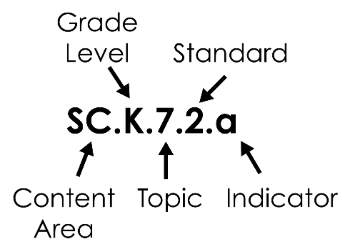
Plus Physics Teacher's Guide to the Nebraska College and Career Ready Standards for Science 2024

Content Area Standards Structure

The overall structure of Nebraska's College and Career Ready Standards for Science (CCR-Science) reflects the two-tier structure common across all Nebraska content area standards. The two levels within the structure include **standards** and **indicators**. The **standards** are broad, overarching content-based statements that describe the basic cognitive, affective, or psychomotor expectations of student learning. The standards, across all grade levels, reflect long-term goals for learning. **Indicators** further describe what students must know and be able to do to meet the standard. These performance-based statements provide clear expectations related to student learning in each content area. Additionally, indicators provide guidance related to the assessment of student learning. This guidance is articulated by including ***assessment boundary*** statements.

The CCR-Science standards describe the knowledge and skills that students should learn, but they do not prescribe particular curriculum, lessons, teaching techniques, or activities. Standards describe what students are expected to know and be able to do, while the local curriculum describes how teachers will help students master the standards. A wide variety of instructional resources may be used to meet the state content area standards. Decisions about curriculum and instruction are made locally by individual school districts and classroom teachers. The Nebraska Department of Education provides guidance related to high-quality instructional materials selection and implementation. Please visit the Nebraska Instructional Materials Collaborative.

In addition to a common structure for content area standards, a consistent numbering system is used for content area standards. The numbering system is as follows:



Content Area Standards Overview

Nebraska Revised Statute 79-760.01 requires the State Board of Education to adopt measurable academic content standards for the areas of reading, writing, mathematics, science, and social studies. Standards describe grade-level expectations for given content areas and provide a framework upon which Nebraska districts develop, establish, and implement curriculum. For effective teaching and learning to occur, the content area standards should drive local decisions related to instructional materials, resources, and interim, formative, and summative assessments.

The Nebraska Department of Education has identified quality criteria in the development of content area standards. These criteria ensure that standards are grounded in a strong research base of human cognition, motivation, and teaching and learning and describe essential knowledge and skills for college, career, and civic readiness. The revised science standards, written by teams of Nebraska educators and reviewed by local and national experts, were developed with the following indicators of quality:

Measurable: Standards provide benchmarks against which student progress toward learning goals can be measured.

Appropriately challenging: Standards must build in complexity so that by the end of grade 12, students are prepared for postsecondary education and the workforce.

Connected: Student learning is most effective when it connects knowledge and skills to related topics and authentic applications.

Clearly worded: Content area standards must effectively communicate what students should know and be able to do.

Scaffolded: Indicators in the Nebraska content area standards scaffold student learning by sequencing connected knowledge and skills across grades so that students build and deepen understanding and ability over time.

Specific: Specificity assures that the language used in standards and indicators is sufficiently detailed to be accurately interpreted by educators

Organization and Structure of College and Career Ready Standards for Science (CCR-Science)

Nebraska's College and Career Ready Standards for Science (CCR-Science) are organized by grade level for grades K-8 and by grade span in high school. K-5 standards are organized to reflect the developmental nature of learning for elementary students and attend to the learning progressions that build foundational understandings of science. By the time students reach middle school (Grades 6-8), they build on this foundation in order to develop more sophisticated understandings of science concepts through high school. The topic progression for the CCR-Science standards is included in Appendix A: Topic Progression.

Within each grade level/span the standards are organized around topics, and each standard addresses one topic. Each CCR-Science standard begins with the common stem: "Gather, analyze, and communicate…" This stem highlights long-term learning goals associated with rigorous science standards and provides guidance for high quality classroom instruction. To facilitate high-quality instruction, students actively gather evidence from multiple sources related to the topics. Evidence is carefully analyzed in order to describe and explain natural phenomena, and then, students communicate their understanding of the content using a variety of tools and strategies. It is important to note that while topics are introduced in a spiraled model, they are connected, and deeper understanding at subsequent grade levels and spans requires foundational understanding of multiple topics.

The indicators reflect the three dimensions of science learning outlined in *A Framework for K-12 Science Education*[1]. Each CCR-Science indicator includes a disciplinary core idea, <u>a crosscutting concept</u> (<u>underline</u>), and a **science and engineering practice** (**bold**).

Disciplinary Core Ideas (DCI)

The disciplinary core ideas are the focused, limited set of science ideas identified in the Framework as necessary for ALL students throughout their education and beyond their K-12 school years to achieve scientific literacy. The limited number of disciplinary core ideas allows more time for students and teachers to engage in the science and engineering practices as they deeply explore science ideas. To allow students to continually build on and revise their knowledge and abilities, the disciplinary core ideas are built on developmental learning progressions (Appendix A).

Crosscutting Concepts (CCC)

The crosscutting concepts are used to organize and make sense of disciplinary core ideas. They serve as tools that bridge disciplinary boundaries and deepen understanding of science content. With grade-appropriate proficiency, students are expected to use patterns (cause and effect, scale, proportion, and quantity), systems and system models (energy and matter, structure and function) and stability and change as they gather, analyze, and communicate scientific understanding. These crosscutting concepts provide structure for synthesizing knowledge from various fields into a coherent and scientifically-based view of the world.

Science and Engineering Practices (SEP)

The science and engineering practices are used by students to demonstrate understanding of the disciplinary core ideas and crosscutting concepts. Engaging in the practices of science and engineering helps students understand the wide range of approaches used to investigate natural phenomena and develop solutions to challenges. Students are expected to demonstrate grade-appropriate proficiency in asking questions and defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, constructing explanations and designing solutions, engaging in argument from evidence, and obtaining, evaluating, and communicating information as they gather, analyze, and communicate scientific information.

Each science indicator focuses on one crosscutting concept and one science and engineering practice as an example to guide assessment. Curriculum, instruction, and assessment should reflect authentic science practice and be phenomena-based. Furthermore, curriculum, instruction, and assessment should use crosscutting concepts and science and engineering practices that go beyond what is stated in the indicator to better reflect authentic science practice. Utilizing the range of SEPs and CCCs will support deeper learning and greater understanding of the DCIs.

The following table lists the disciplinary core ideas, crosscutting concepts, and **science and engineering practices**:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
• Asking Questions and Defining Problems • Developing and Using Models • Planning and Carrying Out Investigations • Analyzing and Interpreting Data • Using Mathematics and Computational Thinking • Constructing Explanations and Designing Solutions • Engaging in Argument from Evidence • Obtaining, Evaluating, and Communicating Information	LS1: From Molecules to Organisms: Structures and Processes LS2: Ecosystems: Interactions, Energy, and Dynamics LS3: Heredity: Inheritance and Variation of Traits LS4: Biological Evolution: Unity & Diversity PS1: Matter and Its Interactions PS2: Motion and Stability: Forces and Interactions PS3: Energy PS4: Waves and Their Applications in Technologies for Information Transfer ESS1: Earth's Place in the Universe ESS2: Earth's Systems ESS3: Earth and Human Activity	Patterns Cause and Effect Scale, Proportion, and Quantity Systems and System Models Energy and Matter

	ETS1: Engineering Design	**Structure and Function** **Stability and Change**

[1] *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* Washington, DC: The National Academies Press, 2012.

Icon Titles & Descriptions

Nebraska Connections

Opportunities to teach science using topics directly relevant to our state (e.g. Ogallala Aquifer, agriculture, Nebraska-specific flora and fauna, Nebraska's rich geologic history, etc.) are listed throughout the CCR-Science standards as "Nebraska Connections." These connections allow educators to use local, regional, and state-specific contexts for teaching, learning, and assessment. Educators should use these as recommendations for investigation with students. Additionally, assessment developers have the opportunity to use the Nebraska contexts to develop Nebraska-specific examples or scenarios from which students would demonstrate their general understanding. This approach provides the opportunity for educators to draw upon Nebraska's natural environment and rich history and resources in engineering design and scientific research to support student learning.

Educator Support & Resources

Implementation

Effective science teaching, learning, and assessments should integrate disciplinary core ideas, crosscutting concepts, and **science and engineering practices**. Integration of the three dimensions will allow students to explain scientific phenomena, engage in sensemaking, design solutions to problems, and build a foundation upon which they can continue to learn and be able to apply science knowledge and skills within and outside the K-12 education arena. While each indicator incorporates the three dimensions, this alone does not drive student outcomes. Ultimately, student learning depends on how the standards are translated to instructional practices.

To support educators while they explore and implement content standards, the Nebraska Department of Education has developed the Content Area Standards Implementation Framework. The Framework is based on implementation science and includes stages from "Exploration" to "Deep Implementation," the types of work and activities associated with each stage, and roles of educators in ensuring successful implementation. The goal of the framework is to guide the alignment of standards, instruction, materials, and assessment to create a coherent system of learning.

Phenomenon-based Instruction

Three-dimensional instruction offers authentic learning experiences when students engage in describing and explaining the natural world. This involves focusing the conceptual learning on anchoring and investigative phenomena to better comprehend their observations. Students utilize evidence in the sensemaking process to build concepts in their minds. Phenomena are natural, observable events that we can explain or predict using our science knowledge (the singular form of phenomena is phenomenon).

Teachers are encouraged to adopt phenomenon-based instruction to fully engage students in three-dimensional science learning. This method can be summarized in three steps:

1. Introduce a new unit or concept with a phenomenon: Start by presenting a phenomenon that is relevant to students' lives. This engages them in asking questions about their observations and fosters a desire to learn more. Many teachers already use this approach by introducing new units or concepts with tangible examples such as pictures, videos, demonstrations, or laboratory experiences.

2. Engaging in science and engineering practices: Provide opportunities for students to gather and reason about information to explain the phenomenon. Sensemaking represents a shift in science instruction where teachers refrain from giving students direct answers. Instead, they should offer multiple opportunities for students to explore the phenomenon individually and in groups, while scaffolding their learning. This approach supports students in developing an understanding of scientific concepts and constructing their own explanations for the phenomenon.

3. Communicating understanding: Ensure students have multiple opportunities to articulate their thinking about why the phenomenon occurs. To deepen their understanding, check that student explanations progress from simple descriptions of what they observe to more complex explanations and predictions of what they think is happening with the phenomenon.

Throughout this process, teachers should not provide direct answers about the phenomenon. Instead, they should facilitate experiences that help students reach an appropriate understanding. Often, this involves engaging students in scientific arguments where they challenge each other's claims and explanations using their observations and collected evidence.

Teacher Guides

The Teacher Guides were created to provide guidance for developing effective instruction aligned to Nebraska's College and Career Ready Science Standards. They are intended to support teachers, administrators, science specialists, ESU's, instructional coaches, parents, and other stakeholders as they plan instruction and assessment at a local level.

The Teacher Guides are meant as a resource document which unwraps the indicators to support teacher's understanding of the standards. They are not meant to be used by students, and therefore they are not written in student-friendly language.

Nebraska Science Classroom Formative Task Repository

The Nebraska Science Classroom Formative Task Repository is a collection of K-12 formative tasks aligned to the indicator level of the standards. Tasks were developed by Nebraska educators and cover the breadth of the standards giving students an opportunity to provide evidence of what they can know and can do related to that standard.

Graduation Requirements

The high school life science, physical science, and Earth and space science standards are intended for **ALL** students to have learned by the end of 30 credit hours of high school science courses.

> **Rule 10**
> 003.05 Graduation Requirements. Each high school must require from grades nine through twelve at least 200 credit hours for graduation, for which at least 80 percent must be from the core curriculum. The number of credit hours given for a course may be less than the number of instructional units and may be increased up to 25 percent above the number of instructional units.
>> 003.05A3 Science. Thirty credit hours of science with course content that includes biological, earth/space, and physical science concepts with corresponding science inquiry skills and laboratory experience.

Course examples that offer the scope and sequence to include all three domains are included in Appendix B: HS Integrated Science Course Model.

High School Plus Standards (HSP)

The High School Plus (HSP) standards represent advanced science topics designed to build upon the foundations established in the on-level standards and guide additional advanced science courses. The standards were developed using postsecondary syllabi from entry level science courses for science majors (e.g. UNL LIFE 120, CHEM 109). Introducing the content to high school students will scaffold their learning providing a bridge between high school science coursework and postsecondary level coursework. If the indicator includes HSP, it is a plus standard which is supplemental.

Explanation of the Teacher's Guide to the Nebraska CCR-Science Standards

Standard
Standard Code [Content Area].[Grade Level].[Topic].[Standard] The standard description is listed here to give broader context to this and other indicators in the standard. The standard description articulates the core ideas and theme. Standards represent significant areas of learning within grade-level progressions and content areas. Each standard introduction is an orientation for the teacher in order to provide an overall view of the concepts needed for foundational understanding.
Indicator
Indicator Code [Content Area].[Grade Level].[Topic].[Standard].[Indicator] Within each standard are indicators. The indicator is listed here as found in the CCR-Science Standards. Indicators in the CCR-Science Standards are written as student performance expectations that describe what students must know and be able to do by the end of an instructional sequence. An indicator represents a proficiency level for that grade. An indicator articulates how a learner may demonstrate their proficiency, incorporating not only the disciplinary core idea but also a crosscutting concept and a science and engineering practice. While some indicators within a standard may be more comprehensive than others, all indicators are essential for a comprehensive understanding of a standard's purpose.

The DCIs will be in ordinary text. <u>The CCCs will be underlined.</u> **The SEPs will be in bold.** Indicators also include clarification statements and assessment boundaries when needed. Clarification statements offer further clarification to the indicators content or offer examples and are indicated with gray text. Assessment boundaries are the limitations given to the state-developed assessments and are indicated with red text.

NGSS Comparison: [NGSS Code]

The CCR-Science Standards are strongly influenced by the Next Generation Science Standards (NGSS). Teachers can use the NGSS code to find instructional resources. There are many resources that have been created that compare to each NGSS code. It is important to note that the NGSS codes use dashes and end in a number (e.g., 5-PS1-3), and the DCIs use dots and end in a letter (e.g., PS1.A).

Other Indicators in this Standard

Each standard requires all of the indicators to provide the full understanding of the concept knowledge, skills, and lenses needed to demonstrate proficiency for that standard. The indicators included in the standard will be listed here under their code.

Concepts and Skills to Master

Foundation Boxes:

The foundation boxes provide clarity for planning by explicitly and intentionally identifying the three dimensions found in the standard. Teachers should frame their planning around what students will be doing to demonstrate 3D learning. The table identifies the minimum level of complexity expected for proficiency in each of the three dimensions of a standard. Individual classroom instruction can and should use additional Science and Engineering Practices (SEPs) and Crosscutting Concepts (CCCs) to support student sense-making. The information in this table is based on research found in A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (NRC, 2012), adds specificity on how a standard should be interpreted and provides additional ideas of instructional practices related to the standard. The intent is to help the teacher move students into deeper and more focused use of the SEP, CCC, and DCI. The use of supporting SEPs and CCCs is an integral part of robust instruction. The purpose of supporting SEPs and CCCs are to allow multiple ways to approach knowledge, skills, and abilities. Teachers should use the focal SEPs and CCCs during instruction but may utilize supporting SEPs and CCCs to broaden instruction.

Science and Engineering Practice (SEP)	Crosscutting Concept (CCC)
[Science and Engineering Practice Name]: • **The science and engineering practice(s) found in the indicator written in the context of the content (DCI).** • Students do and use the Science and Engineering Practice (SEP). Practices refer to the things that scientists and engineers do and how they actively engage in their work. This section provides more clarification for what students should be doing to engage in this practice. There are various ways that each practice can be used, as articulated in the K-12 Framework for Science Education (NRC, 2012). This information primarily comes from the NSTA's SEP Matrix.	**[Crosscutting Concept Name]:** • **The crosscutting concept(s) found in the indicator written in the context of the content (DCI).** • Students think and connect through the Crosscutting Concept (CCC) in order to reason. Crosscutting concepts provide a lens to focus student thinking in order to support students to make sense of science and engineering concepts to be able to explain phenomena. Teachers encourage students to frame their thinking around the terminology of the CCCs through questions and classroom discussions. This information primarily comes from the NSTA's CCC Matrix.
Disciplinary Core Idea (DCI)	
([DCI Code]): [DCI Name] • **Students know and apply the Disciplinary Core Idea (DCI) in their thinking and reasoning.**	

- These are the core ideas from the K-12 Framework for Science Education (NRC, 2012) that align to this standard. This section is NOT a checklist of content for students to memorize. The purpose of this section is to articulate what core ideas students should know and be able to use to support the explanation of phenomena. If a standard identifies multiple DCIs, this section will be repeated for each core idea. This information primarily comes from the K-12 Framework for Science Education.

Possible Science and/or Engineering Phenomena to Support 3D Instruction

In 3D classroom instruction, a real-world phenomenon centered around a scientific concept or engineering problem is used as the starting point for student learning. The phenomenon encourages students to ask questions, investigate, and ultimately construct explanations for why the phenomenon occurs. Each core guide lists potential phenomena that could be used during instruction. It is important for teachers to understand that the best phenomena are those that are relevant to the context of their students' lives and experiences.

Phenomena are also a critical component of science assessment. When developing classroom assessments, teachers should select different phenomena than those used during standard instruction but require the use of the same concepts. This allows the assessment to measure student proficiency in each of the three dimensions through a novel situation rather than simply assessing students' ability to recall a previous classroom experience.

This document provides a list of possible phenomena; however, teachers should not consider this list all-inclusive. Many appropriate phenomena could be used to investigate and assess each standard.

Evidence Statements

What does it look like to demonstrate proficiency on this indicator?

This section provides statements that delineate what students should be able to know and do to demonstrate proficiency of an indicator. These statements can be used for learning goals, tasks, and assessments during the instructional sequence and should address how the three dimensions interact. These proficiency statements are not intended to be used as curriculum.

Critical Background Knowledge

Grade Band Progressions:

This section illustrates how the three dimensions of science, aligned specifically to an indicator, progress developmentally through grade bands and grade levels. Progressions provide insight into what background knowledge and experience students should have had in prior grades, where teachers should focus science learning in the current grade level, and where students will extend their learning in future grades. Grade band progressions identify where teachers should focus instruction for that grade level in each of the three dimensions. Additionally, progressions are intended to be used to identify areas for student intervention. By looking at previous grade bands, teachers can support students where they are currently and scaffold them to where they need to be by the end of the grade level. The progression table is not intended as a guide for supporting accelerated learning by looking to future grade bands. Accelerated learning should remain in the appropriate grade band, but students could be provided with more depth in their learning experience. This information primarily comes from the NGSS Appendices.

Science and Engineering Practices (SEPs): [SEP name]

The SEPs progress over a student's K-12 science experience. The SEP progressions inform teachers as to how students should be engaging in science and engineering practices. These progressions emphasize the importance of teaching science skills at every grade level because it cannot be assumed that students will develop proficiency in using science and engineering practices independently. With increased developmental ability, students can engage in these practices in more complex ways. Teachers can use the progressions to pre-assess student learning from previous grade bands, adjust instruction, and develop necessary interventions. The science and engineering practices should be addressed to an appropriate developmental level in every grade and science course. In each grade within a grade band, students should be progressing towards mastery of these expectations. Each row of the SEP table delineates a different component of the SEP and how it developmentally progresses.

K-2	3-5	6-8	9-12
[SEP name] in K–2 builds on prior experiences and progresses to...	**[SEP name] in 3–5 builds on K–2 experiences and progresses to...**	**[SEP name] in 6– 8 builds on K–5 experiences and progresses to...**	**[SEP name] in 9-12 builds on K–8 experiences and progresses to college or career experiences.**

Crosscutting Concepts (CCCs): [CCC name]

The CCCs progress over a student's K-12 science experience. These progressions inform teachers as to how students should frame their thinking and reasoning. These progressions emphasize the importance of teaching science at every grade level because it cannot be assumed that students will independently be able to use the CCCs to frame their thinking. With increased developmental ability, students will be able to use the crosscutting concepts to think and reason about more complex tasks and phenomena. Teachers can use the progressions to pre-assess student learning from previous grade bands, adjust instruction, and develop interventions as needed. The crosscutting concepts should be addressed to an appropriate developmental level in every grade and science course. In each grade within a grade band, students should be progressing towards mastery of these expectations.

K-2	3-5	6-8	9-12
[CCC name] in K–2 builds on prior experiences and progresses to...	**[CCC name] in 3–5 builds on K–2 experiences and progresses to...**	**[CCC name] in 6– 8 builds on K–5 experiences and progresses to...**	**[CCC name] in 9-12 builds on K–8 experiences and progresses to college or career experiences.**

Disciplinary Core Ideas (DCIs): [DCI code] [DCI title]

The core ideas progress over a student's K-12 science experience. These progressions inform teachers as to what core ideas the student should know and be able to use in this grade band. This progression emphasizes the importance of teaching science and engineering at every level because it cannot be assumed that students will develop science and engineering conceptual understanding independently. The core ideas build in complexity as students progress through grade bands. Thus, core ideas must be taught sequentially. Teachers can use the progressions to pre-assess student learning from previous grade bands, adjust instruction, and develop interventions as needed. Note: Most core ideas are taught, at minimum, once within a grade band and not necessarily in sequential grade levels. For example, the DCI PS1.A is taught in 2nd-grade, 5th-grade, 6th-grade, 8th-grade, and chemistry. To clarify this, the provided table identifies the grade and standard for which the DCI is taught in each grade band.

K-2	3-5	6-8	9-12
[NGSS DCI code] in K–2 builds on prior experiences and progresses to...	**[NGSS DCI code] in 3–5 builds on K–2 experiences and progresses to...**	**[NGSS DCI code] in 6– 8 builds on K–5 experiences and knowledge and progresses to...**	**[NGSS DCI code] in 9–12 builds on K–8 experiences and knowledge and progresses to...**

Connection to other grade level indicators

This section helps teachers identify potential integration with other indicators that have related disciplinary core ideas at the same grade level or band. When designing curriculum around an anchoring phenomenon and investigative phenomena, identifying how other DCIs relate is pivotal for student understanding of the phenomena and the indicators as significant areas of learning culminating in standards.

Related Cross-Curricular Standards: Current Grade Level

Authentic Connections to Other Content Standards:

This section helps teachers identify potential integration with other content area standards within their grade level. The expectation of the CCR-Science Standards is for all students to be scientifically literate. Scientists use literacy, mathematics, and critical thinking components for gathering, reasoning, and communicating information. In science, students use reading, writing, speaking, listening, and language in ways specific to the discipline of science. ISTE computer science standards are also included when appropriate.

Academic Language Development

Effective science instruction requires discipline-specific communication skills. This means that effective science learning occurs when students are expected to speak, listen, read, and write in ways that are appropriate to science. The tools in this section help teachers facilitate the acquisition of science discourse, which includes academic scientific language. Teaching words or concepts in isolation or prior to experiences that give context (frontloading) robs students of sense-making opportunities that lead to a greater depth of conceptual understanding.

Below is a list of words that students should use during science discourse. These words are not meant to be used as a vocabulary list or to frontload vocabulary prior to instruction. The teacher should introduce these words only after students have first experienced the related concept and used their own words to describe it.

Words to support student discourse related to the Disciplinary Core Ideas (DCIs):

- Supporting discourse words will be listed here.

Supporting resources to aide in student discourse:

- STEM Teaching Tool 48: How can teachers guide classroom conversations to support students' science learning?
- STEM Teaching Tool 41: Prompts for Integrating Crosscutting Concepts Into Assessment and Instruction (Download the PDF for example prompts).

Assessment Considerations

Formative Assessment:

A link is provided to the Nebraska-created formative task repository sign-in on the Nebraska Department of Education's website. Exemplar assessments developed by Nebraska teachers are aligned to the indicator. Formative assessments are available for every standard, not every indicator, for grades K-8, and in the domains of physical science, earth science, and life science at the high school level.

Stackable, Instructionally-Embedded, Portable Science (SIPS) Assessments:

"This website houses tools, information, and resources developed as part of the Stackable, Instructionally-embedded, Portable Science (SIPS) Assessments project funded for a 36-month period from 2020 through 2023 by a Competitive Grants for State Assessments Grant from the Office of Elementary and Secondary Education at the US Department of Education, awarded to the Nebraska Department of Education." https://sipsassessments.org/

The principled design process found on this website explains how NSCAS tasks and the formative task repository tasks are developed. The SCILLSS Digital Workbook on Designing High Quality Three-dimensional Science Assessments for Classroom Use are found in the "Resources" tab, then select the "Assessment Resources." There are curriculum, instruction, and assessment resources for fifth and eighth grade found in the "Resources" tab, then select "SIPS Resources."

Knowledge, Skills, and Abilities:

These are statements developed from the Evidence Statements when writing tasks that specify what is expected of students to demonstrate (i.e., knowledge, skills, and abilities) to provide evidence that they have learned one or more aspects of the CCR-Science Indicator. These are example broad statements that scaffold the logic of the concept and skill development.

Achievement Level Descriptors:

Achievement Level Descriptors are scaled evidence statements of the SEPs and CCCs combined by grade that are used in test score interpretation to determine if a student is performing in the categories of developing, on task, or advanced. Currently these statements are only available in fifth grade and eighth grade.

Plus Standards

The High School Plus (HSP) standards represent advanced science topics designed to enhance the rigor of general science curricula or supplement additional advanced science courses. The standards were developed using postsecondary syllabi from entry level science courses for science majors (e.g. UNL LIFE 120, CHEM 109). Introducing the content to high school students will scaffold their learning, providing a bridge between high school science coursework and postsecondary level coursework. These standards and indicators are for an upper-level course, not recommended for all students.

Standard

Topic Code: SC.HSP.1 Forces, Interactions, and Motion

Standard Code: SC.HSP.1.1 Gather, analyze, and communicate evidence of forces, interactions, and motion.

Uniform motion of an object is natural. Changes in motion are caused by a nonzero sum of forces. A “net force” causes an acceleration as predicted by Newton’s 2nd Law. Qualitative and quantitative analysis of position, velocity, and acceleration provide evidence of the effects of forces. Momentum is defined for a particular frame of reference; it is the product of the mass and the velocity of the object. In any system, total momentum is always conserved. 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. The time over which these paired forces are exerted determines the impact force.

Indicator

Indicator Code: SC.HSP.1.1.a

Generate and interpret mathematical and graphical representations to describe the relationships between position, velocity, acceleration and time. Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to no acceleration and objects undergoing a constant acceleration, including projectile motion, free fall, and circular motion. Examples should also include both average and instantaneous velocities. Assessment is limited to one and two-dimensional motion and to objects moving at non-relativistic speeds.

NGSS Comparison: Builds on HS-PS2-1

Other Indicators in this Standard

SC.HSP.1.1.b, SC.HSP.1.1.c, SC.HSP.1.1.d, SC.HSP.1.1.e

Concepts and Skills to Master

Foundation Boxes:

Science and Engineering Practice (SEP)	Crosscutting Concept (CCC)
Analyzing and Interpreting Data: Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.	**Patterns:** • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Disciplinary Core Idea (DCI)
PS2.A: **Forces and Motion:**

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

Possible Science and/or Engineering Phenomena to Support 3D Instruction

- A ball rolling off a table
- Free Fall of an object
- Toy Car moving at constant speed (use toy cars, metronome app, tape and meter sticks in a gym or long hallway)
- Object tossed vertically upward
- Runner accelerating from rest
- Drone ascending
- RC Car changing speeds
- PhET's The Moving Man
- PhET's Projectile Motion
- Using your phone as a motion detector with PhysicsClassroom.com's Motion Detector

Evidence Statements

What does it look like to demonstrate proficiency on this indicator?

