**Physical Science Teacher’s Guide to Nebraska’s College and**

**Career Ready Standards for Science**

**2017**

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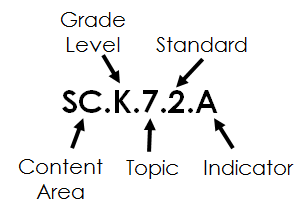
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**Content Area Standards Structure**

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**. At the broadest level, **standards** include broad, overarching content-based statements that describe the basic cognitive, affective, or psychomotor indicators 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 indicators 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 does not mandate the curriculum used within a local school.

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

**Organization and Structure of CCR-Science Standards**

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.

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 science topics. This 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 Education1.* Each CCR-Science indicator includes a disciplinary core idea, a crosscutting concept (underline), and a **science and engineering practice** (**bold**).

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).

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.

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. Instruction aimed toward preparing students should use crosscutting concepts and **science and engineering practices** that go beyond what is stated in the indicator to better reflect authentic science practice.

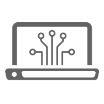
The following table lists the disciplinary core ideas, crosscutting concepts, and **science and engineering practices**:

|  |  |  |
| --- | --- | --- |
| [**Science and Engineering Practices**](https://www.nap.edu/read/13165/chapter/7)   * **[Asking Questions and Defining Problems](https://www.nap.edu/read/13165/chapter/7" \l "54)** * **[Developing and Using Models](https://www.nap.edu/read/13165/chapter/7" \l "56)** * **[Planning and Carrying Out Investigations](https://www.nap.edu/read/13165/chapter/7" \l "59)** * [**Analyzing and Interpreting Data**](https://www.nap.edu/read/13165/chapter/7#61) * **[Using Mathematics and Computational Thinking](https://www.nap.edu/read/13165/chapter/7" \l "64)** * **[Constructing Explanations and Designing Solutions](https://www.nap.edu/read/13165/chapter/7" \l "67)** * **[Engaging in Argument from Evidence](https://www.nap.edu/read/13165/chapter/7" \l "71)** * [**Obtaining, Evaluating, and Communicating Information**](https://www.nap.edu/read/13165/chapter/7#74) | **Disciplinary Core Ideas**  [**LS1**](https://www.nap.edu/read/13165/chapter/10#143)**: From Molecules to Organisms:   Structures and Processes** [**LS2**](https://www.nap.edu/read/13165/chapter/10#150)**: Ecosystems: Interactions, Energy,   and Dynamics** [**LS3**](https://www.nap.edu/read/13165/chapter/10#157)**: Heredity: Inheritance and of Traits** [**LS4**](https://www.nap.edu/read/13165/chapter/10#161)**: Biological Evolution: Unity & Diversity** [**PS1**](https://www.nap.edu/read/13165/chapter/9#106)**: Matter and Its Interactions** [**PS2**](https://www.nap.edu/read/13165/chapter/9#113)**: Motion and Stability: Forces and   Interactions** [**PS3**](https://www.nap.edu/read/13165/chapter/9#120)**: Energy** [**PS4**](https://www.nap.edu/read/13165/chapter/9#130)**: Waves and Their Applications in   Technologies for Information Transfer** [**ESS1**](https://www.nap.edu/read/13165/chapter/11#173)**: Earth’s Place in the Universe** [**ESS2**](https://www.nap.edu/read/13165/chapter/11#179)**: Earth’s Systems** [**ESS3**](https://www.nap.edu/read/13165/chapter/11#190)**: Earth and Human Activity** [**ETS1**](https://www.nap.edu/read/13165/chapter/12#204)**: Engineering Design** | C:\Users\sara.cooper.NDE\Desktop\Standards\Patterns.png[**Crosscutting Concepts**](https://www.nap.edu/read/13165/chapter/8)  [C:\Users\sara.cooper.NDE\Desktop\Standards\CauseEffect.png**Patterns**](https://www.nap.edu/read/13165/chapter/8#85) [**Cause and Effect**](https://www.nap.edu/read/13165/chapter/8#87)  [**Scale, Proportion, and Quantity**](https://www.nap.edu/read/13165/chapter/8#89)C:\Users\sara.cooper.NDE\Desktop\Standards\ScaleProportionQuantity.png  C:\Users\sara.cooper.NDE\Desktop\Standards\Systems.png[**Systems and System Models**](https://www.nap.edu/read/13165/chapter/8#91)  C:\Users\sara.cooper.NDE\Desktop\Standards\EnergyMatter.png  [**Energy and Matter**](https://www.nap.edu/read/13165/chapter/8#94)  C:\Users\sara.cooper.NDE\Desktop\Standards\StructureFunction.png[**Structure and Function**](https://www.nap.edu/read/13165/chapter/8#96)  C:\Users\sara.cooper.NDE\Desktop\Standards\StabilityChange.png  [**Stability and Change**](https://www.nap.edu/read/13165/chapter/8#98) |

**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.

**Civic Science Connections**

****Within the CCR-Science standards, opportunities to create civic science connections have been identified. These connections are designed to call-out the importance for students to engage in the study of civic ideals, principles, and practices through participation in the act of “citizen science.” Citizen science is the public involvement in inquiry and discovery of new scientific knowledge. This engagement helps students build science knowledge and skills while improving social behavior, increasing student engagement, and strengthening community partnerships. Citizen science projects enlist K-12 students to collect or analyze data for real-world research studies. Citizen science in conjunction with the CCR-Science standards help bridge our K-12 students with stakeholders in the community, both locally and globally.

**Computer Science Connections**Natural connections between science and computer science have been identified throughout the standards, especially in the middle level and in high school as students expand their ability to use computational thinking to develop complex models and simulations of natural and designed systems. Computers and other digital tools allow students to collect, record, organize, analyze, and communicate data as they engage in science learning.

**Engineering, Technology, and Applications of Science Connections**Connections to engineering, technology, and applications of science are included at all grade levels and in all domains. These connections highlight the interdependence of science, engineering, and technology that drives the research, innovation, and development cycle where discoveries in science lead to new technologies developed using the engineering design process. Additionally, these connections call attention to the effects of scientific and technological advances on society and the environment.

** Engineering Design**Performance indicators for the engineering design process are intentionally embedded in all grade levels. These indicators allow students to demonstrate their ability to define problems, develop possible solutions, and improve designs. ***These indicators should be reinforced whenever students are engaged in practicing engineering design during instruction.*** Having students engage in the engineering design process will prepare them to solve challenges both in and out of the classroom.

**Instructional Shifts**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.

*3-Dimensional teaching and learning:* Effective science teaching, learning, and assessment should integrate disciplinary core ideas, crosscutting concepts, and **science and engineering** **practices**. Integration of the three dimensions will allow students to explain scientific phenomena, design solutions to real-world challenges, and build a foundation upon which they can continue to learn and to apply science knowledge and skills within and outside the K-12 education arena.

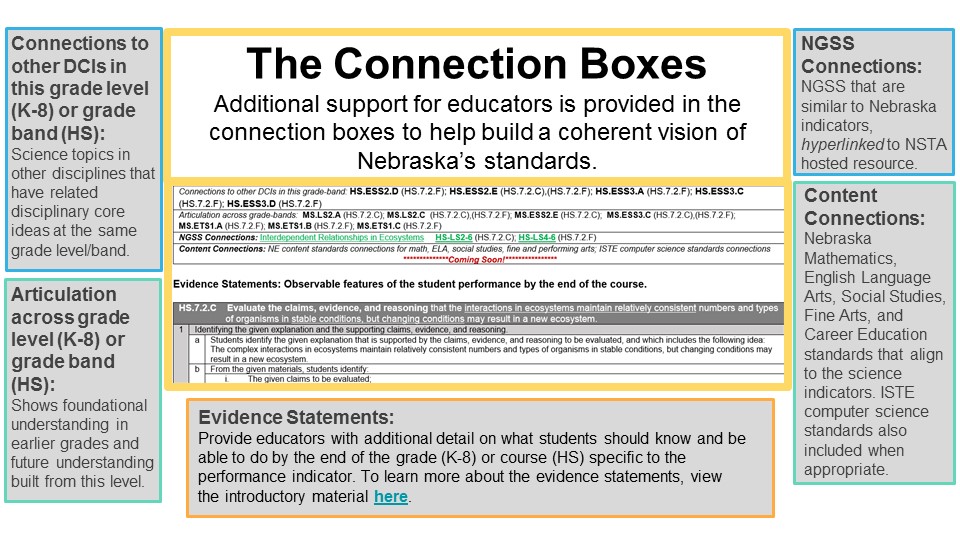
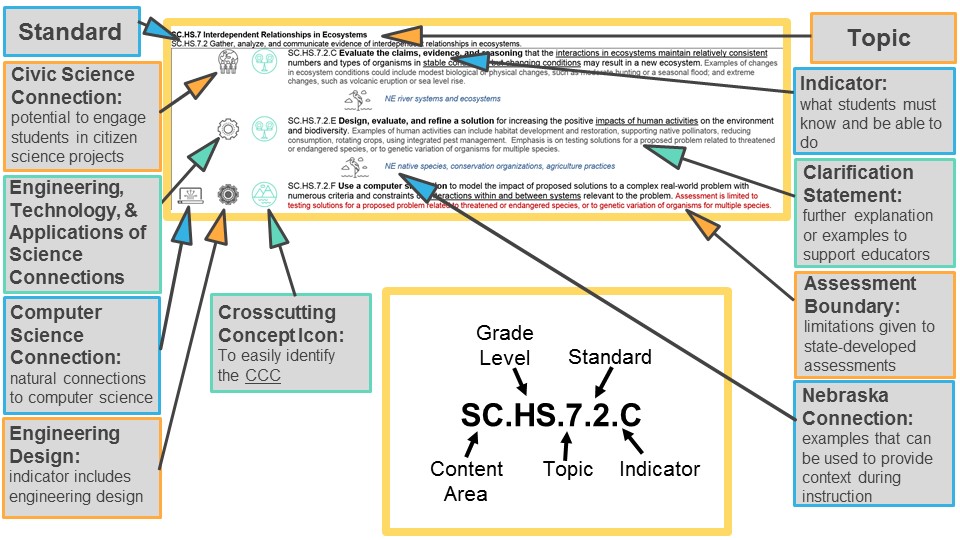
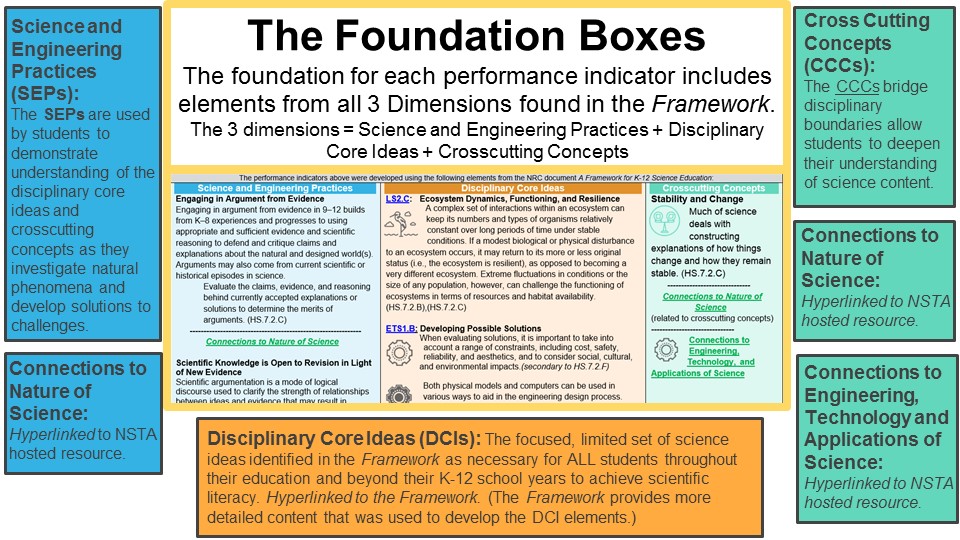
*Integrated science:* Natural phenomena serve as the context for the work of both scientists and engineers. As students explain natural phenomena and design solutions to real-world challenges they connect ideas across science domains. The crosscutting concepts serve as tools that bridge domain boundaries and allow students to deepen their understanding of disciplinary core ideas while using **science and engineering practices** as they explore natural phenomena.

*Interdisciplinary approaches:* The overlapping skills included in the **science and engineering practices** and the intellectual tools provided by the crosscutting concepts build meaningfuland substantive connections to interdisciplinary knowledge and skills in all content areas(English Language Arts, mathematics, social studies, fine arts, career/technical education,etc.) This affords all student equitable access to learning and ensures all students are preparedfor college, career, and citizenship.

**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, 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.

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

**How to Read the Teacher’s Guide**



**[here](https://www.nextgenscience.org/sites/default/files/Front%20Matter%20Evidence%20Statements%20PDF%20Jan%202015_1.pdf)**.

**HS Physical Sciences**

The physical science standards and indicators help students gather, analyze, and communicate evidence as they formulate answers to questions tailored to student interest and current topics that may include but are not limited to:

**How can one explain the structure and properties of matter?**

Students are expected to develop understanding of the substructure of atoms and provide more mechanistic explanations of the properties of substances. Students are able to use the periodic table as a tool to explain and predict the properties of elements.

**How do substances combine or change (react) to make new substances? How does one characterize and explain these reactions and make predictions about them?”**

Students will be able to explain important biological and geophysical phenomena. Students are also able to apply an understanding of the process of optimization in engineering design to chemical reaction systems.

**How can one explain and predict interactions between objects and within systems of objects?**

Students are expected to build an understanding of forces and interactions, total momentum of a system of objects is conserved when there is no net force on the system, and predict the gravitational and electrostatic forces between objects. Students are able to apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.

