or repulsive) their electric fields interact
- When objects are in a magnetic or electric field, the field has a potential energy
- When the objects are brought together they experience either an attractive or repulsive force that causes them to accelerate (move).
- The potential energy of the field is converted to kinetic energy of the objects when the objects are allowed to move together.
- As the objects in fields move towards a lower potential energy, the kinetic energy of their movement is converted to potential energy in the field.

TARGET CROSS CUTTING CONCEPT PROGRESSION

Cause and Effect

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. • Cause and effect relationships may be used to predict phenomena in natural or designed systems. • Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.
Grades 3-5	• Cause and effect relationships are routinely identified, tested, and used to explain change. • Events that occur together with regularity might or might not be a cause and effect relationship.
Grades K-2	• Events have causes that generate observable patterns. • Simple tests can be designed to gather evidence to support or refute student ideas about causes.

9-12 GRADE LEVEL ELEMENT(S)

- Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.

What ideas or concepts are truly unique to this grade band?

- Cause and effect can be predicted
- Mechanisms at the atomic scale suggest and predict mechanisms at the macroscale

Key concepts students need access to in order to be successful:

- Using knowledge of attractive and repulsive forces to predict the visible interactions between two objects
- Use the model to predict how the visible interactions will be different for objects at different positions
- Explain how the charges (atomic scale) lead to the visible interactions (attraction/repulsion) at the macroscale.

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

BUNDLE: Climate Change

Standards included:

HS-PS3-1
HS-ESS2-4
HS-ESS3-1
HS-ESS3-4
HS-ESS3-5
HS-ESS3-6

FOCUS SEPs:

Analyzing and Interpreting Data
Constructing Explanations and Designing Solutions
Developing and Using Models
Using Mathematical and Computational Thinking

FOCUS DCIs:

ESS1.B	Earth and The Solar System
ESS2.A	Earth Materials and Systems
ESS2.D	Weather and Climate
ESS3.A	Natural Resources
ESS3.B	Natural Hazards
ESS3.C	Human Impacts on Earth Systems
ESS3.D	Global Climate Change
ETS1.B	Developing Possible Solutions
PS3.A	Definitions of Energy
PS3.B	Conservation of Energy and Energy Transfer

FOCUS CCCs:

Cause and Effect
Stability and Change
Systems and System Models

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.**]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Using Mathematical and Computational Thinking

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends.
Grades 3-5	• Organize simple data sets to reveal patterns that suggest relationships.
Grades K-2	• Use counting and numbers to identify and describe patterns in the natural and designed world(s).

9-12 GRADE LEVEL ELEMENT(S)

- Create a computational model or simulation of a phenomenon, designed device, process, or system.

What ideas or skills are truly unique to this grade band?

- Creation of own computational model.
- Can be spreadsheet calculations, program, etc.
- Defining system vs. surroundings.

Key experiences students need access to in order to be successful:

- If using spreadsheet, students need to know how to input mathematical functions into a spreadsheet of their choosing to do calculations on data sets.

TARGET DISCIPLINARY CORE IDEA PROGRESSION

PS3.A: Definitions of Energy and **PS3.B**: Conservation of Energy and Energy Transfer

PS3.A: Definitions of Energy

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed. [MS-PS3-1] • A system of objects may also contain stored (potential) energy, depending on their relative positions. [MS-PS3-2] • Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. [MS-PS3-3],[MS-PS3-4] • The term "heat" as used in everyday language refers both to thermal motion (the motion of atoms or molecules within a substance) and radiation (particularly infrared and light). In science, heat is used only for this second meaning; it refers to energy transferred when two objects or systems are at different temperatures. [secondary to MS-PS1-4] • Temperature is not a measure of energy; the relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. [secondary to MS-PS1-4]
Grades 3-5	• The faster a given object is moving, the more energy it possesses. [4-PS3-1] • Energy can be moved from place to place by moving objects or through sound, light, or electric currents. [4-PS3-2],[4-PS3-3]
Grades K-2	• N/A

9-12 GRADE LEVEL ELEMENT(S)

- 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

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• When the motion energy of an object changes, there is inevitably some other change in energy at the same time. [MS-PS3-5] • The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment. [MS-PS3-4] • Energy is spontaneously transferred out of hotter regions or objects and into colder ones. [MS-PS3-3]
Grades 3-5	• Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced. [4-PS3-2],[4-PS3-3] • Light also transfers energy from place to place. [4-PS3-2] • Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy. [4- PS3-2],[4-PS3-4]
Grades K-2	• Sunlight warms Earth's surface. [K-PS3-1],[K-PS3-2]

9-12 GRADE LEVEL ELEMENT(S)

- 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.

Foundational concepts necessary for success that are not covered in previous grade bands:

- Energy is quantitative
- There are multiple different forms of energy
- Energy is continually transferred
- In a closed system, energy is conserved
- Energy can be transferred within the system or transferred from the surroundings to the system
- Energy transfers into a system (from surroundings) is positive
- Definition of system and surroundings
- Describe the initial and final conditions for energy forms in the system.

Key ideas that students need to apply in order to be successful:

- The energy that exits one material is equal to the energy that is absorbed by the other material in a closed system
- Two objects at different energies that interact with each other will have a transfer of energy that may or may not include a conversion of form of energy including mechanical, chemical, thermal, kinetic, or energy in fields, etc.
- Energy that flows into the defined system is considered positive in mathematical reasoning.
- Energy that flows out of the defined system is considered negative in mathematical reasoning.

- The total energy of a system can be expressed as the total amount of energy in each component of the system at any point in time.
- Mathematically show the relationship between the initial and final energy of the system with the known energy flows into and out of the system based on the principle of conservation of energy.
- The energy change of one component of the system can be calculated if given the energy changes within the system due to energy flow.

TARGET CROSS CUTTING CONCEPT PROGRESSION

Systems and System Models

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. • Models can be used to represent systems and their interactions - such as inputs, processes and outputs - and energy, matter, and information flows within systems. • Models are limited in that they only represent certain aspects of the system under study.
Grades 3-5	• A system is a group of related parts that make up a whole and can carry out functions its individual parts cannot. • A system can be described in terms of its components and their interactions.
Grades K-2	• Objects and organisms can be described in terms of their parts. • Systems in the natural and designed world have parts that work together.

9-12 GRADE LEVEL ELEMENT(S)

- 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.

What ideas or concepts are truly unique to this grade band?

- Defining boundaries and initial inputs of the system
- Analyzing inputs and of the system
- Investigation of systems
- Predictions of system based on model
- Predictions based on models are limited based on assumptions and approximations

Key concepts students need access to in order to be successful:

- Experience with defining the system versus the surroundings, especially in complex systems
- Experience with defining whether a system is a closed system or open system
- Identify limitations, assumptions, and approximations that are being used in any given application of a system (e.g. identifying the assumptions we make as scientists when using systems)
- Experience with making predictions from a system based on their model that are reasonable based on the model

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

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. [*Clarification Statement: examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years: long-term changes in atmospheric composition.*] [**Assessment Boundary: Assessment of the results of changes in climate is limited to changes in surface temperatures, precipitation Patterns, glacial ice volumes, sea levels, and biosphere distribution.**]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Developing and Using Models

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Develop or modify a model - based on evidence – to match what happens if a variable or component of a system is changed. • Use and/or develop a model of simple systems with uncertain and less predictable factors. • Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena. • Develop and/or use a model to predict and/or describe phenomena. Develop a model to describe unobservable mechanisms.
Grades 3-5	• Collaboratively develop and/or revise a model based on evidence that shows the relationships among variables for frequent and regular occurring events. • Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution. • Develop and/or use models to describe and/or predict phenomena.
Grades K-2	• Develop and/or use a model to represent amounts, relationships, relative scales (bigger, smaller), and/or patterns in the natural and designed world(s).