SC.HSP.1.1.a **Generate and interpret mathematical and graphical representations** to describe the relationships between position, velocity, acceleration and time		
1	Organizing data	
	a	Students organize data (e.g., with graphs) from (e.g., computational simulations, investigations)
	b	Students describe* what each data set represents.
2	Identifying relationships	
	a	Students analyze the data and identify and describe* relationships within the datasets, including:
		i. Changes over time on multiple scales; and
		ii. Relationships between quantities in the given data.
3	Interpreting data	
	a	Students use their analysis of the data to describe* a selected aspect of the data set.
	b	Students use their analysis of the data to predict future trends.
	c	Students describe* whether the predicted trends are reversible or irreversible.
	d	Students identify one source of uncertainty in the prediction.
	e	In their interpretation of the data, students:
		i. Make a statement regarding how variation or uncertainty in the data (e.g., limitations, accuracy, any bias in the data resulting from choice of sample, scale, instrumentation, etc.) may affect the interpretation of the data; and
		ii. Identify the limitations of the provided data and ranges for their predictions.

Critical Background Knowledge

Grade Band Progressions:

Science and Engineering Practices (SEPs): Analyzing and Interpreting Data

K-2	3-5	6-8	9-12

Analyzing and Interpreting Data in K–2 builds on prior experiences and progresses to... 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).	**Analyzing and Interpreting Data in 3–5 builds on K–2 experiences and progresses to...** Represent data in tables and/or various graphical displays (bar graphs, pictographs, and/or pie charts) to reveal patterns that indicate relationships.	**Analyzing and Interpreting Data in 6– 8 builds on K–5 experiences and progresses to...** 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.	**Analyzing and Interpreting Data in 9-12 builds on K–8 experiences and progresses to college or career experiences.** 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.

Crosscutting Concepts (CCCs): Patterns

K-2	3-5	6-8	9-12
Patterns in K–2 builds on prior experiences and progresses to... Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence.	**Patterns in 3–5 builds on K–2 experiences and progresses to...** Patterns of change can be used to make predictions.	**Patterns in 6– 8 builds on K–5 experiences and progresses to...** Patterns can be used to identify cause and effect relationships.	**Patterns in 9-12 builds on K–8 experiences and progresses to college or career experiences.** 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.

Disciplinary Core Ideas (DCIs): PS2.A: Forces and Motion

K-2	3-5	6-8	9-12
PS2.A in K–2 builds on prior experiences and progresses to... Pushes and pulls can have different strengths and directions and can change the speed or direction of its motion or start or stop it.	**PS2.A in 3–5 builds on K–2 experiences and progresses to...** The effect of unbalanced forces on an object results in a change of motion. Patterns of motion can be used to predict future motion. Some forces act through contact; some forces act even when the objects are not in contact. The	**PS2.A in 6– 8 builds on K–5 experiences and knowledge and progresses to...** The role of the mass of an object must be qualitatively accounted	**PS2.A in 9–12 builds on K–8 experiences and knowledge and progresses to...** Newton's 2nd law (F=ma) and the conservation of momentum can

	gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center.	for in any change of motion due to the application of a force.	be used to predict changes in the motion of macroscopic objects.

Connection to other grade level indicators

ELA Connections:

- LA.10.SL.2.c: Analyze the purpose of information being presented, evaluate its motives (e.g., social, commercial, political), and determine its credibility.

Mathematics Connections:

- N-Q.1. Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and origin in graphs and data displays.
- N-Q.2. Define appropriate quantities for the purpose of descriptive modeling.
- N-Q.3. Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

Social Studies Connections:

Fine and Performing Arts Connections:

Related Cross-Curricular Standards: Current Grade Level

Authentic Connections to Other Content Standards:

- High School Conceptual Progressions Model Course 1 - Bundle 1
  SC.HS.1.1.a, SC.HS.1.1.d, SC.HS.11.1.b, SC.HS.11.1.d
- High School Conceptual Progressions Model Course 1 - Bundle 3
  SC.HS.1.1.b, SC.HS.1.1.c, SC.HS.4.4.b, SC.HS.4.4.e, SC.HS.13.3.b

Academic Language Development

Words to support student discourse related to the Disciplinary Core Ideas (DCIs):

- Velocity, acceleration, mass, vectors, slope, y-intercept, macroscopic, non-relativistic speeds, average velocity, instantaneous velocity, constant acceleration, projectile motion, free fall, circular motion

Assessment Considerations

Formative Assessment:

- https://www.education.ne.gov/assessment/nscas-science/
- Utah Seed Formative Assessment PHYS.1.1
- Wonder of Science: Gyro Drop
- Wonder of Science: Porsche's Claims
- Wonder of Science: Modified Porsche's Claims
- Wonder of Science: Strongest Man
- Wonder of Science: Dropped Spheres

Stackable, Instructionally-Embedded, Portable Science (SIPS) Assessments:

- https://sipsassessments.org/

Knowledge, Skills, and Abilities:

- **KSA1**: Evaluate mathematical or graphical crash data to determine impulse force

- **KSA2**: Calculate the amount of momentum given the mass and velocity of an object to establish patterns in data.
- **KSA3**: Model how Impulse forces can be reduced by increasing the time of impact using different design constraints.
- **KSA4:** Compare how different materials or component structures help reduce impact forces during a collision to help design or refine a device or system.
- **KSA5**: Evaluate systems intended to reduce the impact of collisions to determine which fits with the design criteria and constraints and results in the desired effect(s).

Standard

Topic Code: SC.HSP.1 Forces, Interactions, and Motion

Standard Code: SC.HSP.1.1 Gather, analyze, and communicate evidence of forces, interactions, and motion.

The uniform motion of an object is natural. Changes in motion are caused by a nonzero sum of forces. A "net force" causes an acceleration as predicted by Newton's 2nd Law. Qualitative and quantitative analysis of position, velocity, and acceleration provide evidence of the effects of forces. Momentum is defined for a particular frame of reference; it is the product of the mass and the velocity of the object. In any system, total momentum is always conserved. 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. The time over which these paired forces are exerted determines the impact force.

Indicator

Indicator Code: SC.HSP.1.1.b

Use mathematical and pictorial models as applied to Newton's second law of motion describing the relationship among the net force on a macroscopic object, its mass, and its acceleration. Examples include drawing and using free body diagrams to analyze the net force on the object and the resulting motion; vectors including decomposition and recomposition, addition and subtraction. Assessment is limited to two-dimensional motion.

NGSS Comparison: Builds on HS-PS2-1

Other Indicators in this Standard

SC.HSP.1.1.a, SC.HSP.1.1.c, SC.HSP.1.1.d, SC.HSP.1.1.e

Concepts and Skills to Master

Foundation Boxes:

Science and Engineering Practice (SEP)	Crosscutting Concept (CCC)
Using Mathematics and Computational Thinking: Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Use mathematical representations of phenomena to describe explanations.	**Systems and System Models:** • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined.

Disciplinary Core Idea (DCI)

PS2.A: Forces and Motion:

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

Possible Science and/or Engineering Phenomena to Support 3D Instruction

- The Walking Table
- Magnetic Canon
- Amazing Slinky Tricks
- A Bed of Nails
- Raw or Boiled Egg Experiment
- Flymo Hover Lawnmower

Evidence Statements

What does it look like to demonstrate proficiency on this indicator?

SC.HSP.1.1.b **Use mathematical and pictorial models** as applied to Newton's second law of motion describing the relationship among the net force on a macroscopic object, its mass, and its acceleration.

Representation	
a	Students identify and describe* the components in the given mathematical and/or computational representations (e.g., trends, averages, histograms, graphs, spreadsheets) that are relevant to supporting given explanations
b	Students identify the given claim(s) and/or explanation(s) to be supported,
Mathematical and/or computational modeling	
a	Students use given mathematical and/or computational representations (e.g., trends, averages, histograms, graphs, spreadsheets) to identify changes over time and on different scales.
b	Students use the mathematical or computational representations to model, describe*, and predict
Analysis	
a	Students analyze and use the given mathematical and/or computational representations
	i. To identify the interdependence of variables; and
	ii. As evidence to support the claim(s) and/or explanation(s); and
	iii. Students use mathematical relationships to distinguish between cause and correlation with respect to the supported claims.

Critical Background Knowledge

Grade Band Progressions:

Science and Engineering Practices (SEPs): Using Mathematics and Computational Thinking

K-2	3-5	6-8	9-12
Describe, measure, and/or compare quantitative attributes of different objects and display the data using simple graphs.	Describe, measure, estimate, and/or graph quantities such as area, volume, weight, and time to address scientific and engineering questions and problems.	Use mathematical representations to describe and/or support scientific conclusions and design solutions.	Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Crosscutting Concepts (CCCs): Systems and System Models

K-2	3-5	6-8	9-12
Systems in the natural and designed world have parts that work together.	A system is a group of related parts that make up a whole and can carry out functions its individual parts cannot.	Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems.	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.

Disciplinary Core Ideas (DCIs): PS2.A: Forces and Motion

K-2	3-5	6-8	9-12
Pushes and pulls can have different strengths and directions, and can change the speed or direction of its motion or start or stop it.	The effect of unbalanced forces on an object results in a change of motion. Patterns of motion can be used to predict future motion. Some forces act through contact, some forces act even when the objects are not in contact. The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center	The role of the mass of an object must be qualitatively accounted for in any change of motion due to the application of a force.	Newton's 2nd law (F=ma) and the conservation of momentum can be used to predict changes in the motion of macroscopic objects.

Connection to other grade level indicators

ELA Connections:

- LA.10.SL.2.c: Analyze the purpose of information being presented, evaluate its motives (e.g., social, commercial, political), and determine its credibility.

Mathematics Connections:

- N-Q.1. Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and origin in graphs and data displays.
- N-Q.2. Define appropriate quantities for the purpose of descriptive modeling.
- N-Q.3. Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

Social Studies Connections:

Fine and Performing Arts Connections:

Related Cross-Curricular Standards: Current Grade Level

Authentic Connections to Other Content Standards:

- High School Conceptual Progressions Model Course 1 - Bundle 1
  SC.HS.1.1.a, SC.HS.1.1.d, SC.HS.11.1.b, SC.HS.11.1.d
- High School Conceptual Progressions Model Course 1 - Bundle 3
  SC.HS.1.1.b, SC.HS.1.1.c, SC.HS.4.4.b, SC.HS.4.4.e, SC.HS.13.3.b

Academic Language Development

Words to support student discourse related to the Disciplinary Core Ideas (DCIs):

- Velocity, acceleration, mass, net force, balanced forces, unbalanced forces, friction, air resistance, vectors, slope, y-intercept, macroscopic, non-relativistic speeds

Assessment Considerations

Formative Assessment:

- https://www.education.ne.gov/assessment/nscas-science/
- Utah Seed Formative Assessment PHYS.1.1
- Wonder of Science: Gyro Drop
- Wonder of Science: Porsche's Claims
- Wonder of Science: Modified Porsche's Claims
- Wonder of Science: Strongest Man
- Wonder of Science: Dropped Spheres

Stackable, Instructionally-Embedded, Portable Science (SIPS) Assessments:

- https://sipsassessments.org/

Knowledge, Skills, and Abilities:

- **KSA1**: Evaluate mathematical or graphical crash data to determine impulse force
- **KSA2**: Calculate the amount of momentum given the mass and velocity of an object to establish patterns in data.
- **KSA3**: Model how Impulse forces can be reduced by increasing the time of impact using different design constraints.
- **KSA4:** Compare how different materials or component structures help reduce impact forces during a collision to help design or refine a device or system.
- **KSA5**: Evaluate systems intended to reduce the impact of collisions to determine which fits with the design criteria and constraints and results in the desired effect(s).

Standard

Topic Code: SC.HSP.1 Forces, Interactions, and Motion

Standard Code: SC.HSP.1.1 Gather, analyze, and communicate evidence of forces, interactions, and motion.

Uniform motion of an object is natural. Changes in motion are caused by a nonzero sum of forces. A "net force" causes an acceleration as predicted by Newton's 2nd Law. Qualitative and quantitative analysis of position, velocity, and acceleration provide evidence of the effects of forces. Momentum is defined for a particular frame of reference; it is the product of the mass and the velocity of the object. In any system, total momentum is always conserved. 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. The time over which these paired forces are exerted determines the impact force.

Indicator

Indicator Code: SC.HSP.1.1.c

Use mathematical representations of momentum to predict the outcome of a collision. Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle. Assessment is limited to quantitative analysis of systems of two macroscopic bodies moving in one-dimension and qualitative analysis of multiple macroscopic bodies moving in two or three-dimensions.

NGSS Comparison: Builds on HS-PS2-2

Other Indicators in this Standard

SC.HSP.1.1.a, SC.HSP.1.1.b, SC.HSP.1.1.d, SC.HSP.1.1.e

Concepts and Skills to Master

Foundation Boxes:

Science and Engineering Practice (SEP)	Crosscutting Concept (CCC)
Using Mathematics and Computational Thinking: Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Use mathematical representations of phenomena to describe explanations.	**Patterns:** • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Disciplinary Core Idea (DCI)

PS2.A: Forces and Motion:

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

Possible Science and/or Engineering Phenomena to Support 3D Instruction

- Magnetic Canon
- Giant Newton's Cradle
- Amazing Rube Goldberg Machines
- Raw or Boiled Egg Experiment
- Designing effective crash barriers
- Car crash
- Football helmets
- Basketball and tennis ball drop
- Car crashes with airbags
- Olympic diving

Evidence Statements

What does it look like to demonstrate proficiency on this indicator?

SC.HSP.1.1.C **Use mathematical representations** of momentum to predict the outcome of a collision.	
1	
a	Students identify and describe* the components in the given mathematical and/or computational representations (e.g., trends, averages, histograms, graphs, spreadsheets) that are relevant to supporting given explanations
b	Students identify the given claim(s) and/or explanation(s) to be supported,
2	
a	Students use given mathematical and/or computational representations (e.g., trends, averages, histograms, graphs, spreadsheets) to identify changes over time and on different scales.
b	Students use the mathematical or computational representations to model, describe*, and predict
Analysis	
3	3
	i. To identify the interdependence of variables; and

	ii.	As evidence to support the claim(s) and/or explanation(s); and
	iii.	Students use mathematical relationships to distinguish between cause and correlation with respect to the supported claims.

Critical Background Knowledge

Grade Band Progressions:

Science and Engineering Practices (SEPs): Using Mathematics and Computational Thinking

K-2	3-5	6-8	9-12
Describe, measure, and/or compare quantitative attributes of different objects and display the data using simple graphs.	Describe, measure, estimate, and/or graph quantities such as area, volume, weight, and time to address scientific and engineering questions and problems.	Use mathematical representations to describe and/or support scientific conclusions and design solutions.	Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Crosscutting Concepts (CCCs): Patterns

K-2	3-5	6-8	9-12
Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence.	Similarities and differences in patterns can be used to sort, classify, communicate and analyze simple rates of change for natural phenomena and designed products.	Macroscopic patterns are related to the nature of microscopic and atomic-level structure.	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.

Disciplinary Core Ideas (DCIs): PS2.A: Forces and Motion

K-2	3-5	6-8	9-12
Pushes and pulls can have different strengths and directions, and can change the speed or direction of its motion or start or stop it.	The effect of unbalanced forces on an object results in a change of motion. Patterns of motion can be used to predict future motion. Some forces act through contact, some forces act even when the objects are not in contact. The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center.	The role of the mass of an object must be qualitatively accounted for in any change of motion due to the application of a force.	Newton's 2nd law (F=ma) and the conservation of momentum can be used to predict changes in the motion of macroscopic objects.

Connection to other grade level indicators

ELA Connections:

- LA.10.SL.2.c: Analyze the purpose of information being presented, evaluate its motives (e.g., social, commercial, political), and determine its credibility.

Mathematics Connections:

- N-Q.1. Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and origin in graphs and data displays.
- N-Q.2. Define appropriate quantities for the purpose of descriptive modeling.
- N-Q.3. Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

Social Studies Connections:

Fine and Performing Arts Connections:

Related Cross-Curricular Standards: Current Grade Level

Authentic Connections to Other Content Standards:

- High School Conceptual Progressions Model Course 1 - Bundle 1
  SC.HS.1.1.a, SC.HS.1.1.d, SC.HS.11.1.b, SC.HS.11.1.d
- High School Conceptual Progressions Model Course 1 - Bundle 3
  SC.HS.1.1.b, SC.HS.1.1.c, SC.HS.4.4.b, SC.HS.4.4.e, SC.HS.13.3.b

Academic Language Development

Words to support student discourse related to the Disciplinary Core Ideas (DCIs):

- Momentum, friction, conservation, transfer, frame of reference, net force, acceleration, velocity, mass, internal, external, conversion, closed system, collision, vector, elastic collision, inelastic collision

Assessment Considerations

Formative Assessment:

- https://www.education.ne.gov/assessment/nscas-science/
- Utah SEEd Assessment
- Wonder of Science: Space Balls
- Wonder of Science: Tarzan and Jane

Stackable, Instructionally-Embedded, Portable Science (SIPS) Assessments:

- https://sipsassessments.org/

Knowledge, Skills, and Abilities:

- **KSA1**: Evaluate mathematical or graphical crash data to determine impulse force
- **KSA2**: Calculate the amount of momentum given the mass and velocity of an object to establish patterns in data.
- **KSA3**: Model how Impulse forces can be reduced by increasing the time of impact using different design constraints.
- **KSA4:** Compare how different materials or component structures help reduce impact forces during a collision to help design or refine a device or system.
- **KSA5**: Evaluate systems intended to reduce the impact of collisions to determine which fits with the design criteria and constraints and results in the desired effect(s).

Standard

Topic Code: SC.HSP.1 Forces, Interactions, and Motion

Standard Code: SC.HSP.1.1 Gather, analyze, and communicate evidence of forces, interactions, and motion.

Uniform motion of an object is natural. Changes in motion are caused by a nonzero sum of forces. A “net force” causes an acceleration as predicted by Newton’s 2nd Law. Qualitative and quantitative analysis of position, velocity, and acceleration provide evidence of the effects of forces. Momentum is defined for a particular frame of reference;

it is the product of the mass and the velocity of the object. In any system, total momentum is always conserved. 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. The time over which these paired forces are exerted determines the impact force.

Indicator

Indicator Code: SC.HSP.1.1.d

Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision. 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 by applying the impulse-momentum theorem. Examples of a device could include a football helmet or an airbag. Assessment is limited to qualitative evaluations and/or algebraic manipulations.

NGSS Comparison: Builds on HS-PS2-3 & HS-ETS1-1

Other Indicators in this Standard

SC.HSP.1.1.a, SC.HSP.1.1.b, SC.HSP.1.1.c, SC.HSP.1.1.e

Concepts and Skills to Master

Foundation Boxes:

Science and Engineering Practice (SEP)	Crosscutting Concept (CCC)
Constructing Explanations and Designing Solutions: Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects. ***Connections to the nature of science*** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena:** • Theories and laws provide explanations in science. • Laws are statements or descriptions of the relationships among observable phenomena.	**Cause and Effect:** • Systems can be designed to cause a desired effect.

Disciplinary Core Idea (DCI)

PS2.A: Forces and Motion:

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

ETS1.A: Defining and Delimiting Engineering Problems:

- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. *(secondary to SC.HSP.1.1.D)*

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 to SC.HSP.1.1.D)*

Possible Science and/or Engineering Phenomena to Support 3D Instruction

- Why Don't Woodpeckers Get Concussions?
- Giant Newton's Cradle
- Slow Motion Golf Ball Collision
- Amazing Rube Goldberg Machines

- Designing effective crash barriers
- Car crash
- Football helmets
- Car crashes with airbags
- Car videos

Evidence Statements

What does it look like to demonstrate proficiency on this indicator?

SC.HSP.1.1.D **Apply scientific and engineering ideas** to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.	
Using scientific knowledge to generate the design solution	
a	Students design a solution that relies on scientific knowledge of the problem.
b	Students describe* the ways the proposed solution addresses the problem.
Describing criteria and constraints, including quantification when appropriate	
a	Students describe* and quantify (when appropriate) the criteria and constraints for the solution to the problem, along with the tradeoffs in the solution.
Evaluating potential solutions	
a	Students evaluate the proposed solution for its impact.
b	Students evaluate the cost, safety, and reliability, as well as social, cultural, and environmental impacts, of the proposed solution.
Refining and/or optimizing the design solution	
a	Students refine the proposed solution by prioritizing the criteria and making tradeoffs as necessary.

Critical Background Knowledge

Grade Band Progressions:

Science and Engineering Practices (SEPs): Constructing Explanations and Designing Solutions

K-2	3-5	6-8	9-12
Designing solutions in K–2 builds on prior experiences and progresses to... Use information from observations (firsthand and from media) to construct an evidence-based account for natural phenomena.	**Designing solutions in 3–5 builds on K–2 experiences and progresses to...** Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem.	**Designing solutions in 6– 8 builds on K–5 experiences and progresses to...** Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events.	**Designing solutions in 9-12 builds on K–8 experiences and progresses to college or career experiences.** Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects

Crosscutting Concepts (CCCs): Cause and Effect

K-2	3-5	6-8	9-12
Cause and Effect in K–2 builds on prior experiences and progresses to... Events have causes that generate observable patterns.	**Cause and Effect in 3–5 builds on K–2 experiences and progresses to...** Cause and effect relationships are routinely identified, tested, and used to explain change.	**Cause and Effect in 6–8 builds on K–5 experiences and progresses to...** Cause and effect relationships may be used to predict phenomena in natural or designed systems.	**Cause and Effect in 9-12 builds on K–8 experiences and progresses to college or career experiences.** Systems can be designed to cause a desired effect.

Disciplinary Core Ideas (DCIs): PS2.A: Forces and Motion, ETS1.A: Defining and Delimiting Engineering Problems, ETS1.C: Optimizing the Design Solution

K-2	3-5	6-8	9-12
Forces and Motion in K–2 builds on prior experiences and progresses to... Pushes and pulls can have different strengths and directions and can change the speed or direction of its motion or start or stop it.	**Forces and Motion in 3–5 builds on K–2 experiences and progresses to...** The effect of unbalanced forces on an object result in a change of motion. Patterns of motion can be used to predict future motion. Some forces act through contact; some forces act even when the objects are not in contact. The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center.	**Forces and Motion in 6–8 builds on K–5 experiences and knowledge and progresses to...** The role of the mass of an object must be qualitatively accounted for in any change of motion due to the application of a force.	**Forces and Motion in 9–12 builds on K–8 experiences and knowledge and progresses to...** Newton's 2nd law (F=ma) and the conservation of momentum can be used to predict changes in the motion of macroscopic objects.

Connection to other grade level indicators

ELA Connections:

- LA.10.SL.2.c: Analyze the purpose of information being presented, evaluate its motives (e.g., social, commercial, political), and determine its credibility.

Mathematics Connections:

- N-Q.1. Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and origin in graphs and data displays.
- N-Q.2. Define appropriate quantities for the purpose of descriptive modeling.
- N-Q.3. Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

Social Studies Connections:

- SS HS.2.1 – Apply economic concepts that support rational decision making.
- SS HS.4.4 – Evaluate sources for perspective, limitations, accuracy, and historical context.

Fine and Performing Arts Connections:

- FA 12.2.4 – Students will synthesize understanding of contemporary, historical, and cultural context in art and life.
- FA 12.1.1 – Students will analyze and integrate personal and global connections through media arts.
- FA 12.5.2 – Students will perform ideas and events through movement, speech, and staging for an intended audience.

Related Cross-Curricular Standards: Current Grade Level

Authentic Connections to Other Content Standards:

- High School Conceptual Progressions Model Course 1 - Bundle 1
  SC.HS.1.1.a, SC.HS.1.1.d, SC.HS.11.1.b, SC.HS.11.1.d
- High School Conceptual Progressions Model Course 1 - Bundle 3
  SC.HS.1.1.b, SC.HS.1.1.c, SC.HS.4.4.b, SC.HS.4.4.e, SC.HS.13.3.b

Academic Language Development

Words to support student discourse related to the Disciplinary Core Ideas (DCIs):

- Force, safety, risk, collision, momentum, macroscopic, exert, acceleration, impact, inertia, Newton's First law, Newton's Second Law, Newton's Third Law of Motion, testable, consequence, development, limitation, impact, mass, velocity, qualitative, criteria, theoretical model, optimal, constraint, impulse

Assessment Considerations

Formative Assessment:

- https://www.education.ne.gov/assessment/nscas-science/
- Utah SEED Assessment: https://docs.google.com/document/d/1cAjUNHtua9GQAG5a4_xu_QSAZigRE1T4uZyfG5FyQuc/edit?usp=sharing

Stackable, Instructionally-Embedded, Portable Science (SIPS) Assessments:

- https://sipsassessments.org/

Knowledge, Skills, and Abilities:

- KSA1: Describe the relationship between force, time, and momentum change using the impulse-momentum theorem in the context of real-world collisions.
- KSA2: Identify how different materials and design features affect the force experienced by an object during a collision.
- KSA3: Explain how concepts of Newton's Laws of Motion apply to the design and function of collision protection devices like helmets or airbags.
- KSA4: Apply algebraic manipulation of the impulse-momentum theorem to qualitatively or quantitatively evaluate how changes in time or force affect momentum during a collision.
- KSA5: Construct a conceptual or physical model of a collision protection device.
- KSA6: Use engineering design principles to iteratively develop, test, and refine a collision protection device, justifying each modification with scientific reasoning.
- KSA7: Analyze data from test trials (real or simulated) to determine the effectiveness of the device in minimizing force or damage.
- KSA8: Evaluate the success of a device based on defined criteria (e.g., amount of damage, stopping time, peak force) and constraints (e.g., materials, size, cost).
- KSA9: Communicate design solutions and refinements using evidence-based reasoning, including diagrams, data, and qualitative/algebraic justifications.
- KSA10: Collaborate effectively in a team to develop and optimize design solutions, incorporating feedback and experimental results.

Standard

Topic Code: SC.HSP.1 Forces, Interactions, and Motion
Standard Code: SC.HSP.1.1 Gather, analyze, and communicate evidence of forces, interactions, and motion.

Uniform motion of an object is natural. Changes in motion are caused by a nonzero sum of forces. A "net force" causes an acceleration as predicted by Newton's 2nd Law. Qualitative and quantitative analysis of position, velocity, and acceleration provide evidence of the effects of forces. Momentum is defined for a particular frame of reference; it is the product of the mass and the velocity of the object. In any system, total momentum is always conserved. 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. The time over which these paired forces are exerted determines the impact force.

Indicator

Indicator Code: SC.HSP.1.1.e

Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects. Emphasis is on both quantitative and conceptual descriptions of forces from gravitational and electric sources. Assessment can be expanded to systems with multiple objects.

NGSS Comparison: Builds on HS-PS2-4

Other Indicators in this Standard

SC.HSP.1.1.a, SC.HSP.1.1.b, SC.HSP.1.1.c, SC.HSP.1.1.d

Concepts and Skills to Master

Foundation Boxes:

Science and Engineering Practice (SEP)	Crosscutting Concept (CCC)
Using Mathematics and Computational Thinking: Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Use mathematical representations of phenomena to describe explanations.	**Patterns:** • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Disciplinary Core Idea (DCI)

PS2.B: **Types of Interactions:**

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

Possible Science and/or Engineering Phenomena to Support 3D Instruction

- Magnetic Canon
- Candle-Powered Car
- Felix Baumgartner Space Jump World Record
- Cavendish Experiment
- Weighing the World
- The Gravity Light
- Protecting the Earth from Killer Asteroids
- Programmable Droplets from MIT
- Lenz's Law - link
- Van de Graaff generator
- Space probes
- Black holes
- Planetary orbits
- Comets

- Meteor impacts
- Dancing pith balls
- Sticky tapes
- Motor / generator (EM induction)

Evidence Statements

What does it look like to demonstrate proficiency on this indicator?