**How is energy transferred and conserved?**

Students are expected to develop an understanding that energy at both the macroscopic and the atomic scale can be accounted for as either motions of particles or energy associated with the configuration (relative positions) of particles. In some cases, the energy associated with the configuration of particles can be thought of as stored in fields.

**How are waves used to transfer energy and send and store information?**

Students are expected to apply understanding of how wave properties and the interactions of electromagnetic radiation with matter can transfer information across long distances, store information, and investigate nature on many scales.

**SC.HS.1 Forces and Interactions**

SC.HS.1.1 Gather, analyze, and communicate evidence of forces and interactions.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\CauseEffect.png | SC.HS.1.1.A **Analyze data** to support the claim that Newton's Second Law of Motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object sliding down a ramp, or a moving object being pulled by a constant force. Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds. | |
|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\Systems.png | SC.HS.1.1.B **Use mathematical representations** to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle. Assessment is limited to systems of two macroscopic bodies moving in one dimension. | |
| C:\Users\sara.cooper.NDE\Desktop\Standards\NebraskaConnection.png | *NE roadside and highway safety* |
| **C:\Users\sara.cooper.NDE\Desktop\Standards\ComputerScienceConnection.png** | C:\Users\sara.cooper.NDE\Desktop\Standards\EngineeringConnection'.png | C:\Users\sara.cooper.NDE\Desktop\Standards\CauseEffect.png | SC.HS.1.1.C **Apply science 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. Examples of a device could include a football helmet or a parachute. Assessment is limited to qualitative evaluations and/or algebraic manipulations. | |
|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\Patterns.png | SC.HS.1.1.D **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 gravitational and electric fields. Assessment is limited to systems with two objects. | |
|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\CauseEffect.png | SC.HS.1.1.E **Plan and conduct an investigation** to provide evidence that an electrical current can produce a magnetic field and that a changing magnetic field can produce an electrical current. Assessment is limited to designing and conducting investigations with provided materials and tools. | |
| C:\Users\sara.cooper.NDE\Desktop\Standards\NebraskaConnection.png | *NE energy producers* |

|  |  |  |
| --- | --- | --- |
| The performance indicators above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*: | | |
| **Science and Engineering Practices**  **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. (HS.1.1.E)   **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. (HS.1.1.A)   **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. (HS.1.1.B),(HS.1.1.D)   **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. (HS.1.1.C)   **--------------------------------------------------------------------------**  [***Connections to Nature of Science***](http://nstahosted.org/pdfs/ngss/AppendixH-TheNatureOfScienceInTheNextGenerationScienceStandards-4.9.13.pdf)  **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena**   * Theories and laws provide explanations in science. (HS.1.1.A),(HS.1.1.D) * Laws are statements or descriptions of the relationships among observable phenomena. (HS.1.1.A),(HS.1.1.D) | **Disciplinary Core Ideas**  [**PS2.A**](https://www.nap.edu/read/13165/chapter/9#114)**: Forces and Motion**   * C:\Users\sara.cooper.NDE\Desktop\Standards\NebraskaConnection.pngNewton’s second law accurately predicts changes in the motion of macroscopic objects. (HS.1.1.A)   Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (HS.1.1.B)   * If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. (HS.1.1.B),(HS.1.1.C)   [**PS2.B**](https://www.nap.edu/read/13165/chapter/9#116)**: Types of Interactions**   * C:\Users\sara.cooper.NDE\Desktop\Standards\NebraskaConnection.pngNewton’s law of universal gravitation and Coulomb’s law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (HS.1.1.D)   Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. (HS.1.1.D),(HS.1.1.E)  [**PS3.A**](https://www.nap.edu/read/13165/chapter/9#120)**: Definitions of Energy**   * “Electrical energy” may mean energy stored in a battery or energy transmitted by electric currents. *(secondary to HS.1.1.E)*   [**ETS1.A**](https://www.nap.edu/read/13165/chapter/12#204)**: Defining and Delimiting Engineering Problems**  C:\Users\sara.cooper.NDE\Desktop\Standards\EngineeringConnection'.pngCriteria 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 HS.1.1.C)*  C:\Users\sara.cooper.NDE\Desktop\Standards\EngineeringConnection'.png[**ETS1.C**](https://www.nap.edu/read/13165/chapter/12#208)**: 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 HS.1.1.C)* | **Crosscutting Concepts**  C:\Users\sara.cooper.NDE\Desktop\Standards\Patterns.png**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. (HS.1.1.D)  C:\Users\sara.cooper.NDE\Desktop\Standards\CauseEffect.png**Cause and Effect**  Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS.1.1.A),(HS.1.1.E)   * Systems can be designed to cause a desired effect. (HS.1.1.C)   **Systems and System Models**  C:\Users\sara.cooper.NDE\Desktop\Standards\Systems.pngWhen investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (HS.1.1.B) |
| *Connections to other DCIs in this grade-band:* **HS.PS3.A** (HS.1.1.D),(HS.1.1.E); **HS.PS3.C** (HS.1.1.A); **HS.PS4.B** (HS.1.1.E); **HS.ESS1.A** (HS.1.1.A),(HS.1.1.B),(HS.1.1.D); **HS.ESS1.B** (HS.1.1.D); **HS.ESS2.A** (HS.1.1.E); **HS.ESS1.C** (HS.1.1.A),(HS.1.1.B),(HS.1.1.D); **HS.ESS2.C** (HS.1.1.A),(HS.1.1.D); **HS.ESS3.A** (HS.1.1.D),(HS.1.1.E) | | |
| *Articulation to DCIs across grade-bands:* **MS.PS2.A** (HS.1.1.A),(HS.1.1.B),(HS.1.1.C); **MS.PS2.B** (HS.1.1.D),(HS.1.1.E); **MS.PS3.C** (HS.1.1.A),(HS.1.1.B),(HS.1.1.C); **MS.ESS1.B** (HS.1.1.D),(HS.1.1.E) | | |
| *NGSS Connections:* [Forces and Interactions](http://ngss.nsta.org/DisplayStandard.aspx?view=topic&id=42) [**HS-PS2-1**](http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=95) (HS.1.1.A); [**HS-PS2-2**](http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=96) (HS.1.1.B); [**HS-PS2-3**](http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=97) (HS.1.1.C); [**HS-PS2-4**](http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=98)(HS.1.1.D); [**HS-PS2-5**](http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=100) (HS.1.1.E) | | |
| *ELA Connections:* | | |
| *Mathematics Connections:* | | |
| *Connections:* | | |
| *Connections:* | | |

**Evidence Statements: Observable features of the student performance by the end of the course.**

|  |  |  |
| --- | --- | --- |
| **HS.1.1.A Analyze data** to support the claim that Newton's Second Law of Motion describes the mathematical relationship among the net force   on a macroscopic object, its mass, and its acceleration. | | |
| 1 | Organizing data | |
| a | Students organize data that represent the net force on a macroscopic object, its mass (which is held constant), and its acceleration (e.g., via tables, graphs, charts, vector drawings). |
| 2 | Identifying relationships | |
| a | Students use tools, technologies, and/or models to analyze the data and identify relationships within the datasets, including: |
| 1. A more massive object experiencing the same net force as a less massive object has a smaller acceleration, and a larger net force on a given object produces a correspondingly larger acceleration; and |
| 1. The result of gravitation is a constant acceleration on macroscopic objects as evidenced by the fact that the ratio of net force to mass remains constant. |
| 3 | Interpreting data | |
| a | Students use the analyzed data as evidence to describe\* that the relationship between the observed quantities is accurately modeled across the range of data by the formula a = Fnet/m (e.g., double force yields double acceleration, etc.). |
| b | Students use the data as empirical evidence to distinguish between causal and correlational relationships linking force, mass, and acceleration. |
| c | Students express the relationship Fnet=ma in terms of causality, namely that a net force on an object causes the object to accelerate. |

|  |  |  |
| --- | --- | --- |
| **HS.1.1.B Use mathematical representations** to support the claim that the total momentum of a system of objects is conserved when there is   no net force on the system. | | |
| 1 | Representation | |
| a | Students clearly define the system of the two interacting objects that is represented mathematically, including boundaries and initial conditions. |
| b | Students identify and describe\* the momentum of each object in the system as the product of its mass and its velocity, p = mv (p and v are restricted to one-dimensional vectors), using the mathematical representations. |
| c | Students identify the claim, indicating that the total momentum of a system of two interacting objects is constant if there is no net force on the system. |
| 2 | Mathematical modeling | |
| a | Students use the mathematical representations to model and describe\* the physical interaction of the two objects in terms of the change in the momentum of each object as a result of the interaction. |
| b | Students use the mathematical representations to model and describe\* the total momentum of the system by calculating the vector sum of momenta of the two objects in the system. |
| 3 | Analysis | |
| a | Students use the analysis of the motion of the objects before the interaction to identify a system with essentially no net force on it. |
| b | Based on the analysis of the total momentum of the system, students support the claim that the momentum of the system is the same before and after the interaction between the objects in the system, so that momentum of the system is constant. |
| c | Students identify that the analysis of the momentum of each object in the system indicates that any change in momentum of one object is balanced by a change in the momentum of the other object, so that the total momentum is constant. |

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| **HS.1.1.C Apply science and engineering ideas to design, evaluate, and refine** a device that minimizes the force on a macroscopic object   during a collision. | | |
| 1 | Using scientific knowledge to generate the design solution | |
| a | Students design a device that minimizes the force on a macroscopic object during a collision. In the design, students: |
| 1. Incorporate the concept that for a given change in momentum, force in the direction of the change in momentum is decreased by increasing the time interval of the collision (FΔt = mΔv); and |
| 1. Explicitly make use of the principle above so that the device has the desired effect of reducing the net force applied to the object by extending the time the force is applied to the object during the collision. |
| b | In the design plan, students describe\* the scientific rationale for their choice of materials and for the structure of the device. |
| 2 | Describing criteria and constraints, including quantification when appropriate | |
| a | Students describe\* and quantify (when appropriate) the criteria and constraints, along with the tradeoffs implicit in these design solutions. Examples of constraints to be considered are cost, mass, the maximum force applied to the object, and requirements set by society for widely used collision-mitigation devices (e.g., seatbelts, football helmets). |
| 3 | Evaluating potential solutions | |
| a | Students systematically evaluate the proposed device design or design solution, including describing\* the rationales for the design and comparing the design to the list of criteria and constraints. |
| b | Students test and evaluate the device based on its ability to minimize the force on the test object during a collision. Students identify any unanticipated effects or design performance issues that the device exhibits. |
| 4 | Refining and/or optimizing the design solution | |
| a | Students use the test results to improve the device performance by extending the impact time, reducing the device mass, and/or considering cost-benefit analysis. |

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| **HS.1.1.D Use mathematical representations** of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and   electrostatic forces between objects. | | |
| 1 | Representation | |
| a | Students clearly define the system of the interacting objects that is mathematically represented. |
| b | Using the given mathematical representations, students identify and describe\* the gravitational attraction between two objects as the product of their masses divided by the separation distance squared , where a negative force is understood to be attractive. |
| c | Using the given mathematical representations, students identify and describe\* the electrostatic force between two objects as the product of their individual charges divided by the separation distance squared , where a negative force is understood to be attractive. |
| 2 | Mathematical modeling | |
| a | Students correctly use the given mathematical formulas to predict the gravitational force between objects or predict the electrostatic force between charged objects. |
| 3 | Analysis | |
| a | Based on the given mathematical models, students describe\* that the ratio between gravitational and electric forces between objects with a given charge and mass is a pattern that is independent of distance. |
| b | Students describe\* that the mathematical representation of the gravitational field only predicts an attractive force because mass is always positive. |
| c | Students describe\* that the mathematical representation of the electric field predicts both attraction and repulsion because electric charge can be either positive or negative. |
| d | Students use the given formulas for the forces as evidence to describe\* that the change in the energy of objects interacting through electric or gravitational forces depends on the distance between the objects. |

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| **HS.1.1.E Plan and conduct an investigation** to provide evidence that an electrical current can produce a magnetic field and that a changing   magnetic field can produce an electrical current. | | |
| 1 | Identifying the phenomenon to be investigated | |
| a | Students describe\* the phenomenon under investigation, which includes the following idea: that an electric current produces a magnetic field and that a changing magnetic field produces an electric current. |
| 2 | Identifying the evidence to answer this question | |
| a | Students develop an investigation plan and describe\* the data that will be collected and the evidence to be derived from the data about 1) an observable effect of a magnetic field that is uniquely related to the presence of an electric current in the circuit, and 2) an electric current in the circuit that is uniquely related to the presence of a changing magnetic field near the circuit. Students describe\* why these effects seen must be causal and not correlational, citing specific cause-effect relationships. |
| 3 | Planning for the investigation | |
| a | In the investigation plan, students include: |
| 1. The use of an electric circuit through which electric current can flow, a source of electrical energy that can be placed in the circuit, the shape and orientation of the wire, and the types and positions of detectors; |
| 1. A means to indicate or measure when electric current is flowing through the circuit; |
| 1. A means to indicate or measure the presence of a local magnetic field near the circuit; and |
| 1. A design of a system to change the magnetic field in a nearby circuit and a means to indicate or measure when the magnetic field is changing. |
| b | In the plan, students state whether the investigation will be conducted individually or collaboratively. |
| 4 | Collecting the data | |
| a | Students measure and record electric currents and magnetic fields. |
| 5 | Refining the design | |
| a | Students evaluate their investigation, including an evaluation of: |
| 1. The accuracy and precision of the data collected, as well as limitations of the investigation; and |
| 1. The ability of the data to provide the evidence required. |
| b | If necessary, students refine the investigation plan to produce more accurate, precise, and useful data such that the measurements or indicators of the presence of an electric current in the circuit and a magnetic field near the circuit can provide the required evidence. |

**SC.HS.2 Waves and Electromagnetic Radiation**

SC.HS.2.2 Gather, analyze, and communicate evidence of the interactions of waves.

