Education Goals

These capacity and goal statements of the Kentucky Education Reform Act of 1990, as found in Kentucky Revised Statute (KRS) 158.645 and KRS 158.6451, are the basis for instructional programs in Kentucky public schools. All students shall have the opportunity to acquire the following capacities and learning goals:

- Communication skills necessary to function in a complex and changing civilization
- Knowledge to make economic, social and political choices
- Understanding of governmental processes as they affect the community, the state and the nation
- Sufficient self-knowledge and knowledge of their mental health and physical wellness
- Sufficient grounding in the arts to enable each student to appreciate their cultural and historical heritage
- Sufficient preparation to choose and pursue their life’s work intelligently
- Skills to enable students to compete favorably with students in other states and other parts of the world

Furthermore, schools shall

- expect a high level of achievement from all students.
- develop their students’ abilities to:
  - use basic communication and mathematics skills for purposes and situations they will encounter throughout their lives
  - apply core concepts and principles from mathematics, science, arts and humanities, social studies, English/language arts, health, mathematics, practical living, including, physical education, to situations they will encounter throughout their lives
  - become self-sufficient individuals
  - become responsible members of a family, work group or community as well as an effective participant in community service
  - think and solve problems in school situations and in a variety of situations they will encounter in life
  - connect and integrate experiences and new knowledge from all subject matter fields
  - with what students have previously learned and build on past learning experiences to acquire new information through various media sources

- increase student attendance rates
- reduce dropout and retention rates
- reduce physical and mental health barriers to learning
- be measured on the proportion of students who make a successful transition to work, postsecondary education and the military
Legal Base

The following Kentucky Revised Statutes (KRS) and Kentucky Administrative Regulations (KAR) provide a legal base for this publication:

**KRS 156:160 Promulgation of administrative regulations by the Kentucky Board of Education**
With the advice of the Local Superintendents Advisory Council, the Kentucky Board of Education shall promulgate administrative regulations establishing standards that public school districts shall meet in student, program, service and operational performance. These regulations shall comply with the expected outcomes for students and schools set forth in KRS 158:6451.

Administrative regulations shall be promulgated for:

- Courses of study for the different grades and kinds of common schools; and
- The minimum requirements for high school graduation.

**704 KAR 3:305 Minimum high school graduation requirements**
This administrative regulation establishes the minimum high school graduation requirements necessary for entitlement to a public high school diploma, including the requirements for the graduating class of 2012.

**704 KAR 3:303 Required Kentucky Academic Standards**
This administrative regulation adopts into law the *Kentucky Academic Standards February 2010*. 
PRIMARY SCIENCE
The Kentucky Academic Standards for Science are written as a set of performance expectations that are assessable statements of what students should know and be able to do. An underlying assumption of these standards is that all students should be held accountable for demonstrating their achievement of all performance expectations. A coherent and complete view of what students should be able to do comes when the performance expectations are viewed in tandem with the contents of the foundation boxes that lie just below the performance expectations. These three boxes include the practices, core disciplinary ideas, and crosscutting concepts, derived from the National Research Council’s Framework for K12 Science Education that were used to construct this set of performance expectations.

Science and Engineering Practices. The blue box on the left includes just the science and engineering practices used to construct the performance expectations in the box above. These statements are derived from and grouped by the eight categories detailed in the Framework to further explain the science and engineering practices important to emphasize in each grade band. Most sets of performance expectations emphasize only a few of the practice categories; however, all practices are emphasized within a grade band.

Disciplinary Core Ideas (DCIs). The orange box in the middle includes statements that are taken from the Framework about the most essential ideas in the major science disciplines that all students should understand during 13 years of school. Including these detailed statements was very helpful to the writing team as they analyzed and “unpack” the disciplinary core ideas and sub-ideas to reach a level that is helpful in describing what each student should understand about each sub-idea at the end of grades 2, 5, 8, and 12. Although they appear in paragraph form in the Framework, here they are bulleted to be certain that each statement is distinct.

Crosscutting Concepts. The green box on the right includes statements derived from the Framework’s list of crosscutting concepts, which apply to one or more of the performance expectations in the box above. Most sets of performance expectations limit the number of crosscutting concepts so as focus on those that are readily apparent when considering the DCIs; however, all are emphasized within a grade band. Aspects of the Nature of Science relevant to the standard are also listed in this box, as are the interdependence of science and engineering, and the influence of engineering, technology, and science on society and the natural world.

Connection Boxes
Three Connection Boxes, below the Foundation Boxes, are designed to support a coherent vision of the standards by showing how the performance expectations in each standard connect to other performance expectations in science, as well as to the KAS standards in Mathematics and English/Language Arts. The three boxes include:

- Connections to other DCIs in this grade level or band. This box contains the names of science topics in other disciplines that have related disciplinary core ideas at the same grade level. For example, both Physical Science and Life Science performance expectations contain core ideas related to Photosynthesis, and could be taught in relation to one another.