SC.HSP.1.1.E	**Use mathematical representations** of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.	
Representation		
a	Students identify and describe* the components in the given mathematical and/or computational representations (e.g., trends, averages, histograms, graphs, spreadsheets) that are relevant to supporting given explanations	
b	Students identify the given claim(s) and/or explanation(s) to be supported,	
Mathematical and/or computational modeling		
a	Students use given mathematical and/or computational representations (e.g., trends, averages, histograms, graphs, spreadsheets) to identify changes over time and on different scales.	
b	Students use the mathematical or computational representations to model, describe*, and predict	
Analysis		
a	Students analyze and use the given mathematical and/or computational representations	
	i.	To identify the interdependence of variables; and
	ii.	As evidence to support the claim(s) and/or explanation(s); and
	iii.	Students use mathematical relationships to distinguish between cause and correlation with respect to the supported claims.

Critical Background Knowledge

Grade Band Progressions:

Science and Engineering Practices (SEPs): Using Mathematics and Computational Thinking

K-2	3-5	6-8	9-12
Using Mathematics and Computational Thinking in K–2 builds on prior experiences and progresses to... Describe, measure, and/or compare quantitative attributes of different objects and display the data using simple graphs.	**Using Mathematics and Computational Thinking in 3–5 builds on K–2 experiences and progresses to...** Describe, measure, estimate, and/or graph quantities such as area, volume, weight, and time to address scientific and engineering questions and problems.	**Using Mathematics and Computational Thinking in 6– 8 builds on K–5 experiences and progresses to...** Use mathematical representations to describe and/or support scientific conclusions and design solutions.	**Using Mathematics and Computational Thinking in 9-12 builds on K–8 experiences and progresses to college or career experiences.** Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations

Crosscutting Concepts (CCCs): Patterns

K-2	3-5	6-8	9-12
Patterns in K–2 builds on prior experiences and progresses to... Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence.	**Patterns in 3–5 builds on K–2 experiences and progresses to...** Patterns of change can be used to make predictions.	**Patterns in 6– 8 builds on K–5 experiences and progresses to...** Patterns can be used to identify cause and effect relationships.	**Patterns in 9-12 builds on K–8 experiences and progresses to college or career experiences.** 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.

Disciplinary Core Ideas (DCIs): PS2.B: Types of Interactions

K-2	3-5	6-8	9-12
PS2.B in K–2 builds on prior experiences and progresses to... Pushes and pulls can have different strengths and directions, and can change the speed or direction of its motion or start or stop it.	**PS2.B in 3–5 builds on K–2 experiences and progresses to...** The effect of unbalanced forces on an object results in a change of motion. Patterns of motion can be used to predict future motion. Some forces act through contact, some forces act even when the objects are not in contact. The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center.	**PS2.B in 6– 8 builds on K–5 experiences and knowledge and progresses to...** Forces that act at a distance involve fields that can be mapped by their relative strength and effect on an object.	**PS2.B in 9–12 builds on K–8 experiences and knowledge and progresses to...** Forces at a distance are explained by fields that can transfer energy and can be described in terms of the arrangement and properties of the interacting objects and the distance between them. These forces can be used to describe the relationship between electrical and magnetic fields.

Connection to other grade level indicators

ELA Connections:

- LA.10.SL.2.c: Analyze the purpose of information being presented, evaluate its motives (e.g., social, commercial, political), and determine its credibility.

Mathematics Connections:

- N-Q.1. Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and origin in graphs and data displays.
- N-Q.2. Define appropriate quantities for the purpose of descriptive modeling.
- N-Q.3. Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

Social Studies Connections:

Fine and Performing Arts Connections:

Related Cross-Curricular Standards: Current Grade Level

Authentic Connections to Other Content Standards:

- High School Conceptual Progressions Model Course 1 - Bundle 1
  SC.HS.1.1.a, SC.HS.1.1.d, SC.HS.11.1.b, SC.HS.11.1.d
- High School Conceptual Progressions Model Course 1 - Bundle 3
  SC.HS.1.1.b, SC.HS.1.1.c, SC.HS.4.4.b, SC.HS.4.4.e, SC.HS.13.3.b

Academic Language Development

Words to support student discourse related to the Disciplinary Core Ideas (DCIs):

- Potential energy, conservation, conversion, field, kinetic energy, Coulomb, gravitational force, Newton’s Law of Gravitation, Coulomb's Law

Assessment Considerations

Formative Assessment:

- https://www.education.ne.gov/assessment/nscas-science/
- Utah SEED Assessment: https://docs.google.com/document/d/1MyL2Wrp12cgFYNE3xCr2_liiDS4_FyHSoJgNcHxaucA/edit?usp=sharing

Stackable, Instructionally-Embedded, Portable Science (SIPS) Assessments:

- https://sipsassessments.org/

Knowledge, Skills, and Abilities:

- KSA1: Describe the similarities and differences between gravitational and electrostatic forces in terms of direction, strength, and the types of objects involved.
- KSA2: Identify the variables that influence gravitational and electrostatic forces (mass, charge, distance), and explain their roles qualitatively.
- KSA3: Explain the conceptual meaning of Newton’s Law of Gravitation and Coulomb’s Law and how they represent force interactions between objects.
- KSA4: Calculate gravitational and electrostatic forces between two objects using appropriate units, algebraic substitution, and arithmetic.
- KSA5: Predict how changes in mass, charge, or distance affect the magnitude of the force using proportional reasoning.
- KSA6: Use free-body diagrams and force vectors to represent the direction and relative magnitude of gravitational or electrostatic forces acting on an object.
- KSA7: Analyze systems with multiple objects to determine the net force on an object using vector addition.
- KSA8: Evaluate how gravitational and electrostatic forces play roles in real-world phenomena (e.g., planetary motion, atomic structure, static electricity) using evidence-based reasoning.
- KSA9: Communicate mathematical and conceptual explanations of force interactions clearly, using appropriate terminology, representations, and justifications.

Standard

Topic Code: SC.HSP.2 Waves, Electromagnetic Radiation, and Optics
Standard Code: SC.HSP.2.2 Gather, analyze, and communicate evidence of the interactions of waves and optics.

Waves transfer energy through oscillations of fields or matter. 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 passes. Waves produce interference as they overlap but they emerge unaffected by each other. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. Electromagnetic radiation can be modeled as a wave of changing electric and magnetic fields or as particles called photons. When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy. Because waves depend upon the properties of fields and the predictable transformation of energy, they can be used to interpret the nature of matter and its energy. Waves are utilized to transmit information both in analog and digital forms.

Indicator

Indicator Code: SC.HSP.2.2.a

Use mathematical representations to describe the relationships among the frequency, wavelength, and speed of waves traveling in various media. 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. Examples also include descriptive changes in observed frequency based on relative motion of observer or source (Doppler effect). Assessment is limited to algebraic relationships and describing those relationships qualitatively.

NGSS Comparison: Builds on HS-PS4-1

Other Indicators in this Standard

SC.HSP.2.2.b, SC.HSP.2.2.c, SC.HSP.2.2.d, SC.HSP.2.2.e, SC.HSP.2.2.f

Concepts and Skills to Master

Foundation Boxes:

Science and Engineering Practice (SEP)	Crosscutting Concept (CCC)
Using Mathematics and Computational Thinking: Mathematical and computational thinking at the 9-12 level builds on K-8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations.	**Cause and Effect:** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Disciplinary Core Idea (DCI)

PS4.A: **Wave Properties:**

- The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing.

Possible Science and/or Engineering Phenomena to Support 3D Instruction

- Amazing Slinky Tricks
- Daniel Kish Uses Echolocation to Navigate

- Analog vs. Digital Television
- The Visual Microphone: Passive Recovery of Sound from Video
- Ruben's Tube
- Self-Leveling Pool Table on Cruise Ship
- Trichroic Prism
- Tuning fork vibrates other tuning fork and ball
- Doppler Effect
- Red-Shift vs. Blue-Shift

Evidence Statements

What does it look like to demonstrate proficiency on this indicator?

SC.HSP.2.2.A **Use mathematical representations** to describe the relationships among the frequency, wavelength, and speed of waves traveling in various media.		
Representation		
a	Students identify and describe* the components in the given mathematical and/or computational representations (e.g., trends, averages, histograms, graphs, spreadsheets) that are relevant to supporting given explanations	
b	Students identify the given claim(s) and/or explanation(s) to be supported,	
Mathematical and/or computational modeling		
a	Students use given mathematical and/or computational representations (e.g., trends, averages, histograms, graphs, spreadsheets) to identify changes over time and on different scales.	
b	Students use the mathematical or computational representations to model, describe*, and predict	
Analysis		
a	Students analyze and use the given mathematical and/or computational representations	
	i.	To identify the interdependence of variables; and
	ii.	As evidence to support the claim(s) and/or explanation(s); and
	iii.	Students use the mathematical relationships to distinguish between cause and correlation with respect to the supported claims.

Critical Background Knowledge

Grade Band Progressions:

Science and Engineering Practices (SEPs): Using Mathematics and Computational Thinking

K-2	3-5	6-8	9-12
Using Mathematics and Computational Thinking in K–2 builds on prior experiences and progresses to... Describe, measure, and/or compare quantitative attributes of different	**Using Mathematics and Computational Thinking in 3–5 builds on K–2 experiences and progresses to...** Describe, measure, estimate, and/or graph quantities such as area, volume, weight,	**Using Mathematics and Computational Thinking in 6– 8 builds on K–5 experiences and progresses to...**	**Using Mathematics and Computational Thinking in 9-12 builds on K–8 experiences and progresses to college or career experiences.** Use mathematical, computational, and/or algorithmic representations of phenomena or

objects and display the data using simple graphs.	and time to address scientific and engineering questions and problems.	Use mathematical representations to describe and/or support scientific conclusions and design solutions.	design solutions to describe and/or support claims and/or explanations.

Crosscutting Concepts (CCCs): Cause and Effect

K-2	3-5	6-8	9-12
Cause and Effect in K–2 builds on prior experiences and progresses to... Simple tests can be designed to gather evidence to support or refute student ideas about causes.	**Cause and Effect in 3–5 builds on K–2 experiences and progresses to...** Events that occur together with regularity might or might not be a cause and effect relationship.	**Cause and Effect in 6– 8 builds on K–5 experiences and progresses to...** Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.	**Cause and Effect in 9-12 builds on K–8 experiences and progresses to college or career experiences.** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Disciplinary Core Ideas (DCIs): PS4.A: Wave Properties

K-2	3-5	6-8	9-12
PS4.A in K–2 builds on prior experiences and progresses to... Sound can make matter vibrate, and vibrating matter can make sound.	**PS4.A in 3–5 builds on K–2 experiences and progresses to...** Waves are regular patterns of motion, which can be made in water by disturbing the surface. Waves of the same type can differ in amplitude and wavelength. Waves can make objects move.	**PS4.A in 6– 8 builds on K–5 experiences and knowledge and progresses to....** A simple wave model has a repeating pattern with a specific wavelength, frequency, and amplitude, and mechanical waves need a medium through which they are transmitted. This model can explain many phenomena including sound and light. Waves can transmit energy.	**PS4.A in 9–12 builds on K–8 experiences and knowledge and progresses to...** The wavelength and frequency of a wave are related to one another by the speed of the wave, which depends on the type of wave and the medium through which it is passing. Waves can be used to transmit information and energy.

Connection to other grade level indicators

ELA Connections:

- LA.10.SL.2.c: Analyze the purpose of information being presented, evaluate its motives (e.g., social, commercial, political), and determine its credibility.

Mathematics Connections:

- N-Q.1. Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and origin in graphs and data displays.
- N-Q.2. Define appropriate quantities for the purpose of descriptive modeling.
- N-Q.3. Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

Social Studies Connections:

Fine and Performing Arts Connections:

Related Cross-Curricular Standards: Current Grade Level

Authentic Connections to Other Content Standards:

- High School Conceptual Progressions Model Course 1 - Bundle 1
  SC.HS.1.1.a, SC.HS.1.1.d, SC.HS.11.1.b, SC.HS.11.1.d
- High School Conceptual Progressions Model Course 1 - Bundle 3
  SC.HS.1.1.b, SC.HS.1.1.c, SC.HS.4.4.b, SC.HS.4.4.e, SC.HS.13.3.b

Academic Language Development

Words to support student discourse related to the Disciplinary Core Ideas (DCIs):

- Simple wave, frequency, wavelength, crest, trough, wave speed, amplitude, vacuum, properties of waves, electromagnetic radiation, radiation, wave source, angle of incidence, angle of reflection, normal, interface, diffraction, refraction, doppler effect, red-shift, blue-shift, resonance.

Assessment Considerations

Formative Assessment:

- https://www.education.ne.gov/assessment/nscas-science/
- Utah SEEd Assessment
- Wonder of Science Assessment: Underwater Apple Light
- Wonder of Science Assessment: Imagine Dragons Concert

Stackable, Instructionally-Embedded, Portable Science (SIPS) Assessments:

- https://sipsassessments.org/

Knowledge, Skills, and Abilities:

- KSA1: Define key properties of waves—frequency, wavelength, and speed—and describe how they relate to different types of waves (e.g., sound, light, seismic).
- KSA2: Describe how different media (e.g., air, water, glass, vacuum) affect the speed of wave travel for various types of waves.
- KSA3: Construct mathematical models that relate wave speed, frequency, and wavelength: ($v = f\lambda$) identifying the units and meaning of each variable.
- KSA4: Use algebraic manipulation to solve for any one variable using this relationship.
- KSA5: Predict how changing the medium affects wave speed, and consequently how this influences wavelength or frequency if the other variable is held constant.
- KSA6: Compare wave behavior in different media using qualitative and quantitative reasoning.
- KSA7: Interpret graphical or tabular data showing wave frequency, wavelength, and speed across different media.
- KSA8: Construct representations (tables, graphs, or diagrams) to visualize relationships among wave properties and how they vary with medium.
- KSA9: Describe the Doppler effect qualitatively, including how the motion of the source or observer affects the observed frequency of a wave.
- KSA10: Use mathematical and conceptual reasoning to explain observed changes in wave properties due to motion.
- KSA11: Communicate reasoning clearly by combining conceptual understanding and mathematical calculations to explain wave behavior in written, oral, or visual formats.
- KSA12: Justify conclusions about wave interactions with different media using algebraic evidence and qualitative descriptions.

Standard

Topic Code: SC.HSP.2 Waves, Electromagnetic Radiation, and Optics
Standard Code: SC.HSP.2.2 Gather, analyze, and communicate evidence of the interactions of waves and optics.

Waves transfer energy through oscillations of fields or matter. 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 passes. Waves produce interference as they overlap but they emerge unaffected by each other. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. Electromagnetic radiation can be modeled as a wave of changing electric and magnetic fields or as particles called photons. When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy. Because waves depend upon the properties of fields and the predictable transformation of energy, they can be used to interpret the nature of matter and its energy. Waves are utilized to transmit information both in analog and digital forms

Indicator

Indicator Code: SC.HSP.2.2.b

Develop and use models to predict interactions of longitudinal and transverse waves in various media. Examples could include P, S and Surface seismic waves, water waves, and waves on a spring. Emphasis is on structure and function of waves.

NGSS Comparison: Builds on HS-PS4-1

Other Indicators in this Standard

SC.HSP.2.2.a, SC.HSP.2.2.c, SC.HSP.2.2.d, SC.HSP.2.2.e, SC.HSP.2.2.f

Concepts and Skills to Master

Foundation Boxes:

Science and Engineering Practice (SEP)	Crosscutting Concept (CCC)
Developing and Using Models: Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. • Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.	**Systems and System Models:** • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

Disciplinary Core Idea (DCI)

PS4.A: **Wave Properties:**

- The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing.
- The reflection, refraction, and transmission of waves at an interface between two media can be modeled on the basis of wave properties.

Possible Science and/or Engineering Phenomena to Support 3D Instruction

- P, S, and Surface Seismic waves
- PhET Waves Intro
- PhET Waves Interference
- PhET Waves on a String
- Seismic Waves Sim
- Reflections and Mirrors
- Refractions and Lenses
- The Benjamin Franklin Glasses and the hidden message on the back of the Declaration of Independence from the movie National Treasure

- Waves and Sound
- Why we can't wear other people's glasses

Evidence Statements

What does it look like to demonstrate proficiency on this indicator?

SC.P.2.2.b Develop and use models to predict interactions of longitudinal and transverse waves in various media.		
1	Components of the model	
	a	Students develop models in which they identify and describe* the relevant components.
2	Relationships	
	a	Students describe* the relationships between components in their models.
3	Connections	
	a	Students use their models to illustrate functions of the components and the system.
	b	Students make a distinction between the accuracy of the model and actual system and functions it represents.
	c	Students use the model to predict changes.

Critical Background Knowledge

Grade Band Progressions:

Science and Engineering Practices (SEPs): Developing and Using Models

K-2	3-5	6-8	9-12
Developing and Using Models in K–2 builds on prior experiences and progresses to... Develop and/or use a model to represent amounts, relationships, relative scales (bigger, smaller), and/or patterns in the natural and designed world(s).	**Developing and Using Models in 3–5 builds on K–2 experiences and progresses to...** Collaboratively develop and/or revise a model based on evidence that shows the relationships among variables for frequent and regular occurring events.	**Developing and Using Models in 6– 8 builds on K–5 experiences and progresses to...** 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.	**Developing and Using Models in 9-12 builds on K–8 experiences and progresses to college or career experiences.** Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.

Crosscutting Concepts (CCCs): Systems and System Models

K-2	3-5	6-8	9-12

Systems and System Models in K–2 builds on prior experiences and progresses to... Objects and organisms can be described in terms of their parts. Systems in the natural and designed world have parts that work together.	**Systems and System Models in 3–5 builds on K–2 experiences and progresses to...** 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.	**Systems and System Models in 6– 8 builds on K–5 experiences and progresses to...** Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.	**Systems and System Models in 9-12 builds on K–8 experiences and progresses to college or career experiences.** Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

Disciplinary Core Ideas (DCIs): PS4.A: Wave Properties

K-2	3-5	6-8	9-12
PS4.A in K–2 builds on prior experiences and progresses to... Sound can make matter vibrate, and vibrating matter can make sound.	**PS4.A in 3–5 builds on K–2 experiences and progresses to...** Waves are regular patterns of motion, which can be made in water by disturbing the surface. Waves of the same type can differ in amplitude and wavelength. Waves can make objects move.	**PS4.A in 6– 8 builds on K–5 experiences and knowledge and progresses to...** A simple wave model has a repeating pattern with a specific wavelength, frequency, and amplitude, and mechanical waves need a medium through which they are transmitted. This model can explain many phenomena including sound and light. Waves can transmit energy.	**PS4.A in 9–12 builds on K–8 experiences and knowledge and progresses to...** The wavelength and frequency of a wave are related to one another by the speed of the wave, which depends on the type of wave and the medium through which it is passing. Waves can be used to transmit information and energy.

Connection to other grade level indicators

ELA Connections:

- LA.10.SL.2.c: Analyze the purpose of information being presented, evaluate its motives (e.g., social, commercial, political), and determine its credibility.

Mathematics Connections:

- N-Q.1. Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and origin in graphs and data displays.
- N-Q.2. Define appropriate quantities for the purpose of descriptive modeling.
- N-Q.3. Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

Social Studies Connections:

Fine and Performing Arts Connections:

Related Cross-Curricular Standards: Current Grade Level

Authentic Connections to Other Content Standards:

- High School Conceptual Progressions Model Course 1 - Bundle 1
  SC.HS.1.1.a, SC.HS.1.1.d, SC.HS.11.1.b, SC.HS.11.1.d

- High School Conceptual Progressions Model Course 1 - Bundle 3
  SC.HS.1.1.b, SC.HS.1.1.c, SC.HS.4.4.b, SC.HS.4.4.e, SC.HS.13.3.b

Academic Language Development

Words to support student discourse related to the Disciplinary Core Ideas (DCIs):

- Simple wave, frequency, wavelength, crest, trough, wave speed, amplitude, vacuum, properties of waves, electromagnetic radiation, radiation, wave source, angle of incidence, angle of reflection, normal, interface, diffraction, refraction, doppler effect, red-shift, blue-shift, resonance.

Assessment Considerations

Formative Assessment:

- https://www.education.ne.gov/assessment/nscas-science/
- Utah SEEd Assessment
- Wonder of Science Assessment: Underwater Apple Light
- Wonder of Science Assessment: Imagine Dragons Concert

Stackable, Instructionally-Embedded, Portable Science (SIPS) Assessments:

- https://sipsassessments.org/

Knowledge, Skills, and Abilities:

- KSA1: Differentiate between longitudinal and transverse waves based on the direction of particle motion relative to wave propagation.
- KSA2: Identify examples of longitudinal (e.g., sound, P-waves) and transverse (e.g., light, S-waves, water surface ripples) waves in natural and experimental contexts.
- KSA3: Describe the structural components of each wave type (e.g., compressions/rarefactions for longitudinal waves; crests/troughs for transverse waves).
- KSA4: Explain how different media (solid, liquid, gas) affect the speed and behavior of both longitudinal and transverse waves.
- KSA5: Compare the ability of longitudinal and transverse waves to travel through various media (e.g., P-waves travel through solids and liquids, S-waves only through solids).
- KSA6: Analyze how energy is transferred through wave motion without permanent displacement of matter.
- KSA7: Develop physical, visual, or digital models of both wave types (e.g., using slinkies, diagrams, simulations) to represent wave motion and structure.
- KSA8: Use models to demonstrate how longitudinal and transverse waves behave differently when encountering changes in media (e.g., boundaries between rock layers, air-water interfaces).
- KSA9: Use models to predict how seismic waves (P, S, and surface waves) interact with the Earth's interior and surface, including reflection, refraction, and speed changes.
- KSA10: Predict outcomes of wave interactions such as interference, diffraction, or transmission at boundaries between media.
- KSA11: Use models to explain why surface waves cause more damage in earthquakes compared to P- and S-waves, focusing on wave structure and amplitude.
- KSA12: Construct explanations using models to describe real-world wave phenomena (e.g., seismic activity, water wave interactions, spring demonstrations).
- KSA13: Communicate scientific reasoning that connects wave structure (type, motion, media) with its function (energy transfer, interaction with materials, observed effects).

Standard

Topic Code: SC.HSP.2 Waves, Electromagnetic Radiation, and Optics

Standard Code: SC.HSP.2.2 Gather, analyze, and communicate evidence of the interactions of waves and optics.

Waves transfer energy through oscillations of fields or matter. 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 passes. Waves produce interference as they overlap but they emerge unaffected by each other. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. Electromagnetic radiation can be modeled as a wave of changing electric and magnetic fields or as particles called photons. When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy. Because waves depend upon the properties of fields and the predictable transformation of energy, they can be used to interpret the nature of matter and its energy. Waves are utilized to transmit information both in analog and digital forms.

Indicator

Indicator Code: SC.HSP.2.2.c

Develop and use models to describe the behavior of light at the boundary of various media. Emphasis is on both geometric (ray diagrams) and algebraic models (mirror and thin lens equation, Snell's Law).

NGSS Comparison: Builds on HS-PS4-1

Other Indicators in this Standard

SC.HSP.2.2.a, SC.HSP.2.2.b, SC.HSP.2.2.d, SC.HSP.2.2.e, SC.HSP.2.2.f

Concepts and Skills to Master

Foundation Boxes:

Science and Engineering Practice (SEP)

Developing and Using Models:
Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

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

Crosscutting Concept (CCC)

Systems and System Models:

- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

Disciplinary Core Idea (DCI)

PS4.A: Wave Properties:

- The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing.
- The reflection, refraction, and transmission of waves at an interface between two media can be modeled on the basis of wave properties.

Possible Science and/or Engineering Phenomena to Support 3D Instruction

- P, S, and Surface Seismic waves
- PhET Waves Intro
- PhET Waves Interference
- PhET Waves on a String
- Seismic Waves Sim
- Reflections and Mirrors
- Refractions and Lenses
- The Benjamin Franklin Glasses and the hidden message on the back of the Declaration of Independence from the movie National Treasure
- Waves and Sound
- Why we can't wear other people's glasses

Evidence Statements

What does it look like to demonstrate proficiency on this indicator?

SC.HSP.2.2.c **Develop and use models** to describe the behavior of light at the boundary of various media.		
1	Components of the model:	
	a	From the given model, students identify and describe* the components of the model relevant for their mechanistic descriptions.
	b	From the given model, students identify the relevant different scales on which the factors operate.
2	Relationships	
	a	Students identify and describe* the relationships between components of the given model.
	b	Students describe* the relationships between components of the model as either causal or correlational.
3	Connections	
	a	Students use models to provide a mechanistic account of the relationship between factors represented in the models.

Critical Background Knowledge

Grade Band Progressions:

Science and Engineering Practices (SEPs): Developing and Using Models

K-2	3-5	6-8	9-12
Developing and Using Models in K–2 builds on prior experiences and progresses to... Develop and/or use a model to represent amounts, relationships, relative scales (bigger, smaller), and/or patterns in the natural and designed world(s). Develop a simple model based on evidence to represent a proposed object or tool.	**Developing and Using Models in 3–5 builds on K–2 experiences and progresses to...** Develop and/or use models to describe and/or predict phenomena.	**Developing and Using Models in 6– 8 builds on K–5 experiences and progresses to...** Develop and/or use a model to predict and/or describe phenomena.	**Developing and Using Models in 9-12 builds on K–8 experiences and progresses to college or career experiences.** Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations

Crosscutting Concepts (CCCs): Systems and System Models

K-2	3-5	6-8	9-12
Systems and System Models in K–2 builds on prior experiences and progresses to... Systems in the natural and designed world have parts that work together.	**Systems and System Models in 3–5 builds on K–2 experiences and progresses to...** A system can be described in terms of its components and their interactions.	**Systems and System Models in 6– 8 builds on K–5 experiences and progresses to...** Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.	**Systems and System Models in 9-12 builds on K–8 experiences and progresses to college or career experiences.** Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

Disciplinary Core Ideas (DCIs): PS4.A: Wave Properties

K-2	3-5	6-8	9-12
PS4.A in K–2 builds on prior experiences and progresses to… Sound can make matter vibrate, and vibrating matter can make sound.	**PS4.A in 3–5 builds on K–2 experiences and progresses to…** Waves are regular patterns of motion, which can be made in water by disturbing the surface. Waves of the same type can differ in amplitude and wavelength. Waves can make objects move.	**PS4.A in 6– 8 builds on K–5 experiences and knowledge and progresses to…** A simple wave model has a repeating pattern with a specific wavelength, frequency, and amplitude, and mechanical waves need a medium through which they are transmitted. This model can explain many phenomena including sound and light. Waves can transmit energy.	**PS4.A in 9–12 builds on K–8 experiences and knowledge and progresses to…** The wavelength and frequency of a wave are related to one another by the speed of the wave, which depends on the type of wave and the medium through which it is passing. Waves can be used to transmit information and energy.

Connection to other grade level indicators

ELA Connections:

- LA.10.SL.2.c: Analyze the purpose of information being presented, evaluate its motives (e.g., social, commercial, political), and determine its credibility.