9-12 GRADE LEVEL ELEMENT(S)

- Use a model to provide mechanistic accounts of phenomena.

What ideas or skills are truly unique to this grade band?

- Mechanistic account implies approaching the model as though it were a machine with inputs and outputs and a system of interacting parts.

Key experiences students need access to in order to be successful:

- Students identify the components of the system (components of different spheres)
- Students can track the inputs and outputs on a given model (input and output of electromagnetic radiation to Earth's spheres)
- Students can describe how different components (of Earth's spheres) interact with each other and with the energy that is flowing through the system.
- Students describe what interactions could be causing an imbalance between the input and output (electromagnetic radiation).
- Students describe how changes within the system can cause an imbalance between the input and output.

TARGET DISCIPLINARY CORE IDEA PROGRESSION

ESS1.B: Earth and The Solar System, **ESS2.A**: Earth Materials and Systems, and **ESS2.D**: Weather and Climate

ESS1.B: Earth and The Solar System

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. [MS-ESS1-2], [MS-ESS1-3] • This model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year. [MS-ESS1-1]
Grades 3-5	• The orbits of Earth around the sun and of the moon around Earth, together with the rotation of Earth about an axis between its North and South poles, cause observable Patterns. These include day and night; daily changes in the length and direction of shadows; and different positions of the sun, moon, and stars at different times of the day, month, and year. [5-ESS1-2]
Grades K-2	• Seasonal patterns of sunrise and sunset can be observed, described, and predicted. [1- ESS1-2]

9-12 GRADE LEVEL ELEMENT(S)

- Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes. (secondary)

ESS2.A: Earth Materials and Systems

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms. [MS-ESS2-1] • The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future. [MS-ESS2-2]
Grades 3-5	• Rainfall helps to shape the land and affects the types of living things found in a region. Water, ice, wind, living organisms, and gravity break rocks, soils, and sediments into smaller particles and move them around. [4-ESS2-1] • Earth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth's surface materials and processes. The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather. [5-ESS2-1]
Grades K-2	• Wind and water can change the shape of the land. [2-ESS2-1]

9-12 GRADE LEVEL ELEMENT(S)

- The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles.

ESS2.D: Weather and Climate

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow Patterns. [MS-ESS2-6] • Because these patterns are so complex, weather can only be predicted probabilistically. [MS-ESS2-5] • The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents. [MS-ESS2-6]
Grades 3-5	• Scientists record patterns of the weather across different times and areas so that they can make predictions about what kind of weather might happen next. [3-ESS2-1] • Climate describes a range of an area's typical weather conditions and the extent to which those conditions vary over years. [3- ESS2-2]
Grades K-2	• Weather is the combination of sunlight, wind, snow or rain, and temperature in a particular region at a particular time. People measure these conditions to describe and record the weather and to notice patterns over time. [K-ESS2-1]

9-12 GRADE LEVEL ELEMENT(S)

- 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.

Foundational concepts necessary for success that are not covered in previous grade bands:

- Cycles of changes in Earth's tilt and Earth's orbit around the sun, how long the cycles are (Milankovich cycles, students do not need to know the name)
- How changes in tilt and orbit impact overall climate – more tilt means more extreme seasons, less tilt means less extreme differences in seasons, more eccentricity in orbit leads to more extreme differences – leads to ice ages over time
- Sun's energy output is on a cycle that is thousands of years long that impacts the amount of solar radiation received by Earth
- Long-term tectonic plate movements of landmasses to various latitudes on Earth will impact the climate of those landmasses based on the amount of solar radiation received throughout the year.
- Glaciers reflect solar radiation back to space
- Vegetation absorbs solar radiation to hold in the Earth and atmosphere
- Earth can be studied at different physical and time scales
- Electromagnetic radiation can be reflected or absorbed
- Climate is average temperature and precipitation of a region over a long period of time
- Global climate patterns are determined by ocean currents that circulate warm and cold water across the globe and the ocean currents impact the prevailing winds that determine climate.

Key ideas that students need to apply in order to be successful:

- Sudden changes in climate can occur when there is a dust cloud persisting in the atmosphere due to extremely large scale volcanic activity or meteor impact
- Human activity can increase greenhouse gas concentration in the atmosphere which impacts climate due to changes in radiation energy
- Evidence of past climate events show a rate change to the climate at a much slower scale than the current climate change happening, which is evidence of the human impact on current climate change.
- Changes in sea level and global temperatures have had a larger than typical increase since approximately 1920 due to human generated carbon dioxide, greenhouse gases, and other changes to the environment.
- Reflected electromagnetic energy can be absorbed by the atmosphere, causing a temperature increase, and/or pass through the atmosphere to be re-radiated into space
- Electromagnetic radiation that is absorbed by vegetation can be cycled through Earth's spheres as energy used to grow living things (photosynthesis and cellular respiration)
- Electromagnetic radiation that is absorbed by the geosphere can lead to increasing surface temperatures
- When glaciers melt and more vegetation grows in their place, more solar radiation is absorbed by Earth
- When more energy is absorbed by earth's systems overall climate increases in temperature, some regions are more impacted than others
- When glaciers melt, sea levels eventually rise, changing regional climates for areas near coastlines and global climate by having less reflected radiation sent back to space
- A change to one variable that affects how sunlight interacts with Earth's spheres can cause a change to other variables that will continue to feed further changes, causing an increased rate of change of global climate. (feedback loops)

TARGET CROSS CUTTING CONCEPT PROGRESSION

Cause and Effect

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.
Grades 3-5	• Cause and effect relationships are routinely identified, tested, and used to explain change. • Events that occur together with regularity might or might not be a cause and effect relationship.
Grades K-2	• Events have causes that generate observable patterns. • Simple tests can be designed to gather evidence to support or refute student ideas about causes.

9-12 GRADE LEVEL ELEMENT(S)

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

What ideas or concepts are truly unique to this grade band?

- Empirical evidence
  - Empirical evidence is information gathered directly from observation or experimentation
- Distinguishing between a correlational relationship or a specific cause and effect based on the evidence.

Key concepts students need access to in order to be successful:

- Exposure to data of different time scale climate changes including sea levels, temperature, ice cores, earth's tilt and eccentricity of orbit, solar radiation output
- Exposure to data over the last century about sea levels, greenhouse gas concentrations, average temperatures, ocean temperatures, glacial area, etc.
- Use the data to make and support a claim about specific cause and effect related to climate change
- Use data to refute the counterclaim that recent climate change is merely correlated with human activity instead of caused by it.

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

HS-ESS3-1

Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. [*Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.*]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Constructing Explanations and Designing Solutions

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) 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.
Grades 3-5	• Use evidence (e.g., measurements, observations, Patterns) to construct or support an explanation or design a solution to a problem.
Grades K-2	• Use information from observations (firsthand and from media) to construct an evidence-based account for natural phenomena.

9-12 GRADE LEVEL ELEMENT(S)

- Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, 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.

What ideas or skills are truly unique to this grade band?