- Articulation of DCIs across grade levels. This box contains the names of other science topics that either 1) provide a foundation for student understanding of the core ideas in this set of performance expectations (usually at prior grade levels) or 2) build on the foundation provided by the core ideas in this set of performance expectations (usually at subsequent grade levels).
Connections to the Kentucky Academic Standards in mathematics and English/Language Arts. This box contains the coding and names of pre-requisite or co-requisite Kentucky Academic Standards in English Language Arts & and Literacy and Mathematics that align to the performance expectations. An effort has been made to ensure that the mathematical skills that students need for science were taught in a previous year where possible.
**K. Forces and Interactions: Pushes and Pulls**

**Science and Engineering Practices**

<table>
<thead>
<tr>
<th>Planning and Carrying Out Investigations</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
</table>
| Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.  
- With guidance, plan and conduct an investigation in collaboration with peers. (K-PS2-1) | PS2.A: Forces and Motion  
- Pushes and pulls can have different strengths and directions. (KPS2-1),(K-PS2-2)  
- Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. (KPS2-1),(K-PS2-2) | Cause and Effect  
- Simple tests can be designed to gather evidence to support or refute student ideas about causes. (K-PS2-1),(K-PS2-2) |

| Analyzing and Interpreting Data | PS2.B: Types of Interactions  
- When objects touch or collide, they push on one another and can change motion. (K-PS2-1) |  |
| Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations.  
- Analyze data from tests of an object or tool to determine if it works as intended. (K-PS2-2) | PS3.C: Relationship Between Energy and Forces  
- A bigger push or pull makes things speed up or slow down more quickly. (secondary to K-PS2-1) |  |

| Scientific Investigations Use a Variety of Methods | ETS1.A: Defining Engineering Problems  
- A situation that people want to change or create can be approached as a problem to be solved through engineering. Such problems may have many acceptable solutions. (secondary to KPS2-2) |  |
| Scientists use different ways to study the world. (K-PS2-1) |  |  |

**Connections to Nature of Science**

**Kentucky Academic Standards Connections:**

**ELA/Literacy**

RI.K.1 With prompting and support, ask and answer questions about key details in a text. (K-PS2-2)

W.K.7 Participate in shared research and writing projects (e.g., explore a number of books by a favorite author and express opinions about them). (K-PS2-1)

SL.K.3 Ask and answer questions in order to seek help, get information, or clarify something that is not understood. (K-PS2-2)

**Mathematics**

MP.2 Reason abstractly and quantitatively. (K-PS2-1)

K.MD.A.1 Describe measurable attributes of objects, such as length or weight. Describe several measurable attributes of a single object. (K-PS2-1)

K.MD.A.2 Directly compare two objects with a measurable attribute in common, to see which object has "more of"/"less of" the attribute, and describe the difference. (K-PS2-1)

---

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled “Disciplinary Core Ideas” is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.*
## K. Interdependent Relationships in Ecosystems: Animals, Plants, and Their Environment

<table>
<thead>
<tr>
<th>Task</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students who demonstrate understanding can:</td>
<td></td>
</tr>
<tr>
<td>K-LS1-1. Use observations to describe patterns of what plants and animals (including humans) need to survive.</td>
<td></td>
</tr>
<tr>
<td>K-ESS2-2. Construct an argument supported by evidence for how plants and animals (including humans) can change the environment to meet their needs.</td>
<td></td>
</tr>
<tr>
<td>K-ESS3-1. Use a model to represent the relationship between the needs of different plants or animals (including humans) and the places they live.</td>
<td></td>
</tr>
<tr>
<td>K-ESS3-3. Communicate solutions that will reduce the impact of humans on the land, water, air, and/or other living things in the local environment.</td>
<td></td>
</tr>
</tbody>
</table>