Mathematics Connections:

- N-Q.1. Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and origin in graphs and data displays.
- N-Q.2. Define appropriate quantities for the purpose of descriptive modeling.
- N-Q.3. Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

Social Studies Connections:

Fine and Performing Arts Connections:

Related Cross-Curricular Standards: Current Grade Level

Authentic Connections to Other Content Standards:

- High School Conceptual Progressions Model Course 1 - Bundle 1
  SC.HS.1.1.a, SC.HS.1.1.d, SC.HS.11.1.b, SC.HS.11.1.d
- High School Conceptual Progressions Model Course 1 - Bundle 3
  SC.HS.1.1.b, SC.HS.1.1.c, SC.HS.4.4.b, SC.HS.4.4.e, SC.HS.13.3.b

Academic Language Development

Words to support student discourse related to the Disciplinary Core Ideas (DCIs):

- Simple wave, frequency, wavelength, crest, trough, wave speed, amplitude, vacuum, properties of waves, electromagnetic radiation, radiation, wave source, angle of incidence, angle of reflection, normal, interface, diffraction, refraction, doppler effect, red-shift, blue-shift, resonance.

Assessment Considerations

Formative Assessment:

- https://www.education.ne.gov/assessment/nscas-science/

- Utah SEEd Assessment
- Wonder of Science Assessment: Underwater Apple Light
- Wonder of Science Assessment: Imagine Dragons Concert

Stackable, Instructionally-Embedded, Portable Science (SIPS) Assessments:

- https://sipsassessments.org/

Knowledge, Skills, and Abilities:

- KSA1: Describe light as a wave that travels in straight lines in homogeneous media, and identify common media boundaries (e.g., air-glass, water-air).
- KSA2: Explain what happens to light when it encounters a boundary: reflection, refraction, absorption, or transmission.
- KSA3: Construct ray diagrams to represent the law of reflection: the angle of incidence equals the angle of reflection.
- KSA4: Use ray diagrams to model how light reflects from plane, concave, and convex mirrors, identifying image location, orientation, and size.
- KSA5: Explain why light bends when it enters a different medium using the concept of wave speed and density (refraction).
- KSA6: Construct ray diagrams to model refraction at boundaries, showing bending toward or away from the normal depending on the index of refraction.
- KSA7: Use Snell's Law to calculate unknown angles and describe how this algebraic model supports ray behavior.
- KSA8: Use ray diagrams to model image formation by converging and diverging lenses, as well as curved mirrors.
- KSA9: Use the mirror/lens equation and the magnification equation to calculate image distance, focal length, and magnification.
- KSA10: Compare geometric (ray) and algebraic models to explain image characteristics (e.g., real vs. virtual, magnified vs. reduced).
- KSA11: Use models to predict how changes in object distance or material properties (e.g., index of refraction) affect image location, orientation, and size.
- KSA12: Analyze how geometric and algebraic models align and differ when used to explain the same physical scenario.
- KSA13: Construct explanations of light behavior at media boundaries using a combination of ray diagrams, equations, and conceptual reasoning.
- KSA14: Communicate model-based predictions clearly using labeled diagrams, calculations, and verbal or written scientific arguments.

Standard

Topic Code: SC.HSP.2 Waves, Electromagnetic Radiation, and Optics

Standard Code: SC.HSP.2.2 Gather, analyze, and communicate evidence of the interactions of waves and optics.

Waves transfer energy through oscillations of fields or matter. 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 passes. Waves produce interference as they overlap but they emerge unaffected by each other. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. Electromagnetic radiation can be modeled as a wave of changing electric and magnetic fields or as particles called photons. When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy. Because waves depend upon the properties of fields and the predictable transformation of energy, they can be used to interpret the nature of matter and its energy. Waves are utilized to transmit information both in analog and digital forms.

Indicator

Indicator Code: SC.HSP.2.2.d

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. 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, photoelectric effect and the idea that photons associated with different frequencies of light have different energies. Assessment includes qualitative and quantitative models of light.

NGSS Comparison: Builds on HS-PS4-3

Other Indicators in this Standard

SC.HSP.2.2.a, SC.HSP.2.2.b, SC.HSP.2.2.c, SC.HSP.2.2.e, SC.HSP.2.2.f

Concepts and Skills to Master

Foundation Boxes:

Science and Engineering Practice (SEP)

Engaging in Argument from Evidence:
Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about natural and designed worlds. Arguments may also come from current scientific or historical episodes in science.

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

Connections to the nature of science
Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena:

- A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.

Crosscutting Concept (CCC)

Cause and Effect:

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

Connections to Engineering, Technology, and Applications of Science
Influence of Engineering, Technology, and Science on Society and the Natural World:

- Modern civilization depends on major technological systems.
- Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.

Disciplinary Core Idea (DCI)

PS4.A: **Wave Properties:**

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

PS4.B: **Electromagnetic Radiation:**

- Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features.
- The energy of electromagnetic radiation is directly related to its frequency. This energy can be found using Planck's constant and the frequency of the wave.
- 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.

Possible Science and/or Engineering Phenomena to Support 3D Instruction

- Photoelectric Effect
- Solar Cars
- Levitating Moon Dust (video, Space Dust in a Vacuum - APS Physics)
- Interference (destructive vs. constructive)
- The angler fish
- Quantum computers

- Absorption/Emission Spectra
- Schrödinger's cat
- Electron microscope
- Many-worlds interpretation
- X-ray machine
- Environmental mutations of DNA
- Radiation treatment for cancer
- Gas discharge tubes
- Greenhouse gases

Evidence Statements

What does it look like to demonstrate proficiency on this indicator?

SC.HSP.2.2.D **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.	
Articulating the explanation of phenomena	
a	Students construct an explanation that addresses the phenomenon at hand.
Evidence	
a	Students identify and describe* evidence to construct their explanation
b	Students use a variety of valid and reliable sources for the evidence (e.g., data from investigations, theories, simulations, peer review).
c	Students describe* the source of the evidence and the technology used to obtain that evidence.
Reasoning	
a	Students use reasoning to connect the evidence, along with 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, to construct the explanation.
b	Students describe* reasoning for how the evidence allows for the distinction between causal and correlational relationships.
Revising the explanation	
a	Given new evidence or context, students construct a revised or expanded explanation about the phenomenon at hand and justify the revision.

Critical Background Knowledge

Grade Band Progressions:

Science and Engineering Practices (SEPs): Engaging in Argument from Evidence

K-2	3-5	6-8	9-12
Engaging in Argument from Evidence in K–2 builds on prior experiences and progresses to... Identify arguments that are supported by evidence.	**Engaging in Argument from Evidence in 3–5 builds on K–2 experiences and progresses to...** Compare and refine arguments based on an evaluation of the evidence presented.	**Engaging in Argument from Evidence in 6– 8 builds on K–5 experiences and progresses to...** Compare and critique two arguments on the same topic and analyze whether they emphasize similar or	**Engaging in Argument from Evidence in 9-12 builds on K–8 experiences and progresses to college or career experiences.** Evaluate the claims, evidence, and/or reasoning behind currently accepted

Distinguish between explanations that account for all gathered evidence and those that do not.	Distinguish among facts, reasoned judgment based on research findings, and speculation in an explanation.	different evidence and/or interpretations of facts.	explanations or solutions to determine the merits of arguments.

Crosscutting Concepts (CCCs): Cause and Effect

K-2	3-5	6-8	9-12
Cause and Effect in K–2 builds on prior experiences and progresses to... Events have causes that generate observable patterns. Simple tests can be designed to gather evidence to support or refute student ideas about causes.	**Cause and Effect in 3–5 builds on K–2 experiences and progresses to...** Cause and effect relationships are routinely identified, tested, and used to explain change.	**Cause and Effect in 6– 8 builds on K–5 experiences and progresses to...** Cause and effect relationships may be used to predict phenomena in natural or designed systems.	**Cause and Effect in 9-12 builds on K–8 experiences and progresses to college or career experiences.** 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.

Disciplinary Core Ideas (DCIs): PS4.A: Wave Properties, PS4.B: Electromagnetic Radiation

K-2	3-5	6-8	9-12
PS4.A in K–2 builds on prior experiences and progresses to... Sound can make matter vibrate, and vibrating matter can make sound. **PS4.B in K–2 builds on prior experiences and progresses to...** Objects can be seen only when light is available to illuminate them.	**PS4.A in 3–5 builds on K–2 experiences and progresses to...** Waves are regular patterns of motion, which can be made in water by disturbing the surface. Waves of the same type can differ in amplitude and wavelength. Waves can make objects move. **PS4.B in 3–5 builds on K–2 experiences and progresses to...** Objects can be seen when light reflected from their surface enters our eyes.	**PS4.A in 6– 8 builds on K–5 experiences and knowledge and progresses to...** A simple wave model has a repeating pattern with a specific wavelength, frequency, and amplitude, and mechanical waves need a medium through which they are transmitted. This model can explain many phenomena including sound and light. Waves can transmit energy. **PS4.B in 6– 8 builds on K–5 experiences and knowledge and progresses to...** The construct of a wave is used to model how light interacts with objects.	**PS4.A in 9–12 builds on K–8 experiences and knowledge and progresses to...** The wavelength and frequency of a wave are related to one another by the speed of the wave, which depends on the type of wave and the medium through which it is passing. Waves can be used to transmit information and energy. **PS4.B in 9–12 builds on K–8 experiences and knowledge and progresses to...** Both an electromagnetic wave model and a photon model explain features of electromagnetic radiation broadly and describe common applications of electromagnetic radiation.

Connection to other grade level indicators

ELA Connections:

- LA.10.SL.2.c: Analyze the purpose of information being presented, evaluate its motives (e.g., social, commercial, political), and determine its credibility.

Mathematics Connections:

- N-Q.1. Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and origin in graphs and data displays.
- N-Q.2. Define appropriate quantities for the purpose of descriptive modeling.
- N-Q.3. Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

Social Studies Connections:

Fine and Performing Arts Connections:

Related Cross-Curricular Standards: Current Grade Level

Authentic Connections to Other Content Standards:

- High School Conceptual Progressions Model Course 1 - Bundle 1
  SC.HS.1.1.a, SC.HS.1.1.d, SC.HS.11.1.b, SC.HS.11.1.d
- High School Conceptual Progressions Model Course 1 - Bundle 3
  SC.HS.1.1.b, SC.HS.1.1.c, SC.HS.4.4.b, SC.HS.4.4.e, SC.HS.13.3.b

Academic Language Development

Words to support student discourse related to the Disciplinary Core Ideas (DCIs):

- Electromagnetic spectrum, wave properties, resonance, interference, wavelength, crest, trough, amplitude, wave speed, reflection, refraction, mechanical waves, speed of light, medium, photon, photon energy, diffraction, photoelectric effect

Assessment Considerations

Formative Assessment:

- https://www.education.ne.gov/assessment/nscas-science/
- Utah Seed Assessment: https://docs.google.com/document/d/1U9_vgPA5fs6vM82MAPlqYWoaE-oCAcg8RMivz4Hl2tU/edit?usp=sharing
- Wonder of Science Assessment: Argument Duality
- Wonder of Science Assessment: Smartphone Laser Diffraction

Stackable, Instructionally-Embedded, Portable Science (SIPS) Assessments:

- https://sipsassessments.org/

Knowledge, Skills, and Abilities:

- KSA1: Describe the basic properties of electromagnetic radiation (e.g., speed, frequency, wavelength, and energy).
- KSA2: Identify phenomena best explained by a wave model (e.g., diffraction, interference, refraction) and those best explained by a particle model (e.g., photoelectric effect, discrete energy absorption/emission).
- KSA3: Construct a wave model of electromagnetic radiation to explain behaviors such as reflection, refraction, and interference.
- KSA4: Construct a particle (photon) model to explain phenomena like the photoelectric effect and quantized energy levels.
- KSA5: Explain how electromagnetic radiation can be characterized both as a wave (continuous energy transfer) and as a particle (quantized packets of energy).
- KSA6: Identify scientific claims that support the wave model of light, citing phenomena such as Young’s double-slit experiment.
- KSA7: Identify scientific claims that support the particle model, citing phenomena such as the photoelectric effect or blackbody radiation.

- KSA8: Analyze experimental evidence and reasoning used historically and currently to justify each model's validity in explaining specific behaviors of electromagnetic radiation.
- KSA9: Evaluate the strengths and limitations of each model in explaining different behaviors of electromagnetic radiation.
- KSA10: Determine which model is more useful in a given context (e.g., wave model for radio transmission; particle model for solar panels) and justify the choice with evidence and reasoning.
- KSA11: Develop arguments supported by evidence and reasoning that justify why electromagnetic radiation cannot be fully described by a single model.
- KSA12: Communicate the dual nature of electromagnetic radiation through clear, evidence-based explanations, using both wave and particle terminology appropriately.

Standard

Topic Code: SC.HSP.2 Waves, Electromagnetic Radiation, and Optics
Standard Code: SC.HSP.2.2 Gather, analyze, and communicate evidence of the interactions of waves and optics.

Waves transfer energy through oscillations of fields or matter. 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 passes. Waves produce interference as they overlap but they emerge unaffected by each other. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. Electromagnetic radiation can be modeled as a wave of changing electric and magnetic fields or as particles called photons. When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy. Because waves depend upon the properties of fields and the predictable transformation of energy, they can be used to interpret the nature of matter and its energy. Waves are utilized to transmit information both in analog and digital forms.

Indicator

Indicator Code: SC.HSP.2.2.e
Use evidence to support explanations for causes of emission and absorption spectra of electromagnetic radiation. Emphasis is on the idea that photons associated with different frequencies of light have different energies. This could include the displacement and broadening of spectral lines (redshift and blueshift). Examples could include different elements absorb or emit specific frequencies of light. Assessment is limited to qualitative descriptions.

NGSS Comparison: Builds on HS-PS4-4

Other Indicators in this Standard

SC.HSP.2.2.a, SC.HSP.2.2.b, SC.HSP.2.2.c, SC.HSP.2.2.d, SC.HSP.2.2.f

Concepts and Skills to Master

Foundation Boxes:

Science and Engineering Practice (SEP)	Crosscutting Concept (CCC)
Constructing explanations and designing solutions: Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.	**Cause and Effect:** • Argue from evidence when attributing an observed phenomenon to a specific cause.

Disciplinary Core Idea (DCI)

PS4.B: Electromagnetic Radiation:

- When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells.
- Atoms of each element emit and preferentially absorb characteristic frequencies of light. These spectral lines allow identification of the presence of the element, even in microscopic quantities or for remote objects, such as a star.

Possible Science and/or Engineering Phenomena to Support 3D Instruction

- How do we know what other stars are made of?
- How the Sun Sees You
- How do we know the universe is expanding?
- How can we tell which substances are present on distant planets?
- How does cosmic microwave background radiation provide evidence for the big bang?
- Radiation treatments for cancer
- How does sunscreen work?
- Environmental mutations of DNA
- Greenhouse gases

Evidence Statements

What does it look like to demonstrate proficiency on this indicator?

SC.HSP.2.2.e **Use evidence to support explanations** for causes of emission and absorption spectra of electromagnetic radiation.		
1	Identifying the given explanation and associated claims, evidence, and reasoning	
	a	Students identify the given explanation that is to be supported by the claims, evidence, and reasoning to be evaluated.
	b	Students identify the given claims to be evaluated.
	c	Students identify the given evidence to be evaluated.
	d	Students identify the given reasoning to be evaluated.
2	Evaluating given evidence and reasoning and Identifying potential additional evidence	
	a	Students evaluate the given evidence to determine how well it supports the argument.
	b	Students identify and describe* additional evidence (in the form of data, information, or other appropriate forms) that was not provided but is relevant to the explanation and to evaluating the given claims, evidence, and reasoning.
3	Evaluating and critiquing	
	a	Students describe* the strengths and weaknesses of the given claim.
	b	Students use their additional evidence to assess the validity and reliability of the given evidence and its ability to support the argument.
	c	Students assess the logic of the reasoning and the utility of the reasoning in supporting the explanation.
	d	Students evaluate the reliability, strengths, and weaknesses of the given evidence along with its ability to support logical and reasonable arguments about the phenomenon.

Critical Background Knowledge

Grade Band Progressions:

Science and Engineering Practices (SEPs): Constructing Explanations and Designing Solutions

K-2	3-5	6-8	9-12
Constructing Explanations in K–2 builds on prior experiences and progresses to... Use information from observations (firsthand and from media) to construct an evidence-based account for natural phenomena.	**Constructing Explanations in 3–5 builds on K–2 experiences and progresses to...** Identify the evidence that supports particular points in an explanation.	**Constructing Explanations in 6– 8 builds on K–5 experiences and progresses to...** Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion.	**Constructing Explanations in 9-12 builds on K–8 experiences and progresses to college or career experiences.** Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.

Crosscutting Concepts (CCCs): Cause and Effect

K-2	3-5	6-8	9-12
Cause and Effect in K–2 builds on prior experiences and progresses to... Events have causes that generate observable patterns. Simple tests can be designed to gather evidence to support or refute student ideas about causes.	**Cause and Effect in 3–5 builds on K–2 experiences and progresses to...** Cause and effect relationships are routinely identified, tested, and used to explain change.	**Cause and Effect in 6– 8 builds on K–5 experiences and progresses to...** Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.	**Cause and Effect in 9-12 builds on K–8 experiences and progresses to college or career experiences.** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Disciplinary Core Ideas (DCIs): PS4.B: Electromagnetic Radiation

K-2	3-5	6-8	9-12
PS4.B in K–2 builds on prior experiences and progresses to... Objects can be seen only when light is available to illuminate them.	**PS4.B in 3–5 builds on K–2 experiences and progresses to...** Object can be seen when light reflected from their surface enters our eyes.	**PS4.B in 6– 8 builds on K–5 experiences and knowledge and progresses to...** The construct of a wave is used to model how light interacts with objects.	**PS4.B in 9–12 builds on K–8 experiences and knowledge and progresses to...** Both an electromagnetic wave model and a photon model explain features of electromagnetic radiation broadly and describe common applications of electromagnetic radiation.

Connection to other grade level indicators

ELA Connections:

- LA.10.SL.2.c: Analyze the purpose of information being presented, evaluate its motives (e.g., social, commercial, political), and determine its credibility.

Mathematics Connections:

- N-Q.1. Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and origin in graphs and data displays.
- N-Q.2. Define appropriate quantities for the purpose of descriptive modeling.
- N-Q.3. Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

Social Studies Connections:

Fine and Performing Arts Connections:

Related Cross-Curricular Standards: Current Grade Level

Authentic Connections to Other Content Standards:

- High School Conceptual Progressions Model Course 1 - Bundle 1
  SC.HS.1.1.a, SC.HS.1.1.d, SC.HS.11.1.b, SC.HS.11.1.d
- High School Conceptual Progressions Model Course 1 - Bundle 3
  SC.HS.1.1.b, SC.HS.1.1.c, SC.HS.4.4.b, SC.HS.4.4.e, SC.HS.13.3.b

Academic Language Development

Words to support student discourse related to the Disciplinary Core Ideas (DCIs):

- Electromagnetic radiation, wavelength, frequency, speed of light, Photon energy, media, photon, tissues, cells, organism, ionization,

Assessment Considerations

Formative Assessment:

- https://www.education.ne.gov/assessment/nscas-science/
- Utah SEED Assessment: Chernobyl radiation vs. Cell Phone radiation
- Wonder of Science Assessment: Evaluating Radiation Protection
- Wonder of Science Assessment: Sunscreen
- Wonder of Science Assessment: Electroscope

Stackable, Instructionally-Embedded, Portable Science (SIPS) Assessments:

- https://sipsassessments.org/

Knowledge, Skills, and Abilities:

- KSA1: Describe light as electromagnetic radiation that can be characterized by its wavelength, frequency, and energy.
- KSA2: Explain qualitatively how photons with shorter wavelengths (higher frequency) carry more energy than those with longer wavelengths.
- KSA3: Describe atoms as having quantized energy levels and explain that electrons absorb or emit photons when transitioning between these levels.
- KSA4: Explain that the energy of absorbed/emitted photons corresponds to specific frequencies of light, resulting in absorption or emission lines.
- KSA5: Identify and describe emission spectra as sets of discrete colored lines produced when excited atoms emit photons.
- KSA6: Identify and describe absorption spectra as continuous spectra with dark lines where light at specific frequencies has been absorbed.
- KSA7: Explain how different elements produce unique spectral lines, acting as “fingerprints” for identifying elements in stars and gases.
- KSA8: Describe qualitatively how motion between a light source and observer causes spectral lines to shift (i.e., redshift when moving away, blueshift when approaching).
- KSA9: Explain how redshift and blueshift can be used to infer motion and relative velocity of celestial objects.
- KSA10: Use observed spectral lines to identify elements present in a gas or star and explain how these lines serve as evidence of electron transitions.
- KSA11: Construct explanations of spectral line patterns based on the energy differences between atomic energy levels.

- KSA12: Use redshift/blueshift evidence to explain relative motion between light-emitting objects and observers, connecting the change in frequency to photon energy and wave behavior.
- KSA13: Communicate explanations using appropriate vocabulary (e.g., photon, frequency, energy level, emission, absorption, redshift) to support scientific claims.
- KSA14: Evaluate explanations by comparing spectral data and reasoning qualitatively about energy and light-matter interactions.

Standard

Topic Code: SC.HSP.2 Waves, Electromagnetic Radiation, and Optics
Standard Code: SC.HSP.2.2 Gather, analyze, and communicate evidence of the interactions of waves and optics.

Waves transfer energy through oscillations of fields or matter. 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 passes. Waves produce interference as they overlap but they emerge unaffected by each other. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. Electromagnetic radiation can be modeled as a wave of changing electric and magnetic fields or as particles called photons. When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy. Because waves depend upon the properties of fields and the predictable transformation of energy, they can be used to interpret the nature of matter and its energy. Waves are utilized to transmit information both in analog and digital forms.

Indicator

Indicator Code: SC.HSP.2.2.f
Communicate technical information about how some technological devices <u>use the principles of wave behavior and wave interactions</u> with matter to transmit and capture information and energy. Examples could include solar cells capturing light and converting it to electricity; medical imaging; communications technology; lasers. Assessments are limited to qualitative information. Assessments do not include band theory.

NGSS Comparison: Builds on HS-PS4-5

Other Indicators in this Standard

SC.HSP.2.2.a, SC.HSP.2.2.b, SC.HSP.2.2.c, SC.HSP.2.2.d, SC.HSP.2.2.e

Concepts and Skills to Master

Foundation Boxes:

Science and Engineering Practice (SEP)	Crosscutting Concept (CCC)
Obtaining, Evaluating, and Communicating Information: Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs. • Communicate technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).	**Cause and Effect:** • Systems can be designed to cause a desired effect. ***Connections to Engineering, Technology, and Applications of Science*** **Interdependence of Science, Engineering, and Technology:** • Science and engineering complement each other in the cycle known as research and development (R&D). **Influence of Engineering, Technology, and Science on Society and the Natural World:** • Modern civilization depends on major technological systems.
Disciplinary Core Idea (DCI)	

PS3.D: **Energy in Chemical Processes**

- Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy. *(secondary to SC.HSP.2.2.F)*

PS4.A: **Wave Properties**

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

PS4.B: **Electromagnetic Radiation**

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

PS4.C: **Information Technologies and Instrumentation**

- Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them.

Possible Science and/or Engineering Phenomena to Support 3D Instruction

- Photoelectric Effect - HS-PS4-3, HS-PS4-5
- Solar Cars - HS-PS4-5
- Digital storage advantages
- Music fidelity - album vs. cassette vs. CD vs. MP3
- Interference (destructive vs. constructive)
- Acoustic beats in sound waves
- AM and FM waves
- 3G vs 4G vs 5G cellular

Evidence Statements

What does it look like to demonstrate proficiency on this indicator?

SC.HSP.2.2.f **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.	
Communication style and format	
a	Students use at least two different formats (including oral, graphical, textual and mathematical) to communicate scientific and technical information. Students cite the origin of the information as appropriate.
Connecting the DCIs and the CCCs	
a	Students identify and communicate the evidence about the phenomenon or design.
b	Students describe the phenomenon or design using causality, patterns, and/or systems.

Critical Background Knowledge

Grade Band Progressions:

Science and Engineering Practices (SEPs): Obtaining, Evaluating, and Communicating Information

K-2	3-5	6-8	9-12

Obtaining, Evaluating, and Communicating Information in K–2 builds on prior experiences and progresses to... Use information from observations (firsthand and from media) to construct an evidence-based account for natural phenomena.	**Obtaining, Evaluating, and Communicating Information in 3–5 builds on K–2 experiences and progresses to...** Identify the evidence that supports particular points in an explanation.	**Obtaining, Evaluating, and Communicating Information in 6– 8 builds on K–5 experiences and progresses to...** Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion.	**Obtaining, Evaluating, and Communicating Information in 9-12 builds on K–8 experiences and progresses to college or career experiences.** Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.

Crosscutting Concepts (CCCs): Cause and Effect

K-2	3-5	6-8	9-12
Cause and Effect in K–2 builds on prior experiences and progresses to... Simple tests can be designed to gather evidence to support or refute student ideas about causes.	**Cause and Effect in 3–5 builds on K–2 experiences and progresses to...** Events that occur together with regularity might or might not be a cause and effect relationship.	**Cause and Effect in 6– 8 builds on K–5 experiences and progresses to...** Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.	**Cause and Effect in 9-12 builds on K–8 experiences and progresses to college or career experiences.** Systems can be designed to cause a desired effect.

Disciplinary Core Ideas (DCIs): PS3.D: Energy in Chemical Processes, PS4.A: Wave Properties, PS4.B: Electromagnetic Radiation, PS4.C: Information Technologies and Instrumentation

K-2	3-5	6-8	9-12
PS3.D in K–2 builds on prior experiences and progresses to... Sunlight warms Earth's surface. **PS4.A in K–2 builds on prior experiences and progresses to...** Sound can make matter vibrate, and vibrating matter can make sound.	**PS3.D in 3–5 builds on K–2 experiences and progresses to...** Energy can be "produced," "used," or "released" by converting stored energy. Plants capture energy from sunlight, which can later be used as fuel or food. **PS4.A in 3–5 builds on K–2 experiences and progresses to...** Waves are regular patterns of motion, which can be made in water by disturbing the surface. Waves of the same type can differ in amplitude and	**PS3.D in 6– 8 builds on K–5 experiences and knowledge and progresses to...** Sunlight is captured by plants and used in a reaction to produce sugar molecules, which can be reversed by burning those molecules to release energy. **PS4.A in 6– 8 builds on K–5 experiences and knowledge and progresses to...** A simple wave model has a repeating pattern with a specific wavelength, frequency, and amplitude, and mechanical waves need a medium through which they are transmitted.	**PS3.D in 9–12 builds on K–8 experiences and knowledge and progresses to...** Photosynthesis is the primary biological means of capturing radiation from the sun; energy cannot be destroyed; it can be converted to less useful forms. **PS4.A in 9–12 builds on K–8 experiences and knowledge and progresses to...** The wavelength and frequency of a wave are related to one another by the speed of the wave, which depends on the type of wave and the

PS4.B in K–2 builds on prior experiences and progresses to... Objects can be seen only when light is available to illuminate them. **PS4.C in K–2 builds on prior experiences and progresses to...** People use devices to send and receive information.	wavelength. Waves can make objects move. **PS4.B in 3–5 builds on K–2 experiences and progresses to...** Objects can be seen when light reflected from their surface enters our eyes. **PS4.C in 3–5 builds on K–2 experiences and progresses to...** Patterns can encode, send, receive and decode information.	This model can explain many phenomena including sound and light. Waves can transmit energy. **PS4.B in 6– 8 builds on K–5 experiences and knowledge and progresses to...** The construct of a wave is used to model how light interacts with objects. **PS4.C in 6– 8 builds on K–5 experiences and knowledge and progresses to...** Waves can be used to transmit digital information. Digitized information is comprised of a pattern of 1s and 0s.	medium through which it is passing. Waves can be used to transmit information and energy. **PS4.B in 9–12 builds on K–8 experiences and knowledge and progresses to...** Both an electromagnetic wave model and a photon model explain features of electromagnetic radiation broadly and describe common applications of electromagnetic radiation. **PS4.C in 9–12 builds on K–8 experiences and knowledge and progresses to...** Large amounts of information can be stored and shipped around as a result of being digitized.