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|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\CauseEffect.png | SC.HS.2.2.A **Use mathematical representations** to support a claim regarding 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. Assessment is limited to algebraic relationships and describing those relationships qualitatively. |
|  | **C:\Users\sara.cooper.NDE\Desktop\Standards\ComputerScienceConnection.png** | C:\Users\sara.cooper.NDE\Desktop\Standards\StabilityChange.png | SC.HS.2.2.B **Evaluate questions** about the advantages of using digital transmission and storage of information. Examples of advantages could include that digital information is stable because it can be stored reliably in computer memory, transferred easily, and copied and shared rapidly. Disadvantages could include issues of easy deletion, security, and theft. |
|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\Systems.png | SC.HS.2.2.C **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, and photoelectric effect. Assessment does not include using quantum theory. |
|  | **C:\Users\sara.cooper.NDE\Desktop\Standards\ComputerScienceConnection.png** | C:\Users\sara.cooper.NDE\Desktop\Standards\CauseEffect.png | SC.HS.2.2.D **Evaluate the validity and reliability of claims** in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter. Emphasis is on the idea that photons associated with different frequencies of light have different energies, and the damage to living tissue from electromagnetic radiation depends on the energy of the radiation. Examples of published materials could include trade books, magazines, web resources, videos, and other passages that may reflect bias. Assessment is limited to qualitative descriptions. |
| **C:\Users\sara.cooper.NDE\Desktop\Standards\ComputerScienceConnection.png** | C:\Users\sara.cooper.NDE\Desktop\Standards\EngineeringConnection'.png | C:\Users\sara.cooper.NDE\Desktop\Standards\CauseEffect.png | SC.HS.2.2.E **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. Examples could include solar cells capturing light and converting it to electricity; medical imaging; and communications technology. Assessments are limited to qualitative information. Assessments do not include band theory. |

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| The performance indicators above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*: | | |
| **Science and Engineering Practices**  **Asking Questions and Defining Problems**  Asking questions and defining problems in grades 9–12 builds from grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.   * Evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design. (HS.2.2.B)   **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. (HS.2.2.A)   **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. (HS.2.2.C)   **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.   * Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible. (HS.2.2.D) * 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). (HS.2.2.E)   **-------------------------------------------------------------------**  [***Connections to Nature of Science***](http://nstahosted.org/pdfs/ngss/AppendixH-TheNatureOfScienceInTheNextGenerationScienceStandards-4.9.13.pdf)  **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. (HS.2.2.C) | **Disciplinary Core Ideas**  [**PS3.D**](https://www.nap.edu/read/13165/chapter/9#128)**: Energy in Chemical Processes**   * Solar cells are human-made devices that likewise capture the sun’s energy and produce electrical energy. *(secondary to HS.2.2.E)*   [**PS4.A**](https://www.nap.edu/read/13165/chapter/9#131)**: 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. (HS.2.2.A) * Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. (HS.2.2.B),(HS.2.2.E) * [From the 3–5 grade band endpoints] Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.) (HS.2.2.C)   [**PS4.B**](https://www.nap.edu/read/13165/chapter/9#133)**: Electromagnetic Radiation**   * Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. (HS.2.2.C) * When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells. (HS.2.2.D) * Photoelectric materials emit electrons when they absorb light of a high-enough frequency. (HS.2.2.E)   [**PS4.C**](https://www.nap.edu/read/13165/chapter/9#136)**: 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. (HS.2.2.E) | **Crosscutting Concepts**  **Cause and Effect**  C:\Users\sara.cooper.NDE\Desktop\Standards\CauseEffect.pngEmpirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS.2.2.A)   * 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. (HS.2.2.D) * Systems can be designed to cause a desired effect. (HS.2.2.E)   C:\Users\sara.cooper.NDE\Desktop\Standards\Systems.png**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. (HS.2.2.C)  **Stability and Change**  C:\Users\sara.cooper.NDE\Desktop\Standards\StabilityChange.pngSystems can be designed for greater or lesser stability. (HS.2.2.B)  C:\Users\sara.cooper.NDE\Desktop\Standards\EngineeringConnection'.png**---------------------------------------------**  ***[Connections to Engineering, Technology,](http://nstahosted.org/pdfs/ngss/20130509/AppendixJ-ScienceTechnologySocietyAndTheEnvironment_0.pdf)***  ***[and Applications of Science](http://nstahosted.org/pdfs/ngss/20130509/AppendixJ-ScienceTechnologySocietyAndTheEnvironment_0.pdf)***  **Interdependence of Science, Engineering, and Technology**   * Science and engineering complement each other in the cycle known as research and development (R&D). (HS.2.2.E)   **Influence of Engineering, Technology, and Science on Society and the Natural World**   * Modern civilization depends on major technological systems. (HS.2.2.B),(HS.2.2.E) * Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HS.2.2.B) |
| *Connections to other DCIs in this grade-band:* **HS.PS1.C** (HS.2.2.D); **HS.PS3.A** (HS.2.2.D),(HS.2.2.E); **HS.PS3.D** (HS.2.2.C),(HS.2.2.D); **HS.LS1.C** (HS.2.2.D); **HS.ESS1.A** (HS.2.2.C); **HS.ESS2.A** (HS.2.2.A); **HS.ESS2.D** ( HS.2.2.C) | | |
| *Articulation to DCIs across grade-bands:* **MS.PS3.D** (HS.2.2.D); **MS.PS4.A** (HS.2.2.A),(HS.2.2.B),(HS.2.2.E); **MS.PS4.B** (HS.2.2.A),(HS.2.2.B),( HS.2.2.C),(HS.2.2.D),(HS.2.2.E); **MS.PS4.C** (HS.2.2.B),(HS.2.2.E); **MS.LS1.C** (HS.2.2.D); **MS.ESS2.D** (HS.2.2.D) | | |
| *NGSS Connections:* [Waves and Electromagnetic Radiation](http://ngss.nsta.org/DisplayStandard.aspx?view=topic&id=44)  [**HS-PS4-1**](http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=116) (HS.2.2.A); [**HS-PS4-2**](http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=117) (HS.2.2.B); [**HS-PS4-3**](http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=118) (HS.2.2.C); [**HS-PS4-4**](http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=120) (HS.2.2.D); [**HS-PS4-5**](http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=122) (HS.2.2.E) | | |
| *ELA Connections:* | | |
| *Mathematics Connections:* | | |
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**Evidence Statements: Observable features of the student performance by the end of the course.**

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| **HS.2.2.A Use mathematical representations** to support a claim regarding relationships among the frequency, wavelength, and speed of   waves traveling in various media. | | |
| 1 | Representation | |
| a | Students identify and describe\* the relevant components in the mathematical representations: |
| 1. Mathematical values for frequency, wavelength, and speed of waves traveling in various specified media; and |
| 1. The relationships between frequency, wavelength, and speed of waves traveling in various specified media. |
| 2 | Mathematical modeling | |
| a | Students show that the product of the frequency and the wavelength of a particular type of wave in a given medium is constant, and identify this relationship as the wave speed according to the mathematical relationship . |
| b | Students use the data to show that the wave speed for a particular type of wave changes as the medium through which the wave travels changes. |
| c | Students predict the relative change in the wavelength of a wave when it moves from one medium to another (thus different wave speeds using the mathematical relationship ). Students express the relative change in terms of cause (different media) and effect (different wavelengths but same frequency). |
| 3 | Analysis | |
| a | Using the mathematical relationship , students assess claims about any of the three quantities when the other two quantities are known for waves travelling in various specified media. |
| b | Students use the mathematical relationships to distinguish between cause and correlation with respect to the supported claims. |

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| **HS.2.2.B Evaluate questions** about the advantages of using digital transmission and storage of information. | | |
| 1 | Addressing phenomena or scientific theories | |
| a | Students evaluate the given questions in terms of whether or not answers to the questions would: |
| 1. Provide examples of features associated with digital transmission and storage of information (e.g., can be stored reliably without degradation over time, transferred easily, and copied and shared rapidly; can be easily deleted; can be stolen easily by making a copy; can be broadly accessed); and |
| b | In their evaluation of the given questions, students: |
| 1. Describe\* the stability and importance of the systems that employ digital information as they relate to the advantages and disadvantages of digital transmission and storage of information; and |
| 1. Discuss the relevance of the answers to the question to real-life examples (e.g., emailing your homework to a teacher, copying music, using the internet for research, social media). |
| 2 | Evaluating empirical testability | |
|  | Students evaluate the given questions in terms of whether or not answers to the questions would provide means to empirically determine whether given features are advantages or disadvantages. |

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| **HS.2.2.C 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. | | |
| 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, and that includes the following idea: Electromagnetic radiation can be described either by a wave model or a particle model, and for some situations one model is more useful than the other. |
| b | Students identify the given claims to be evaluated. |
| c | Students identify the given evidence to be evaluated, including the following phenomena: |
| 1. Interference behavior by electromagnetic radiation; and |
| 1. The photoelectric effect. |
| d | Students identify the given reasoning to be evaluated. |
| 2 | Evaluating given evidence and reasoning | |
| a | Students evaluate the given evidence for interference behavior of electromagnetic radiation to determine how it supports the argument that electromagnetic radiation can be described by a wave model. |
| b | Students evaluate the phenomenon of the photoelectric effect to determine how it supports the argument that electromagnetic radiation can be described by a particle model. |
| c | Students evaluate the given claims and reasoning for modeling electromagnetic radiation as both a wave and particle, considering the transfer of energy and information within and between systems, and why for some aspects the wave model is more useful and for other aspects the particle model is more useful to describe the transfer of energy and information. |

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| **HS.2.2.D Evaluate the validity and reliability of claims** in published materials of the effects that different frequencies of electromagnetic   radiation have when absorbed by matter. | | |
| 1 | Obtaining information | |
| a | Students obtain at least two claims proposed in published material (using at least two sources per claim) regarding the effect of electromagnetic radiation that is absorbed by matter. One of these claims deals with the effect of electromagnetic radiation on living tissue. |
| 2 | Evaluating information | |
| a | Students use reasoning about the data presented, including the energies of the photons involved (i.e., relative wavelengths) and the probability of ionization, to analyze the validity and reliability of each claim. |
| b | Students determine the validity and reliability of the sources of the claims. |
| c | Students describe\* the cause and effect reasoning in each claim, including the extrapolations to larger scales from cause and effect relationships of mechanisms at small scales (e.g., extrapolating from the effect of a particular wavelength of radiation on a single cell to the effect of that wavelength on the entire organism). |

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| **HS.2.2.E 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. | | |
| 1 | Communication style and format | |
| a | Students use at least two different formats (e.g., oral, graphical, textual, and mathematical) to communicate technical information and ideas, including fully describing\* at least two devices and the physical principles upon which the devices depend. One of the devices must depend on the photoelectric effect for its operation. Students cite the origin of the information as appropriate. |
| 2 | Connecting the DCIs and the CCCs | |
| a | When describing\* how each device operates, students identify the wave behavior utilized by the device or the absorption of photons and production of electrons for devices that rely on the photoelectric effect, and qualitatively describe\* how the basic physics principles were utilized in the design through research and development to produce this functionality (e.g., absorbing electromagnetic energy and converting it to thermal energy to heat an object; using the photoelectric effect to produce an electric current). |
| b | For each device, students discuss the real-world problem it solves or need it addresses, and how civilization now depends on the device. |
| c | Students identify and communicate the cause and effect relationships that are used to produce the functionality of the device. |

**SC.HS.3 Structure and Properties of Matter**

SC.HS.3.3 Gather, analyze, and communicate evidence of the structure, properties, and interactions of matter.