- Explanations are supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.
- Students determine best evidence sources to support their explanation
- Evidence can include models, theories, simulations, peer review
- Student developed evidence can include investigations, models, theories, simulations, peer review

Key experiences students need access to in order to be successful:

- Evaluate multiple sources of evidence (provided or student generated) for each source's relevance to the explanation requested.
- Write explanations of phenomena or observed data

TARGET DISCIPLINARY CORE IDEA PROGRESSION

ESS3.A: Natural Resources and ESS3.B: Natural Hazards

ESS3.A: Natural Resources

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes. [MS-ESS3-1]
Grades 3-5	• Energy and fuels that humans use are derived from natural sources, and their use affects the environment in multiple ways. Some resources are renewable over time, and others are not. [4-ESS3-1]
Grades K-2	• Living things need water, air, and resources from the land, and they live in places that have the things they need. Humans use natural resources for everything they do. [K-ESS3-1]

9-12 GRADE LEVEL ELEMENT(S)

- Resource availability has guided the development of human society.

ESS3.B: Natural Hazards

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events. [MS-ESS3-2]
Grades 3-5	• A variety of natural hazards result from natural processes. Humans cannot eliminate natural hazards but can take steps to reduce their impacts. [3-ESS3-1] [4-ESS3-2]
Grades K-2	• Some kinds of severe weather are more likely than others in a given region. Weather scientists forecast severe weather so that the communities can prepare for and respond to these events. [K-ESS3-2]

9-12 GRADE LEVEL ELEMENT(S)

- Natural hazards and other geologic events have shaped the course of human history; [they] have significantly altered the sizes of human populations and have driven human migrations.

Foundational concepts necessary for success that are not covered in previous grade bands:

- Resource availability has guided the development of human society.
- Human history has been shaped by natural hazards and other geologic events.
- Migration is driven by natural hazards and other geologic events.
- Human population size is influenced by natural hazards and other geologic events.

Key ideas that students need to apply in order to be successful:

- Identify the resources that humans have needed over time and which resources are limited.
- Identify and describe natural hazards(interior processes, surface processes and/or severe weather) and how they could impact humans in the area.
- Describe how climate change could cause the mass migration of human populations.

TARGET CROSS CUTTING CONCEPT PROGRESSION

Cause and Effect

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. • Cause and effect relationships may be used to predict phenomena in natural or designed systems. • Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.
Grades 3-5	• Cause and effect relationships are routinely identified, tested, and used to explain change. • Events that occur together with regularity might or might not be a cause and effect relationship.
Grades K-2	• Events have causes that generate observable patterns. • Simple tests can be designed to gather evidence to support or refute student ideas about causes.

9-12 GRADE LEVEL ELEMENT(S)

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

What ideas or concepts are truly unique to this grade band?

- Empirical evidence
  - Empirical evidence is information gathered directly from observation or experimentation.
- Distinguishing between a correlational relationship or a specific cause and effect based on the evidence.

Key concepts students need access to in order to be successful:

- Exposure to data or other evidence related to the availability of resources and human society.
- Exposure to data or other evidence related to historical natural hazards or geologic events and changes in human population size and location.
- Exposure to data about how climate change is currently impacting human society, population size and location.
- Use the data to make and support a claim about specific cause and effect related to how natural resources and events impact human activity.

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

HS-ESS3-4

Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.* [*Clarification Statement: Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).*]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Constructing Explanations and Designing Solutions

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process or system. • Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints. • Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and retesting.
Grades 3-5	• Apply scientific ideas to solve design problems. • Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution.
Grades K-2	• Use tools and/or materials to design and/or build a device that solves a specific problem or a solution to a specific problem. • Generate and/or compare multiple solutions to a problem.

9-12 GRADE LEVEL ELEMENT(S)

- Design* or refine a solution to a complex real-world problem based on scientific knowledge, student generated sources of evidence, prioritized criteria, and tradeoff considerations.

What ideas or skills are truly unique to this grade band?

- Students refine a design solution
- Students evaluate a provided design solution
- The solution is designed to address a complex real world problem
- Changes to the designed solution are based on student generated evidence

Key experiences students need access to in order to be successful:

- Exposure to real world problems where human activity is causing pollution, an increase in pollution or waste and/or negatively impacting ecosystems
- Identify a technology solution to a real world problems where human activity is causing pollution, an increase in pollution or waste and/or negatively impacting ecosystems
- Describe how the technological solution functions and may be stabilizing or destabilizing the natural system.
- Identify criteria and constraints for the solution to the problem

- Describe the tradeoffs in the solution, considering priorities and other kinds of research-driven tradeoffs in explaining why this particular solution is or is not needed.
    - Tradeoffs include: cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts

Additional Information:

- The grade level element says, "design or refine" however the standard is phrased "evaluate or refine." The unpacking and key experiences are based on the wording of the standard to evaluate, not design.

TARGET DISCIPLINARY CORE IDEA PROGRESSION

ESS3.C: Human Impacts on Earth Systems and **ETS1.B**: Developing Possible Solutions

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things. [MS-ESS3-3] • Typically, as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise. [MS-ESS3-3],[MS-ESS3-4]
Grades 3-5	• Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments. [5-ESS3-1]
Grades K-2	• Things that people do to live comfortably can affect the world around them. But they can make choices that reduce their impacts on the land, water, air, and other living things. [K-ESS3-3] [secondary to K-ESS2-2]

9-12 GRADE LEVEL ELEMENT(S)

ESS3.C: Human Impacts on Earth Systems

- Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation.

ETS1.B: Developing Possible Solutions

- 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. (secondary)

Foundational concepts necessary for success that are not covered in previous grade bands:

- Scientists and engineers can work to create technology to reduce pollution and waste.
- Ecosystem destruction can be prevented by technology created that reduces pollution and waste

Key ideas that students need to apply in order to be successful:

- Identify the scientific knowledge and reasoning on which the solution is based
- Identify how human activity produces pollution and waste.
- Identify how human land surface use has changed the surface of the Earth.
- Identify characteristics of a stable and functioning ecosystem and the ways that human activity can change an ecosystem.
- Identify ways that scientists and engineers claim to use technology to limit human impact on the environment.

Additional Information:

- The ETS element was not specifically unpacked in the DCI because the critical content of this ETS element is covered through the SEP for this standard.

TARGET CROSS CUTTING CONCEPT PROGRESSION

Stability and Change

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale. • Small changes in one part of a system might cause large changes in another part. • Stability might be disturbed either by sudden events or gradual changes that accumulate over time. • Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms.
Grades 3-5	• Change is measured in terms of differences over time and may occur at different rates. • Some systems appear stable, but over long periods of time will eventually change.
Grades K-2	• Some things stay the same while other things change. • Things may change slowly or rapidly.

9-12 GRADE LEVEL ELEMENT(S)

- Feedback (negative or positive) can stabilize or destabilize a system.

What ideas or concepts are truly unique to this grade band?

- Feedback can be positive or negative.
- Feedback can stabilize or destabilize a system

Key concepts students need access to in order to be successful:

- Experience identifying inputs and outputs of a system and how the outputs can impact the inputs to create a feedback loop
- Identify if a feedback loop is stabilizing or destabilizing to the system.
- Identify the effect of the proposed solution on the overall stability of and changes in natural systems.