Connection to other grade level indicators

ELA Connections:

- LA.10.SL.2.c: Analyze the purpose of information being presented, evaluate its motives (e.g., social, commercial, political), and determine its credibility.

Mathematics Connections:

- N-Q.1. Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and origin in graphs and data displays.
- N-Q.2. Define appropriate quantities for the purpose of descriptive modeling.
- N-Q.3. Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

Social Studies Connections:

Fine and Performing Arts Connections:

Related Cross-Curricular Standards: Current Grade Level

Authentic Connections to Other Content Standards:

- High School Conceptual Progressions Model Course 1 - Bundle 1
  SC.HS.1.1.a, SC.HS.1.1.d, SC.HS.11.1.b, SC.HS.11.1.d
- High School Conceptual Progressions Model Course 1 - Bundle 3
  SC.HS.1.1.b, SC.HS.1.1.c, SC.HS.4.4.b, SC.HS.4.4.e, SC.HS.13.3.b

Academic Language Development

Words to support student discourse related to the Disciplinary Core Ideas (DCIs):

- Frequency, wavelength, electromagnetic radiation, photon, photon energy, antenna, transmitter, receiver

Assessment Considerations

Formative Assessment:

- https://www.education.ne.gov/assessment/nscas-science/
- Utah SEEd Assessment
- Wonder of Science Assessment: Perserverance Rover
- Wonder of Science Assessment: Photoelectric Effect

Stackable, Instructionally-Embedded, Portable Science (SIPS) Assessments:

- https://sipsassessments.org/

Knowledge, Skills, and Abilities:

- KSA1: Describe the basic properties of waves (e.g., wavelength, frequency, amplitude, speed) and distinguish between different types (e.g., sound, light, electromagnetic).
- KSA2: Explain qualitatively how waves interact with matter through reflection, refraction, absorption, transmission, and diffraction.
- KSA3: Identify that electromagnetic waves (e.g., visible light, radio waves, X-rays) do not require a medium and can carry energy through space.
- KSA4: Identify every day and scientific technologies that use wave behaviors to transmit or capture information or energy (e.g., cell phones, X-rays, solar panels).
- KSA5: Describe how these technologies rely on specific wave properties (e.g., frequency, speed, direction) or interactions with materials (e.g., absorption in a solar cell or transmission in fiber optics).
- KSA6: Explain how solar cells capture electromagnetic radiation and convert light energy into electrical energy using the principle of photon energy absorption.
- KSA7: Explain how medical imaging technologies (e.g., ultrasound, X-rays, MRI) use wave interactions (e.g., reflection, absorption, resonance) to form images of internal body structures.
- KSA8: Describe how communication technologies (e.g., radio, fiber optics, satellites) use wave transmission, encoding, and reflection/refraction to transmit information over distances.
- KSA9: Explain how lasers produce coherent light and how that property allows precise delivery of energy in applications such as surgery, communications, or barcode scanning.
- KSA10: Gather qualitative information from reliable sources about how a selected technology uses wave behavior and wave-matter interactions.
- KSA11: Summarize and communicate technical information using appropriate scientific vocabulary and visuals (e.g., diagrams, models, descriptions).
- KSA12: Evaluate the effectiveness or efficiency of different technologies based on their use of wave principles (e.g., compare fiber optics to traditional electrical cables).
- KSA13: Construct explanations of how specific wave behaviors are used intentionally in the design of technological devices.
- KSA14: Present a clear argument supported by evidence about why certain technologies use specific types of waves or wave behaviors (e.g., why X-rays are used for imaging bones and not radio waves).
- KSA15: Communicate technical information in writing, verbally, or visually to a variety of audiences, emphasizing how wave behavior supports the function of the technology.

Standard

Topic Code: SC.HSP.4 Energy: Physics
Standard Code: SC.HSP.4.3 Gather, analyze, and communicate evidence of the interactions of energy.

Energy describes the motion and interactions of matter and radiation within a system. Energy is a quantifiable property that is conserved in isolated systems and in the universe as a whole. At the macroscopic scale, energy manifests itself in multiple ways such as in motion, sound, light, and thermal energy. Uncontrolled systems always evolve toward more stable states— that is, toward more uniform energy distribution. Examining the world through an energy lens allows us to model and predict complex interactions of multiple objects within a system and address societal needs.

Indicator

Indicator Code: SC.HSP.4.3.a
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. Emphasis is on explaining the meaning of mathematical expressions used in the model including the Work-Energy theorem. 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.

NGSS Comparison: Builds on HS-PS3-1

Other Indicators in this Standard

SC.HSP.4.3.b, SC.HSP.4.3.c, SC.HSP.4.3.d, SC.HSP.4.3.e, SC.HSP.4.3.f

Concepts and Skills to Master

Foundation Boxes:

Science and Engineering Practice (SEP)	Crosscutting Concept (CCC)
Using Mathematics and Computational Thinking: Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Create a computational model or simulation of a phenomenon, designed device, process, or system.	**Systems and System Models:** • Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. ***Connections to Nature of Science*** **Scientific Knowledge Assumes an Order and Consistency in Natural Systems:** • Science assumes the universe is a vast single system in which basic laws are consistent.

Disciplinary Core Idea (DCI)

PS3.A: **Definitions of Energy:**
- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.

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

- Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
- The availability of energy limits what can occur in any system.

Possible Science and/or Engineering Phenomena to Support 3D Instruction

- Coupled pendulum
- Magnetic cannon
- Amazing Rube Goldberg Machines
- Candle-Powered Car
- The Gravity Light
- Newton's Cradle
- Roller Coaster
- Combustion Engine
- Battery
- Electric Motor / Generator
- Hydraulic Dam
- Trebuchet
- Hand-cranked Generator
- Solar Panel
- Wind Turbine

Evidence Statements

What does it look like to demonstrate proficiency on this indicator?

SC.HSP.4.3.a **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.	
Representation	
a	Students identify and describe* the components to be computationally modeled.
b	Students describe* the variables that can be changed to evaluate the proposed solutions, tradeoffs, or other decisions.
Computational Modeling	
a	Students create a computational simulation (using a spreadsheet or a provided multi-parameter program) that contains representations of the relevant components of the phenomenon at hand.
b	Students use the computational model to calculate changes in one component of the system when changes in other components are known.
c	Students use the simulation to identify possible negative consequences of solutions that would outweigh their benefits.
Analysis	
a	Students use the computational model to predict changes.
b	Students identify and describe* the limitations of the computational model relative to the phenomenon at hand.

c	Students compare the simulation results to real-world example(s) and determine if the simulation can be viewed as realistic.
d	Students use the results of the simulation to identify feedback between the components.
e	Students use the results of the simulation to illustrate the effect on one component by altering other components in the system or the relationships between components.
Revision	
a	Students revise the simulation as needed to provide sufficient information to evaluate the solution.

Critical Background Knowledge

Grade Band Progressions:

Science and Engineering Practices (SEPs): Using Mathematics and Computational Thinking

K-2	3-5	6-8	9-12
Using Mathematics and Computational Thinking in K–2 builds on prior experiences and progresses to... Use counting and numbers to identify and describe patterns in the natural and designed world(s).	**Using Mathematics and Computational Thinking in 3–5 builds on K–2 experiences and progresses to...** Organize simple data sets to reveal patterns that suggest relationships	**Using Mathematics and Computational Thinking in 6– 8 builds on K–5 experiences and progresses to...** Use mathematical representations to describe and/or support scientific conclusions and design solutions	**Using Mathematics and Computational Thinking in 9-12 builds on K–8 experiences and progresses to college or career experiences.** Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Crosscutting Concepts (CCCs): Systems and System Models

K-2	3-5	6-8	9-12
Systems and System Models in K–2 builds on prior experiences and progresses to... Students understand objects and organisms can be described in terms of their parts; and systems in the natural and designed world have parts that work together.	**Systems and System Models in 3–5 builds on K–2 experiences and progresses to...** Students understand that a system is a group of related parts that make up a whole and can carry out functions its individual parts cannot.	**Systems and System Models in 6– 8 builds on K–5 experiences and progresses to...** They can use models to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.	**Systems and System Models in 9-12 builds on K–8 experiences and progresses to college or career experiences.** Use models and simulations to predict the behavior of a system and recognize that these predictions have limited precision and reliability due to the assumptions and approximations inherent in the models.

Disciplinary Core Ideas (DCIs): PS3.A: Definitions of Energy, PS3.B: Conservation of Energy and Energy Transfer

K-2	3-5	6-8	9-12
PS3.A and PS3.B in K–2 builds on prior experiences and progresses to... N/A	**PS3.A and PS3.B in 3–5 builds on K–2 experiences and progresses to...** 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	**PS3.A and PS3.B in 6– 8 builds on K–5 experiences and knowledge and progresses to...** 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.	**PS3.A and PS3.B in 9–12 builds on K–8 experiences and knowledge and progresses to...** The total energy within a system is conserved. Energy transfer within and between systems can be described and predicted in terms of energy associated with the motion or configuration of particles (objects). Systems move toward stable states.

Connection to other grade level indicators

ELA Connections:

- **SL.11-12.5: Make** strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.

Mathematics Connections:

- **MP.2: Reason** abstractly and quantitatively.
- **MP.4: Model** with mathematics.
- **HSN.Q.A.1: Use** units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.
- **HSN.Q.A.2: Define** appropriate quantities for the purpose of descriptive modeling.
- **HSN.Q.A.3: Choose** a level of accuracy appropriate to limitations on measurement when reporting quantities.

Social Studies Connections:

Fine and Performing Arts Connections:

Related Cross-Curricular Standards: Current Grade Level

Authentic Connections to Other Content Standards:

- High School Modified Domains Model Course II - Physics Bundle 3: What Happens When Energy Moves from One Place to Another?
- SC.HS.1.1.b, SC.HS.1.1.c, SC.HS.4.4.b, SC.HS.4.4.e, SC.HS.13.3.b

Academic Language Development

Words to support student discourse related to the Disciplinary Core Ideas (DCIs):

- System and boundaries, Components, Energy flow, Mechanical energy, chemical energy, electrical energy, potential energy, thermal energy, heat, conservation, conversion, kinetic energy, momentum, conservation of energy, Law of Conservation of Energy

Assessment Considerations

Formative Assessment:

- https://www.education.ne.gov/assessment/science-classroom-formative-task-repository-for-grades-5-8/

- Utah SEED Assessement
- Wonder of Science Assessment: Algodoo Ball Bounce
- Wonder of Science Assessment: Bouncing Ball Energy
- Wonder of Science Assessment: Pole Vault Energy Transfer

Stackable, Instructionally-Embedded, Portable Science (SIPS) Assessments:

- https://sipsassessments.org/

Knowledge, Skills, and Abilities:

- KSA1: Define a physical system and its components, distinguishing between energy within the system and energy flowing into or out of the system.
- KSA2: Identify and describe different forms of energy relevant to systems: kinetic energy, thermal energy, and potential energy in gravitational, magnetic, or electric fields.
- KSA3: Explain how the system demonstrates the principle of energy conservation: energy cannot be created or destroyed, only transferred or transformed.
- KSA4: Derive basic algebraic expressions that represent energy changes in the system, based on the law of conservation of energy or the work-energy theorem.
- KSA5: Relate terms in these equations to physical meaning (e.g., work done by an external force results in a change in kinetic energy).
- KSA6: Construct a computational model (e.g. spreadsheet, coding environment, etc) that uses known energy values or changes to compute unknown quantities and/or tracks energy flow through 2-3 components.
- KSA7: Explain how the model represents energy conservation and transformation using both mathematical expressions and real-world meaning.
- KSA8: Run simulations or calculate outputs from the model using a variety of initial conditions.
- KSA9: Compare model outputs to qualitative predictions or real-world observations and evaluate whether the results are reasonable.
- KSA10: Revise the model or its parameters to better reflect energy flows (e.g., adding a thermal loss term or adjusting input values to reflect measured data).
- KSA11: Use the model to explain how energy is conserved and redistributed in physical systems.
- KSA12: Communicate findings clearly with labeled diagrams, verbal reasoning, and mathematical representations that connect system components and energy changes.

Standard

Topic Code: SC.HSP.4 Energy: Physics

Standard Code: SC.HSP.4.3 Gather, analyze, and communicate evidence of the interactions of energy.

Energy describes the motion and interactions of matter and radiation within a system. Energy is a quantifiable property that is conserved in isolated systems and in the universe as a whole. At the macroscopic scale, energy manifests itself in multiple ways such as in motion, sound, light, and thermal energy. Uncontrolled systems always evolve toward more stable states— that is, toward more uniform energy distribution. Examining the world through an energy lens allows us to model and predict complex interactions of multiple objects within a system and address societal needs.

Indicator

Indicator Code: SC.HSP.4.3.b

Plan and conduct an investigation to rate the power and efficiency used in performing work on a system. Emphasis is on the quantitative determination of power in interactions. Examples could include the use of pulleys and electric motors.

NGSS Comparison: Builds on HS-PS3-1 and HS-PS3-3

Other Indicators in this Standard

SC.HSP.4.3.a, SC.HSP.4.3.c, SC.HSP.4.3.d, SC.HSP.4.3.e, SC.HSP.4.3.f

Concepts and Skills to Master

Foundation Boxes:

Science and Engineering Practice (SEP)

Planning and Carrying Out Investigations:
Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.

- Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.

Crosscutting Concept (CCC)

Energy and Matter:

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

Disciplinary Core Idea (DCI)

PS3.A: Definitions of Energy:

- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.

PS3.B: Conservation of Energy and Energy Transfer:

- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- The availability of energy limits what can occur in any system.

Possible Science and/or Engineering Phenomena to Support 3D Instruction

- Gravity Light
- Roller coaster or ramp system
- Electric motor lifting a mass
- Pulley system lifting a mass
- Battery powered fan or car
- Regenerative braking systems
- Human Power Output for Stair Climbing or Cycling
- Hand Crank Generator
- Solar Panel Charging a battery
- Rubber Band Launcher

Evidence Statements

What does it look like to demonstrate proficiency on this indicator?

SC.HSP.4.3.b **Plan and conduct an investigation** to rate the power and efficiency used in performing work on a system.	
Identifying the phenomenon to be investigated	
a	Students describe* the phenomenon under investigation
Identifying the evidence to answer this question	
a	Students develop an investigation plan and describe* the data that will be collected and the evidence to be derived from the data.

b	Students describe* why the data would provide information that serves as the basis for evidence.
Planning for the investigation	
a	In the investigation plan, students include:
	i. A rationale for the choice of variables.
	ii. A description* of how the data will be collected, the number of trials, and the experimental set up and equipment required.
b	Students describe* how the data will be collected, the number of trials, the experimental set up, and the equipment required.
Collecting the data	
a	Students collect and record data — quantitative and/or qualitative.
Refining the design	
a	Students evaluate their investigation, including evaluation of:
	i. Assessing the accuracy and precision of the data collected, as well as the limitations of the investigation; and
	ii. The ability of the data to provide the evidence required.
b	If necessary, students refine the plan to produce more accurate, precise, and useful data.

Critical Background Knowledge

Grade Band Progressions:

Science and Engineering Practices (SEPs): Planning and Carrying Out Investigations

K-2	3-5	6-8	9-12
Planning and Carrying Out Investigations in K–2 builds on prior experiences and progresses to... With guidance, plan and conduct an investigation in collaboration with peers (for K).	**Planning and Carrying Out Investigations in 3–5 builds on K–2 experiences and progresses to...** 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.	**Planning and Carrying Out Investigations in 6–8 builds on K–5 experiences and progresses to...** 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.	**Planning and Carrying Out Investigations in 9-12 builds on K–8 experiences and progresses to college or career experiences.** Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.

Crosscutting Concepts (CCCs): Energy and Matter

K-2	3-5	6-8	9-12

Energy and Matter in K–2 builds on prior experiences and progresses to... Students observe objects may break into smaller pieces, be put together into larger pieces, or change shapes.	**Energy and Matter in 3–5 builds on K–2 experiences and progresses to...** Students learn matter is made of particles and energy can be transferred in various ways and between objects. Students observe the conservation of matter by tracking matter flows and cycles before and after processes and recognizing the total weight of substances does not change.	**Energy and Matter in 6– 8 builds on K–5 experiences and progresses to...** Students learn matter is conserved because atoms are conserved in physical and chemical processes. They also learn 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.	**Energy and Matter in 9-12 builds on K–8 experiences and progresses to college or career experiences.** Students learn that the total amount of energy and matter in closed systems is conserved. They can describe changes of energy and matter in a system in terms of energy and matter flows into, out of, and within that system. They also learn that energy cannot be created or destroyed. It only moves between one place and another place, between objects and/or fields, or between systems. Energy drives the cycling of matter within and between systems. In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

Disciplinary Core Ideas (DCIs): PS3.A: Definitions of Energy, PS3.B: Conservation of Energy and Energy Transfer

K-2	3-5	6-8	9-12
PS3.A and PS3.B in K–2 builds on prior experiences and progresses to... N/A	**PS3.A and PS3.B in 3–5 builds on K–2 experiences and progresses to...** 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.	**PS3.A and PS3.B in 6– 8 builds on K–5 experiences and knowledge and progresses to...** 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.	**PS3.A and PS3.B in 9–12 builds on K–8 experiences and knowledge and progresses to...** The total energy within a system is conserved. Energy transfer within and between systems can be described and predicted in terms of energy associated with the motion or configuration of particles (objects). Systems move toward stable states.

Connection to other grade level indicators

ELA Connections:

- RST.11-12.3 – Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
- RST.11-12.7 – Integrate and evaluate multiple sources of information presented in diverse formats and media.
- WHST.11-12.2 – Write informative/explanatory texts to examine and convey complex ideas clearly and accurately.
- WHST.11-12.7 – Conduct short as well as sustained research projects to answer a question or solve a problem.

Mathematics Connections:

- HSF-IF.4 – Interpret key features of graphs and tables in terms of the quantities.
- HSA-CED.2 – Create equations in two or more variables to represent relationships between quantities.
- HSA-SSE.1 – Interpret expressions that represent a quantity in terms of its context.
- HSS-ID.1 – Represent data with plots on the real number line (dot plots, histograms, box plots).

- HSS-ID.6 – Summarize, represent, and interpret data on two quantitative variables.

Social Studies Connections:

Fine and Performing Arts Connections:

Related Cross-Curricular Standards: Current Grade Level

Authentic Connections to Other Content Standards:

- High School Domains Model Course 1 – Chemistry – Bundle 3
- High School Domains Model Course 2 – Physics – Bundle 3

Academic Language Development

Words to support student discourse related to the Disciplinary Core Ideas (DCIs):

- Energy, power, efficiency, system, system boundary, component, total energy, Law of Conservation of Energy

Assessment Considerations

Formative Assessment:

- https://www.education.ne.gov/assessment/science-classroom-formative-task-repository-for-grades-5-8/
- Wonder of Science Assessment: Efficiency of a System

Stackable, Instructionally-Embedded, Portable Science (SIPS) Assessments:

- https://sipsassessments.org/

Knowledge, Skills, and Abilities:

- **KSA1:** Describe a system where there is work being done on or by the system.
- **KSA2:** Identify data that could be collected to provide evidence to rate the system's power and efficiency.
- **KSA3**: Explain why the data collected would provide evidence for rating the power and efficiency of the system.
- **KSA4**: Describe how the data will be collected, the number of trials, the equipment required, and the experimental setup.
- **KSA5:** Collect and record quantitative and/or qualitative data.
- **KSA6:** Assess the accuracy and precision of the data collected.
- **KSA7:** Identify limitations of the investigation.
- **KSA8:** Evaluate whether the data collected provided the evidence required to rate the power and efficiency of the system.
- **KSA9:** Refine the investigation plan and explain how the revisions will produce more accurate, precise and useful data.

Standard

Topic Code: SC.HSP.4 Energy: Physics

Standard Code: SC.HSP.4.3 Gather, analyze, and communicate evidence of the interactions of energy.

Energy describes the motion and interactions of matter and radiation within a system. Energy is a quantifiable property that is conserved in isolated systems and in the universe as a whole. At the macroscopic scale, energy manifests itself in multiple ways such as in motion, sound, light, and thermal energy. Uncontrolled systems always evolve toward more stable states— that is, toward more uniform energy distribution. Examining the world through an energy lens allows us to model and predict complex interactions of multiple objects within a system and address societal needs.

Indicator

Indicator Code: SC.HSP.4.3.c

Design, build, and refine a device that works within given constraints to <u>convert one form of energy into another form of energy</u>. Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, generators, heat engines and heat pumps. Examples of constraints could include use of renewable energy forms and efficiency. Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students.

NGSS Comparison: Builds on HS-PS3-3

Other Indicators in this Standard

SC.HSP.4.3.a, SC.HSP.4.3.b, SC.HSP.4.3.d, SC.HSP.4.3.e, SC.HSP.4.3.f

Concepts and Skills to Master

Foundation Boxes:

Science and Engineering Practice (SEP)	Crosscutting Concept (CCC)
Constructing Explanations and Designing Solutions: Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • 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.	**Energy and Matter:** • Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. ***Connections to Engineering, Technology, and Applications of Science*** **Influence of Science, Engineering, and Technology on Society and the Natural World** • Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.

Disciplinary Core Idea (DCI)

PS3.A: Definitions of Energy

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

PS3.B: Conservation of Energy and Energy Transfer

- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.

PS3.D: Energy in Chemical Processes

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

ETS1.A: Defining and Delimiting Engineering Problems

- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. *(secondary to SC.HSP.4.3.C)*

Possible Science and/or Engineering Phenomena to Support 3D Instruction

- Drinking bird
- Magnetic cannon
- Amazing Slinky Tricks
- Amazing Rube Goldberg Machines

- Earthships
- Solar Cars
- Candle-Powered Car
- The Gravity Light

Evidence Statements

What does it look like to demonstrate proficiency on this indicator?

SC.HSP.4.3.c **Design, build and refine a device** that works within given constraints to convert one form of energy into another form of energy.	
Using scientific knowledge to generate the design solution	
a	Students design a device that converts one form of energy into another form of energy.
b	Students develop a plan for the device in which they:
	i. Identify what scientific principles provide the basis for the energy conversion design;
	ii. Identify the forms of energy that will be converted from one form to another in the designed system;
	iii. Identify losses of energy by the design system to the surrounding environment;
	iv. Describe* the scientific rationale for choices of materials and structure of the device, in cluding how student-generated evidence influenced the design; and
	v. Describe* that this device is an example of how the application of scientific knowledge and engineering design can increase benefits for modern civilization while decreasing costs and risk.
Describing criteria and constraints, including quantification when appropriate	
a	Students describe* and quantify (when appropriate) prioritized criteria and constraints for the design of the device, along with the tradeoffs implicit in these design solutions. Examples of constraints to be considered are cost and efficiency of energy conversion.
Evaluating potential solutions	
a	Students build and test the device according to the plan.
b	Students systematically and quantitatively evaluate the performance of the device against the criteria and constraints.
Refining and/or optimizing the design solution	
a	Students use the results of the tests to improve the device performance by increasing the efficiency of energy conversion, keeping in mind the criteria and constraints, and noting any modifications in tradeoffs.

Critical Background Knowledge

Grade Band Progressions:

Science and Engineering Practices (SEPs): Constructing Explanations and Designing Solutions

K-2	3-5	6-8	9-12
Constructing Explanations and Designing Solutions in K–2 builds on prior	**Constructing Explanations and Designing Solutions in 3–5 builds**	**Constructing Explanations and Designing Solutions in 6– 8 builds on K–5 experiences and progresses to...**	**Constructing Explanations and Designing Solutions in 9-12 builds on K–8 experiences and progresses to college or career experiences.**

experiences and progresses to... Generate and/or compare multiple solutions to a problem	**on K–2 experiences and progresses to...** Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution	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.	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.

Crosscutting Concepts (CCCs): Energy and Matter

K-2	3-5	6-8	9-12
Energy and Matter in K–2 builds on prior experiences and progresses to... Students observe objects may break into smaller pieces, be put together into larger pieces, or change shapes	**Energy and Matter in 3–5 builds on K–2 experiences and progresses to...** Students learn that matter is made of particles and energy can be transferred in various ways and between objects. Students observe the conservation of matter by tracking matter flows and cycles before and after processes and recognizing the total weight of substances does not change.	**Energy and Matter in 6– 8 builds on K–5 experiences and progresses to...** Students learn matter is conserved because atoms are conserved in physical and chemical processes. They also learn 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.	**Energy and Matter in 9-12 builds on K–8 experiences and progresses to college or career experiences.** Students learn that the total amount of energy and matter in closed systems is conserved. They can describe changes of energy and matter in a system in terms of energy and matter flows into, out of, and within that system. They also learn that energy cannot be created or destroyed. It only moves between one place and another place, between objects and/or fields, or between systems. Energy drives the cycling of matter within and between systems. In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

Disciplinary Core Ideas (DCIs): PS3.A: Definitions of Energy, PS3.B: Conservation of Energy and Energy Transfer, PS3.D: Energy in Chemical Processes, ETS1.A: Defining and Delimiting Engineering Problems

K-2	3-5	6-8	9-12
PS3.A in K–2 builds on prior experiences and progresses to... **N/A**	**PS3.A and PS3.B in 3–5 builds on K–2 experiences and progresses to...** 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,	**PS3.A and PS3.B in 6– 8 builds on K–5 experiences and knowledge and progresses to...** 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	**PS3.A and PS3.B in 9–12 builds on K–8 experiences and knowledge and progresses to...** The total energy within a system is conserved. Energy transfer within and between systems can be described and predicted in terms of

PS3.B and PS3.D in K–2 builds on prior experiences and progresses to... Sunlight warms Earth's surface.	or electrical currents. Energy can be converted from one form to another form. **PS3.D in 3–5 builds on K–2 experiences and progresses to...** Energy can be "produced," "used," or "released" by converting stored energy. Plants capture energy from sunlight, which can later be used as fuel or food,	and the total energy of a system depends on the types, states, and amounts of matter **PS3.D in 6– 8 builds on K–5 experiences and knowledge and progresses to...** Sunlight is captured by plants and used in a reaction to produce sugar molecules, which can be reversed by burning those molecules to release energy.	energy associated with the motion or configuration of particles (objects). **PS3.D in 9–12 builds on K–8 experiences and knowledge and progresses to...** Photosynthesis is the primary biological means of capturing radiation from the sun; energy cannot be destroyed, it can be converted to less useful forms.

Connection to other grade level indicators

ELA Connections:

- **WHST.9-12.7:** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

Mathematics Connections:

- **MP.2: Reason** abstractly and quantitatively.
- **MP.4: Model** with mathematics.
- **HSN.Q.A.1: Use** units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.
- **HSN.Q.A.2: Define** appropriate quantities for the purpose of descriptive modeling.
- **HSN.Q.A.3: Choose** a level of accuracy appropriate to limitations on measurement when reporting quantities.

Social Studies Connections:

- SS HS.2.1 – Apply economic concepts that support rational decision making.
- SS HS.4.4 – Evaluate sources for perspective, limitations, accuracy, and historical context.

Fine and Performing Arts Connections:

- FA 12.2.4 – Students will synthesize understanding of contemporary, historical, and cultural context in art and life.
- FA 12.1.1 – Students will analyze and integrate personal and global connections through media arts.
- FA 12.5.2 – Students will perform ideas and events through movement, speech, and staging for an intended audience.