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|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\Patterns.png | SC.HS.3.3.A **Use the periodic table as a model** to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms. Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen. Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends. | |
| C:\Users\sara.cooper.NDE\Desktop\Standards\NebraskaConnection.png | *NE Geology* |
|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\Patterns.png | SC.HS.3.3.B **Plan and conduct an investigation** to gather evidence to compare the structure of substances at the macro scale to infer the strength of electrical forces between particles. Emphasis is on understanding the strengths of forces between particles, not on naming specific intermolecular forces (such as dipole-dipole). Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite). Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension. Assessment does not include Raoult’s law calculations of vapor pressure. | |
|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\EnergyMatter.png | SC.HS.3.3.C **Develop models** to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay. Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations. Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays. | |
| C:\Users\sara.cooper.NDE\Desktop\Standards\NebraskaConnection.png | *NE Geologic history and nuclear power production* |
|  | C:\Users\sara.cooper.NDE\Desktop\Standards\EngineeringConnection'.png | **C:\Users\sara.cooper.NDE\Desktop\Standards\StructureFunction.png** | SC.HS.3.3.D **Communicate scientific and technical information** about why the molecular-level structure is important in the functioning of designed materials. Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors. Assessment is limited to provided molecular structures of specific designed materials. | |
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| The performance indicators above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*: | | |
| **Science and Engineering Practices**  **Developing and Using Models**  Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.   * Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS.3.3.C) * Use a model to predict the relationships between systems or between components of a system. (HS.3.3.A)   **Planning and Carrying Out Investigations**  Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.   * Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS.3.3.B)   **Obtaining, Evaluating, and Communicating Information**  Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.   * Communicate scientific and technical information (e.g. about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS.3.3.D) | **Disciplinary Core Ideas**  [**PS1.A**](https://www.nap.edu/read/13165/chapter/9#106)**: Structure and Properties of Matter**   * Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. (HS.3.3.A)   C:\Users\sara.cooper.NDE\Desktop\Standards\NebraskaConnection.pngThe periodic table orders elements horizontally by the number of protons in the atom’s nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.   (HS.3.3.A)   * The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (HS.3.3.B),*(secondary to HS.3.3.D)*   [**PS1.C**](https://www.nap.edu/read/13165/chapter/9#111)**: Nuclear Processes**  C:\Users\sara.cooper.NDE\Desktop\Standards\NebraskaConnection.png Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process. (HS.3.3.C)  [**PS2.B**](https://www.nap.edu/read/13165/chapter/9#116)**: Types of Interactions**  Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. *(secondary to HS.3.3.A),(secondary to HS.3.3.B),*(HS.3.3.D) | **Crosscutting Concepts**  C:\Users\sara.cooper.NDE\Desktop\Standards\Patterns.png**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. (HS.3.3.A),(HS.3.3.B)  C:\Users\sara.cooper.NDE\Desktop\Standards\EnergyMatter.png**Energy and Matter**  In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HS.3.3.C)  **C:\Users\sara.cooper.NDE\Desktop\Standards\StructureFunction.pngStructure and Function**  Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. (HS.3.3.D) |
| *Connections to other DCIs in this grade-band:* **HS.PS3.A** (HS.3.3.C); **HS.PS3.B** (HS.3.3.C); **HS.PS3.C** (HS.3.3.C); **HS.PS3.D** (HS.3.3.C); **HS.LS1.C** (HS.3.3.A); **HS.ESS1.A** (HS.3.3.C); **HS.ESS1.C** (HS.3.3.C); **HS.ESS2.C** (HS.3.3.B) | | |
| *Articulation to DCIs across grade-bands:* **MS.PS1.A** (HS.3.3.A),(HS.3.3.B),(HS.3.3.C),(HS.3.3.D); **MS.PS1.B** (HS.3.3.A),(HS.3.3.C); **MS.PS1.C** (HS.3.3.C); **MS.PS2.B** (HS.3.3.B),(HS.3.3.D); **MS.ESS2.A** (HS.3.3.C) | | |
| *NGSS Connections:* [Structure and Properties of Matter](http://ngss.nsta.org/DisplayStandard.aspx?view=topic&id=40) [**HS-PS1-1**](http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=85) (HS.3.3.A); [**HS-PS1-3**](http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=87)(HS.3.3.B); [**HS-PS1-8**](http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=92)(HS.3.3.C); [**HS-PS2-6**](http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=101) (HS.3.3.D) | | |
| *ELA Connections:* | | |
| *Mathematics Connections:* | | |
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| *Connections:* | | |

**Evidence Statements: Observable features of the student performance by the end of the course.**

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| **HS.3.3.A** **Use the periodic table as a model** to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of   atoms. | | |
| 1 | Components of the model | |
| a | From the given model, students identify and describe\* the components of the model that are relevant for their predictions, including: |
| 1. Elements and their arrangement in the periodic table; |
| 1. A positively-charged nucleus composed of both protons and neutrons, surrounded by negatively-charged electrons; |
| 1. Electrons in the outermost energy level of atoms (i.e., valence electrons); and |
| 1. The number of protons in each element. |
| 2 | Relationships | |
| a | Students identify and describe\* the following relationships between components in the given model, including: |
| 1. The arrangement of the main groups of the periodic table reflects the patterns of outermost electrons. |
| 1. Elements in the periodic table are arranged by the numbers of protons in atoms. |
| 3 | Connections | |
| a | Students use the periodic table to predict the patterns of behavior of the elements based on the attraction and repulsion between electrically charged particles and the patterns of outermost electrons that determine the typical reactivity of an atom. |
| b | Students predict the following patterns of properties: |
| 1. The number and types of bonds formed (i.e. ionic, covalent, metallic) by an element and between elements; |
| 1. The number and charges in stable ions that form from atoms in a group of the periodic table; |
| 1. The trend in reactivity and electronegativity of atoms down a group, and across a row in the periodic table, based on attractions of outermost (valence) electrons to the nucleus; and |
| 1. The relative sizes of atoms both across a row and down a group in the periodic table. |

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| **HS.3.3.B Plan and conduct an investigation** to gather evidence to compare the structure of substances at the macro scale to infer the strength of electrical   forces between particles. | | |
| 1 | Identifying the phenomenon to be investigated | |
| a | Students describe\* the phenomenon under investigation, which includes the following idea: the relationship between the measurable properties (e.g., melting point, boiling point, vapor pressure, surface tension) of a substance and the strength of the electrical forces between the particles of the substance. |
| 2 | Identifying the evidence to answer this question | |
| a | Students develop an investigation plan and describe\* the data that will be collected and the evidence to be derived from the data, including bulk properties of a substance (e.g., melting point and boiling point, volatility, surface tension) that would allow inferences to be made about the strength of electrical forces between particles. |
| b | Students describe\* why the data about bulk properties would provide information about strength of the electrical forces between the particles of the chosen substances, including the following descriptions\*: |
| 1. The spacing of the particles of the chosen substances can change as a result of the experimental procedure even if the identity of the particles does not change (e.g., when water is boiled the molecules are still present but further apart). |
| 1. Thermal (kinetic) energy has an effect on the ability of the electrical attraction between particles to keep the particles close together. Thus, as more energy is added to the system, the forces of attraction between the particles can no longer keep the particles close together. |
|  |  | 1. The patterns of interactions between particles at the molecular scale are reflected in the patterns of behavior at the macroscopic scale. |
|  |  | 1. Together, patterns observed at multiple scales can provide evidence of the causal relationships between the strength of the electrical forces between particles and the structure of substances at the bulk scale. |
| 3 | Planning for the investigation | |
| a | In the investigation plan, students include: |
| 1. A rationale for the choice of substances to compare and a description\* of the composition of those substances at the atomic molecular scale. |
| 1. 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. |
| 4 | Collecting the data | |
| a | Students collect and record data — quantitative and/or qualitative — on the bulk properties of substances. |
| 5 | Refining the design | |
| a | Students evaluate their investigation, including evaluation of: |
| 1. Assessing the accuracy and precision of the data collected, as well as the limitations of the investigation; and |
| 1. 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. |

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| **HS.3.3.C Develop models** to illustrate the changes in the composition of the nucleus of the atom and the energy released during the   processes of fission, fusion, and radioactive decay. | | |
| 1 | Components of the model | |
| a | Students develop models in which they identify and describe\* the relevant components of the models, including: |
| 1. Identification of an element by the number of protons; |
| 1. The number of protons and neutrons in the nucleus before and after the decay; |
| 1. The identity of the emitted particles (i.e., alpha, beta — both electrons and positrons, and gamma); and |
| 1. The scale of energy changes associated with nuclear processes, relative to the scale of energy changes associated with chemical processes. |
| 2 | Relationships | |
| a | Students develop five distinct models to illustrate the relationships between components underlying the nuclear processes of 1) fission, 2) fusion and 3) three distinct types of radioactive decay. |
| b | Students include the following features, based on evidence, in all five models: |
| 1. The total number of neutrons plus protons is the same both before and after the nuclear process, although the total number of protons and the total number of neutrons may be different before and after. |
| 1. The scale of energy changes in a nuclear process is much larger (hundreds of thousands or even millions of times larger) than the scale of energy changes in a chemical process. |
| 3 | Connections | |
| a | Students develop a fusion model that illustrates a process in which two nuclei merge to form a single, larger nucleus with a larger number of protons than were in either of the two original nuclei. |
| b | Students develop a fission model that illustrates a process in which a nucleus splits into two or more fragments that each have a smaller number of protons than were in the original nucleus. |
| c | In both the fission and fusion models, students illustrate that these processes may release energy and may require initial energy for the reaction to take place. |
| d | Students develop radioactive decay models that illustrate the differences in type of energy (e.g., kinetic energy, electromagnetic radiation) and type of particle (e.g., alpha particle, beta particle) released during alpha, beta, and gamma radioactive decay, and any change from one element to another that can occur due to the process. |
| e | Students develop radioactive decay models that describe\* that alpha particle emission is a type of fission reaction, and that beta and gamma emission are not. |

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| **HS.3.3.D Communicate scientific and technical information** about why the molecular-level structure is important in the functioning of designed materials. | | |
| 1 | |  | | --- | | Communication style and format | | |
| a | Students use at least two different formats (including oral, graphical, textual and mathematical) to communicate scientific and technical information, including fully describing\* the structure, properties, and design of the chosen material(s). Students cite the origin of the information as appropriate. |
| 2 | Connecting the DCIs and the CCCs | |
| a | Students identify and communicate the evidence for why molecular level structure is important in the functioning of designed materials, including: |
| i. How the structure and properties of matter and the types of interactions of matter at the atomic scale determine the function of the chosen designed material(s); and |
| ii. How the material’s properties make it suitable for use in its designed function. |
| b | Students explicitly identify the molecular structure of the chosen designed material(s) (using a representation appropriate to the specific type of communication — e.g., geometric shapes for drugs and receptors, ball and stick models for long-chained molecules). |
|  | c | Students describe\* the intended function of the chosen designed material(s). |
|  | d | Students describe\* the relationship between the material’s function and its macroscopic properties (e.g., material strength, conductivity, reactivity, state of matter, durability) and each of the following: |
| i. Molecular level structure of the material; |
| ii. Intermolecular forces and polarity of molecules; and |
| iii. The ability of electrons to move relatively freely in metals. |
|  | e | Students describe\* the effects that attractive and repulsive electrical forces between molecules have on the arrangement (structure) of the chosen designed material(s) of molecules (e.g., solids, liquids, gases, network solid, polymers). |
|  | f | Students describe\* that, for all materials, electrostatic forces on the atomic and molecular scale results in contact forces (e.g., friction, normal forces, stickiness) on the macroscopic scale. |

**SC.HS.4 Energy**

SC.HS.4.4 Gather, analyze, and communicate evidence of the interactions of energy.

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|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\Systems.png | SC.HS.4.4.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. 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. | |
|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\EnergyMatter.png | SC.HS.4.4.B **Develop and use models** to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative positions of particles (objects). Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically-charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations. | |
|  | C:\Users\sara.cooper.NDE\Desktop\Standards\EngineeringConnection'.png | C:\Users\sara.cooper.NDE\Desktop\Standards\EnergyMatter.png | SC.HS.4.4.C **Design, build, and refine a device** that works within given constraints to convert one form of energy into another form of energy. Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency. Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students. | |
| C:\Users\sara.cooper.NDE\Desktop\Standards\NebraskaConnection.png | *NE energy producers* |
|  | C:\Users\sara.cooper.NDE\Desktop\Standards\EngineeringConnection'.png |  | SC.HS.4.4.D **Analyze a major global challenge** to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants. | |
|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\Systems.png | SC.HS.4.4.E **Plan and conduct an investigation** to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics). Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water. Assessment is limited to investigations based on materials and tools provided to students. | |
|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\CauseEffect.png | SC.HS.4.4.F **Develop and use a model** of two objects interacting through electrical 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. | |

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| The performance indicators above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*: | | |
| **Science and Engineering Practices**  **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 evidenceto illustrate the relationships between systems or between components of a system. (HS.4.4.B),(HS.4.4.F)   **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. (HS.4.4.E)   **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. (HS.4.4.A)   **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. (HS.4.4.C)   **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. (HS.4.4.D) | **Disciplinary Core Ideas**  [**PS3.A**](https://www.nap.edu/read/13165/chapter/9#120)**: 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. (HS.4.4.A),(HS.4.4.B)   C:\Users\sara.cooper.NDE\Desktop\Standards\NebraskaConnection.pngAt the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HS.4.4.B) (HS.4.4.C)   * These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. (HS.4.4.B)   [**PS3.B**](https://www.nap.edu/read/13165/chapter/9#124)**: 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. (HS.4.4.A) * Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS.4.4.A),(HS.4.4.E) * Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (HS.4.4.A) * The availability of energy limits what can occur in any system. (HS.4.4.A) * 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). (HS.4.4.E)   [**PS3.C**](https://www.nap.edu/read/13165/chapter/9#126)**: Relationship Between Energy and Forces**   * When two objects interacting through a field change relative position, the energy stored in the field is changed. (HS.4.4.F)   [**PS3.D**](https://www.nap.edu/read/13165/chapter/9#128)**: 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. (HS.4.4.C),(HS.4.4.E)   [**ETS1.A**](https://www.nap.edu/read/13165/chapter/12#204)**: 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. (HS.4.4.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. (HS.4.4.D) | **Crosscutting Concepts**  C:\Users\sara.cooper.NDE\Desktop\Standards\CauseEffect.png**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. (HS.4.4.F)  C:\Users\sara.cooper.NDE\Desktop\Standards\Systems.png**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. (HS.4.4.E)   * 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. (HS.4.4.A)   C:\Users\sara.cooper.NDE\Desktop\Standards\EnergyMatter.png**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. (HS.4.4.C)   * Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems. (HS.4.4.B)   C:\Users\sara.cooper.NDE\Desktop\Standards\EngineeringConnection'.png**-----------------------------------------------------**  [***Connections to Engineering, Technology, and Applications of Science***](http://nstahosted.org/pdfs/ngss/20130509/AppendixJ-ScienceTechnologySocietyAndTheEnvironment_0.pdf)  **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. (HS.4.4.C) * Science assumes the universe is a vast single system in which basic laws are consistent. (HS.4.4.A)   **-------------------------------------------------------**  [***Connections to Nature of Science***](http://nstahosted.org/pdfs/ngss/AppendixH-TheNatureOfScienceInTheNextGenerationScienceStandards-4.9.13.pdf)  **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. (HS.4.4.A) |
| *Connections to other DCIs in this grade-band:* **HS.PS1.A** (HS.4.4.B); **HS.PS1.B** (HS.4.4.A),(HS.4.4.B); **HS.PS2.B** (HS.4.4.B),(HS.4.4.F); **HS.LS2.B** (HS.4.4.A); **HS.ESS1.A** (HS.4.4.A),(HS.4.4.E); **HS.ESS2.A** (HS.4.4.A),(HS.4.4.B),(HS.4.4.E); **HS.ESS2.D** (HS.4.4.E); **HS.ESS3.A** (HS.4.4.C)  *Connections to HS-ETS1.A: Defining and Delimiting Engineering Problems include:* **Physical Science:** HS.1.1.C | | |
| *Articulation to DCIs across grade-bands:* **MS.PS1.A** (HS.4.4.B); **MS.PS2.B** (HS.4.4.B),(HS.4.4.F); **MS.PS3.A** (HS.4.4.A),(HS.4.4.B),(HS.4.4.C); **MS.PS3.B** (HS.4.4.A),(HS.4.4.C),(HS.4.4.E); **MS.PS3.C** (HS.4.4.B),(HS.4.4.F); **MS.ESS2.A** (HS.4.4.A),(HS.4.4.C); **MS.ETS1.A** (HS.4.4.D) | | |
| *NGSS Connections:* [Energy](http://ngss.nsta.org/DisplayStandard.aspx?view=topic&id=43) [**HS-PS3-1**](http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=105)(HS.4.4.A); [**HS-PS3-2**](http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=106) (HS.4.4.B); [**HS-PS3-3**](http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=107) (HS.4.4.C); [**HS-PS3-4**](http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=108) (HS.4.4.E); [**HS-PS3-5**](http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=109)(HS.4.4.F)  [Engineering Design](http://ngss.nsta.org/DisplayStandard.aspx?view=topic&id=55) [**HS-ETS1-1**](http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=202) (HS.4.4.D) | | |
| *ELA Connections:* | | |
| *Mathematics* | | |
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**Evidence Statements: Observable features of the student performance by the end of the course.**