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

HS-ESS3-5

Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth's systems. [*Clarification Statement: Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature) and their associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition).*] [**Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.**]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Analyzing and Interpreting Data

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships. • Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships. • Distinguish between causal and correlational relationships in data. • Analyze and interpret data to provide evidence for phenomena.
Grades 3-5	• Represent data in tables and/or various graphical displays (bar graphs, pictographs, and/or pie charts) to reveal patterns that indicate relationships.
Grades K-2	• Record information (observations, thoughts, and ideas). • Use and share pictures, drawings, and/or writings of observations. • Use observations (firsthand or from media) to describe patterns and/or relationships in the natural and designed world(s) in order to answer scientific questions and solve problems. • Compare predictions (based on prior experiences) to what occurred (observable events).

9-12 GRADE LEVEL ELEMENT(S)

- Analyze data using computational models in order to make valid and reliable scientific claims.

What ideas or skills are truly unique to this grade band?

- Using computational models for data analysis
- Making valid and reliable scientific claims based on data analysis.

Key experiences students need access to in order to be successful:

- Examine and/or organize climate data (precipitation and temperature) across multiple time scales using a computational model such as a graph or a computational simulation to identify rate of change.
- Analyze data related to climate change impacts (sea level, glacial ice volume, ocean and atmospheric composition) to make a claim about the relationship between climate change and the associated impacts.
- Use the data analysis to make predictions about future impacts on earth's systems due to climate change
- Identify if the predicted future impacts can be reversed or prevented.
- Identify at least one source of uncertainty in the prediction.
- Identify limitations of the model used in analyzing data.

TARGET DISCIPLINARY CORE IDEA PROGRESSION

ESS3.D: Global Climate Change

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities. [MS-ESS3-5]
Grades 3-5	• N/A
Grades K-2	• N/A

9-12 GRADE LEVEL ELEMENT(S)

- Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.
    - Foundational concepts necessary for success that are not covered in previous grade bands:
    - The magnitude of human impact on the climate and earth's systems is greater than ever before.
    - Humans have the ability to model, predict, and manage current and future impacts on climate and earth's system

    Key ideas that students need to apply in order to be successful:

    - Identify how global or regional climate change impacts earth's systems.
    - Make connections between climate data/models about how temperature and precipitation patterns are changing which then causes additional impacts on the environment such as sea level, glacial ice volumes, or atmosphere and ocean composition
    - Describe how the magnitude of change is driven by recent human activity.

TARGET CROSS CUTTING CONCEPT PROGRESSION

Stability and Change

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale. • Small changes in one part of a system might cause large changes in another part. • Stability might be disturbed either by sudden events or gradual changes that accumulate over time. • Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms.
Grades 3-5	• Change is measured in terms of differences over time and may occur at different rates. • Some systems appear stable, but over long periods of time will eventually change.
Grades K-2	• Some things stay the same while other things change. • Things may change slowly or rapidly.

9-12 GRADE LEVEL ELEMENT(S)

- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

What ideas or concepts are truly unique to this grade band?

- Some system changes are irreversible.
- Time scales can be "very short" or "very long"
- Both change and rates of change can be quantified

Key concepts students need access to in order to be successful:

- Data sets need to cover long range earth history as well as the last 100 years of human impact on climate
- Identify that rates of change can themselves change and increase or decrease over time.
- Identify that climate data and associated impacts are changing at an increasing rate of change compared to historical data
- Identify if the predicted future impacts can be reversed or prevented.

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

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. [*Clarification Statement: Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere. An example of the far-reaching impacts from human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations.*] [**Assessment Boundary: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.**]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Using Mathematics and Computational Thinking

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends. • Use mathematical representations to describe and/or support scientific conclusions and design solutions.
Grades 3-5	• Describe, measure, estimate, and/or graph quantities (e.g., area, volume, weight, time) to address scientific and engineering questions and problems.
Grades K-2	• Describe, measure, and/or compare quantitative attributes of different objects and display the data using simple graphs.

9-12 GRADE LEVEL ELEMENT(S)

- Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations.

What ideas or skills are truly unique to this grade band?

- Computational representation of phenomena
- Supporting claims and/or explanations

Key experiences students need access to in order to be successful:

- Students need access to published results of scientific computational models
- Experience analyzing results of scientific computational models
- Explain how the results of a scientific computational model can be used as evidence to support a claim.

TARGET DISCIPLINARY CORE IDEA PROGRESSION

ESS2.D: Weather and Climate and ESS3.D: Global Climate Change

ESS2.D: Weather and Climate

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow Patterns. [MS-ESS2-6] • The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents. [MS-ESS2-6]
Grades 3-5	• Climate describes a range of an area's typical weather conditions and the extent to which those conditions vary over years. [3- ESS2-2]
Grades K-2	• N/A

9-12 GRADE LEVEL ELEMENT(S)

- Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere. (secondary)

ESS3.D: Global Climate Change

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities. [MS-ESS3-5]
Grades 3-5	• N/A
Grades K-2	• N/A

9-12 GRADE LEVEL ELEMENT(S)

- Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities.

Foundational concepts necessary for success that are not covered in previous grade bands:

- Identification of what makes up the hydrosphere, atmosphere, cryosphere, geosphere, and biosphere.
- Purpose of computer simulations and climate models used to investigate and understand complex systems.
- Ways that human activity causes rapid changes in each system (hydrosphere, atmosphere, cryosphere, geosphere, and biosphere).
- Understand that changes to the spheres are still being studied and understood because climate and sphere interaction are complex systems.

Key ideas that students need to apply in order to be successful:

- Describe the relationships among any two systems (hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere).
- Describe how changes in one of Earth's systems can drive changes in another system (hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere).
- Describe how human activity can cause a change in one of Earth's systems, which then can cause changes in another system (hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere).
- Describe the effects of when a change in one system causes a change in another system (hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere).

TARGET CROSS CUTTING CONCEPT PROGRESSION

Systems and System Models

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. • Models can be used to represent systems and their interactions - such as inputs, processes and outputs - and energy, matter, and information flows within systems. • Models are limited in that they only represent certain aspects of the system under study.
Grades 3-5	• A system is a group of related parts that make up a whole and can carry out functions its individual parts cannot. • A system can be described in terms of its components and their interactions.
Grades K-2	• Systems in the natural and designed world have parts that work together.

9-12 GRADE LEVEL ELEMENT(S)

- 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.

What ideas or concepts are truly unique to this grade band?

- Defining boundaries and initial conditions of systems.
- Analyzing inputs and outputs of systems.

Key concepts students need access to in order to be successful:

- Define the initial conditions and boundaries of at least two of earth's systems (hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere).
- Identify the input (from humans) to one system and the output (change caused to that system. Describe how the output of the first system becomes the input for the second interacting system.
- Identify the output of the final interacting system as the effect of the original input of human interaction with the first system.

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

BUNDLE: Electromagnetic Radiation and Technology

Standards included:

HS-PS4-1
HS-PS4-2
HS-PS4-3
HS-PS4-4
HS-PS4-5

FOCUS SEPs:

Asking Questions and Defining Problems
Engaging In Argument from Evidence
Using Mathematics and Computational Thinking
Obtaining, Evaluating, and Communicating Information

FOCUS DCIs:

PS3.D	Energy in Chemical Processes
PS4.A	Wave Properties
PS4.B	Electromagnetic Radiation
PS4.C	Information Technologies and Instrumentation

FOCUS CCCs:

Cause and Effect
Stability and Change
Systems and System Models

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.**]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Using Mathematics and Computational Thinking

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Use mathematical representations to describe and/or support scientific conclusions and design solutions.
Grades 3-5	• Describe, measure, estimate, and/or graph quantities such as area, volume, weight, and time to address scientific and engineering questions and problems.
Grades K-2	• Describe, measure, and/or compare quantitative attributes of different objects and display the data using simple graphs.