Related Cross-Curricular Standards: Current Grade Level

Authentic Connections to Other Content Standards:

- High School Domains Model Course 2: Physics – Bundle 3. What Happens When Energy Moves from One Place to Another?
  - SC.HS.1.1.b, SC.HS.1.1.c, SC.HS.4.4.b, SC.HS.4.4.e, SC.HS.13.3.b
- High School Domains Model Course 1: Bundle 5. Changes in Energy

Academic Language Development

Words to support student discourse related to the Disciplinary Core Ideas (DCIs):

- Mechanical energy, chemical energy, electric energy, thermal energy, power, Watts, efficiency, heat, work

Assessment Considerations

Formative Assessment:

- https://www.education.ne.gov/assessment/science-classroom-formative-task-repository-for-grades-5-8/
- Utah SEEd Assessment
- Wonder of Science Assessment: Renewable Energy Prototype
- Wonder of Science Assessment: Efficiency of a System

Stackable, Instructionally-Embedded, Portable Science (SIPS) Assessments:

- https://sipsassessments.org/

Knowledge, Skills, and Abilities:

- **KSA1:** Describe and quantify (where appropriate) criteria and constraints for the design of a device that converts one form of energy into another form of energy.
- **KSA2:** Design a device that converts one form of energy into another form of energy.
- **KSA2**: Justify design choices using scientific principles of energy conversion.
- **KSA3**: Identify all forms of energy present in the device.
- **KSA4**: Identify points in the device where energy is transferred out of the system to the surrounding environment.
- **KSA5:** Use scientific principles to justify choices about materials and structure of the device including how student-generated evidence influenced design choices.
- **KSA6:** Use planning experience as evidence to support the claim that scientific knowledge and engineering design can increase benefits and decrease costs and risk.
- **KSA8**: Describe tradeoffs that were made during the design process.
- **KSA9**: Build and test the device according to the design plan.
- **KSA10:** Evaluate the performance of the device based on criteria and constraints.
- **KSA11**: Use the results of the testing and evaluation to refine and improve device performance by increasing the efficiency of energy conversion.

Standard

Topic Code: SC.HSP.4 Energy: Physics

Standard Code: SC.HSP.4.3 Gather, analyze, and communicate evidence of the interactions of energy.

Energy describes the motion and interactions of matter and radiation within a system. Energy is a quantifiable property that is conserved in isolated systems and in the universe as a whole. At the macroscopic scale, energy manifests itself in multiple ways such as in motion, sound, light, and thermal energy. Uncontrolled systems always evolve toward more stable states— that is, toward more uniform energy distribution. Examining the world through an energy lens allows us to model and predict complex interactions of multiple objects within a system and address societal needs.

Indicator

Indicator Code: SC.HSP.4.3.d

Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants. Examples could include analysis of renewable energy systems for electricity generation and the effect of autonomous electric cars on the economy, society and the environment.

NGSS Comparison: Builds on HS-PS3-3 and HS-ETS1-2

Other Indicators in this Standard

SC.HSP.4.3.a, SC.HSP.4.3.b, SC.HSP.4.3.c, SC.HSP.4.3.e, SC.HSP.4.3.f

Concepts and Skills to Master

Foundation Boxes:

Science and Engineering Practice (SEP)	Crosscutting Concept (CCC)
Asking Questions and Defining Problems: Asking questions and defining problems in 9-12 builds on K-8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. • Analyze complex real-world problems by specifying criteria and constraints for successful solutions	**Systems and System Models:** • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. ***Connections to Engineering, Technology, and Applications of Science*** **Influence of Science, Engineering, and Technology on Society and the Natural World:** • Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.

Disciplinary Core Idea (DCI)

PS3.A: **Definitions of Energy:**

- 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 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.

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

- Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down).

PS3.D: **Energy in Chemical Processes:**

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

ETS1.A: **Defining and Delimiting Engineering Problems:**

- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. *(secondary to SC.HSP.4.3.D)*
- Humanity faces major global challenges today, such as the need for supplies of clean water and food, or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.

Possible Science and/or Engineering Phenomena to Support 3D Instruction

- Renewable Energy from Wind Turbines
- Solar Panel Design & Placement
- Hydroelectric Power Systems
- Electric Vehicle Efficiency and Charging Infrastructure
- Insulation and Building Energy Efficiency
- Nuclear Power as a Clean Energy Option
- Designing Earthquake-Resistant Structures
- Reducing Urban Light Pollution
- Water Purification with UV or Solar Technologies

- High Speed Magnetic Levitation Trains

Evidence Statements

What does it look like to demonstrate proficiency on this indicator?

SC.HSP.4.3.d **Analyze a major global challenge** to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.	
Identifying the problem to be solved	
a	Students analyze a major global problem. In their analysis, students:
	i. Describe the challenge with a rationale for why it is a major global challenge;
	ii. Describe, qualitatively and quantitatively, the extent and depth of the problem and its major consequences to society and/or the natural world on both global and local scales if it remains unsolved; and
	iii. Document background research on the problem from two or more sources, including research journals.
Defining the process or system boundaries, and the components of the process or system	
a	In their analysis, students identify the physical system in which the problem is embedded, including the major elements and relationships in the system and boundaries so as to clarify what is and is not part of the problem.
b	In their analysis, students describe societal needs and wants that are relative to the problem (e.g., for controlling CO_2 emissions, societal needs include the need for cheap energy).
Defining the criteria and constraints	
a	Students specify qualitative and quantitative criteria and constraints for acceptable solutions to the problem.

Critical Background Knowledge

Grade Band Progressions:

Science and Engineering Practices (SEPs): Asking Questions and Defining Problems

K-2	3-5	6-8	9-12
Asking Questions and Defining Problems in K–2 builds on prior experiences and progresses to... Define a simple problem that can be solved through the development of a new or improved object or tool.	**Asking Questions and Defining Problems in 3–5 builds on K–2 experiences and progresses to...** Use prior knowledge to describe problems that can be solved. Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost.	**Asking Questions and Defining Problems in 6– 8 builds on K–5 experiences and progresses to...** Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.	**Asking Questions and Defining Problems in 9-12 builds on K–8 experiences and progresses to college or career experiences.** Analyze complex real-world problems by specifying criteria and constraints for successful solutions.

Crosscutting Concepts (CCCs): Systems and System Models:

K-2	3-5	6-8	9-12
Systems and System Models in K–2 builds on prior experiences and progresses to... Objects and organisms can be described in terms of their parts. Systems in the natural and designed world have parts that work together.	**Systems and System Models in 3–5 builds on K–2 experiences and progresses to...** 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.	**Systems and System Models in 6– 8 builds on K–5 experiences and progresses to...** 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.	**Systems and System Models in 9-12 builds on K–8 experiences and progresses to college or career experiences.** Systems can be designed to do specific tasks. 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. Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. 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.

Disciplinary Core Ideas (DCIs): PS3.A: Definitions of Energy, PS3.B: Conservation of Energy and Energy Transfer, PS3.D: Energy in Chemical Processes, ETS1.A: Defining and Delimiting Engineering Problems

K-2	3-5	6-8	9-12
PS3.A in K–2 builds on prior experiences and progresses to...N/A **PS3.B and PS3.D in K–2 builds on prior experiences and progresses to...** Sunlight warms Earth's surface.	**PS3.A and PS3.B in 3–5 builds on K–2 experiences and progresses to...** 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. **PS3.D in 3–5 builds on K–2 experiences and progresses to...** Energy can be "produced," "used," or "released" by converting stored energy. Plants capture energy from sunlight, which can later be used as fuel or food,	**PS3.A and PS3.B in 6– 8 builds on K–5 experiences and knowledge and progresses to...** 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 **PS3.D in 6– 8 builds on K–5 experiences and knowledge and progresses to...** Sunlight is captured by plants and used in a reaction to produce sugar molecules, which can be reversed by burning those molecules to release energy.	**PS3.A and PS3.B in 9–12 builds on K–8 experiences and knowledge and progresses to...** The total energy within a system is conserved. Energy transfer within and between systems can be described and predicted in terms of energy associated with the motion or configuration of particles (objects). **PS3.D in 9–12 builds on K–8 experiences and knowledge and progresses to...** Photosynthesis is the primary biological means of capturing radiation from the

			sun; energy cannot be destroyed, it can be converted to less useful forms.

Connection to other grade level indicators

ELA Connections:

- **WHST.9-12.7:** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

Mathematics Connections:

- **MP.2: Reason** abstractly and quantitatively.
- **MP.4: Model** with mathematics.
- **HSN.Q.A.1: Use** units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.
- **HSN.Q.A.2: Define** appropriate quantities for the purpose of descriptive modeling.
- **HSN.Q.A.3: Choose** a level of accuracy appropriate to limitations on measurement when reporting quantities.

Social Studies Connections:

- SS HS.2.1 – Apply economic concepts that support rational decision making.
- SS HS.4.4 – Evaluate sources for perspective, limitations, accuracy, and historical context.

Fine and Performing Arts Connections:

- FA 12.2.4 – Students will synthesize understanding of contemporary, historical, and cultural context in art and life.
- FA 12.1.1 – Students will analyze and integrate personal and global connections through media arts.
- FA 12.5.2 – Students will perform ideas and events through movement, speech, and staging for an intended audience.

Related Cross-Curricular Standards: Current Grade Level

Authentic Connections to Other Content Standards:

- N/A

Academic Language Development

Words to support student discourse related to the Disciplinary Core Ideas (DCIs):

- Mechanical energy, chemical energy, electric energy, thermal energy, efficiency, power, Watts, kiloWatt-hours, radiation, greenhouse effect, climate change, renewable, non-renewable, storage, gravitational potential energy, batteries

Assessment Considerations

Formative Assessment:

- https://www.education.ne.gov/assessment/science-classroom-formative-task-repository-for-grades-5-8/
- Utah SEEd Assessment

Stackable, Instructionally-Embedded, Portable Science (SIPS) Assessments:

- https://sipsassessments.org/

Knowledge, Skills, and Abilities:

- **KSA1:** Research and describe a major global problem related to energy and explain why it is problematic, documenting two or more sources, including research journals.

- **KSA2:** Describe qualitatively and quantitatively the extent and depth of the problem.
- **KSA3**: Identify the major consequences of not solving this major global problem for society on both global and local scales.
- **KSA4:** Identify the major consequences of not solving this major global problem for the natural world on both global and local scales.
- **KSA5**: Analyze the physical system in which the problem is embedded to identify the major components and system boundaries.
- **KSA6**: Analyze the physical system in which the problem is embedded to identify relationships between the major components.
- **KSA7**: Describe the societal needs and wants that are relative to the problem.
- **KSA8**: Specify qualitative and quantitative criterial and constraints

Standard

Topic Code: SC.HSP.4 Energy: Physics

Standard Code: SC.HSP.4.3 Gather, analyze, and communicate evidence of the interactions of energy.

Energy describes the motion and interactions of matter and radiation within a system. Energy is a quantifiable property that is conserved in isolated systems and in the universe as a whole. At the macroscopic scale, energy manifests itself in multiple ways such as in motion, sound, light, and thermal energy. Uncontrolled systems always evolve toward more stable states— that is, toward more uniform energy distribution. Examining the world through an energy lens allows us to model and predict complex interactions of multiple objects within a system and address societal needs.

Indicator

Indicator Code: SC.HSP.4.3.e

Plan and conduct an investigation to provide evidence for the transfer of thermal energy within a system based on the Laws of Thermodynamics. Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually, such as changes in entropy of a system. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water, changes from kinetic to thermal energy, and heat engines and heat pumps. Assessment is limited to investigations based on materials and tools provided to students.

NGSS Comparison: Builds on HS-PS3-4

Other Indicators in this Standard

SC.HSP.4.3.a, SC.HSP.4.3.b, SC.HSP.4.3.c, SC.HSP.4.3.d, SC.HSP.4.3.f

Concepts and Skills to Master

Foundation Boxes:

Science and Engineering Practice (SEP)	Crosscutting Concept (CCC)
Planning and Carrying Out Investigations: Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. • Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.	**Systems and System Models:** • 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.

Disciplinary Core Idea (DCI)
PS3.A: Definitions of Energy: • At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.
Possible Science and/or Engineering Phenomena to Support 3D Instruction
• Drinking bird - HS-PS3-4, HS-PS3-3 • Brinicles - HS-PS3-4, HS-PS3-2 • Earthships - HS-PS3-3, HS-PS3-4 • Candle-Powered Car - HS-PS3-1, HS-PS3-3, HS-PS3-4, HS-PS3-5 • Ice-cutting Experiment - HS-PS3-2, HS-PS3-4 • Heat Packs or Cold Packs • Refrigeration • Lava Lams • Ring and Brass Ball • Geothermal Energy • Solar Panels • Stirling Engine • Dry Ice • “Magic” Soda Can • Metal v. Plastic – Which feels colder?

Evidence Statements

What does it look like to demonstrate proficiency on this indicator?

SC.HSP.4.3.e **Plan and conduct an investigation** to provide evidence for the transfer of thermal energy <u>within a system</u> based on the Laws of Thermodynamics.	
Identifying the phenomenon to be investigated	
a	Students describe* the phenomenon under investigation
Identifying the evidence to answer this question	
a	Students develop an investigation plan and describe* the data that will be collected and the evidence to be derived from the data.
b	Students describe* why the data would provide information that serves as the basis for evidence.
Planning for the investigation	
a	In the investigation plan, students include:
	i. A rationale for the choice of variables.
	ii. A description* of how the data will be collected, the number of trials, and the experimental setup and equipment required.
Collecting the data	
a	Students collect and record data – quantitative and/or qualitative.
Refining the design	
a	Students evaluate their investigation, including evaluation of:
	i. Assessing the accuracy and precision of the data collected, as well as the limitations of the investigation; and
	ii. The ability of the data to provide the evidence required.

b	If necessary, students refine the plan to produce more accurate, precise, and useful data.

Critical Background Knowledge

Grade Band Progressions:

Science and Engineering Practices (SEPs): Planning and Carrying Out Investigations

K-2	3-5	6-8	9-12
Planning and Carrying Out Investigations in K–2 builds on prior experiences and progresses to... With guidance, plan and conduct an investigation in collaboration with peers (for K).	**Planning and Carrying Out Investigations in 3–5 builds on K–2 experiences and progresses to...** 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.	**Planning and Carrying Out Investigations in 6– 8 builds on K–5 experiences and progresses to...** 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.	**Planning and Carrying Out Investigations in 9-12 builds on K–8 experiences and progresses to college or career experiences.** Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.

Crosscutting Concepts (CCCs): Systems and System Models

K-2	3-5	6-8	9-12
Systems and System Models in K–2 builds on prior experiences and progresses to... Students understand objects and organisms can be described in terms of their parts; and systems in the natural and designed world have parts that work together	**Systems and System Model in 3–5 builds on K–2 experiences and progresses to...** Students understand that a system is a group of related parts that make up a whole and can carry out functions its individual parts cannot. They can also describe a system in terms of its components and their interactions	**Systems and System Model in 6– 8 builds on K–5 experiences and progresses to...** Students can understand that systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. They can use models to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. They can also learn that models are limited in that they only represent certain aspects of the system under study.	**Systems and System Model in 9-12 builds on K–8 experiences and progresses to college or career experiences.** Students can investigate or analyze a system by defining its boundaries and initial conditions, as well as its inputs and outputs. They can use models (e.g., physical, mathematical, computer models) to simulate the flow of energy, matter, and interactions within and between systems at different scales. They can also use models and simulations to predict the behavior of a system and recognize that these predictions have limited precision and reliability due to the assumptions and approximations inherent in the models. They can also design systems to do specific tasks.

Disciplinary Core Ideas (DCIs): PS3.A: Definitions of Energy

K-2	3-5	6-8	9-12
PS3.A: Definitions of Energy in K–2 builds on prior experiences and progresses to... N/A	**PS3.A: Definitions of Energy in 3–5 builds on K–2 experiences and progresses to...** 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.	**PS3.A: Definitions of Energy in 6– 8 builds on K–5 experiences and knowledge and progresses to...** 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.	**PS3.A: Definitions of Energy in 9–12 builds on K–8 experiences and knowledge and progresses to...** The total energy within a system is conserved. Energy transfer within and between systems can be described and predicted in terms of energy associated with the motion or configuration of particles (objects).

Connection to other grade level indicators

ELA Connections:

- **RST.11-12.1: Cite** specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- **WHST.9-12.7:** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
- **WHST.11-12.8:** Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.
- **WHST.9-12.9: Draw** evidence from informational texts to support analysis, reflection, and research.

Mathematics Connections:

- **MP.2: Reason** abstractly and quantitatively.
- **MP.4: Model** with mathematics.

Social Studies Connections:

Fine and Performing Arts Connections:

Related Cross-Curricular Standards: Current Grade Level

Authentic Connections to Other Content Standards:

- High School Domains Model Course 1: Chemistry - Bundle 3
- High School Domains Model Course 2: Physics – Bundle 3
- High School Conceptual Progressions Model Course 1 – Bundle 3

Academic Language Development

Words to support student discourse related to the Disciplinary Core Ideas (DCIs):

- Specific heat, specific heat capacity, store, transfer, kinetic energy, temperature, conservation of energy, microscopic scale, macroscopic scale, thermal energy, heat conduction, heat radiation, heat convection, Law of Conservation of Energy, First Law of Thermodynamics, Second Law of Thermodynamics, Joules, Kelvin

Assessment Considerations

Formative Assessment:

- https://www.education.ne.gov/assessment/science-classroom-formative-task-repository-for-grades-5-8/
- Utah SEEd Assessment
- Wonder of Science: Cup of Coffee
- Wonder of Science: Biodegradable Styrofoam
- Wonder of Science: Squirrel Roadkill

Stackable, Instructionally-Embedded, Portable Science (SIPS) Assessments:

- https://sipsassessments.org/

Knowledge, Skills, and Abilities:

- **KSA1:** Describe a system where components transfer thermal energy based on the Laws of Thermodynamics.
- **KSA2:** Identify data that could be collected from this system to provide evidence of the transfer of thermal energy.
- **KSA3**: Explain why the data collected would provide evidence of the transfer of thermal energy.
- **KSA4**: Describe how the data will be collected, the number of trials, the equipment required, and the experimental setup.
- **KSA5:** Collect and record quantitative and/or qualitative data.
- **KSA6:** Assess the accuracy and precision of the data collected.
- **KSA7:** Identify limitations of the investigation.
- **KSA8:** Evaluate whether the data collected provided the evidence required to support the transfer of thermal energy between objects according to the Laws of Thermodynamics.
- **KSA9:** Refine the investigation plan and explain how the revisions will produce more accurate, precise and useful data.

Standard

Topic Code: SC.HSP.4 Energy: Physics

Standard Code: SC.HSP.4.3 Gather, analyze, and communicate evidence of the interactions of energy.

Energy describes the motion and interactions of matter and radiation within a system. Energy is a quantifiable property that is conserved in isolated systems and in the universe as a whole. At the macroscopic scale, energy manifests itself in multiple ways such as in motion, sound, light, and thermal energy. Uncontrolled systems always evolve toward more stable states— that is, toward more uniform energy distribution. Examining the world through an energy lens allows us to model and predict complex interactions of multiple objects within a system and address societal needs.

Indicator

Indicator Code: SC.HSP.4.3.f

Develop and use a model of two objects interacting through gravitational, electric, or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction. 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 is limited to systems containing two objects.

NGSS Comparison: Builds on HS-PS3-5

Other Indicators in this Standard

SC.HSP.4.3.a, SC.HSP.4.3.b, SC.HSP.4.3.c, SC.HSP.4.3.d, SC.HSP.4.3.e

Concepts and Skills to Master

Foundation Boxes:

Science and Engineering Practice (SEP)	Crosscutting Concept (CCC)
Developing and Using Models: Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. • Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.	**Cause and Effect:** • Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.

Disciplinary Core Idea (DCI)

PS3.A: **Definitions of 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.

PS3.C: **Relationship Between Energy and Forces**

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

Possible Science and/or Engineering Phenomena to Support 3D Instruction

- Magnetic Slime
- Magnetic cannon
- Programmable Magnets
- Solar Cars
- Candle-Powered Car
- The Gravity Light
- Planetary Orbits
- Firing a Cannon from a Ship
- Trebuchet
- Sticky Tape Electrostatics
- Van de Graff Generator
- Electric Wire & Compass
- Batteries
- Solenoids
- Magnetic Door Locks
- MagLev Trains

Evidence Statements

What does it look like to demonstrate proficiency on this indicator?

SC.HSP.4.3.f **Develop and use a model** of two objects interacting through gravitational, electric, or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.	
Components of the model	
a	Students develop a model in which they identify and describe* the relevant components to illustrate the forces and changes in energy involved when two objects interact, including:
	i. The two objects in the system, including their initial positions and velocities.
	ii. The nature of the interaction (gravitational, electric, or magnetic) between the two objects.
	iii. The relative magnitude and direction of the net force on each of the objects.
	iv. Representation of a field as a quantity that has a magnitude and direction at all points in space and which contains energy.
Relationships	
a	In the model, students describe* the relationships between components, including the change in the energy of the objects, given the initial and final positions and velocities of the objects.
Connections	
a	Students use the model to determine whether the energy stored in the field increased, decreased, or remained the same when the objects interacted.
b	Students use the model to support the claim that the change in the energy stored in the field (which is qualitatively determined to be either positive, negative, or zero) is consistent with the change in energy of the objects.
c	Using the model, students describe* the cause-and-effect relationships on a quantitative level between forces produced by gravitational, electric or magnetic fields, and the change in energy of the objects in the system.

Critical Background Knowledge

Grade Band Progressions:

Science and Engineering Practices (SEPs): Developing and Using Models

K-2	3-5	6-8	9-12
Developing and Using Models in K–2 builds on prior experiences and progresses to... Develop and/or use a model to represent amounts, relationships, relative scales (bigger, smaller), and/or patterns in the natural and designed world(s).	**Developing and Using Models in 3–5 builds on K–2 experiences and progresses to...** Develop and/or use models to describe and/or predict phenomena.	**Developing and Using Models in 6– 8 builds on K–5 experiences and progresses to...** Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena.	**Developing and Using Models in 9-12 builds on K–8 experiences and progresses to college or career experiences.** Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.

Crosscutting Concepts (CCCs): Cause and Effect

K-2	3-5	6-8	9-12
Cause and Effect in K–2 builds on prior experiences and progresses to... Students learn that events have causes that generate observable patterns. They design simple tests to gather evidence to support or refute their own ideas about causes.	**Cause and Effect in 3–5 builds on K–2 experiences and progresses to...** Students routinely identify and test causal relationships and use these relationships to explain change. They understand events that occur together with regularity might or might not signify a cause-and-effect relationship.	**Cause and Effect in 6– 8 builds on K–5 experiences and progresses to...** Students classify relationships as causal or correlational and recognize that correlation does not necessarily imply causation. They use cause and effect relationships to predict phenomena in natural or designed systems. They also understand that phenomena may have more than one cause, and some cause-and-effect relationships in systems can only be described using probability.	**Cause and Effect in 9-12 builds on K–8 experiences and progresses to college or career experiences.** Students understand that empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects. They suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. They also propose causal relationships by examining what is known about smaller scale mechanisms within the system. They recognize changes in systems may have various causes that may not have equal effects.

Disciplinary Core Ideas (DCIs): PS3.A: Definitions of Energy, PS3.C: Relationship Between Energy and Forces

K-2	3-5	6-8	9-12
PS3.A: Definitions of Energy in K–2 builds on prior experiences and progresses to... N/A	**PS3.A: Definitions of Energy in 3–5 builds on K–2 experiences and progresses to...** 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.	**PS3.A: Definitions of Energy in 6– 8 builds on K–5 experiences and knowledge and progresses to...** 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.	**PS3.A: Definitions of Energy in 9–12 builds on K–8 experiences and knowledge and progresses to...** The total energy within a system is conserved. Energy transfer within and between systems can be described and predicted in terms of energy associated with the motion or configuration of particles (objects).

Connection to other grade level indicators

ELA Connections:

- **WHST.9-12.7:** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
- **WHST.11-12.8:** Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.
- **WHST.9-12.9: Draw** evidence from informational texts to support analysis, reflection, and research.
- **SL.11-12.5: Make** strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.

Mathematics Connections:

- **MP.2: Reason** abstractly and quantitatively.
- **MP.4: Model** with mathematics.

Social Studies Connections:

Fine and Performing Arts Connections:

Related Cross-Curricular Standards: Current Grade Level

Authentic Connections to Other Content Standards:

- High School Modified Domains Model Course 2: Physics – Bundle 1

Academic Language Development

Words to support student discourse related to the Disciplinary Core Ideas (DCIs):

- Force, exert, store, transfer, electrical charge, mechanical energy, potential energy, kinetic energy, electric field, conservation of energy, microscopic scale, macroscopic scale, circuit, current, heat radiation, Law of Conservation of Energy

Assessment Considerations

Formative Assessment:

- https://www.education.ne.gov/assessment/science-classroom-formative-task-repository-for-grades-5-8/
- Utah SEEd Assessment
- Wonder of Science: Space Station Transport System
- Wonder of Science: Energy in Electric Fields
- Wonder of Science: MagLev

Stackable, Instructionally-Embedded, Portable Science (SIPS) Assessments:

- https://sipsassessments.org/

Knowledge, Skills, and Abilities:

- **KSA1:** Develop a model of two objects interacting through field forces, including their initial positions and velocities.
- **KSA2:** Identify the nature of the interaction (gravitational, electric, or magnetic).
- **KSA3**: Identify the relative magnitude and direction of the net force on each of the objects.
- **KSA4**: Modify the model to include a representation of the field as a quantity that has a magnitude and direction at all points in space and which contains energy.
- **KSA5:** Use a model to describe relationships between two objects interacting through field forces, including the changes in energy given the initial and final positions and velocities of the objects.
- **KSA6**: Use a model to determine whether the energy stored in the field increased, decreased, or remained the same when the objects interacted.
- **KSA7**: Use a model to qualitatively determine whether the change in energy stored in a field of two interacting objects is positive, negative or zero.
- **KSA8:** Use a model to support a claim about whether the change in energy stored in a field of two interacting objects is consistent with the change in energy of the objects.
- **KSA9**: Calculate the changes in energy of two interacting objects in a gravitational, electric, or magnetic field, given the initial and final positions and velocities of the objects.
- **KSA10**: Use a model to describe the cause-and-effect relationships between the forces produced by gravitational, electric or magnetic fields and the change in energy of the objects in the system.

Standard

Topic Code: SC.HSP.16 Electricity and Magnetism
Standard Code: SC.HSP.16.4 Gather, analyze, and communicate evidence of electricity and magnetism.

Fields describe how forces act through space and how potential energy is stored in systems. These take on different forms of electric, magnetic, or gravitational fields, but similarly provide a mechanism for how matter interacts. When two objects interacting through a field change relative position, the energy stored in the field is changed. These fields are important at a wide variety of scales, ranging from the subatomic to the astronomic.

Indicator

Indicator Code: SC.HSP.16.4.a
Use mathematical representations of field forces to describe and predict forces at a distance between objects. Emphasis is on both quantitative and conceptual descriptions of forces from gravitational and electric sources. Assessment can be expanded to systems with multiple objects.

NGSS Comparison: Builds on HS-PS2-4

Other Indicators in this Standard

SC.HSP.16.4.b, SC.HSP.16.4.c, SC.HSP.16.4.d, SC.HSP.16.4.e, SC.HSP.16.4.f, SC.HSP.16.4.g

Concepts and Skills to Master

Foundation Boxes:

Science and Engineering Practice (SEP)

Using Mathematics and Computational Thinking:
Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Use mathematical representations of phenomena to describe explanations.