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| **HS.4.4.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. | | |
| 1 | Representation | |
| a | Students identify and describe\* the components to be computationally modeled, including: |
| 1. The boundaries of the system and that the reference level for potential energy = 0 (the potential energy of the initial or final state does not have to be zero); |
| 1. The initial energies of the system’s components (e.g., energy in fields, thermal energy, kinetic energy, energy stored in springs — all expressed as a total amount of Joules in each component), including a quantification in an algebraic description to calculate the total initial energy of the system; |
| 1. The energy flows in or out of the system, including a quantification in an algebraic description with flow into the system defined as positive; and |
| 1. The final energies of the system components, including a quantification in an algebraic description to calculate the total final energy of the system. |
| 2 | Computational Modeling | |
| a | Students use the algebraic descriptions of the initial and final energy state of the system, along with the energy flows to create a computational model (e.g., simple computer program, spreadsheet, simulation software package application) that is based on the principle of the conservation of energy. |
| b | Students use the computational model to calculate changes in the energy of one component of the system when changes in the energy of the other components and the energy flows are known. |
| 3 | Analysis | |
| a | Students use the computational model to predict the maximum possible change in the energy of one component of the system for a given set of energy flows. |
| b | Students identify and describe\* the limitations of the computational model, based on the assumptions that were made in creating the algebraic descriptions of energy changes and flows in the system. |

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| **HS.4.4.B Develop and use models** to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy   associated with the motion of particles (objects) and energy associated with the relative positions of particles (objects). | | |
| 1 | Components of the model | |
| a | Students develop models in which they identify and describe\* the relevant components, including: |
| 1. All the components of the system and the surroundings, as well as energy flows between the system and the surroundings; |
| 1. Clearly depicting both a macroscopic and a molecular/atomic-level representation of the system; and |
| 1. Depicting the forms in which energy is manifested at two different scales: |
| 1. Macroscopic , such as motion, sound, light, thermal energy, potential energy or energy in fields; and |
| 1. Molecular/atomic, such as motions (kinetic energy) of particles (e.g., nuclei and electrons), the relative positions of particles in fields (potential energy), and energy in fields. |
| 2 | Relationships | |
| a | Students describe\* the relationships between components in their models, including: |
| 1. Changes in the relative position of objects in gravitational, magnetic or electrostatic fields can affect the energy of the fields (e.g., charged objects moving away from each other change the field energy). |
| 1. Thermal energy includes both the kinetic and potential energy of particle vibrations in solids or molecules and the kinetic energy of freely moving particles (e.g., inert gas atoms, molecules) in liquids and gases. |
| 1. The total energy of the system and surroundings is conserved at a macroscopic and molecular/atomic level. |
| 1. Chemical energy can be considered in terms of systems of nuclei and electrons in electrostatic fields (bonds). |
| 1. As one form of energy increases, others must decrease by the same amount as energy is transferred among and between objects and fields. |
| 3 | Connections | |
| a | Students use their models to show that in closed systems the energy is conserved on both the macroscopic and molecular/atomic scales so that as one form of energy changes, the total system energy remains constant, as evidenced by the other forms of energy changing by the same amount or changes only by the amount of energy that is transferred into or out of the system. |
| b | Students use their models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles/objects and energy associated with the relative positions of particles/objects on both the macroscopic and microscopic scales. |

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| **HS.4.4.C Design, build, and refine a device** that works within given constraints to convert one form of energy into another form of energy. | | |
| 1 | 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: |
| 1. Identify what scientific principles provide the basis for the energy conversion design; |
| 1. Identify the forms of energy that will be converted from one form to another in the designed system; |
| 1. Identify losses of energy by the design system to the surrounding environment; |
| 1. Describe\* the scientific rationale for choices of materials and structure of the device, including how student-generated evidence influenced the design; and |
| 1. 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. |
| 2 | 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. |
| 3 | 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. |
| 4 | 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. |

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| **HS.4.4.D 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: |
| 1. Describe\* the challenge with a rationale for why it is a major global challenge; |
| 1. 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 |
| 1. Document background research on the problem from two or more sources, including research journals. |
| 2 | Defining the process or system boundaries, and the components of the process or system | |
| a | In their analysis, students identify the physical system in which the problem is embedded, including the major elements and relationships in the system and boundaries so as to clarify what is and is not part of the problem. |
| b | In their analysis, students describe\* societal needs and wants that are relative to the problem (e.g., for controlling CO2 emissions, societal needs include the need for cheap energy). |
| 3 | Defining the criteria and constraints | |
| a | Students specify qualitative and quantitative criteria and constraints for acceptable solutions to the problem. |

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| **HS.4.4.E Plan and conduct an investigation** to provide evidence that the transfer of thermal energy when two components of different   temperature are combined within a closed system results in a more uniform energy distribution among the components in the system   (second law of thermodynamics). | | |
| 1 | Identifying the phenomenon to be investigated | |
| a | Students describe\* the purpose of the investigation, which includes the following idea, that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics). |
| 2 | Identifying the evidence to answer this question | |
| a | Students develop an investigation plan and describe\* the data that will be collected and the evidence to be derived from the data, including: |
| 1. The measurement of the reduction of temperature of the hot object and the increase in temperature of the cold object to show that the thermal energy lost by the hot object is equal to the thermal energy gained by the cold object and that the distribution of thermal energy is more uniform after the interaction of the hot and cold components; and |
| 1. The heat capacity of the components in the system (obtained from scientific literature). |
| 3 | Planning for the investigation | |
| a | In the investigation plan, students describe\*: |
| 1. How a nearly closed system will be constructed, including the boundaries and initial conditions of the system; |
| 1. The data that will be collected, including masses of components and initial and final temperatures; and |
| 1. The experimental procedure, including how the data will be collected, the number of trials, the experimental set up, and equipment required. |
| 4 | Collecting the data | |
| a | Students collect and record data that can be used to calculate the change in thermal energy of each of the two components of the system. |
| 5 | Refining the design | |
| a | Students evaluate their investigation, including: |
| 1. The accuracy and precision of the data collected, as well as the limitations of the investigation; and |
| 1. The ability of the data to provide the evidence required. |
| b | If necessary, students refine the plan to produce more accurate, precise, and useful data that address the experimental question. |
| c | Students identify potential causes of the apparent loss of energy from a closed system (which should be zero in an ideal system) and adjust the design of the experiment accordingly. |

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| **HS.4.4.F Develop and use a model** of two objects interacting through electrical or magnetic fields to illustrate the forces between objects and   the changes in energy of the objects due to the interaction. | | |
| 1 | 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: |
| 1. The two objects in the system, including their initial positions and velocities (limited to one dimension). |
| 1. The nature of the interaction (electric or magnetic) between the two objects. |
| 1. The relative magnitude and the direction of the net force on each of the objects. |
| 1. Representation of a field as a quantity that has a magnitude and direction at all points in space and which contains energy. |
| 2 | 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. |
| 3 | 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 qualitative level between forces produced by electric or magnetic fields and the change of energy of the objects in the system. |

**SC.HS.5 Chemical Reactions**

SC.HS.5.5 Gather, analyze, and communicate evidence of chemical reactions.

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|  | **C:\Users\sara.cooper.NDE\Desktop\Standards\ComputerScienceConnection.png** | C:\Users\sara.cooper.NDE\Desktop\Standards\Patterns.png | SC.HS.5.5.A **Construct and revise an explanation** for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen. Assessment is limited to chemical reactions involving main group elements and combustion reactions. | |
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|  | **C:\Users\sara.cooper.NDE\Desktop\Standards\ComputerScienceConnection.png** | C:\Users\sara.cooper.NDE\Desktop\Standards\EnergyMatter.png | SC.HS.5.5.B **Develop a model** to illustrate that the release or absorption of energy from a chemical reaction system depends on the changes in total bond energy. Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved. Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products. | |
| C:\Users\sara.cooper.NDE\Desktop\Standards\NebraskaConnection.png | *NE energy and ethanol production* |
|  | **C:\Users\sara.cooper.NDE\Desktop\Standards\ComputerScienceConnection.png** | C:\Users\sara.cooper.NDE\Desktop\Standards\Patterns.png | SC.HS.5.5.C **Apply scientific principles** and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs. Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules. Assessment is limited to simple reactions in which there are only two reactants; evidence from temperature, concentration, and rate data; and qualitative relationships between rate and temperature. | |
| C:\Users\sara.cooper.NDE\Desktop\Standards\NebraskaConnection.png | *NE energy and ethanol production* |
|  | C:\Users\sara.cooper.NDE\Desktop\Standards\EngineeringConnection'.png | C:\Users\sara.cooper.NDE\Desktop\Standards\StabilityChange.png | SC.HS.5.5.D **Refine the design** of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium. Emphasis is on the application of Le Chatelier’s Principle and on refining designs of chemical reaction systems, including descriptions of the connection between changes made at the macroscopic level and what happens at the molecular level. Examples of designs could include different ways to increase product formation including adding reactants or removing products. Assessment is limited to specifying the change in only one variable at a time. Assessment does not include calculating equilibrium constants and concentrations. | |
| C:\Users\sara.cooper.NDE\Desktop\Standards\NebraskaConnection.png | *NE energy and ethanol production* |
|  |  |  | SC.HS.5.5.E **Design a solution** to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. | |
|  | **C:\Users\sara.cooper.NDE\Desktop\Standards\ComputerScienceConnection.png** | C:\Users\sara.cooper.NDE\Desktop\Standards\EnergyMatter.png | SC.HS.5.5.F **Use mathematical representations** to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students’ use of mathematical thinking and not on memorization and rote application of problem-solving techniques. Assessment does not include complex chemical reactions. | |
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| The performance indicators above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*: | | |
| **Science and Engineering Practices**  **Developing and Using Models**  Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.   * Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS.5.5.B)   **Using Mathematics and Computational Thinking**  Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.   * Use mathematical representations of phenomena to support claims. (HS.5.5.F)   **Constructing Explanations and Designing Solutions**  Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.   * Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. (HS.5.5.C) * Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students’ own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS.5.5.A) * Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS.5.5.D) * Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS.5.5.E) | **Disciplinary Core Ideas**  [**PS1.A**](https://www.nap.edu/read/13165/chapter/9#106)**: Structure and Properties of Matter**   * The periodic table orders elements horizontally by the number of protons in the atom’s nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. (HS.5.5.A) *(Note: This Disciplinary Core Idea is also addressed by HS.3.3.A.)*   C:\Users\sara.cooper.NDE\Desktop\Standards\NebraskaConnection.pngA stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. (HS.5.5.B)  C:\Users\sara.cooper.NDE\Desktop\Standards\NebraskaConnection.png[**PS1.B**](https://www.nap.edu/read/13165/chapter/9#109)**: Chemical Reactions**  Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. (HS.5.5.B),(HS.5.5.C)   * In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. (HS.5.5.D) * The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. (HS.5.5.A),(HS.5.5.F)   [**ETS1.C**](https://www.nap.edu/read/13165/chapter/12#208)**: 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. (HS.5.5.E) | **Crosscutting Concepts**  **Patterns**  C:\Users\sara.cooper.NDE\Desktop\Standards\Patterns.pngDifferent 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. (HS.5.5.A),(HS.5.5.C)  C:\Users\sara.cooper.NDE\Desktop\Standards\EnergyMatter.png**Energy and Matter**  The total amount of energy and matter in closed systems is conserved. (HS.5.5.F)   * 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. (HS.5.5.B)   C:\Users\sara.cooper.NDE\Desktop\Standards\StabilityChange.png**Stability and Change**  Much of science deals with constructing explanations of how things change and how they remain stable. (HS.5.5.D)  **--------------------------------------------------**  [***Connections to Nature of Science***](http://nstahosted.org/pdfs/ngss/AppendixH-TheNatureOfScienceInTheNextGenerationScienceStandards-4.9.13.pdf)  **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. (HS.5.5.F) |
| *Connections to other DCIs in this grade-band:* **HS.PS3.A** (HS.5.5.B),(HS.5.5.C); **HS.PS3.B** (HS.5.5.B),(HS.5.5.D),(HS.5.5.F); **HS.PS3.D** (HS.5.5.B); **HS.LS1.C** (HS.5.5.A),(HS.5.5.B),(HS.5.5.F); **HS.LS2.B** (HS.5.5.F); **HS.ESS2.C** (HS.5.5.A) *Connections to HS-ETS1.C: Optimizing the Design Solution include:*  **Physical Science:** HS.5.5.D, HS.1.1.C | | |
| *Articulation to DCIs across grade-bands:* **MS.PS1.A** (HS.5.5.A),(HS.5.5.B),(HS.5.5.C),(HS.5.5.F); **MS.PS1.B** (HS.5.5.A),(HS.5.5.B),(HS.5.5.C),(HS.5.5.D),(HS.5.5.F); **MS.PS2.B** (HS.3.3.B),(HS.5.5.B),(HS.5.5.C); **MS.PS3.A** (HS.5.5.C); **MS.PS3.B** (HS.5.5.C); **MS.PS3.D** (HS.5.5.B); **MS.LS1.C** (HS.5.5.B),(HS.5.5.F); **MS.LS2.B** (HS.5.5.F); **MS.ESS2.A** (HS.5.5.F); **MS.ETS1.A** (HS.5.5.E); **MS.ETS1.B** (HS.5.5.E); **MS.ETS1.C** (HS.5.5.E) | | |
| *NGSS Connections:* [Chemical Reactions](http://ngss.nsta.org/DisplayStandard.aspx?view=topic&id=41) [**HS-PS1-2**](http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=86) **(**HS.5.5.A); [**HS-PS1-4**](http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=88) (HS.5.5.B); [**HS-PS1-5**](http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=89) (HS.5.5.C); [**HS-PS1-6**](http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=90) (HS.5.5.D); [**HS-PS1-7**](http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=91)(HS.5.5.F) [Engineering Design](http://ngss.nsta.org/DisplayStandard.aspx?view=topic&id=55) [**HS-ETS1-2**](http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=203)(HS.5.5.E) | | |
| *ELA Connections:* | | |
| *Mathematics Connections:* | | |
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**Evidence Statements: Observable features of the student performance by the end of the course.**