9-12 GRADE LEVEL ELEMENT(S)

- Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations.

What ideas or skills are truly unique to this grade band?

- Representations of phenomena
- Supporting claims and explanations

Key experiences students need access to in order to be successful:

- Students identify the variables in the mathematical relationship $v = f\lambda$
- Opportunities to use the mathematical relationship $v = f\lambda$ for known waves in various media
- Use the mathematical relationship to support a claim about one variable of a known wave traveling through various media when the other two variables are known quantities.
- Use data to show how the speed of a given wave changes if the medium that the wave travels in changes.
- Make a claim about what students predict if the wavelength of a wave will increase, decrease, or stay the same when it changes from one medium to another based on the mathematical relationships.

TARGET DISCIPLINARY CORE IDEA PROGRESSION

PS4.A: Wave Properties

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. [MS-PS4-1] • A sound wave needs a medium through which it is transmitted. [MS-PS4-2]
Grades 3-5	• Waves of the same type can differ in amplitude (height of the wave) and wavelength (spacing between wave peaks). [4-PS4-1]
Grades K-2	• Sound can make matter vibrate, and vibrating matter can make sound. [1-PS4-1]

9-12 GRADE LEVEL ELEMENT(S)

- 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.

Foundational concepts necessary for success that are not covered in previous grade bands:

- There are different types of waves, including waves that are not directly observable by humans
- Waves can be measured by speed.
- Speed of wave = wavelength * frequency.
- There is a relationship between wavelength, frequency, and wave speed.
- There is a direct relationship between wavelength and speed.
- Waves can travel through different media.
- Different types of waves are affected by different media in different ways.
    - Light can only travel through translucent media.
    - Sound can travel through opaque as well as translucent media.
    - Some media do not impact gamma rays at all, while others will slow it down.
    - Seismic waves are mechanical waves that move both in Earth's interior and on the surface of the Earth.

Key ideas that students need to apply in order to be successful:

- Frequency and wavelength are constant in a given media.
- The frequency of a given wave does not change when traveling through different media.
- When a mechanical wave travels through a denser medium the wave compresses, which causes a shorter wavelength.
- When a light wave travels through a material with a higher index of refraction the wave compresses which causes a shorter wavelength.
- Since the wavelength shortens, but the frequency remains the same then the speed of the wave becomes slower.

TARGET CROSS CUTTING CONCEPT PROGRESSION

Cause and Effect

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. • Cause and effect relationships may be used to predict phenomena in natural or designed systems. • Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.
Grades 3-5	• Cause and effect relationships are routinely identified, tested, and used to explain change. • Events that occur together with regularity might or might not be a cause and effect relationship.
Grades K-2	• Events have causes that generate observable patterns. • Simple tests can be designed to gather evidence to support or refute student ideas about causes.

9-12 GRADE LEVEL ELEMENT(S)

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

What ideas or concepts are truly unique to this grade band?

- Empirical evidence
  - Empirical evidence is information gathered directly from observation or experimentation.
- Distinguishing between a correlational relationship or a specific cause and effect based on the evidence.

Key concepts students need access to in order to be successful:

In a data set students identify that when wavelength changes then frequency changes if the material the waves are passing through remains the same
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).
Students use the mathematical relationships to distinguish between cause and correlation with respect to the supported claims.

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

HS-PS4-2

Evaluate questions about the advantages of using digital transmission and storage of information.
[*Clarification Statement: Examples of advantages could include that digital information is stable because it can be stored reliably in computer memory, transferred easily, and copied and shared rapidly. Disadvantages could include issues of easy deletion, security, and theft.*]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Asking Questions and Defining Problems

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Ask questions that challenge the premise(s) of an argument or the interpretation of a data set.
Grades 3-5	• N/A
Grades K-2	• N/A

9-12 GRADE LEVEL ELEMENT(S)

- Evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set or the suitability of a design.

What ideas or skills are truly unique to this grade band?

- Evaluation of questions that challenge the premise of an argument.
- Evaluation of questions challenging the suitability of a design.

Key experiences students need access to in order to be successful:

- Provide students with questions related to specific features of digital transmission and storage of information.
- Evaluate the questions for if they are related to the advantages or disadvantages of digital transmission of information.
- Identify what would be needed to answer the question (i.e., what type of investigation).
- Evaluate whether or not answering the question would lead to empirical evidence related to digital transmission of information.

TARGET DISCIPLINARY CORE IDEA PROGRESSION

PS4.A: Wave Properties

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. [MS-PS4-1] • A sound wave needs a medium through which it is transmitted. [MS-PS4-2]
Grades 3-5	• Waves, which are regular patterns of motion, can be made in water by disturbing the surface. When waves move across the surface of deep water, the water goes up and down in place; it does not move in the direction of the wave except when the water meets the beach. (Note: This grade band endpoint was moved from K–2.) [4- PS4-1] • Waves of the same type can differ in amplitude (height of the wave) and wavelength (spacing between wave peaks). [4-PS4-1]
Grades K-2	• Sound can make matter vibrate, and vibrating matter can make sound. [1-PS4-1]

9-12 GRADE LEVEL ELEMENT(S)

- 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.

Foundational concepts necessary for success that are not covered in previous grade bands:

- Different types of data can be stored digitally or analog.
  - Analog storage includes things like paper, film, tapes, vinyl.
  - Digital storage includes things like hard-drives, flash drives, CDs, DVDs, etc which all store the information through a code of 1s and 0s.
- Digital Data is stored in a computer's memory.
- Waves can be described using wavelength, amplitude, and frequency.

Key ideas that students need to apply in order to be successful:

- There are pros and cons to analog storage
  - Pros – Have physical "analogous" representations or copies of items, can be physically locked up
  - Cons – Can physically degrade, sometimes quickly, can be lost easily
- The are pros and cons to digital storage
  - Pros - More reliable without degradation over time, transferred easily, copied and shared easily
  - Cons - Can be easily deleted, can be stolen by making a copy, can be accessed by outsiders more easily
- There are pros and cons to analog transmission
  - Pros – Sharing original copies of objects and artifacts, easy to validate (see/hear) the legitimacy of the copy
  - Cons – Takes a long time to transmit or copy (physically mail, or record a song in real time), if the original degrades then copies will not be as good either, can transmit additional noise (wave) interference as waves interact
- There are pros and cons to digital transmission
  - Pros - Information can be shared almost instantaneously (depending on method), multiple sets of information can be copied and shared without degradation, large amounts of information can be shared easily because it is broken into smaller pieces and coded, Can "filter" outside noise (waves) that may interfere because the code is being read
  - Cons - Dependant on technology working properly, requires electricity
- Explain how waves transmit information
  - Analog waves are a continuous transmission of the initial sound or electromagnetic waves that were captured

  - Digital waves are modified to transmit information via digital code
  - Waves can be modified to be read as code by changing the amplitude of a wave (i.e., tall waves = 1, short waves = 0)
  - Waves can be modified to be read as code by changing the frequency of a wave (i.e., long frequency =1, short frequency = 0)
- Analyze real-life situations that are improved by digital storage and transmission

TARGET CROSS CUTTING CONCEPT PROGRESSION

Stability and Change

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale. • Small changes in one part of a system might cause large changes in another part. • Stability might be disturbed either by sudden events or gradual changes that accumulate over time. • Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms.
Grades 3-5	• Change is measured in terms of differences over time and may occur at different rates. • Some systems appear stable, but over long periods of time will eventually change.
Grades K-2	• Some things stay the same while other things change. • Things may change slowly or rapidly.