### The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:

<table>
<thead>
<tr>
<th>Developing and Using Models</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modeling in K-2 builds on prior experiences and progresses to include using and developing models (i.e., diagram, drawing, physical replica, diorama, dramatization, or storyboard) that represent concrete events or design solutions.</td>
<td>LS1.C: Organization for Matter and Energy Flow in Organisms • All animals need food in order to live and grow. They obtain their food from plants or from other animals. Plants need water and light to live and grow. (K-LS1-1)</td>
<td>Patterns • Patterns in the natural and human designed world can be observed and used as evidence. (K-LS1-1)</td>
</tr>
<tr>
<td>Analyzing and Interpreting Data</td>
<td>ESS2.E: Biogeology • Plants and animals can change their environment. (K-ESS2-2)</td>
<td>Cause and Effect • Events have causes that generate observable patterns. (K-ESS3-3)</td>
</tr>
<tr>
<td>Engaging in Argument from Evidence</td>
<td>ESS3.A: Natural Resources • Living things need water, air, and resources from the land, and they live in places that have the things they need. Humans use natural resources for everything they do. (K-ESS3-1)</td>
<td>Systems and System Models • Systems in the natural and designed world have parts that work together. (K-ESS2-2), (K-ESS3-1)</td>
</tr>
<tr>
<td>Obtaining, Evaluating, and Communicating Information</td>
<td>ESS3.C: Human Impacts on Earth Systems • Things that people do to live comfortably can affect the world around them. But they can make choices that reduce their impacts on the land, water, air, and other living things. (secondary to K-ESS2-2), (K-ESS3-3)</td>
<td></td>
</tr>
<tr>
<td>Engaging in Argument from evidence in K-2 builds on prior experiences and progresses to comparing ideas and representations about the natural and designed world(s)</td>
<td>ETS1.B: Developing Possible Solutions • Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem’s solutions to other people. (secondary to K-ESS3-3)</td>
<td></td>
</tr>
</tbody>
</table>

### The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

K. Weather and Climate

Students who demonstrate understanding can:

K-PS3.1. **Make observations to determine the effect of sunlight on Earth’s surface.** [Clarification Statement: Examples of Earth’s surface could include sand, soil, rocks, and water] [Assessment Boundary: Assessment of temperature is limited to relative measures such as warmer/cooler.]

K-PS3.2. **Use tools and materials to design and build a structure that will reduce the warming effect of sunlight on an area.** [Clarification Statement: Examples of tools and materials could include umbrellas, canopies, and tents that minimize the warming effect of the sun] [Assessment Boundary: Assessment of quantitative observations could include numbers of sunny, windy, and rainy days in a month. Examples of patterns could include that it is usually cooler in the morning than in the afternoon]

K-ESS2.1. **Use and share observations of local weather conditions to describe patterns over time.** [Clarification Statement: Examples of qualitative observations could include descriptions of the weather (such as sunny, cloudy, rainy, and warm); examples of quantitative observations could include numbers of sunny, windy, and rainy days in a month. Examples of patterns could include that it is usually cooler in the morning than in the afternoon and the number of sunny days versus cloudy days in different months.] [Assessment Boundary: Assessment of quantitative observations limited to whole numbers and relative measures such as warmer/cooler.]

K-ESS3.2. **Ask questions to obtain information about the purpose of weather forecasting to prepare for, and respond to, severe weather.** [Clarification Statement: Emphasis is on local forms of severe weather.]

The performance expectations 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 K–2 builds on prior experiences and progresses to simple descriptive questions that can be tested.
  - Ask questions based on observations to find more information about the designed world. (K-ESS3-2)

- **Planning and Carrying Out Investigations**
  - Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.
  - Make observations (firsthand or from media) to collect data that can be used to make comparisons. (K-PS3-1)

- **Analyzing and Interpreting Data**
  - Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations.
  - Use observations (firsthand or from media) to describe patterns in the natural world in order to answer scientific questions. (K-PS3-1)

- **Constructing Explanations and Designing Solutions**
  - Constructing explanations and designing solutions in K–2 builds on prior experiences and progresses to use of evidence and ideas in constructing evidence-based accounts of natural phenomena and designing solutions.
  - Use tools and materials provided to design and build a device that solves a specific problem or a solution to a specific problem. (K-PS3-2)

- **Obtaining, Evaluating, and Communicating Information**
  - Obtaining, evaluating, and communicating information in K–2 builds on prior experiences and uses observations and texts to communicate new information.
  - Read grade-appropriate texts and/or use media to obtain scientific information to describe patterns in the natural world. (K-ESS3-2)

**Disciplinary Core Ideas**

- **PS3.B: Conservation of Energy and Energy Transfer**
  - Sunlight warms Earth’s surface. (K-PS3-1), (K-PS3-2)

- **ESS2.D: Weather and Climate**
  - Weather is the combination of sunlight, wind, snow or rain, and temperature in a particular region at a particular time. People measure these conditions to describe and record the weather and to notice patterns over time. (K-ESS2-1)

- **ESS3.B: Natural Hazards**
  - Some kinds of severe weather are more likely than others in a given region. Weather scientists forecast severe weather so that the communities can prepare for and respond to these events. (K-ESS2-2)

**Patterns**

- Patterns in the natural world can be observed, used to describe phenomena, and used as evidence. (K-ESS2-1)

**Connections to Other DCIs in Kindergarten**:

- K.ETS1.A (K-PS3-2), (K-ESS3-2); K.ETS1.B (K-PS3-2)