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| **HS.5.5.A Construct and revise an explanation** for the outcome of a simple chemical reaction based on the outermost electron states of   atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. | | |
| 1 | Articulating the explanation of phenomena | |
| a | Students construct an explanation of the outcome of the given reaction, including: |
| 1. The idea that the total number of atoms of each element in the reactant and products is the same; |
| 1. The numbers and types of bonds (i.e., ionic, covalent) that each atom forms, as determined by the outermost (valence) electron states and the electronegativity; |
| 1. The outermost (valence) electron state of the atoms that make up both the reactants and the products of the reaction is based on their position in the periodic table; and |
| 1. A discussion of how the patterns of attraction allow the prediction of the type of reaction that occurs (e.g., formation of ionic compounds, combustion of hydrocarbons). |
| 2 | Evidence | |
| a | Students identify and describe\* the evidence to construct the explanation, including: |
| 1. Identification of the products and reactants, including their chemical formulas and the arrangement of their outermost (valence) electrons; |
| 1. Identification that the number and types of atoms are the same both before and after a reaction; |
| 1. Identification of the numbers and types of bonds (i.e., ionic, covalent) in both the reactants and the products; |
| 1. The patterns of reactivity (e.g., the high reactivity of alkali metals) at the macroscopic level as determined by using the periodic table; and |
| 1. The outermost (valence) electron configuration and the relative electronegativity of the atoms that make up both the reactants and the products of the reaction based on their position in the periodic table. |
| 3 | Reasoning | |
| a | Students describe\* their reasoning that connects the evidence, along with the assumption that theories and laws that describe their natural world operate today as they did in the past and will continue to do so in the future, to construct an explanation for how the patterns of outermost electrons and the electronegativity of elements can be used to predict the number and types of bonds each element forms. |
| b | In the explanation, students describe\* the causal relationship between the observable macroscopic patterns of reactivity of elements in the periodic table and the patterns of outermost electrons for each atom and its relative electronegativity. |
| 4 | Revising the explanation | |
| a | Given new evidence or context, students construct a revised or expanded explanation about the outcome of a chemical reaction and justify the revision. |

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| **HS.5.5.B Develop a model** to illustrate that the release or absorption of energy from a chemical reaction system depends on the changes in   total bond energy. | | |
| 1 | Components of the model | |
| a | Students use evidence to develop a model in which they identify and describe\* the relevant components, including: |
| 1. The chemical reaction, the system, and the surroundings under study; |
| 1. The bonds that are broken during the course of the reaction; |
| 1. The bonds that are formed during the course of the reaction; |
| 1. The energy transfer between the systems and their components or the system and surroundings; |
| 1. The transformation of potential energy from the chemical system interactions to kinetic energy in the surroundings (or vice versa) by molecular collisions; and |
| 1. The relative potential energies of the reactants and the products. |
| 2 | Relationships | |
| a | In the model, students include and describe\* the relationships between components, including: |
| 1. The net change of energy within the system is the result of bonds that are broken and formed during the reaction (Note: This does not include calculating the total bond energy changes.); |
| 1. The energy transfer between system and surroundings by molecular collisions; |
| 1. The total energy change of the chemical reaction system is matched by an equal but opposite change of energy in the surroundings (Note: This does not include calculating the total bond energy changes.); and |
| 1. The release or absorption of energy depends on whether the relative potential energies of the reactants and products decrease or increase. |
| 3 | Connections | |
| a | Students use the developed model to illustrate: |
| 1. The energy change within the system is accounted for by the change in the bond energies of the reactants and products. (Note: This does not include calculating the total bond energy changes.) |
| 1. Breaking bonds requires an input of energy from the system or surroundings, and forming bonds releases energy to the system and the surroundings. |
| 1. The energy transfer between systems and surroundings is the difference in energy between the bond energies of the reactants and the products. |
| 1. The overall energy of the system and surroundings is unchanged (conserved) during the reaction. |
| 1. Energy transfer occurs during molecular collisions. |
| 1. The relative total potential energies of the reactants and products can be accounted for by the changes in bond energy. |

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| **HS.5.5.C Apply scientific principles** and evidence to provide an explanation about the effects of changing the temperature or concentration   of the reacting particles on the rate at which a reaction occurs. | | |
| 1 | Articulating the explanation of phenomena | |
| a | Students construct an explanation that includes the idea that as the kinetic energy of colliding particles increases and the number of collisions increases, the reaction rate increases. |
| 2 | Evidence | |
| a | Students identify and describe\* evidence to construct the explanation, including: |
| 1. Evidence (e.g., from a table of data) of a pattern that increases in concentration (e.g., a change in one concentration while the other concentration is held constant) increase the reaction rate, and vice versa; and |
| 1. Evidence of a pattern that increases in temperature usually increase the reaction rate, and vice versa. |
| 3 | Reasoning | |
| a | Students use and describe\* the following chain of reasoning that integrates evidence, facts, and scientific principles to construct the explanation: |
| 1. Molecules that collide can break bonds and form new bonds, producing new molecules. |
| 1. The probability of bonds breaking in the collision depends on the kinetic energy of the collision being sufficient to break the bond, since bond breaking requires energy. |
| 1. Since temperature is a measure of average kinetic energy, a higher temperature means that molecular collisions will, on average, be more likely to break bonds and form new bonds. |
| 1. At a fixed concentration, molecules that are moving faster also collide more frequently, so molecules with higher kinetic energy are likely to collide more often. |
| 1. A high concentration means that there are more molecules in a given volume and thus more particle collisions per unit of time at the same temperature. |

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| **HS.5.5.D Refine the design** of a chemical system by specifying a change in conditions that would produce increased amounts of products at   equilibrium. | | |
| 1 | Using scientific knowledge to generate the design solution | |
| a | Students identify and describe\* potential changes in a component of the given chemical reaction system that will increase the amounts of particular species at equilibrium. Students use evidence to describe\* the relative quantities of a product before and after changes to a given chemical reaction system (e.g., concentration increases, decreases, or stays the same), and will explicitly use Le Chatelier’s principle, including: |
| 1. How, at a molecular level, a stress involving a change to one component of an equilibrium system affects other components; |
| 1. That changing the concentration of one of the components of the equilibrium system will change the rate of the reaction (forward or backward) in which it is a reactant, until the forward and backward rates are again equal; and |
| 1. A description\* of a system at equilibrium that includes the idea that both the forward and backward reactions are occurring at the same rate, resulting in a system that appears stable at the macroscopic level. |
| 2 | Describing criteria and constraints, including quantification when appropriate | |
| a | Students describe\* the prioritized criteria and constraints, and quantify each when appropriate. Examples of constraints to be considered are cost, energy required to produce a product, hazardous nature and chemical properties of reactants and products, and availability of resources. |
| 3 | Evaluating potential solutions | |
| a | Students systematically evaluate the proposed refinements to the design of the given chemical system. The potential refinements are evaluated by comparing the redesign to the list of criteria (i.e., increased product) and constraints (e.g., energy required, availability of resources). |
| 4 | Refining and/or optimizing the design solution | |
| a | Students refine the given designed system by making tradeoffs that would optimize the designed system to increase the amount of product, and describe\* the reasoning behind design decisions. |

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| **HS.5.5.E Design a solution** to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved   through engineering. | | |
| 1 | Using scientific knowledge to generate the design solution | |
| a | Students restate the original complex problem into a finite set of two or more sub-problems (in writing or as a diagram or flow chart). |
| b | For at least one of the sub-problems, students propose two or more solutions that are based on student-generated data and/or scientific information from other sources. |
| c | Students describe\* how solutions to the sub-problems are interconnected to solve all or part of the larger problem. |
| 2 | Describing criteria and constraints, including quantification when appropriate | |
| a | Students describe\* criteria and constraints for the selected sub-problem. |
| b | Students describe\* the rationale for the sequence of how sub-problems are to be solved, and which criteria should be given highest priority if tradeoffs must be made. |

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| **HS.5.5.F Use mathematical representations** to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. | | |
| 1 | Representation | |
| a | Students identify and describe\* the relevant components in the mathematical representations: |
| 1. Quantities of reactants and products of a chemical reaction in terms of atoms, moles, and mass; |
| 1. Molar mass of all components of the reaction; |
| 1. Use of balanced chemical equation(s); and |
| 1. Identification of the claim that atoms, and therefore mass, are conserved during a chemical reaction. |
| b | The mathematical representations may include numerical calculations, graphs, or other pictorial depictions of quantitative information. |
| c | Students identify the claim to be supported: that atoms, and therefore mass, are conserved during a chemical reaction. |
| 2 | Mathematical modeling | |
| a | Students use the mole to convert between the atomic and macroscopic scale in the analysis. |
| b | Given a chemical reaction, students use the mathematical representations to |
| 1. Predict the relative number of atoms in the reactants versus the products at the atomic molecular scale; and |
| 1. Calculate the mass of any component of a reaction, given any other component. |
| 3 | Analysis | |
| a | Students describe\* how the mathematical representations (e.g., stoichiometric calculations to show that the number of atoms or number of moles is unchanged after a chemical reaction where a specific mass of reactant is converted to product) support the claim that atoms, and therefore mass, are conserved during a chemical reaction. |
| b | Students describe\* how the mass of a substance can be used to determine the number of atoms, molecules, or ions using moles and mole relationships (e.g., macroscopic to atomic molecular scale conversion using the number of moles and Avogadro’s number). |

**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.

**Physics**

**SC.HSP.1 Forces, Interactions, and Motion**  
SC.HSP.1.1 Gather, analyze, and communicate evidence of forces, interactions, and motion.

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|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\Patterns.png | 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. |
|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\Systems.png | 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. |
|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\Patterns.png | 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. |
|  | C:\Users\sara.cooper.NDE\Desktop\Standards\EngineeringConnection'.png | C:\Users\sara.cooper.NDE\Desktop\Standards\CauseEffect.png | 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.** |
|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\Patterns.png | 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. |

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| The performance indicators above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*: | | |
| **Science and Engineering Practices**  **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. (SC.HSP.1.1.A)   **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. (SC.HSP.1.1.B),(SC.HSP.1.1.C),(SC.HSP.1.1.E)   **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. (SC.HSP.1.1.D)   **-------------------------------------------------------------------------------**  [***Connections to Nature of Science***](http://nstahosted.org/pdfs/ngss/AppendixH-TheNatureOfScienceInTheNextGenerationScienceStandards-4.9.13.pdf)  **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena**   * Theories and laws provide explanations in science. (SC.HSP.1.1.A),(SC.HSP.1.1.D) * Laws are statements or descriptions of the relationships among observable phenomena. (SC.HSP.1.1.A),(SC.HSP.1.1.D) | **Disciplinary Core Ideas**  [**PS2.A**](https://www.nap.edu/read/13165/chapter/9#114)**:  Forces and Motion**   * Newton’s second law accurately predicts changes in the motion of macroscopic objects. (SC.HSP.1.1.A, SC.HSP.1.1.B) * Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (SC.HSP.1.1.C) * 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. (SC.HSP.1.1.C),(SC.HSP.1.1.D)   [**PS2.B**](https://www.nap.edu/read/13165/chapter/9#116)**:  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. (SC.HSP.1.1.E) * 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. (SC.HSP.1.1.B),(SC.HSP.1.1.E)   C:\Users\sara.cooper.NDE\Desktop\Standards\EngineeringConnection'.png[**ETS1.A**](https://www.nap.edu/read/13165/chapter/12#204)**:  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)*  C:\Users\sara.cooper.NDE\Desktop\Standards\EngineeringConnection'.png[**ETS1.C**](https://www.nap.edu/read/13165/chapter/12#208)**:  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)* | **Crosscutting Concepts**  C:\Users\sara.cooper.NDE\Desktop\Standards\Patterns.png**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. (SC.HSP.1.1.A),(SC.HSP.1.1.C),(SC.HSP.1.1.E)  **Cause and Effect**  C:\Users\sara.cooper.NDE\Desktop\Standards\CauseEffect.pngSystems can be designed to cause a desired effect. (SC.HSP.1.1.D)  C:\Users\sara.cooper.NDE\Desktop\Standards\Systems.png**Systems and System Models**  When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (SC.HSP.1.1.B) |