9-12 GRADE LEVEL ELEMENT(S)

- Systems can be designed for greater or lesser stability.

What ideas or concepts are truly unique to this grade band?

- Systems can be purposefully designed
- A system can be designed to be more or less stability

Key concepts students need access to in order to be successful:

- Exposure to real-world examples of information storage that represents stability and lack of stability
  - Examples might include the military records that were destroyed in a fire when stored on paper, medical records stored digitally that can be accessed at multiple locations of the same network
- Exposure to questions related to stability of digital transmission and storage
- Describe how the level of importance of the data stored determines the importance of stability of the storage system
  - Some types of data/files are very important to not be corrupted or lost (money, personal information, medical information) while some does not have as much dire impact if lost

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

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.**]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Engaging In Argument from Evidence

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Compare and critique two arguments on the same topic and analyze whether they emphasize similar or different evidence and/or interpretations of facts.
Grades 3-5	• Compare and refine arguments based on an evaluation of the evidence presented. • Distinguish among facts, reasoned judgment based on research findings, and speculation in an explanation.
Grades K-2	• Identify arguments that are supported by evidence. • Distinguish between explanations that account for all gathered evidence and those that do not. • Analyze why some evidence is relevant to a scientific question and some is not. • Distinguish between opinions and evidence in one's own explanations.

9-12 GRADE LEVEL ELEMENT(S)

- Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.

What ideas or skills are truly unique to this grade band?

- An argument is composed of claim, evidence, and reasoning.
- Evaluating currently accepted explanations and solutions.
- Determine merits of arguments.

Key experiences students need access to in order to be successful:

- Students need opportunities to see how scientific theories are based on experimental evidence and when that when technology improves and new experimental evidence is discovered, theories are updated
- Students need to be given the currently accepted claims for wave particle duality
- Students need evidence from experiments showing light as a wave
- Students need evidence from experiments showing the particle nature of light
- Evaluate the evidence and reasoning for each accepted claim (wave model vs particle model) to determine which claim is more appropriate for a given situation

TARGET DISCIPLINARY CORE IDEA PROGRESSION

PS4.A: Wave Properties and **PS4.B**: Electromagnetic Radiation

PS4.A: Wave Properties

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. [MS-PS4-1] • A sound wave needs a medium through which it is transmitted. [MS-PS4-2]
Grades 3-5	• Waves of the same type can differ in amplitude (height of the wave) and wavelength (spacing between wave peaks). [4-PS4-1]
Grades K-2	• Sound can make matter vibrate, and vibrating matter can make sound. [1-PS4-1]

9-12 GRADE LEVEL ELEMENT(S)

- [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

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. [MS-PS4-2] • The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends. [MS-PS4-2] • A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media. [MS-PS4-2] • However, because light can travel through space, it cannot be a matter wave, like sound or water waves. [MS-PS4-2]
Grades 3-5	• An object can be seen when light reflected from its surface enters the eyes. [4-PS4-2]
Grades K-2	• Objects can be seen only when light is available to illuminate them. Some objects give off their own light. [1-PS4-2] • Some materials allow light to pass through them, others allow only some light through and others block all the light and create a dark shadow on any surface beyond them, where the light cannot reach. Mirrors can be used to redirect a light beam. (Boundary: The idea that light travels from place to place is developed through experiences with light sources, mirrors, and shadows, but no attempt is made to discuss the speed of light.) [1- PS4-3]

9-12 GRADE LEVEL ELEMENT(S)

- 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.

Foundational concepts necessary for success that are not covered in previous grade bands:

- Electromagnetic radiation is energy released by electrons and modeled as either a photon or a wave of radiation.
- Waves can interfere (interact) during the time that they cross each other: if they are in phase they add, if they are out of phase they cancel one another.
- When interacting waves continue moving and separate they are unaffected by each other (i.e., no collision effect).
- The photoelectric effect is the ejection of electrons from a metal plate when light hits it.
- Electromagnetic radiation as a wave can be described using frequency, wavelength, amplitude, speed, and energy.
- Electromagnetic radiation as a particle uses photons that can be described using energy changes of the electrons in an atom.

Key ideas that students need to apply in order to be successful:

- Phenomena related to electromagnetic radiation can be modeled with electromagnetic radiation represented as a wave or a particle (photon) and in some situations one model is more appropriate than the other.
- The wave model is used to represent electromagnetic radiation when explaining how two sources of electromagnetic radiation interact with each other.
    - Electromagnetic radiation waves that are in phase with each other are represented in a wave model to show the additive effect to their amplitude.
    - Electromagnetic radiation waves that are out of phase with each other are represented in a wave model to show the canceling effect to their amplitude.
    - When electromagnetic radiation waves are no longer interacting there is no lasting effect from the interaction.
- The wave model is used to represent what happens when electromagnetic radiation is passed through diffraction grating.
    - Diffraction grating bends electromagnetic radiation as it passes through.
    - Each wavelength is bent at a different angle which causes the separation of the light waves based on wavelength.
- The wave model is used to represent the phenomenon of redshift and blueshift.
    - Observable shifts in colors (observed frequencies) depend on the relative velocities of the observer and object emitting the signal.
    - Redshift occurs when the distance between objects increases over time. Blueshift occurs when the distance between objects decreases over time.
- The wave model is used to represent what happens when information is transmitted via waves.
    - Information can be sent via amplitude modification (tall vs. short represent 1s and 0s) (AM).
    - Information can be sent via frequency modification (short frequency vs long frequency represent 1s and 0s) (FM).
- The particle model is used to represent electromagnetic radiation when explaining the photoelectric effect.
    - Photons displace electrons in the metal plate, requiring the particle model over the wave model.
- The particle model is used to represent reflective properties of different surfaces.
    - If a surface is rough then individual particles are scattered in multiple directions so there is not a clear reflective image.
    - If a surface is smooth the particles all bounce the same direction to produce a clear reflective image.
    - Note: the wave model works for modeling reflection from smooth surfaces as well.

- The particle model is used to represent electron energy level changes in atoms.
  - Incoming energy can excite an electron which then emits the particle of energy as a photon when it returns to a lower energy level.
  - The specific change in energy levels produce photons of different energies (frequencies).

Additional Information:

- This standard should be taught with HS-PS4-5 to connect the phenomena of a technological device from HS-PS4-5 to the critical content of wave/particle models of electromagnetic radiation in this standard.

TARGET CROSS CUTTING CONCEPT PROGRESSION

Systems and System Models

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. • Models can be used to represent systems and their interactions - such as inputs, processes and outputs - and energy, matter, and information flows within systems. • Models are limited in that they only represent certain aspects of the system under study.
Grades 3-5	• A system can be described in terms of its components and their interactions.
Grades K-2	• Systems in the natural and designed world have parts that work together.

9-12 GRADE LEVEL ELEMENT(S)

- 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.

What ideas or concepts are truly unique to this grade band?