Connections to the nature of science
Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena:

- Theories and laws provide explanations in science.
- Laws are statements or descriptions of the relationships among observable phenomena.

Crosscutting Concept (CCC)

Patterns:

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Disciplinary Core Idea (DCI)

PS2.A: Forces and Motion:

- Newton's second law accurately predicts changes in the motion of macroscopic objects. (SC.HSP.16.4.A)

PS2.B: Types of Interactions:

- Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects.

Possible Science and/or Engineering Phenomena to Support 3D Instruction

- Magnetic Canon
- Candle-Powered Car
- Felix Baumgartner Space Jump World Record

- Cavendish Experiment
- The Gravity Light
- Protecting the Earth from Killer Asteroids
- Programmable Droplets from MIT

Evidence Statements

What does it look like to demonstrate proficiency on this indicator?

SC.HSP.16.4.a **Use mathematical representations** of field forces to describe and predict forces at a distance between objects.		
1	Representation	
	a	Students identify and describe* the components in the given mathematical and/or computational representations (e.g., trends, averages, histograms, graphs, spreadsheets) that are relevant to supporting given explanations
	b	Students identify the given claim(s) and/or explanation(s) to be supported,
2	Mathematical and/or computational modeling	
	a	Students use given mathematical and/or computational representations (e.g., trends, averages, histograms, graphs, spreadsheets) to identify changes over time and on different scales.
	b	Students use the mathematical or computational representations to model, describe*, and predict
3	Analysis	
	a	Students analyze and use the given mathematical and/or computational representations
		i. To identify the interdependence of variables; and
		ii. As evidence to support the claim(s) and/or explanation(s); and
		iii. Students use mathematical relationships to distinguish between cause and correlation with respect to the supported claims.

Critical Background Knowledge

Grade Band Progressions:

Science and Engineering Practices (SEPs): Using Mathematics and Computational Thinking

K-2	3-5	6-8	9-12
Using Mathematics and Computational Thinking in K–2 builds on prior experiences and progresses to... Use counting and numbers to identify and describe patterns in the natural and designed world(s).	**Using Mathematics and Computational Thinking in 3–5 builds on K–2 experiences and progresses to...** Organize simple data sets to reveal patterns that suggest relationships.	**Using Mathematics and Computational Thinking in 6– 8 builds on K–5 experiences and progresses to...** Use mathematical representations to describe and/or support scientific conclusions and design solutions.	**Using Mathematics and Computational Thinking in 9-12 builds on K–8 experiences and progresses to college or career experiences.** Use mathematical representations of phenomena to describe explanations.

Crosscutting Concepts (CCCs): Patterns

K-2	3-5	6-8	9-12
Patterns in K–2 builds on prior experiences and progresses to... Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence.	**Patterns in 3–5 builds on K–2 experiences and progresses to...** Similarities and differences can be used in order to sort and classify natural objects and designed products. Patterns related to time, including simple rates of change and cycles, and can be used to make predictions.	**Patterns in 6– 8 builds on K–5 experiences and progresses to...** 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, and graphs and charts can be used to identify patterns in data.	**Patterns in 9-12 builds on K–8 experiences and progresses to college or career experiences.** 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.

Disciplinary Core Ideas (DCIs): PS2.A: Forces and Motion, PS2.B: Types of Interactions

K-2	3-5	6-8	9-12
PS2.A and PS2.B in K–2 build on prior experiences and progress to... Pushes and pulls can have different strengths and directions and can change the speed or direction of its motion or start or stop it.	**PS2.A and PS2.B in 3–5 build on K–2 experiences and progress to...** The effect of unbalanced forces on an object result in a change of motion. Patterns of motion can be used to predict future motion. Some forces act through contact; some forces act even when the objects are not in contact. The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center.	**PS2.A in 6– 8 builds on K–5 experiences and knowledge and progresses to...** The role of the mass of an object must be qualitatively accounted for in any change of motion due to the application of a force. **PS2.B in 6– 8 builds on K–5 experiences and knowledge and progresses to...** Forces that act at a distance involve fields that can be mapped by their relative strength and effect on an object.	**PS2.A in 9–12 builds on K–8 experiences and knowledge and progresses to...** Newton's second law accurately predicts changes in the motion of macroscopic objects. **PS2.B in 9–12 builds on K–8 experiences and knowledge and progresses to...** Newton's law of universal gravitation and Coulomb's law provide mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects.

Connection to other grade level indicators

ELA Connections:

Mathematics Connections:

- **MP.2: Reason** abstractly and quantitatively.
- **MP.4: Model** with mathematics.
- **HSN.Q.A.1: Use** units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.
- **HSN.Q.A.2: Define** appropriate quantities for the purpose of descriptive modeling.
- **HSN.Q.A.3: Choose** a level of accuracy appropriate to limitations on measurement when reporting quantities.

- **HSA.SSE.A.1: Interpret** expressions that represent a quantity in terms of its context.
- **HSA.SSE.B.3: Choose** and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression.

Social Studies Connections:

Fine and Performing Arts Connections:

Related Cross-Curricular Standards: Current Grade Level

Authentic Connections to Other Content Standards:

- High School Domains Model Course 2: Physics – Bundle 1
- High School Conceptual Progressions Course 1 – Bundle 1

Academic Language Development

Words to support student discourse related to the Disciplinary Core Ideas (DCIs):

- Potential energy, conservation, conversion, field, kinetic energy, Coulomb, gravitational force, Newton's Law of Gravitation, Coulomb's Law

Assessment Considerations

Formative Assessment:

- https://www.education.ne.gov/assessment/science-classroom-formative-task-repository-for-grades-5-8/
- Utah SEEd Assessment
- Wonder of Science: Torsion Balances
- Wonder of Science: Two Mass Movement

Stackable, Instructionally-Embedded, Portable Science (SIPS) Assessments:

- https://sipsassessments.org/

Knowledge, Skills, and Abilities:

- **KSA1:** Identify and describe the variables in a mathematical representation of field forces.
- **KSA2:** Use mathematical representations of field forces to predict how changes in the variables affect forces at a distance between objects.
- **KSA3**: Use mathematical representations to identify changes over time and on different scales in forces at a distance between objects.
- **KSA4:** Develop mathematical representations that model and describe field forces.
- **KSA5**: Analyze and use mathematical representations to identify the interdependence of variables for field forces.
- **KSA6**: Analyze and use mathematical representations as evidence to support claims about how changes in variables can change forces at a distance between objects.
- **KSA7**: Make claims distinguishing causation and correlation with respect to changes in forces at a distance between objects.
- **KSA8**: Use mathematical relationships to support claims about causation and correlation with respect to changes in forces at a distance between objects.

Standard

Topic Code: SC.HSP.16 Electricity and Magnetism

Standard Code: SC.HSP.16.4 Gather, analyze, and communicate evidence of electricity and magnetism.

Fields describe how forces act through space and how potential energy is stored in systems. These take on different forms of electric, magnetic, or gravitational fields, but similarly provide a mechanism for how matter interacts. When two objects interacting through a field change relative position, the energy stored in the field is changed. These fields are important at a wide variety of scales, ranging from the subatomic to the astronomic.

Indicator

Indicator Code: SC.HSP.16.4.b

Use models to visualize and describe gravitational, magnetic and electrical fields and predict resulting forces on nearby objects. Examples of fields include point charges, charged parallel plates/rings/spheres, and bar magnets. Also could include electromagnetic forces, such as the magnetic force acting on a moving charge. Assessment is limited to descriptive analysis of the fields and the forces they produce.

NGSS Comparison: Builds on HS-PS2-4, HS-PS2-5, HS-PS2-6 & HS-PS3-5

Other Indicators in this Standard

SC.HSP.16.4.a, SC.HSP.16.4.c, SC.HSP.16.4.d, SC.HSP.16.4.e, SC.HSP.16.4.f, SC.HSP.16.4.g

Concepts and Skills to Master

Foundation Boxes:

Science and Engineering Practice (SEP)	Crosscutting Concept (CCC)
Developing and Using Models: Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. • Use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.	**Systems and System Models:** • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined.

Disciplinary Core Idea (DCI)

PS2.B: Types of Interactions:

- 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.

Possible Science and/or Engineering Phenomena to Support 3D Instruction

- Magnetic Canon
- Candle-Powered Car
- Felix Baumgartner Space Jump World Record
- Cavendish Experiment
- The Gravity Light
- Protecting the Earth from Killer Asteroids
- Programmable Droplets from MIT
- Planetary Orbits
- Projectile Motion (cannon launch or free fall)
- Sticky Tape Electrostatics
- Van de Graaff Generator
- Electrostatic Charging by Induction (balloon/wall, pencil/wall, electroscope)
- Electric Field Mapping with Conductive Paper
- Bar Magnet & Iron Filings
- Solenoid & Compass
- Electric Wire & Compass

- Magnetic Levitation (floating pencil)
- Electric Field Hockey
- Grapes in a Microwave

Evidence Statements

What does it look like to demonstrate proficiency on this indicator?

SC.HSP.16.4.b **Use models** to visualize and describe gravitational, magnetic and electrical fields and predict resulting forces on nearby objects.		
1	Components of the model	
	a	Students develop models in which they identify and describe* the relevant components.
2	Relationships	
	a	Students describe* the relationships between components in their models.
3	Connections	
	a	Students use their models to illustrate functions of the components and the system.
	b	Students make a distinction between the accuracy of the model and actual system and functions it represents.
	c	Students use the model to predict changes.

Critical Background Knowledge

Grade Band Progressions:

Science and Engineering Practices (SEPs): Developing and Using Models

K-2	3-5	6-8	9-12
Developing and using models in K–2 builds on prior experiences and progresses to … Develop a simple model based on evidence to represent a proposed object or tool.	**Developing and using models in 3–5 builds on K–2 experiences and progresses to …** Use a model to test cause and effect relationships or interactions concerning the functioning of a natural or designed system.	**Developing and using models in 6– 8 builds on K–5 experiences and progresses to…** Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.	**Developing and using models in 9-12 builds on K–8 experiences and progresses to college or career experiences.** Use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.

Crosscutting Concepts (CCCs): Systems and System Models

K-2	3-5	6-8	9-12
Systems and system models in K–2 builds on prior experiences and progresses to …	**Systems and system models in 3–5 builds on K–2 experiences and progresses to …**	**Systems and system models in 6– 8 builds on K–5 experiences and progresses to…** Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. Models can	**Systems and system models in 9-12 builds on K–8 experiences and progresses to college or career experiences.**

Objects and organisms can be described in terms of their parts; and systems in the natural and designed world have parts that work together.	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.	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.	When investigating or describing a system, the boundaries and initial conditions of the system need to be defined.

Disciplinary Core Ideas (DCIs): PS2.B: Types of Interactions

K-2	3-5	6-8	9-12
PS2.B in K–2 builds on prior experiences and progresses to... Pushes and pulls can have different strengths and directions and can change the speed or direction of its motion or start or stop it.	**PS2.B in 3–5 builds on K–2 experiences and progresses to ...** The effect of unbalanced forces on an object results in a change of motion. Patterns of motion can be used to predict future motion. Some forces act through contact, some forces act even when the objects are not in contact. The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center.	**PS2.B in 6– 8 builds on K–5 experiences and knowledge and progresses to...** Forces that act at a distance involve fields that can be mapped by their relative strength and effect on an object.	**PS2.B in 9–12 builds on K–8 experiences and knowledge and progresses to...** 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.

Connection to other grade level indicators

ELA Connections:

- RST.11-12.2 – Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information.
- RST.11-12.3 – Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
- RST.11-12.7 – Integrate and evaluate multiple sources of information presented in diverse formats and media.
- RST.11-12.9 – Synthesize information from a range of sources into a coherent understanding of a process or phenomenon.
- WHST.11-12.1 – Write arguments focused on discipline-specific content.
- WHST.11-12.2 – Write informative texts to examine and convey complex ideas, concepts, and information clearly and accurately.
- WHST.11-12.7 – Conduct short as well as more sustained research projects to answer a question or solve a problem.

Mathematics Connections:

- HS.MP.4 – Model with mathematics.
- HS.F-IF.4 – Interpret key features of graphs and tables in terms of the quantities.
- HS.A-CED.2 – Create equations in two or more variables to represent relationships between quantities; graph equations.
- HS.G-MG.2 – Apply concepts of density based on area and volume in modeling situations.
- HS.G-GPE.5 – Derive the equation of a circle given a center and a point; relate geometric representations to physical models (e.g., equipotential lines or orbit paths).

Social Studies Connections:

Fine and Performing Arts Connections:

Related Cross-Curricular Standards: Current Grade Level

Authentic Connections to Other Content Standards:

- N/A

Academic Language Development

Words to support student discourse related to the Disciplinary Core Ideas (DCIs):

- Field, Field line, Vector, Direction, Magnitude, Force, Interaction, Attraction, Repulsion, Source object, Test object, Model, Representation, Prediction, Inverse-square law, Superposition (of fields), gravitational field (g), mass, weight, gravitational force, free fall, orbit, center of mass, acceleration due to gravity, electric field, charge, Coulomb's Law, voltage, equipotential lines, conductors, insulators, induction, polarization, magnetic field (B), pole, electromagnet, solenoid, current (I), right hand rule

Assessment Considerations

Formative Assessment:

- https://www.education.ne.gov/assessment/science-classroom-formative-task-repository-for-grades-5-8/
- Sample assessments for HS-PS2-4:
  - Utah SEEd Assessment
  - Wonder of Science: Torsion Balances
  - Wonder of Science: Two Mass Movement
- Sample assessments for HS-PS2-5:
  - Utah SEEd Assessment
  - Wonder of Science: Investigating the Faraday Flashlight
  - Wonder of Science: Cornelius Circuit
- Sample assessments for HS-PS2-6:
  - Wonder of Science: Prescription Drugs
  - Wonder of Science: How Chemistry Saves the World
- Sample assessments for HS-PS3-5:
  - Utah SEEd Assessment: Electromagnet
  - Utah SEEd Assessment: Electromagnetic Suction
  - Wonder of Science: Space Station Transport System
  - Wonder of Science: Energy in Electric Fields
  - Wonder of Science: MagLev

Stackable, Instructionally-Embedded, Portable Science (SIPS) Assessments:

- https://sipsassessments.org/

Knowledge, Skills, and Abilities:

- **KSA1:** Identify and describe the relevant components in models of gravitational, magnetic, and electrical fields.
- **KSA2:** Develop models of gravitational, magnetic, and electrical fields.
- **KSA3:** Describe relationships between components in a model of gravitational, magnetic, and electrical fields.
- **KSA4**: Use models to predict resulting forces on nearby objects in gravitational, magnetic, and electrical fields.
- **KSA5**: Explain limitations in the accuracy of the model compared to actual gravitational, magnetic, and electrical systems.
- **KSA6:** Use models to predict changes in resulting forces on nearby objects in gravitational, magnetic, and electrical fields.

Standard

Topic Code: SC.HSP.16 Electricity and Magnetism

Standard Code: SC.HSP.16.4 Gather, analyze, and communicate evidence of electricity and magnetism.

Fields describe how forces act through space and how potential energy is stored in systems. These take on different forms of electric, magnetic, or gravitational fields, but similarly provide a mechanism for how matter interacts. When two objects interacting through a field change relative position, the energy stored in the field is changed. These fields are important at a wide variety of scales, ranging from the subatomic to the astronomic.

Indicator

Indicator Code: SC.HSP.16.4.c

Use mathematical representations to provide evidence that describes and predicts relationships between power, current, voltage, and resistance. Emphasis is on insulators and conductors accounting for Ohm's Law, total resistance for combinations of resistors and P=IV.

NGSS Comparison: Builds on HS-PS2-4, HS-PS2-5, HS-PS2-6 & HS-PS3-5

Other Indicators in this Standard

SC.HSP.16.4.a, SC.HSP.16.4.b, SC.HSP.16.4.d, SC.HSP.16.4.e, SC.HSP.16.4.f, SC.HSP.16.4.g

Concepts and Skills to Master

Foundation Boxes:

Science and Engineering Practice (SEP)	Crosscutting Concept (CCC)
Using Mathematics and Computational Thinking: Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. ***Connections to the nature of science*** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena:** • Theories and laws provide explanations in science. • Laws are statements or descriptions of the relationships among observable phenomena.	**Patterns:** • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Disciplinary Core Idea (DCI)

PS1.A: Structure and Properties of Matter:

- Properties (e.g. conductivity) of matter can be described and predicted based on the types, interactions, and motions of the atoms within it.
- Electrical attractions and repulsions between charged particles (i.e., atomic nuclei and electrons) in matter explain the structure of atoms) The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. *(secondary to SC.HSP.16.4.C)*

Possible Science and/or Engineering Phenomena to Support 3D Instruction

- Magnetic Canon
- Candle-Powered Car
- Felix Baumgartner Space Jump World Record
- Cavendish Experiment
- The Gravity Light

- Protecting the Earth from Killer Asteroids
- Programmable Droplets from MIT
- Planetary Orbits
- Projectile Motion (cannon launch or free fall)
- Sticky Tape Electrostatics
- Van de Graaff Generator
- Electrostatic Charging by Induction (balloon/wall, pencil/wall, electroscope)
- Electric Field Mapping with Conductive Paper
- Bar Magnet & Iron Filings
- Solenoid & Compass
- Electric Wire & Compass
- Magnetic Levitation (floating pencil)
- Electric Field Hockey
- Grapes in a Microwave

Evidence Statements

What does it look like to demonstrate proficiency on this indicator?

SC.HSP.16.4.c **Use mathematical representations** to provide evidence that describes and predicts relationships between power, current, voltage, and resistance.		
1	Representation	
	a	Students identify and describe* the components in the given mathematical and/or computational representations (e.g., trends, averages, histograms, graphs, spreadsheets) that are relevant to supporting given explanations
	b	Students identify the given claim(s) and/or explanation(s) to be supported,
2	Mathematical and/or computational modeling	
	a	Students use given mathematical and/or computational representations (e.g., trends, averages, histograms, graphs, spreadsheets) to identify changes over time and on different scales.
	b	Students use the mathematical or computational representations to model, describe*, and predict
3	Analysis	
	a	Students analyze and use the given mathematical and/or computational representations
		i. To identify the interdependence of variables; and
		ii. As evidence to support the claim(s) and/or explanation(s); and
		iii. Students use the mathematical relationships to distinguish between cause and correlation with respect to the supported claims.

Critical Background Knowledge

Grade Band Progressions:

Science and Engineering Practices (SEPs): Using Mathematics and Computational Thinking

K-2	3-5	6-8	9-12

Mathematics and computational thinking in K–2 builds on prior experiences and progresses to... Use counting and numbers to identify and describe patterns in the natural and designed world(s).	**Mathematics and computational thinking in 3–5 builds on K–2 experiences and progresses to...** Organize simple data sets to reveal patterns that suggest relationships.	**Mathematics and computational thinking in 6– 8 builds on K–5 experiences and progresses to...** Use mathematical representations to describe and/or support scientific conclusions and design solutions.	**Mathematics and computational thinking in 9-12 builds on K–8 experiences and progresses to college or career experiences.** Use mathematical representations of phenomena to describe explanations.

Crosscutting Concepts (CCCs): Patterns

K-2	3-5	6-8	9-12
Patterns in K–2 builds on prior experiences and progresses to... Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence.	**Patterns in 3–5 builds on K–2 experiences and progresses to...** Similarities and differences can be used in order to sort and classify natural objects and designed products. Patterns can be related to time, including simple rates of change and cycles, and used to make predictions.	**Patterns in 6– 8 builds on K–5 experiences and progresses to...** 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, and graphs and charts can be used to identify patterns in data.	**Patterns in 9-12 builds on K–8 experiences and progresses to college or career experiences.** 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.

Disciplinary Core Ideas (DCIs): PS1.A: Structure and Properties of Matter

K-2	3-5	6-8	9-12
PS1.A in K–2 builds on prior experiences and progresses to... Matter exists as different substances that have observable different properties. Different properties are suited to different purposes. Objects can be built up from smaller parts.	**PS1.A in 3–5 builds on K–2 experiences and progresses to...** Matter exists as particles that are too small to see, and so matter is always conserved even if it seems to disappear. Measurements of a variety of observable properties can be used to identify particular materials.	**PS1.A in 6– 8 builds on K–5 experiences and knowledge and progresses to...** The fact that matter is composed of atoms and molecules can be used to explain the properties of substances, diversity of materials, states of matter, phase changes, and conservation of matter.	**PS1.A in 9–12 builds on K–8 experiences and knowledge and progresses to...** Properties (e.g. conductivity) of matter can be described and predicted based on the types, interactions, and motions of the atoms within it. Electrical attractions and repulsions between charged particles (i.e., atomic nuclei and electrons) in matter explain the structure of atoms) The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. *(secondary to SC.HSP.16.4.C)*

Connection to other grade level indicators

ELA Connections:

- RST.11-12.2 – Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information.
- RST.11-12.3 – Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
- RST.11-12.7 – Integrate and evaluate multiple sources of information presented in diverse formats and media.
- RST.11-12.9 – Synthesize information from a range of sources into a coherent understanding of a process or phenomenon.
- WHST.11-12.1 – Write arguments focused on discipline-specific content.
- WHST.11-12.2 – Write informative texts to examine and convey complex ideas, concepts, and information clearly and accurately.
- WHST.11-12.7 – Conduct short as well as more sustained research projects to answer a question or solve a problem.

Mathematics Connections:

- HS.MP.4 – Model with mathematics.
- HS.F-IF.4 – Interpret key features of graphs and tables in terms of the quantities.
- HS.A-CED.2 – Create equations in two or more variables to represent relationships between quantities; graph equations.
- HS.G-MG.2 – Apply concepts of density based on area and volume in modeling situations.
- HS.G-GPE.5 – Derive the equation of a circle given a center and a point; relate geometric representations to physical models (e.g., equipotential lines or orbit paths).

Social Studies Connections:

Fine and Performing Arts Connections:

Related Cross-Curricular Standards: Current Grade Level

Authentic Connections to Other Content Standards:

- N/A

Academic Language Development

Words to support student discourse related to the Disciplinary Core Ideas (DCIs):

- Power, current, voltage, resistance, electron, insulator, conductor, Ohm's Law, resistor, circuit, wire, system, component

Assessment Considerations

Formative Assessment:

- https://www.education.ne.gov/assessment/science-classroom-formative-task-repository-for-grades-5-8/
- Sample assessments for HS-PS2-4:
    - Utah SEEd Assessment
    - Wonder of Science: Torsion Balances
    - Wonder of Science: Two Mass Movement
- Sample assessments for HS-PS2-5:
    - Utah SEEd Assessment
    - Wonder of Science: Investigating the Faraday Flashlight
    - Wonder of Science: Cornelius Circuit
- Sample assessments for HS-PS2-6:

- Wonder of Science: Prescription Drugs
- Wonder of Science: How Chemistry Saves the World

- Sample assessments for HS-PS3-5:
  - Utah SEEd Assessment: Electromagnet
  - Utah SEEd Assessment: Electromagnetic Suction
  - Wonder of Science: Space Station Transport System
  - Wonder of Science: Energy in Electric Fields
  - Wonder of Science: MagLev

Stackable, Instructionally-Embedded, Portable Science (SIPS) Assessments:

- https://sipsassessments.org/

Knowledge, Skills, and Abilities:

- **KSA1**: Identify components in a given mathematical representation that are relevant to supporting given explanations about power, current, voltage, and resistance.
- **KSA2**: Use mathematical representations as evidence for the predictions of the relationships between power, current, voltage, and resistance.
- **KSA3**: Use given mathematical representations to identify changes over time and on different scales
- **KSA4**: Use mathematical and computational representations to model, describe, and predict the relationships between power, current, voltage, and resistance.
- **KSA5**: Analyze and use mathematical and/or computational representations to identify the interdependence between power, current, voltage, and resistance.
- **KSA6**: Analyze and use mathematical and/or computational representations as evidence to support claims or explanations about power, current, voltage, and resistance.
- **KSA7**: Make claims distinguishing causation and correlation with respect to changes in power, current, voltage, and resistance.
- **KSA8**: Use mathematical relationships to support claims about causation and correlation with respect to changes in power, current, voltage, and resistance.

Standard

Topic Code: SC.HSP.16 Electricity and Magnetism

Standard Code: SC.HSP.16.4 Gather, analyze, and communicate evidence of electricity and magnetism.

Fields describe how forces act through space and how potential energy is stored in systems. These take on different forms of electric, magnetic, or gravitational fields, but similarly provide a mechanism for how matter interacts. When two objects interacting through a field change relative position, the energy stored in the field is changed. These fields are important at a wide variety of scales, ranging from the subatomic to the astronomic.

Indicator

Indicator Code: SC.HSP.16.4.d

Evaluate competing design solutions for construction and use of electrical consumer products accounting for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts. Examples could include efficiency of light bulbs (visible intensity vs. power) and thermal energy limits of wire.

NGSS Comparison: Builds on HS-PS3-5 and HS-ETS1-3

Other Indicators in this Standard

SC.HSP.16.4.a, SC.HSP.16.4.b, SC.HSP.16.4.c, SC.HSP.16.4.e, SC.HSP.16.4.f, SC.HSP.16.4.g

Concepts and Skills to Master

Foundation Boxes:

Science and Engineering Practice (SEP)	Crosscutting Concept (CCC)

Engaging in Argument from Evidence:
Engaging in argument from evidence in 9–12 builds on K– 8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.

- Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and/or logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations).

Energy and Matter: Flows, Cycles, and Conservation:

- Examine, characterize, and model the transfers and cycles of matter and energy in a system.

Disciplinary Core Idea (DCI)

PS3.A: Definitions of Energy:

- "Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. (secondary to SC.HSP.16.4.D)

Possible Science and/or Engineering Phenomena to Support 3D Instruction

- Why are LED light bulbs more efficient than incandescent?
- Why do different gauges of insulated wire have different temperature ratings?
- Why do we need transformers on power lines?
- Why are newer TVs or computer screens flat, while older models were not?
- Lithium ion batteries vs. Lead ion batteries
- Electric vs. Hybrid vs. Internal Combustion engines

Evidence Statements

What does it look like to demonstrate proficiency on this indicator?

SC.HSP.16.4.d **Evaluate competing design solutions** for construction and use of electrical consumer products accounting for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.	
Supported claims	
a	Students describe* the nature of the problem each design solution addresses.
b	Students identify the solution that has the most preferred cost-benefit ratios.
Identifying scientific evidence	
a	Students identify evidence used to justify the effectiveness and feasibility of each design solution.
Evaluation and critique	
a	Students evaluate the given design solutions, including:
	i. The relative strengths of the given design solutions, based on associated economic, environmental, and geopolitical costs, risks, and benefits;
	ii. The reliability and validity of the evidence used to evaluate the design solutions; and
	iii. Constraints, including cost, safety, reliability, aesthetics, cultural effects environmental effects.
Reasoning/synthesis	
a	Students use logical arguments based on their evaluation of the design solutions, costs and benefits, empirical evidence, and scientific ideas to support one design over the other(s) in their evaluation.
b	Students describe* that a decision on the "best" solution may change over time as engineers and scientists work to increase the benefits of design solutions while decreasing costs and risks.

Critical Background Knowledge

Grade Band Progressions:

Science and Engineering Practices (SEPs): Engaging in Argument from Evidence

K-2	3-5	6-8	9-12
Engaging in argument from evidence in K–2 builds on prior experiences and progresses to... Make a claim about the effectiveness of an object, tool, or solution that is supported by relevant evidence.	**Engaging in argument from evidence in 3–5 builds on K–2 experiences and progresses to...** Make a claim about the merit of a solution to a problem by citing relevant evidence about how it meets the criteria and constraints of the problem.	**Engaging in argument from evidence in 6– 8 builds on K–5 experiences and progresses to...** Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.	**Engaging in argument from evidence in 9-12 builds on K–8 experiences and progresses to college or career experiences.** Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and/or logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations).