**Evidence Statements: Observable features of the student performance by the end of the course.**

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| 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: |
| 1. Changes over time on multiple scales; and |
| 1. 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: |
| 1. 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 |
| 1. Identify the limitations of the provided data and ranges for their predictions. |

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| 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 |
| 1. To identify the interdependence of variables; and |
| 1. As evidence to support the claim(s) and/or explanation(s); and |
|  | 1. Students use the mathematical relationships to distinguish between cause and correlation with respect to the supported claims. |

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| 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 |
| 1. To identify the interdependence of variables; and |
| 1. As evidence to support the claim(s) and/or explanation(s); and |
|  | 1. Students use the mathematical relationships to distinguish between cause and correlation with respect to the supported claims. |

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| 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. |

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| 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 |
| 1. To identify the interdependence of variables; and |
| 1. As evidence to support the claim(s) and/or explanation(s); and |
|  | 1. Students use the mathematical relationships to distinguish between cause and correlation with respect to the supported claims. |

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| b | Students use the computational model to predict changes. |
| c | Students identify and describe\* the limitations of the computational model relative to the phenomenon at hand. |
| d | Students compare the simulation results to a real world example(s) and determine if the simulation can be viewed as realistic. |
| e | Students use the results of the simulation to identify feedbacks between the components. |
| f | 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. |

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

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|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\CauseEffect.png | 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. |
|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\Systems.png | SC.P.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. |
|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\Systems.png | 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). |
|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\CauseEffect.png | 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. |
|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\CauseEffect.png | 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. |
|  | C:\Users\sara.cooper.NDE\Desktop\Standards\EngineeringConnection'.png | C:\Users\sara.cooper.NDE\Desktop\Standards\CauseEffect.png | 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. 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. |

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| The performance indicators above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*: | | |
| **Science and Engineering Practices**  **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. (SC.HSP.2.2.B) * 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. (SC.HSP.2.2.C)   **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. (SC.HSP.2.2.A)   **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. (SC.HSP.2.2.E)   **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. (SC.HSP.2.2.D)   **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). (SC.HSP.2.2.F)   **------------------------------------------------------------------------------**  [***Connections to Nature of Science***](http://nstahosted.org/pdfs/ngss/AppendixH-TheNatureOfScienceInTheNextGenerationScienceStandards-4.9.13.pdf)  **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. (SC.HSP.2.2.D) | **Disciplinary Core Ideas**  [**PS3.D**](https://www.nap.edu/read/13165/chapter/9#128)**:   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**](https://www.nap.edu/read/13165/chapter/9#131)**:  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. (SC.HSP.2.2.A),(SC.HSP.2.2.B) * The reflection, refraction, and transmission of waves at an interface between two media can be modeled on the basis of wave properties. (SC.HSP.2.2.B),(SC.HSP.2.2.C) * 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. (SC.HSP.2.2.D),(SC.HSP.2.2.F) * 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. (SC.HSP.2.2.C),(SC.HSP.2.2.D)   [**PS4.B**](https://www.nap.edu/read/13165/chapter/9#133)**:  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. (SC.HSP.2.2.D) * 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. (SC.HSP.2.2.D) * 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. (SC.HSP.2.2.D),(SC.HSP.2.2.E) * 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. (SC.HSP.2.2.E) * Photoelectric materials emit electrons when they absorb light of a high-enough frequency. (SC.HSP.2.2.F)   [**PS4.C**](https://www.nap.edu/read/13165/chapter/9#136)**:  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. (SC.HSP.2.2.F) | **Crosscutting Concepts**  **Cause and Effect**  C:\Users\sara.cooper.NDE\Desktop\Standards\CauseEffect.pngEmpirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (SC.HSP.2.2.A)   * 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. (SC.HSP.2.2.D) * Argue from evidence when attributing an observed phenomenon to a specific cause. (SC.HSP.2.2.E) * Systems can be designed to cause a desired effect. (SC.HSP.2.2.F)   **Systems and System Models**  C:\Users\sara.cooper.NDE\Desktop\Standards\Systems.pngModels (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. (SC.HSP.2.2.B), (SC.HSP.2.2.C)  C:\Users\sara.cooper.NDE\Desktop\Standards\EngineeringConnection'.png**---------------------------------------------**  [***Connections to Engineering, Technology,*** ***and Applications of Science***](http://nstahosted.org/pdfs/ngss/20130509/AppendixJ-ScienceTechnologySocietyAndTheEnvironment_0.pdf)  **Interdependence of Science, Engineering, and Technology**   * Science and engineering complement each other in the cycle known as research and development (R&D). (SC.HSP.2.2.F)   **Influence of Engineering, Technology, and Science on Society and the Natural World**   * Modern civilization depends on major technological systems. (SC.HSP.2.2.D),(SC.HSP.2.2.F) * Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (SC.HSP.2.2.D) |

**Evidence Statements: Observable features of the student performance by the end of the course.**

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| 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 |
| 1. To identify the interdependence of variables; and |
| 1. As evidence to support the claim(s) and/or explanation(s); and |
|  | 1. Students use the mathematical relationships to distinguish between cause and correlation with respect to the supported claims. |

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| **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. |

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| 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. |

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| 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. |

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| 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. |

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| 4 | Reasoning/synthesis | |
| a | Students describe\* how the evidence supports the explanation of the phenomenon. |
| b | Students synthesize the relevant evidence to describe\* causality, patterns, and systems. |

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| 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. |

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

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|  | **C:\Users\sara.cooper.NDE\Desktop\Standards\ComputerScienceConnection.png** | C:\Users\sara.cooper.NDE\Desktop\Standards\Systems.png | 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. |
|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\EnergyMatter.png | 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 use of pulleys and electric motors. |
|  | C:\Users\sara.cooper.NDE\Desktop\Standards\EngineeringConnection'.png | C:\Users\sara.cooper.NDE\Desktop\Standards\EnergyMatter.png | 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. 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. |
|  | C:\Users\sara.cooper.NDE\Desktop\Standards\EngineeringConnection'.png |  | 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. |
|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\Systems.png | 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. |
|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\CauseEffect.png | 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. |

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| The performance indicators above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*: | | |
| **Science and Engineering Practices**  **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 evidenceto illustrate the relationships between systems or between components of a system. (SC.HSP.4.3.F)   **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. (SC.HSP.4.3.B), (SC.HSP.4.3.E)   **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. (SC.HSP.4.3.A)   **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. (SC.HSP.4.3.C),(SC.HSP.4.3.D) | **Disciplinary Core Ideas**  [**PS3.A**](https://www.nap.edu/read/13165/chapter/9#120)**:  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. (SC.HSP.4.3.A),(SC.HSP.4.3.B) * At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (SC.HSP.4.3.C),(SC.HSP.4.3.D),(SC.HSP.4.3.E) * 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. (SC.HSP.4.3.D), (SC.HSP.4.3.F)   [**PS3.B**](https://www.nap.edu/read/13165/chapter/9#124)**:  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. (SC.HSP.4.3.A) * Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (SC.HSP.4.3.A),(SC.HSP.4.3.B),(SC.HSP.4.3.C) * 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. (SC.HSP.4.3.A) * The availability of energy limits what can occur in any system. (SC.HSP.4.3.A),(SC.HSP.4.3.B) * 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). (SC.HSP.4.3.D)   [**PS3.C**](https://www.nap.edu/read/13165/chapter/9#126)**:  Relationship Between Energy and Forces**   * When two objects interacting through a field change relative position, the energy stored in the field is changed. (SC.HSP.4.3.F)   [**PS3.D**](https://www.nap.edu/read/13165/chapter/9#128)**:  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. (SC.HSP.4.3.C),(SC.HSP.4.3.D)   [**ETS1.A**](https://www.nap.edu/read/13165/chapter/12#204)**:  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, SC.HSP.4.3.D)* | **Crosscutting Concepts**  C:\Users\sara.cooper.NDE\Desktop\Standards\CauseEffect.png**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. (SC.HSP.4.3.F)  **Systems and System Models**  C:\Users\sara.cooper.NDE\Desktop\Standards\Systems.pngWhen 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. (SC.HSP.4.3.D)   * 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. (SC.HSP.4.3.A)   C:\Users\sara.cooper.NDE\Desktop\Standards\EnergyMatter.png**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. (SC.HSP.4.3.C)   * Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems. (SC.HSP.4.3.B)   **------------------------------------------------**  C:\Users\sara.cooper.NDE\Desktop\Standards\EngineeringConnection'.png[***Connections to Engineering, Technology, and Applications of Science***](http://nstahosted.org/pdfs/ngss/20130509/AppendixJ-ScienceTechnologySocietyAndTheEnvironment_0.pdf)  **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. (SC.HSP.4.3.C), (SC.HSP.4.3.D)   **---------------------------------------------**  [***Connections to Nature of Science***](http://nstahosted.org/pdfs/ngss/AppendixH-TheNatureOfScienceInTheNextGenerationScienceStandards-4.9.13.pdf)  **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. (SC.HSP.4.3.A) |

**Evidence Statements: Observable features of the student performance by the end of the course.**

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| 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 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 a real world example(s) and determine if the simulation can be viewed as realistic. |
| d | Students use the results of the simulation to identify feedbacks 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. |

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| 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: |
| 1. A rationale for the choice of variables. |
| 1. 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: |
| 1. Assessing the accuracy and precision of the data collected, as well as the limitations of the investigation; and |
| 1. 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. |

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| 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. | |
| 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. |

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| 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. | |
| 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. |

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| 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. | |
| 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: |
| 1. A rationale for the choice of variables. |
| 1. 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: |
| 1. Assessing the accuracy and precision of the data collected, as well as the limitations of the investigation; and |
| 1. 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. |

**SC.HSP.16 Electricity and Magnetism**

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

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|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\Patterns.png | SC.HSP.16.4.A **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. |
|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\Systems.png | 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. |
|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\Patterns.png | 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. |
|  | C:\Users\sara.cooper.NDE\Desktop\Standards\EngineeringConnection'.png | C:\Users\sara.cooper.NDE\Desktop\Standards\EnergyMatter.png | 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. |
|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\ScaleProportionQuantity.png | 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. |
|  | C:\Users\sara.cooper.NDE\Desktop\Standards\EngineeringConnection'.png | C:\Users\sara.cooper.NDE\Desktop\Standards\CauseEffect.png | 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. |
| C:\Users\sara.cooper.NDE\Desktop\Standards\EngineeringConnection'.png |  | C:\Users\sara.cooper.NDE\Desktop\Standards\CauseEffect.png | 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. |

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| The performance indicators above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*: | | |
| **Science and Engineering Practices**  **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. (SC.HSP.16.4.G)   **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. (SC.HSP.16.4.B)   **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. (SC.HSP.16.4.A),(SC.HSP.16.4.C)   **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. (SC.HSP.16.4.F)   **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). (SC.HSP.16.4.D)   **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 (SC.HSP.16.4.E)   **-----------------------------------------------------**  [***Connections to Nature of Science***](http://nstahosted.org/pdfs/ngss/AppendixH-TheNatureOfScienceInTheNextGenerationScienceStandards-4.9.13.pdf)  **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena**   * Theories and laws provide explanations in science. (SC.HSP.16.4.A),(SC.HSP.16.4.C) * Laws are statements or descriptions of the relationships among observable phenomena. (SC.HSP.16.4.A),(SC.HSP.16.4.C) | **Disciplinary Core Ideas**  [**PS1.A**](https://www.nap.edu/read/13165/chapter/9#106)**:  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 (SC.HSP.16.4.C) * 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)*   [**PS2.A**](https://www.nap.edu/read/13165/chapter/9#114)**:  Forces and Motion**   * Newton’s second law accurately predicts changes in the motion of macroscopic objects. (SC.HSP.16.4.A)   [**PS2.B**](https://www.nap.edu/read/13165/chapter/9#116)**:  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. (SC.HSP.16.4.A) * 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. (SC.HSP.16.4.B),(SC.HSP.16.4.E),(SC.HSP.16.4.F)   [**PS3.A**](https://www.nap.edu/read/13165/chapter/9#120)**:  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, SC.HSP.16.4.E)   [**ETS1.A**](https://www.nap.edu/read/13165/chapter/12#204)**:  Defining and Delimiting Engineering Problems**  C:\Users\sara.cooper.NDE\Desktop\Standards\EngineeringConnection'.pngCriteria 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)*  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. (SC.HSP.16.4.G)  [**ETS1.C**](https://www.nap.edu/read/13165/chapter/12#208)**:  Optimizing the Design Solution**  C:\Users\sara.cooper.NDE\Desktop\Standards\EngineeringConnection'.pngCriteria 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)* | **Crosscutting Concepts**  C:\Users\sara.cooper.NDE\Desktop\Standards\Patterns.png**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. (SC.HSP.16.4.A),(SC.HSP.16.4.C)  C:\Users\sara.cooper.NDE\Desktop\Standards\CauseEffect.png**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. (SC.HSP.16.4.F),(SC.HSP.16.4.G)  C:\Users\sara.cooper.NDE\Desktop\Standards\Systems.png**Systems and System Models**  When investigating or describing a system, the boundaries and initial conditions of the system need to be defined.(SC.HSP.16.4.B)  **Energy and Matter: Flows, Cycles, and Conservation**  C:\Users\sara.cooper.NDE\Desktop\Standards\EnergyMatter.pngExamine, characterize, and model the transfers and cycles of matter and energy in a system,(SC.HSP.16.4.D)  **Scale and Proportion**  C:\Users\sara.cooper.NDE\Desktop\Standards\ScaleProportionQuantity.pngThe 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). (SC.HSP.16.4.E)  [***Connections to Engineering, Technology, and Applications of Science***](http://nstahosted.org/pdfs/ngss/20130509/AppendixJ-ScienceTechnologySocietyAndTheEnvironment_0.pdf)  **Influence of Science, Engineering, and Technology on Society and the Natural World**  C:\Users\sara.cooper.NDE\Desktop\Standards\EngineeringConnection'.pngNew 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. (SC.HSP.16.4.G) |

**Evidence Statements: Observable features of the student performance by the end of the course.**

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| SC.HSP.16.4.A **Use mathematical representations** of Newton’s Law of Gravitation and Coulomb’s Law to describe and predict the gravitational and electrostatic   forces 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 |
| 1. To identify the interdependence of variables; and |
| 1. As evidence to support the claim(s) and/or explanation(s); and |
|  |  | 1. Students use the mathematical relationships to distinguish between cause and correlation with respect to the supported claims. |

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| 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. |

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| 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 |
| 1. To identify the interdependence of variables; and |
| 1. As evidence to support the claim(s) and/or explanation(s); and |
|  |  | 1. Students use the mathematical relationships to distinguish between cause and correlation with respect to the supported claims. |

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| 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 for the design solutions, i |
| Evaluation and critique | |
| a | Students evaluate the given design solutions, including: |
| 1. The relative strengths of the given design solutions, based on associated economic, environmental, and geopolitical costs, risks, and benefits; |
| 1. The reliability and validity of the evidence used to evaluate the design solutions; and |
| 1. 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. |

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| 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. |

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| 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. |

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| 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: |
| 1. Describe\* the challenge with a rationale for why it is a major global challenge; |
| 1. 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 |
| 1. 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. |

**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.

**Chemistry**

**SC.HSP.3 Structure and Properties of Matter**

SC.HSP.3.1 Gather, analyze, and communicate evidence of the structure, properties, and interactions of matter.