- Models can be simulations
- Different scales

Key concepts students need access to in order to be successful:

- Students need to be given multiple models of electromagnetic radiation as a wave and as a particle
- Explain the similarities and differences between the models including the representation of energy and matter
- Identify under which circumstances each model is more useful
- The particle model is more useful for describing particle interactions and the wave model is more useful for describing observable behavior

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

HS-PS4-4

Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter. [*Clarification Statement: Emphasis is on the idea that photons associated with different frequencies of light have different energies, and the damage to living tissue from electromagnetic radiation depends on the energy of the radiation. Examples of published materials could include trade books, magazines, web resources, videos, and other passages that may reflect bias.*] [**Assessment Boundary: Assessment is limited to qualitative descriptions.**]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Obtaining, Evaluating, and Communicating Information

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Gather, read, synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence. • Evaluate data, hypotheses, and/or conclusions in scientific and technical texts in light of competing information or accounts.
Grades 3-5	• Obtain and combine information from books and/or other reliable media to explain phenomena or solutions to a design problem.
Grades K-2	• Obtain information using various texts, text features (e.g., headings, tables of contents, glossaries, electronic menus, icons), and other media that will be useful in answering a scientific question and/or supporting a scientific claim.

9-12 GRADE LEVEL ELEMENT(S)

- Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible.

What ideas or skills are truly unique to this grade band?

- Validity and reliability of claims.
- Possible verification of data.

Key experiences students need access to in order to be successful:

- Given claims from published materials related to the absorption of different frequencies of electromagnetic radiation in matter, including living tissue matter.
- Students need to be given multiple related claims to evaluate.
- Evaluate the claim for validity by considering the evidence presented and determining how strongly the evidence supports the claim and directly related to the problem being investigated.
- Evaluate the claim for reliability by considering the methods used to collect evidence and if those methods could be reproduced.

TARGET DISCIPLINARY CORE IDEA PROGRESSION

PS4.B: Electromagnetic Radiation

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. [MS-PS4-2] • The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends. [MS-PS4-2] • A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media. [MS-PS4-2] • However, because light can travel through space, it cannot be a matter wave, like sound or water waves. [MS-PS4-2]
Grades 3-5	• An object can be seen when light reflected from its surface enters the eyes. [4-PS4-2]
Grades K-2	• Objects can be seen only when light is available to illuminate them. Some objects give off their own light. [1-PS4-2] • Some materials allow light to pass through them, others allow only some light through and others block all the light and create a dark shadow on any surface beyond them, where the light cannot reach. Mirrors can be used to redirect a light beam. (Boundary: The idea that light travels from place to place is developed through experiences with light sources, mirrors, and shadows, but no attempt is made to discuss the speed of light.) [1- PS4-3]

9-12 GRADE LEVEL ELEMENT(S)

- 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.

Foundational concepts necessary for success that are not covered in previous grade bands:

- Wavelength is often used to describe and define different types of electromagnetic radiation and colors of light, however frequency is the variable that actually determines type of electromagnetic radiation
- For light, frequency and wavelength have an inverse relationship
- For light, frequency and energy have a direct relationship
- As electromagnetic radiation travels through different matter the frequency remains the same
- Electromagnetic radiation can interact with matter by being transmitted, absorbed, reflected, or refracted.

Key ideas that students need to apply in order to be successful:

- Electromagnetic radiation with a lower frequency (longer wavelength) is generally converted to thermal energy when absorbed by matter.
  - i.e., microwaves, visible light, infrared, radio waves
- Electromagnetic radiation with a higher frequency (shorter wavelength) can ionize atoms when absorbed by matter
  - i.e., ultraviolet waves, x-rays, gamma rays
- Ionization due to absorbing high frequency radiation can damage living tissues

TARGET CROSS CUTTING CONCEPT PROGRESSION

Cause and Effect

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. • Cause and effect relationships may be used to predict phenomena in natural or designed systems.
Grades 3-5	• Cause and effect relationships are routinely identified, tested, and used to explain change. • Events that occur together with regularity might or might not be a cause and effect relationship.
Grades K-2	• Events have causes that generate observable patterns. • Simple tests can be designed to gather evidence to support or refute student ideas about causes.

9-12 GRADE LEVEL ELEMENT(S)

- Cause and effect relationships can be suggested and predicted for complex natural and human-designed systems by examining what is known about smaller scale mechanisms within the system.

What ideas or concepts are truly unique to this grade band?

- Looking at smaller scale mechanisms to infer the outcomes of a cause and effect relationship at a macroscale.
- Considering more complex systems.

Key concepts students need access to in order to be successful:

- Be given multiple claims in order to identify cause and effect reasoning in each claim.
- Be given multiple claims that extrapolate large scale cause and effect relationships from small scale relationships.
- Explain that the cause and effect relationship of ionizing radiation on a single molecule or cell within a body can lead to a larger scale overall effect on the organism.
- If the effect of electromagnetic radiation at the smaller scale of molecules, cells, or tissue is known then the possible outcome to the larger scale of the overall organism can be predicted.

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

HS-PS4-5

Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy. [*Clarification Statement: Examples could include solar cells capturing light and converting it to electricity; medical imaging; and communications technology.*] [**Assessment Boundary: Assessments are limited to qualitative information. Assessments do not include band theory.**]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Obtaining, Evaluating, and Communicating Information

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Communicate scientific and/or technical information (e.g. about a proposed object, tool, process, system) in writing and/or through oral presentations.
Grades 3-5	• Communicate scientific and/or technical information orally and/or in written formats, including various forms of media as well as tables, diagrams, and charts.
Grades K-2	• Communicate information or design ideas and/or solutions with others in oral and/or written forms using models, drawings, writing, or numbers that provide detail about scientific ideas, practices, and/or design ideas.

9-12 GRADE LEVEL ELEMENT(S)

- Communicate technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).

What ideas or skills are truly unique to this grade band?

- Multiple formats
- Format options include: graphically, textually, and mathematically
- Process of development
- Design and performance of a proposed process or solution
- Phenomena

Key experiences students need access to in order to be successful:

- Organize thinking to identify key ideas before communicating
- Determining best methods of communication for the ideas related to the topic and intended audience
  - Students need to choose at least two different formats to communicate information about the structure, properties, and design of chosen materials.
  - Formats can include: oral, graphical, textual, mathematical
- Technical writing experiences.
- Oral presentation experiences.

- Create a multimodal explanation of a specific technological device that explains how it uses the principles of wave behavior.
  - Must include how the device uses or is impacted by wave interactions with matter.
  - Must include how the device transmits and captures information and energy.
  - Organize information graphically
    - i.e., if using a slide style or infographic format having it organized in a visually engaging manner that is accessible to all who will be receiving the information; or ensuring all graphics are correct, legible, relevant, proper citations, in a poster or paper presentation etc.
  - Cite information used as appropriate

TARGET DISCIPLINARY CORE IDEA PROGRESSION

PS4.A: Wave Properties, **PS4.B**: Electromagnetic Radiation, **PS4.C**: Information Technologies and Instrumentation and **PS3.D**: Energy in Chemical Processes

PS4.A: Wave Properties

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. [MS-PS4-1]
Grades 3-5	• Waves of the same type can differ in amplitude (height of the wave) and wavelength (spacing between wave peaks). [4-PS4-1]
Grades K-2	• N/A

9-12 GRADE LEVEL ELEMENT(S)

- Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. .

PS4.B: Electromagnetic Radiation

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. [MS-PS4-2] • A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media. [MS-PS4-2]
Grades 3-5	• An object can be seen when light reflected from its surface enters the eyes. [4-PS4-2]
Grades K-2	• Objects can be seen only when light is available to illuminate them. Some objects give off their own light. [1-PS4-2] • Some materials allow light to pass through them, others allow only some light through and others block all the light and create a dark shadow on any surface beyond them, where the light cannot reach. Mirrors can be used to redirect a light beam. (Boundary: The idea that light travels from place to place is developed through experiences with light sources, mirrors, and shadows, but no attempt is made to discuss the speed of light.) [1- PS4-3]

9-12 GRADE LEVEL ELEMENT(S)

- Photoelectric materials emit electrons when they absorb light of a high-enough frequency.