Crosscutting Concepts (CCCs): Energy and Matter: Flows, Cycles, and Conservation

K-2	3-5	6-8	9-12
Energy and Matter in K–2 builds on prior experiences and progresses to... Objects may break into smaller pieces, be put together into larger pieces, or change shapes.	**Energy and Matter in 3–5 builds on K–2 experiences and progresses to...** Matter is made of particles and energy can be transferred in various ways and between objects. The conservation of matter can be observed by tracking matter flows and cycles before and after processes and recognizing the total weight of substances does not change.	**Energy and Matter in 6– 8 builds on K–5 experiences and progresses to...** Matter is conserved because atoms are conserved in physical and chemical processes. 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.	**Energy and Matter in 9-12 builds on K–8 experiences and progresses to college or career experiences.** Examine, characterize, and model the transfers and cycles of matter and energy in a system.

Disciplinary Core Ideas (DCIs): PS3.A: Definitions of Energy

K-2	3-5	6-8	9-12
PS3.A in K–2 builds on prior experiences and progresses to...	**PS3.A in 3–5 builds on K–2 experiences and progresses to...** 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	**PS3.A in 6– 8 builds on K–5 experiences and knowledge and progresses to...** 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	**PS3.A in 9–12 builds on K–8 experiences and knowledge and progresses to...** “Electrical energy” may mean energy stored in a battery or

[Intentionally left blank]	through sound, light, or electrical currents. Energy can be converted from one form to another form.	relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter.	energy transmitted by electric currents.

Connection to other grade level indicators

ELA Connections:

- RST.11-12.7: Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.
- RST.11-12.8: Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
- RST.11-12.9: Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

Mathematics Connections:

- MP.2: Reason abstractly and quantitatively.
- MP.4: Model with mathematics.

Social Studies Connections:

- SS HS.2.1 – Apply economic concepts that support rational decision making.
- SS HS.4.4 – Evaluate sources for perspective, limitations, accuracy, and historical context.

Fine and Performing Arts Connections:

- FA 12.2.4 – Students will synthesize understanding of contemporary, historical, and cultural context in art and life.
- FA 12.1.1 – Students will analyze and integrate personal and global connections through media arts.
- FA 12.5.2 – Students will perform ideas and events through movement, speech, and staging for an intended audience.

Related Cross-Curricular Standards: Current Grade Level

Authentic Connections to Other Content Standards:

- N/A

Academic Language Development

Words to support student discourse related to the Disciplinary Core Ideas (DCIs):

- Electric fields, electric current, interacting objects, forces, electrical energy in the field, cause and effect

Assessment Considerations

Formative Assessment:

- https://www.education.ne.gov/assessment/science-classroom-formative-task-repository-for-grades-5-8/
- Sample assessments for HS-PS3-5:
  - Utah SEEd Assessment: Electromagnet
  - Utah SEEd Assessment: Electromagnetic Suction
  - Wonder of Science: Space Station Transport System
  - Wonder of Science: Energy in Electric Fields
  - Wonder of Science: MagLev

Stackable, Instructionally-Embedded, Portable Science (SIPS) Assessments:

- https://sipsassessments.org/

Knowledge, Skills, and Abilities:

- **KSA1**: Describe the nature of the problem the design solutions address.
- **KSA2**: Identify criteria for the success of the design solutions, including economic, environmental, and geopolitical considerations.
- **KSA3**: Identify constraints for the design solution, including cost, safety, reliability, aesthetics, cultural effects, and environmental effects.
- **KSA4**: Analyze the reliability and validity of each design solution based on the criteria and constraints.
- **KSA5**: Make a claim regarding the "best" design solution.
- **KSA6**: Use evidence from analysis to support claims regarding the best design solution.
- **KSA7**: Explain how the "best" design solution may change over time as engineers and scientists work to increase the benefits of design solutions, while decreasing costs and risks.

Standard

Topic Code: SC.HSP.16 Electricity and Magnetism

Standard Code: SC.HSP.16.4 Gather, analyze, and communicate evidence of electricity and magnetism.

Fields describe how forces act through space and how potential energy is stored in systems. These take on different forms of electric, magnetic, or gravitational fields, but similarly provide a mechanism for how matter interacts. When two objects interacting through a field change relative position, the energy stored in the field is changed. These fields are important at a wide variety of scales, ranging from the subatomic to the astronomic.

Indicator

Indicator Code: SC.HSP.16.4.e

Obtain and communicate technical information about how some technological devices use alternating current and others use direct current. Examples could include why public utilities use AC while many devices use DC and energy loss in transmission of electricity.

NGSS Comparison: Builds on HS-PS2-5 and HS-PS3-5

Other Indicators in this Standard

SC.HSP.16.4.a, SC.HSP.16.4.b, SC.HSP.16.4.c, SC.HSP.16.4.d, SC.HSP.16.4.f, SC.HSP.16.4.g

Concepts and Skills to Master

Foundation Boxes:

Science and Engineering Practice (SEP)	Crosscutting Concept (CCC)
Obtaining, Evaluating, and Communicating Information: Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs. • Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source	**Scale, Quantity, and Proportion:** • The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. (I.e. the amount of energy flowing through systems such as lightbulbs and power grids).

Disciplinary Core Idea (DCI)

PS2.B: Types of Interactions:

- 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:**

- "Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. (secondary to SC.HSP.16.4.E)

ETS1.A: **Defining and Delimiting Engineering Problems:**

- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. *(secondary to SC.HSP.16.4.E)*

Possible Science and/or Engineering Phenomena to Support 3D Instruction

- How do adapters for phone chargers work?
- Why do some devices come with safety warnings about using different cords/adapters?
- The Execution of Topsy the Elephant
- Battle of the Currents

Evidence Statements

What does it look like to demonstrate proficiency on this indicator?

SC.HSP.16.4.e **Obtain and communicate technical information** about how some technological devices use alternating current and others use direct current.	
Obtaining information	
a	Students obtain at least two claims proposed in published material (using at least two sources per claim).
Evaluating information	
a	Students use reasoning about the data presented to analyze the validity and reliability of each claim.
b	Students determine the validity and reliability of the sources of the claims.

Critical Background Knowledge

Grade Band Progressions:

Science and Engineering Practices (SEPs): Obtaining, Evaluating, and Communicating Information

K-2	3-5	6-8	9-12
Obtaining, evaluating, and communicating information in K–2 builds on prior experiences and progresses to... 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.	**Obtaining, evaluating, and communicating information in 3–5 builds on K–2 experiences and progresses to...** Combine information in written text with that contained in corresponding tables, diagrams, and/or charts to support the engagement in other scientific and/or engineering practices.	**Obtaining, evaluating, and communicating information in 6– 8 builds on K–5 experiences and progresses to...** Gather, read, and 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.	**Obtaining, evaluating, and communicating information in 9-12 builds on K–8 experiences and progresses to college or career experiences.** Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.

Crosscutting Concepts (CCCs): Scale, Quantity, and Proportion

K-2	3-5	6-8	9-12
Scale, Quantity, and Proportion in K–2 builds on prior experiences and progresses to... Relative scales (e.g., bigger and smaller; hotter and colder; faster and slower) can be used to describe objects. Standard units are used to measure length.	**Scale, Quantity, and Proportion in 3–5 builds on K–2 experiences and progresses to...** Natural objects and observable phenomena exist from the very small to the immensely large. Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume.	**Scale, Quantity, and Proportion in 6– 8 builds on K–5 experiences and progresses to...** Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. Phenomena observed at one scale may not be observable at another scale, and the function of natural and designed systems may change with scale. Proportional relationships (e.g., speed as the ratio of distance traveled to time taken) can be used to gather information about the magnitude of properties and processes. Scientific relationships can be represented through the use of algebraic expressions and equations.	**Scale, Quantity, and Proportion in 9-12 builds on K–8 experiences and progresses to college or career experiences.** The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. (I.e. the amount of energy flowing through systems such as lightbulbs and power grids).

Disciplinary Core Ideas (DCIs): PS2.B: Types of Interactions, PS3.A: Definitions of Energy, ETS1.A: Defining and Delimiting Engineering Problems

K-2	3-5	6-8	9-12
PS2.B in K–2 builds on prior experiences and progresses to... Pushes and pulls can have different strengths and directions, and can change the speed or direction of its motion or start or stop it. **PS3.A in K–2 builds on prior experiences and progresses to...** [Intentionally left blank] **ETS1.A in K–2 builds on prior experiences and progresses to...**	**PS2.B in 3–5 builds on K–2 experiences and progresses to...** The effect of unbalanced forces on an object results in a change of motion. Patterns of motion can be used to predict future motion. Some forces act through contact, some forces act even when the objects are not in contact. The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center. **PS3.A in 3–5 builds on K–2 experiences and progresses to...** 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.	**PS2.B in 6– 8 builds on K–5 experiences and knowledge and progresses to...** Forces that act at a distance involve fields that can be mapped by their relative strength and effect on an object. **PS3.A in 6– 8 builds on K–5 experiences and knowledge and progresses to...** 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.	**PS2.B in 9–12 builds on K–8 experiences and knowledge and progresses to...** 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 in 9–12 builds on K–8 experiences and knowledge and progresses to...** "Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents.

A situation that people want to change or create can be approached as a problem to be solved through engineering. Such problems may have many acceptable solutions. Asking questions, making observations, and gathering information are helpful in thinking about problems.	**ETS1.A in 3–5 builds on K–2 experiences and progresses to...** Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account.	**ETS1.A in 6– 8 builds on K–5 experiences and knowledge and progresses to...** The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions.	**ETS1.A in 9–12 builds on K–8 experiences and knowledge and progresses to...** 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.

Connection to other grade level indicators

ELA Connections:

- RST.6-8.2: "…provide an accurate summary of the text distinct from prior knowledge or opinions."
- RST.11-12.2: "…summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms."
- RST.9-10.7: "Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.
- RST.9-10.9: "Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts."
- RST.11-12.9: "Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible."
- WHST.11-12.8: "…using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas …"
- SL.11-12.4: "Present information, findings, and supporting evidence, conveying a clear and distinct perspective… alternative or opposing perspectives are addressed…"

Mathematics Connections:

- N-Q.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and origin in graphs and data displays.
- N-Q.2.Define appropriate quantities for the purpose of descriptive modeling.
- N-Q.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

Social Studies Connections:

- SS HS.2.1 – Apply economic concepts that support rational decision making.
- SS HS.4.4 – Evaluate sources for perspective, limitations, accuracy, and historical context.

Fine and Performing Arts Connections:

- FA 12.2.4 – Students will synthesize understanding of contemporary, historical, and cultural context in art and life.
- FA 12.1.1 – Students will analyze and integrate personal and global connections through media arts.
- FA 12.5.2 – Students will perform ideas and events through movement, speech, and staging for an intended audience.

Related Cross-Curricular Standards: Current Grade Level

Authentic Connections to Other Content Standards:

- N/A

Academic Language Development

Words to support student discourse related to the Disciplinary Core Ideas (DCIs):

- Electric current, electric circuit, direct current, alternating current, cause and effect

Assessment Considerations

Formative Assessment:

- https://www.education.ne.gov/assessment/science-classroom-formative-task-repository-for-grades-5-8/
- Sample assessments for HS-PS2-5:
  - Utah SEEd Assessment
  - Wonder of Science: Investigating the Faraday Flashlight
  - Wonder of Science: Cornelius Circuit
- Sample assessments for HS-PS3-5:
  - Utah SEEd Assessment: Electromagnet
  - Utah SEEd Assessment: Electromagnetic Suction
  - Wonder of Science: Space Station Transport System
  - Wonder of Science: Energy in Electric Fields
  - Wonder of Science: MagLev

Stackable, Instructionally-Embedded, Portable Science (SIPS) Assessments:

- https://sipsassessments.org/

Knowledge, Skills, and Abilities:

- **KSA1**: Obtain at least two claims proposed in published material (citing at least authoritative two sources per claim) that some technological devices are best suited for alternating current while others are best suited for direct current.
- **KSA2**: Obtain evidence (citing at least two authoritative sources) of the benefits and drawbacks of alternating current.
- **KSA3**: Obtain evidence (citing at least two authoritative sources) of the benefits and drawbacks of direct current.
- **KSA4**: Obtain evidence about how scales/quantities, (e.g, transmission distance, or amount of energy flowing through a system) can determine the suitability of alternating/direct current for technologies.
- **KSA5**: Use scientific reasoning about alternating and direct current to evaluate the evidence presented and analyze the validity and reliability of each claim.
- **KSA6**: Use scientific reasoning about alternating and direct current to evaluate the validity and reliability of the sources of the claims.

Standard

Topic Code: SC.HSP.16 Electricity and Magnetism

Standard Code: SC.HSP.16.4 Gather, analyze, and communicate evidence of electricity and magnetism.

Fields describe how forces act through space and how potential energy is stored in systems. These take on different forms of electric, magnetic, or gravitational fields, but similarly provide a mechanism for how matter interacts. When two objects interacting through a field change relative position, the energy stored in the field is changed. These fields are important at a wide variety of scales, ranging from the subatomic to the astronomic.

Indicator

Indicator Code: SC.HSP.16.4.f

Design a solution to a problem using the fact that an electric current can produce a magnetic field and/or that a changing magnetic field can produce an electric current.
Emphasis is on both quantitative and conceptual descriptions of electric and magnetic fields. Examples include designing a generator, motor or transformer. Assessment is limited to systems with two objects.

NGSS Comparison: Builds on HS-PS2-5 and HS-PS3-5

Other Indicators in this Standard

SC.HSP.16.4.a, SC.HSP.16.4.b, SC.HSP.16.4.c, SC.HSP.16.4.d, SC.HSP.16.4.e, SC.HSP.16.4.g

Concepts and Skills to Master

Foundation Boxes:

Science and Engineering Practice (SEP)	Crosscutting Concept (CCC)
Constructing Explanations and Designing Solutions: Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • 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.	**Cause and Effect:** • Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.

Disciplinary Core Idea (DCI)

PS2.B: Types of Interactions
- 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.

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 to SC.HSP.16.4.F)*

Possible Science and/or Engineering Phenomena to Support 3D Instruction

- Programmable Droplets from MIT
- Candle Powered Car
- Programmable Magnets

Evidence Statements

What does it look like to demonstrate proficiency on this indicator?

SC.HSP.16.4.f **Design a solution** to a problem using the fact that an electric current can produce a magnetic field and/or that a changing magnetic field can produce an electric current.	
Using scientific knowledge to generate the design solution	
a	Students design a solution that relies on scientific knowledge of the problem.
b	Students describe* the ways the proposed solution addresses the problem.
Describing criteria and constraints, including quantification when appropriate	
a	Students describe* and quantify (when appropriate) the criteria and constraints for the solution to the problem, along with the tradeoffs in the solution.
Evaluating potential solutions	
a	Students evaluate the proposed solution for its impact.

b	Students evaluate the cost, safety, and reliability, as well as social, cultural, and environmental impacts, of the proposed solution.
Refining and/or optimizing the design solution	
a	Students refine the proposed solution by prioritizing the criteria and making tradeoffs as necessary.

Critical Background Knowledge

Grade Band Progressions:

Science and Engineering Practices (SEPs): Constructing Explanations and Designing Solutions

K-2	3-5	6-8	9-12
Constructing Explanations and Designing Solutions in K–2 builds on prior experiences and progresses to... Generate and/or compare multiple solutions to a problem.	**Constructing Explanations and Designing Solutions in 3–5 builds on K–2 experiences and progresses to...** 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.	**Constructing Explanations and Designing Solutions in 6– 8 builds on K–5 experiences and progresses to...** 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.	**Constructing Explanations and Designing Solutions in 9-12 builds on K–8 experiences and progresses to college or career experiences.** 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.

Crosscutting Concepts (CCCs): Cause and Effect

K-2	3-5	6-8	9-12
Cause and Effect in K–2 builds on prior experiences and progresses to... Events have causes that generate observable patterns. Simple tests can be designed to gather evidence to support or refute ideas about causes.	**Cause and Effect in 3–5 builds on K–2 experiences and progresses to...** Causal relationships can be tested and used to explain change. Events that occur together with regularity might or might not signify a cause and effect relationship.	**Cause and Effect in 6– 8 builds on K–5 experiences and progresses to...** Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Cause and effect relationships can 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.	**Cause and Effect in 9-12 builds on K–8 experiences and progresses to college or career experiences.** 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.

Disciplinary Core Ideas (DCIs): PS2.B: Types of Interactions, ETS1.C: Optimizing the Design Solution

K-2	3-5	6-8	9-12
PS2.B in K–2 builds on prior experiences and progresses to... Pushes and pulls can have different strengths and directions, and can change the speed or direction of its motion or start or stop it. **ETS1.C in K–2 builds on prior experiences and progresses to...** Because there is always more than one possible solution to a problem, it is useful to compare and test designs.	**PS2.B in 3–5 builds on K–2 experiences and progresses to...** The effect of unbalanced forces on an object results in a change of motion. Patterns of motion can be used to predict future motion. Some forces act through contact, some forces act even when the objects are not in contact. The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center. **ETS1.C in 3–5 builds on K–2 experiences and progresses to...** Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints.	**PS2.B in 6– 8 builds on K–5 experiences and knowledge and progresses to...** Forces that act at a distance involve fields that can be mapped by their relative strength and effect on an object **ETS1.C in 6– 8 builds on K–5 experiences and knowledge and progresses to...** Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of the characteristics may be incorporated into the new design. The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.	**PS2.B in 9–12 builds on K–8 experiences and knowledge and progresses to...** 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. **ETS1.C in 9–12 builds on K–8 experiences and knowledge and progresses to...** 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.

Connection to other grade level indicators

ELA Connections:

- WHST.11-12.7 - Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
- WHST.11-12.8 - Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and over reliance on any one source and following a standard format for citation.
- WHST.11-12.9 - Draw evidence from informational texts to support analysis, reflection, and research.

Mathematics Connections:

- HSN-Q.A.1 - Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.
- HSN-Q.A.2 - Define appropriate quantities for the purpose of descriptive modeling.

Social Studies Connections:

- SS HS.2.1 – Apply economic concepts that support rational decision making.
- SS HS.4.4 – Evaluate sources for perspective, limitations, accuracy, and historical context.

Fine and Performing Arts Connections:

- FA 12.2.4 – Students will synthesize understanding of contemporary, historical, and cultural context in art and life.
- FA 12.1.1 – Students will analyze and integrate personal and global connections through media arts.
- FA 12.5.2 – Students will perform ideas and events through movement, speech, and staging for an intended audience.

Related Cross-Curricular Standards: Current Grade Level

Authentic Connections to Other Content Standards:

- N/A

Academic Language Development

Words to support student discourse related to the Disciplinary Core Ideas (DCIs):

- Electric current, electric circuit, magnetic field, magnet, cause and effect

Assessment Considerations

Formative Assessment:

- https://www.education.ne.gov/assessment/science-classroom-formative-task-repository-for-grades-5-8/
- Sample assessments for HS-PS2-5:
  - Utah SEEd Assessment
  - Wonder of Science: Investigating the Faraday Flashlight
  - Wonder of Science: Cornelius Circuit
- Sample assessments for HS-PS3-5:
  - Utah SEEd Assessment: Electromagnet
  - Utah SEEd Assessment: Electromagnetic Suction
  - Wonder of Science: Space Station Transport System
  - Wonder of Science: Energy in Electric Fields
  - Wonder of Science: MagLev

Stackable, Instructionally-Embedded, Portable Science (SIPS) Assessments:

- https://sipsassessments.org/

Knowledge, Skills, and Abilities:

- **KSA1**: Identify a real-world problem that can be addressed by using an electric current to produce a magnetic field, or a magnetic field to produce an electric current.
- **KSA2**: Describe and quantify (where appropriate) the criteria for a successful solution.
- **KSA3**: Describe and quantify (where appropriate) the constraints within which the solution must operate, including cost, safety, and reliability.
- **KSA4**: Propose a design solution to the real-world problem that relies on scientific knowledge of electromagnetism.
- **KSA5**: Evaluate the proposed solution based on criteria and constraints.
- KSA6: Prioritize criteria and identify tradeoffs for social, cultural, and environmental impacts and provide justification for these design choices.
- KSA7: Refine the design solution based on prioritized criteria, making necessary tradeoffs.

Standard

Topic Code: SC.HSP.16 Electricity and Magnetism
Standard Code: SC.HSP.16.4 Gather, analyze, and communicate evidence of electricity and magnetism.

Fields describe how forces act through space and how potential energy is stored in systems. These take on different forms of electric, magnetic, or gravitational fields, but similarly provide a mechanism for how matter interacts. When two objects interacting through a field change relative position, the energy stored in the field is changed. These fields are important at a wide variety of scales, ranging from the subatomic to the astronomic.

Indicator

Indicator Code: SC.HSP.16.4.g

Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants. Examples could include analysis of renewable energy systems for electricity generation and the effect of autonomous electric cars on the economy, society and the environment.

NGSS Comparison: Builds on HS-ETS1-1

Other Indicators in this Standard

SC.HSP.16.4.a, SC.HSP.16.4.b, SC.HSP.16.4.c, SC.HSP.16.4.d, SC.HSP.16.4.e, SC.HSP.16.4.f

Concepts and Skills to Master

Foundation Boxes:

Science and Engineering Practice (SEP)	Crosscutting Concept (CCC)
Asking Questions and Defining Problems: Asking questions and defining problems in 9–12 builds on grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. • Analyze complex real-world problems by specifying criteria and constraints for successful solutions.	**Cause and Effect:** • Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. ***Connections to Engineering, Technology, and Applications of Science*** **Influence of Science, Engineering, and Technology on Society and the Natural World:** • New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.

Disciplinary Core Idea (DCI)

ETS1.A: Defining and Delimiting Engineering Problems:

- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (SC.HSP.16.4.G)
- Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.

Possible Science and/or Engineering Phenomena to Support 3D Instruction

- Solar Storms, Earth's magnetic field & effects on global communications/technology
- Renewable energy systems
- Autonomous electric cars
- Maglev trains

Evidence Statements

What does it look like to demonstrate proficiency on this indicator?

SC.HSP.16.4.g **Analyze a major global challenge** to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants		
1	Identifying the problem to be solved	
	a	Students analyze a major global problem. In their analysis, students:
		i. Describe* the challenge with a rationale for why it is a major global challenge;

		ii. Describe*, qualitatively and quantitatively, the extent and depth of the problem and its major consequences to society and/or the natural world on both global and local scales if it remains unsolved; and
		iii. Document background research on the problem from two or more sources, including research journals.
2	Defining the process or system boundaries, and the components of the process or system	
	a	In their analysis, students identify the physical system in which the problem is embedded, including the major elements and relationships in the system and boundaries so as to clarify what is and is not part of the problem.
	b	In their analysis, students describe* societal needs and wants that are relative to the problem.
3	Defining the criteria and constraints	
	a	Students specify qualitative and quantitative criteria and constraints for acceptable solutions to the problem.

Critical Background Knowledge

Grade Band Progressions:

Science and Engineering Practices (SEPs): Asking Questions and Defining Problems

K-2	3-5	6-8	9-12
Asking Questions and Defining Problems in K–2 builds on prior experiences and progresses to... Define a simple problem that can be solved through the development of a new or improved object or tool.	**Asking Questions and Defining Problems in 3–5 builds on K–2 experiences and progresses to...** Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost.	**Asking Questions and Defining Problems in 6– 8 builds on K–5 experiences and progresses to...** Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.	**Asking Questions and Defining Problems in 9-12 builds on K–8 experiences and progresses to college or career experiences.** Analyze complex real-world problems by specifying criteria and constraints for successful solutions.

Crosscutting Concepts (CCCs): Cause and Effect

K-2	3-5	6-8	9-12
Cause and Effect in K–2 builds on prior experiences and progresses to... Events have causes that generate observable patterns. Simple tests can be designed to gather evidence to support or refute ideas about causes.	**Cause and Effect in 3–5 builds on K–2 experiences and progresses to...** Causal relationships can be tested and used to explain change. Events that occur together with regularity might or might not	**Cause and Effect in 6– 8 builds on K–5 experiences and progresses to...** Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Cause and effect relationships can 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.	**Cause and Effect in 9-12 builds on K–8 experiences and progresses to college or career experiences.** 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.

	signify a cause and effect relationship.		

Disciplinary Core Ideas (DCIs): ETS1.A: Defining and Delimiting Engineering Problems

K-2	3-5	6-8	9-12
ETS1.A in K–2 builds on prior experiences and progresses to... A situation that people want to change or create can be approached as a problem to be solved through engineering. Such problems may have many acceptable solutions. Asking questions, making observations, and gathering information are helpful in thinking about problems.	**ETS1.A in 3–5 builds on K–2 experiences and progresses to...** Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account.	**ETS1.A in 6– 8 builds on K–5 experiences and knowledge and progresses to...** The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions.	**ETS1.A in 9–12 builds on K–8 experiences and knowledge and progresses to...** Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.

Connection to other grade level indicators

ELA Connections:

- RST.11-12.7: Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.
- RST.11-12.8: Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
- RST.11-12.9: Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

Mathematics Connections:

- MP.2: Reason abstractly and quantitatively.
- MP.4: Model with mathematics.

Social Studies Connections:

- SS HS.2.1 – Apply economic concepts that support rational decision making.
- SS HS.4.4 – Evaluate sources for perspective, limitations, accuracy, and historical context.

Fine and Performing Arts Connections:

- FA 12.2.4 – Students will synthesize understanding of contemporary, historical, and cultural context in art and life.
- FA 12.1.1 – Students will analyze and integrate personal and global connections through media arts.
- FA 12.5.2 – Students will perform ideas and events through movement, speech, and staging for an intended audience.

Related Cross-Curricular Standards: Current Grade Level

Authentic Connections to Other Content Standards:

- High School Conceptual Progressions Course 1 – Bundle 3
- High School Conceptual Progressions Course 2 – Bundle 4
- High School Conceptual Progressions Course 3 - Bundle 3
- High School Domains Model Course 1 – Chemistry - Bundle 4
- High School Domains Model Course 2 – Physics – Bundle 2
- High School Modified Domains Model Course 3 – Life Sciences – Bundle 2
- High School Modified Domains Model Course 3 – Life Sciences – Bundle 3
- High School Modified Domains Model Course 3 – Life Sciences – Bundle 5

Academic Language Development

Words to support student discourse related to the Disciplinary Core Ideas (DCIs):

- Constraints, criteria, data, design, engineering, iterative, model, optimize, prototype, solution, system, technology, system boundaries

Assessment Considerations

Formative Assessment:

- https://www.education.ne.gov/assessment/science-classroom-formative-task-repository-for-grades-5-8/

Stackable, Instructionally-Embedded, Portable Science (SIPS) Assessments:

- https://sipsassessments.org/

Knowledge, Skills, and Abilities:

- **KSA1:** Ask questions about a major global challenge and provide rationale for why it is significant.
- **KSA2**: Formulate and refine empirically testable questions and design problems using models and simulations.
- **KSA3**: Identify and describe the physical system in which the problem is embedded to define the system, system boundaries, and relevant variables.
- **KSA4:** Identify and describe cause and effect relationships between variables within the physical system.
- **KSA5:** Develop qualitative and quantitative criteria and constraints for solutions to the major global challenge,
- **KSA6**: Evaluate and refine the design problem based on documented research from two or more sources, including research journals.
- **KSA7:** Identify current technologies/solutions and evaluate them using qualitative and quantitative criteria and constraints, potential impacts on society and the environment at global and local scales, and unintended consequences.