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|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\Patterns.png | SC.HSP.3.1.A **Use the periodic table as a model** to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms. Assessment does not include quantitative understanding of ionization energy beyond relative trends. |
|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\Patterns.png | SC.HSP.3.1.B **Plan and conduct an investigation** to gather evidence to compare the structure of substances at the macro scale to infer the strength of electrical forces between particles. Examples of intramolecular forces include bond type, polarity of bonds and, resonance structures. Examples of intermolecular forces include hydrogen bonds, dipole-dipole. Assessment does not include Raoult’s law calculations of vapor pressure. |
|  |  | **C:\Users\sara.cooper.NDE\Desktop\Standards\StructureFunction.png** | SC.HSP.3.1.C **Develop and use models** to predict and explain forces that are in and between molecules. Examples of intramolecular forces include bond type, polarity of bonds and, resonance structures. Examples of intermolecular forces include hydrogen bonds, dipole-dipole. |
|  | C:\Users\sara.cooper.NDE\Desktop\Standards\EngineeringConnection'.png |  | SC.HSP.3.3.D **Evaluate a solution** to a complex, real-world problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts. Examples could include the effects of concentration of solutions on the freezing/boiling point (melting of ice on roadways), aspartame and caffeine in beverages, fluoride in drinking water. |
|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\EnergyMatter.png | SC.HSP.3.3.E **Develop models** to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay. Assessment is limited to alpha, beta, and gamma radioactive decays. |
|  |  | **C:\Users\sara.cooper.NDE\Desktop\Standards\StructureFunction.png** | SC.HSP.3.3.F.**Develop and use models** to describe and predictmechanisms of the quantum mechanical model of the atom. Examples of representation include Aufbau Diagram, Hund’s Rule, Pauli Exclusion, and orbital shapes, Hybridization of orbitals, and electron configuration. |
|  |  | **C:\Users\sara.cooper.NDE\Desktop\Standards\StructureFunction.png** | SC.HSP.3.3.G **Evaluate the evidence** supporting claims about how atoms absorb and emit energy in the form of electromagnetic radiation. Examples include using mathematical relationships to demonstrate the relationship between observed light spectrum, wavelength of light and emission spectrum. |
|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\ScaleProportionQuantity.png | SC.HSP.3.3.H **Use mathematical representations** to quantify matter through the analysis of patterns in chemical compounds at different scales.Emphasis is on the mole concept, empirical formula, molecular formula, percent composition, and law of constant composition. |

**SC.HSP.4 Energy: Chemistry**

SC.HSP.4.2 Gather, analyze, and communicate evidence of the interactions of energy.

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|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\EnergyMatter.png | SC.HSP.4.2.A **Use statistical and mathematical techniques** to describe qualitative and quantitative thermodynamic relationships. Thermodynamic relationships may include: Enthalpy, Hess’s Law, Heats of Formation. Examples of data displays or graphs could include energy diagrams to communicate bond energies of products or reactants. Lab investigations may include calorimetry. |
|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\CauseEffect.png | SC.HSP.4.2.B **Plan and conduct an investigation** to gather evidenceof how the Kinetic Molecular Theory and gas laws are related. Examples include Dalton’s Law of particle pressures, Graham’s Law of Diffusion and Effusion, and empirical gas laws. |
|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\Systems.png | SC.HSP.4.2.C **Analyze and interpret data** to explain changes in energy within a system and/or energy flows in and out of a system.Emphasis is on the use of mathematical expressions to describe the change in energy within the system. Investigations could include electrochemistry (electrolysis). |
|  | C:\Users\sara.cooper.NDE\Desktop\Standards\EngineeringConnection'.png |  | SC.HSP.4.2.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 alternative energies, carbon footprint, and crude oil refining process. |

**SC.HSP.5 Chemical Reactions**

SC.HSP.5.3 Gather, analyze, and communicate evidence of chemical reactions.

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|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\StabilityChange.png | SC.HSP.5.3.A **Plan and conduct an investigation** to generate evidence that answers scientific questions related to changes in solution chemistry. Examples include titrations, solubility, and Le Chatelier’s Principle |
|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\EnergyMatter.png | SC.HSP.5.3.B **Use a model** to identify electron transfer and balance a redox reaction. Emphasis would be on using half reaction method for balancing equations and understanding electron transfer. Examples include electrochemical cells and electroplating. |
|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\Patterns.png | SC.HSP.5.3.C **Use mathematical and/or computational representations** to predict and explain relationships within chemical systems. Examples include stoichiometric calculations, gas stoichiometry, limiting reactant, empirical formula/molecular formula calculations, % comp % yield. |
|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\ScaleProportionQuantity.png | SC.HSP.5.3.D **Use mathematical representations** to analyze the proportion and quantity of particles in solution.Emphasis is on molarity and developing net ionic equations. |
|  |  | C:\Users\sara.cooper.NDE\Desktop\Standards\Patterns.png | SC.HSP.5.3.E **Plan and conduct an investigation** to predict the outcome of a chemical reaction based on patterns of chemical properties.Examples of reaction types could include single replacement, double replacement, etc. Examples of patterns could include the use of solubility rules, activity series. |
|  | **C:\Users\sara.cooper.NDE\Desktop\Standards\ComputerScienceConnection.png** | C:\Users\sara.cooper.NDE\Desktop\Standards\Patterns.png | SC.HS.5.3.F **Construct and revise an explanation** for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. |

**HS Crosscutting Concept Elements**

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| **C:\Users\sara.cooper.NDE\Desktop\Standards\Patterns.pngPatterns – Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.** | | |
| **9-12 Crosscutting Statements**   * 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. * Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus requiring improved investigations and experiments. | * Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system. * Mathematical representations are needed to identify some patterns. * Empirical evidence is needed to identify patterns. | |
| C:\Users\sara.cooper.NDE\Desktop\Standards\CauseEffect.png**Cause and Effect: Mechanism and Prediction** – Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering. | | |
| **9-12 Crosscutting Statements**   * Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. * Systems can be designed to cause a desired effect. | * Changes in systems may have various causes that may not have equal effects. * 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. | |
| C:\Users\sara.cooper.NDE\Desktop\Standards\ScaleProportionQuantity.png**Scale, Proportion, and Quantity** – In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change. | | |
| **9-12 Crosscutting Statements**   * The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. * Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. * Patterns observable at one scale may not be observable or exist at other scales. | * Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale. * Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). | |
| C:\Users\sara.cooper.NDE\Desktop\Standards\Systems.png**Systems and System Models –** A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems. | | |
| **9-12 Crosscutting Statements**   * 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. | | * Systems can be designed to do specific tasks. * 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. |
| C:\Users\sara.cooper.NDE\Desktop\Standards\EnergyMatter.png**Energy and Matter: Flows, Cycles, and Conservation** – Tracking energy and matter flows, into, out of, and within systems helps one understand their system’s behavior. | | |
| **9-12 Crosscutting Statements**   * The total amount of energy and matter in closed systems is conserved. * 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. | * Energy cannot be created or destroyed—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. | |
| C:\Users\sara.cooper.NDE\Desktop\Standards\StructureFunction.png**Structure and Function** – The way an object is shaped or structured determines many of its properties and functions. | | |
| **9-12 Crosscutting Statements**   * Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. | * The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. | |
| C:\Users\sara.cooper.NDE\Desktop\Standards\StabilityChange.png**Stability and Change** – For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand. | | |
| **9-12 Crosscutting Statements**   * Much of science deals with constructing explanations of how things change and how they remain stable. * Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. | * Feedback (negative or positive) can stabilize or destabilize a system. * Systems can be designed for greater or lesser stability. | |

\* Adapted from: National Research Council (2011). A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academy Press. Chapter 4: Crosscutting Concepts.

**HS Science and Engineering Practice Elements**

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| |  | | --- | | **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.   * Ask questions   + that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information.   + that arise from examining models or a theory, to clarify and/or seek additional information and relationships.   + to determine relationships, including quantitative relationships, between independent and dependent variables.   + to clarify and refine a model, an explanation, or an engineering problem. * Evaluate a question to determine if it is testable and relevant. * Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory. * Ask and/or evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design. * Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical, and/or environmental considerations. | | **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.   * Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. * Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students’ own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. * Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. * 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. * 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. |
| **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.   * Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism or system in order to select or revise a model that best fits the evidence or design criteria. * Design a test of a model to ascertain its reliability. * 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. * 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. * Develop a complex model that allows for manipulation and testing of a proposed process or system. * Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems. | **Mathematical and computational thinking** in 9- 12 builds on K-8 experiences 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 and/or revise a computational model or simulation of a phenomenon, designed device, process, or system. * Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. * Apply techniques of algebra and functions to represent and solve scientific and engineering problems. * Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model “makes sense” by comparing the outcomes with what is known about the real world. * Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.). |
| **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 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. * 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. * Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts. * Select appropriate tools to collect, record, analyze, and evaluate data. * Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated. * Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables. | **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.   * Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues. * Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. * Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence, challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining additional information required to resolve contradictions. * Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence. * Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence. * 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). |
| **Analyzing data** in 9–12 builds on K–8 experiences 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. * Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. * Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data. * Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations. * Evaluate the impact of new data on a working explanation and/or model of a proposed process or system. * Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success. | **Obtaining, evaluating, and communicating information** in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs.   * Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. * Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. * Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. * Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible. * Communicate scientific and/or 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 (i.e., orally, graphically, textually, mathematically). |

\* Adapted from: National Research Council (2011). A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academy Press. Chapter 3: Science and Engineering Practices.

**Topic Progression Chart**

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Topic\Grade** | **K** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **HS** |
| **1** Forces & Interactions | **SC.K.1** |  |  | **SC.3.1** |  |  |  |  | **SC.8.1** | **SC.HS.1** |
| **2** Waves & Electro-magnetic Radiation |  | **SC.1.2** |  |  | **SC.4.2** |  |  |  | **SC.8.2** | **SC.HS.2** |
| **3** Structure & Properties of Matter |  |  | **SC.2.3** |  |  | **SC.5.3** |  | **SC.7.3** |  | **SC.HS.3** |
| **4** Energy |  |  |  |  | **SC.4.4** |  | **SC.6.4** |  | **SC.8.4** | **SC.HS.4** |
| **5** Chemical Reactions |  |  |  |  |  |  |  | **SC.7.5** |  | **SC.HS.5** |
| **6** Structure & Function |  | **SC.1.6** |  |  | **SC.4.6** |  | **SC.6.6** |  |  | **SC.HS.6** |
| **7** Inter-dependent Relationships in Ecosystems | **SC.K.7** |  | **SC.2.7** | **SC.3.7** |  |  |  | **SC.7.7** |  | **SC.HS.7** |
| **8** Matter & Energy in Organisms & Ecosystems |  |  |  |  |  | **SC.5.8** |  | **SC.7.8** |  | **SC.HS.8** |
| **9** Heredity: Inheritance & Variation of Traits |  |  |  | **SC.3.9** |  |  | **SC.6.9** |  | **SC.8.9** | **SC.HS.9** |
| **10** Biological Evolution |  |  |  |  |  |  |  |  | **SC.8.10** | **SC.HS.10** |
| **11** Space Systems |  | **SC.1.11** |  |  |  | **SC.5.11** |  |  | **SC.8.11** | **SC.HS.11** |
| **12** Weather & Climate | **SC.K.12** |  |  | **SC.3.12** |  |  | **SC.6.12** |  |  | **SC.HS.12** |
| **13** Earth’s Systems |  |  | **SC.2.13** |  | **SC.4.13** | **SC.5.13** | **SC.6.13** | **SC.7.13** |  | **SC.HS.13** |
| **14** History of Earth |  |  |  |  |  |  |  | **SC.7.14** | **SC.8.14** | **SC.HS.14** |
| **15** Sustainability |  |  |  |  |  |  |  |  |  | **SC.HS.15** |