PS4.C: Information Technologies and Instrumentation

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information. [MS-PS4-3]
Grades 3-5	• Digitized information transmitted over long distances without significant degradation. High-tech devices, such as computers or cell phones, can receive and decode information - convert it from digitized form to voice - and vice versa. [4-PS4-3]
Grades K-2	• People also use a variety of devices to communicate (send and receive information) over long distances. [1-PS4-4]

9-12 GRADE LEVEL ELEMENT(S)

- 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.

PS3.D: Energy in Chemical Processes

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• N/A
Grades 3-5	• The expression "produce energy" typically refers to the conversion of stored energy into a desired form for practical use. [4-PS3- 4]
Grades K-2	• N/A

9-12 GRADE LEVEL ELEMENT(S)

- Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy. (secondary)

Foundational concepts necessary for success that are not covered in previous grade bands:

- Different types of data can be stored digitally or analog.
  - Analog storage includes things like paper, film, tapes, vinyl which stores information as a continuous value.
  - Digital storage includes things like hard-drives, flash drives, CDs, DVDs, etc. which all store the information through a code of 1s and 0s.
- Analog information from a wave can be converted to digital information.
- Information can be sent via amplitude modification (tall vs. short represent 1s and 0s).
- Information can be sent via frequency modification (short frequency vs long frequency represents 1s and 0s).
- Digital Data is stored in a computer's memory.
- Waves can be described using wavelength, amplitude, and frequency.
- Frequency is the variable that actually determines type of electromagnetic radiation.
- Electromagnetic radiation is energy released by electrons and modeled as either a photon or a wave of radiation.
- Waves can interfere (interact) during the time that they cross each other: if they are in phase they add, if they are out of phase they cancel one another.
- When interacting waves continue moving and separate they are unaffected by each other (i.e., no collision effect).
- The photoelectric effect is the ejection of electrons from a metal plate when light hits it.
- As electromagnetic radiation travels through different matter the frequency remains the same, but the speed and wavelength can change.
- Electromagnetic radiation can interact with matter by being transmitted, absorbed, reflected, or refracted.

Key ideas that students need to apply in order to be successful:

- Describe how wave behavior affects the operation of certain devices based on a specific scenario (i.e., how different wavelengths are used for imaging, how different frequencies affect the amount of energy a photon has that can be transferred).
- Identify and describe how information and/or energy are transmitted or transferred in the specific situation.

Additional Information:

- The unpacking of this standard for the DCI key ideas is intentionally non-specific with regards to wave behavior, specific devices, or how devices use principles of wave behavior to transmit and store information because there are multiple possible technological devices that can be used as a phenomenon for this standard.
- This standard should be taught with HS-PS4-3 to connect the chosen phenomena of a technological device from this standard to the critical content of wave/particle models of electromagnetic radiation in HS-PS4-3.

TARGET CROSS CUTTING CONCEPT PROGRESSION

Cause and Effect

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. • Cause and effect relationships may be used to predict phenomena in natural or designed systems. • Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.
Grades 3-5	• Cause and effect relationships are routinely identified, tested, and used to explain change. • Events that occur together with regularity might or might not be a cause and effect relationship.
Grades K-2	• Events have causes that generate observable patterns. • Simple tests can be designed to gather evidence to support or refute student ideas about causes.

9-12 GRADE LEVEL ELEMENT(S)

- Systems can be designed to cause a desired effect.

What ideas or concepts are truly unique to this grade band?

- A system can be purposefully designed to cause a specific effect

Key concepts students need access to in order to be successful:

- Identify the system components that make up the technical device.
- Identify what the system was designed to do (desired outcome).
- Identify what components are critical to the design and desired outcome of the system.
- Identify the cause and effect relationship based on the wave properties and behavior within the system of the technological device.

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

Glossary of Terms

Cross Cutting Concept[1]

These are concepts that hold true across the natural and engineered world. Students can use them to make connections across seemingly disparate disciplines or situations, connect new learning to prior experiences, and more deeply engage with material across the other dimensions. The NGSS requires that students explicitly use their understanding of the CCCs to make sense of phenomena or solve problems.

Disciplinary Core Idea[1]

The fundamental ideas that are necessary for understanding a given science discipline. The core ideas all have broad importance within or across science or engineering disciplines, provide a key tool for understanding or investigating complex ideas and solving problems, relate to societal or personal concerns, and can be taught over multiple grade levels at progressive levels of depth and complexity.

Elements[1]

The bulleted practices, disciplinary core ideas, and crosscutting concepts that are articulated in the foundation boxes of the standards as well as the in the NGSS appendices on each dimension.

Next Generation Science Standards (NGSS)[1]

K–12 science content standards. Standards set the expectations for what students should know and be able to do. Adopted in as Kansas Science Standards in 2013

Performance Expectation[1]

Each NGSS standard is written as a performance expectation that sets the learning goals for students, but does not describe how students get there. Each standard is not a daily standard but an expectation of what students should be able to do by the end of instruction (years or grade-bands).

Science and Engineering Practice[1]

The practices are what students DO to make sense of phenomena. They are both a set of skills and a set of knowledge to be internalized. The SEPs reflect the major practices that scientists and engineers use to investigate the world and design and build systems.

Standards[2]

End of instruction goals or benchmarks for student proficiency.

Standards Alignment[3]

Standards-Aligned instruction has clearly defined student learning expectations aligned to Kansas State Standards and supported with evidence-based instruction and materials.

1 Next Generation Science Standards. https://www.nextgenscience.org/
2 NGSS Glossary. https://www.nextgenscience.org/glossary
3 KSDE. 2023 Science HS Scope and Sequence Guidance. https://community.ksde.gov/LinkClick.aspx?fileticket=wmQyOpyeCBs%3d&tabid=5675&mid=13857

GLOSSARY OF TERMS

Standards Bundles[4]

Grouping elements or concepts from multiple PEs in lessons, units, and/or assessments that students can develop and use together to build toward proficiency on a set of PEs in a coherent manner.

Standards Unpacking

A systematic process of identifying the key ideas, experiences, and concepts that students need to demonstrate to show mastery of a standard.

Three-Dimensions[1]

These are the three strands of knowledge and skills that students should explicitly be able to use to explain phenomena and design solutions to problems. The three dimensions are the Disciplinary Core Ideas (DCIs), Crosscutting Concepts (CCCs), and Science and Engineering Practices (*"the Practices"* or SEPs).

Unpacked Standard

The key ideas, experiences, and concepts that are identified as necessary for a student to demonstrate to show mastery of a standard. An unpacked standard is intended to provide clarity on the expectations of the standard and intentionally does not include any ideas, concepts, or experiences beyond the standard.

4 Bundling the NGSS. https://www.nextgenscience.org/resources/bundling-ngss

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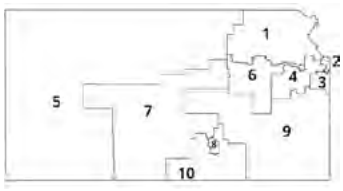

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- Civic engagement

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OUTCOMES

- Social-emotional growth
- Kindergarten readiness
- Individual Plan of Study
- Civic engagement
- Academically prepared for postsecondary
- High school graduation
- Postsecondary success

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