**Connections to Nature of Science**

- Scientists look for patterns and order when making observations about the world. (K-ESS2-1)

- Connections to other DCIs across grade-levels: 1.PS4.B (K-PS3-1), (K-PS3-2); 2.ESS1.C (K-ESS3-2); 2.ESS2.A (K-ESS3-2); 2.ESS1.B (K-PS3-2); 3.ESS2.D (K-PS3-1), (K-ESS2-1); 3.ESS3.B (K-ESS3-2); 4.ESS2.A (K-ESS2-1); 4.ESS3.B (K-ESS3-2); 4.ESS1.A (K-PS3-1)

**Kentucky Academic Standards Connections**:

- ELA: Literacy
  - **RI.K.1** With prompting and support, ask and answer questions about key details in a text. (K-ESS3-2)
  - **W.K.7** Participate in shared research and writing projects (e.g., explore a number of books by a favorite author and express opinions about them). (K-PS3-1), (K-PS3-2), (K-ESS2-1)

- **SL.K.3** Ask and answer questions in order to seek help, get information, or clarify something that is not understood. (K-ESS3-2)

- **Mathematics**
  - **MP.2** Reason abstractly and quantitatively. (K-ESS2-1)
  - **MP.4** Model with mathematics. (K-ESS2-1), (K-ESS3-2)
  - **K.CC** Counting and Cardinality (K-ESS3-2)
  - **K.CC.A** Know number names and the count sequence. (K-ESS2-1)
  - **K.MD.A.1** Describe measurable attributes of objects, such as length or weight. Describe several measurable attributes of a single object. (K-ESS2-1)
  - **K.MD.A.2** Directly compare two objects with a measurable attribute in common, to see which object has "more of"/"less of" the attribute, and describe the difference. (K-PS3-1), (K-ESS2-1)
  - **K.MD.B.3** Classify objects into given categories; count the number of objects in each category and sort the categories by count. (K-ESS2-1)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled "Disciplinary Core Ideas" is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas.
# 1. Waves: Light and Sound

**Science and Engineering Practices**

<table>
<thead>
<tr>
<th>Planning and Carrying Out Investigations</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
</table>
| Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions. | PS4.A: Wave Properties  
- Sound can make matter vibrate, and vibrating matter can make sound. (1-PS4-1)  
PS4.B: Electromagnetic Radiation  
- Objects can be seen if light is available to illuminate them or if they give off their own light. (1-PS4-2)  
- Some materials allow light to pass through them, others allow only some light through and others block all the light and create a dark shadow on any surface beyond them, where the light cannot reach. Mirrors can be used to redirect a light beam. (Boundary: The idea that light travels from place to place is developed through experiences with light sources, mirrors, and shadows, but no attempt is made to discuss the speed of light.) (1-PS4-3)  
PS4.C: Information Technologies and Instrumentation  
- People also use a variety of devices to communicate (send and receive information) over long distances. (1-PS4-4) | Cause and Effect  
- Simple tests can be designed to gather evidence to support or refute student ideas about causes. (1-PS4-1),(1-PS4-2),(1-PS4-3)  
- Connections to Engineering, Technology, and Applications of Science  
- Influence of Engineering, Technology, and Science, on Society and the Natural World  
- People depend on various technologies in their lives; human life would be very different without technology. (1-PS4-4) |
| Connections to Nature of Science |

**Scientific Investigations Use a Variety of Methods**

- Science investigations begin with a question. (1-PS4-1)  
- Scientists use different ways to study the world. (1-PS4-1)  
- Scientific investigations build on prior experiences and progress to simple investigations, based on fair tests, which provide data to support explanations or design solutions. (1-PS4-1)

**Connections to other DCIs in first grade:** N/A

**Articulation of DCIs across grade-levels:** K.ETS1.A (1-PS4-4); 2.PS1.A (1-PS4-3); 2.ETS1.B (1-PS4-4); 4.PS4.C (1-PS4-4); 4.PS4.B (1-PS4-2); 4.ETS1.A (1-PS4-4)

---

Kentucky Academic Standards Connections:

- **ELA/Literacy**
  - W.1.2 Write informative/explanatory texts in which they name a topic, supply some facts about the topic, and provide some sense of closure. (1-PS4-2)
  - W.1.7 Participate in shared research and writing projects (e.g., explore a number of “how-to” books on a given topic and use them to write a sequence of instructions). (1-PS4-1),(1-PS4-2),(1-PS4-3),(1-PS4-4)
  - W.1.8 With guidance and support from adults, recall information from experiences or gather information from provided sources to answer a question. (1-PS4-1),(1-PS4-2),(1-PS4-3)
  - SL.1.1 Participate in collaborative conversations with diverse partners about grade 1 topics and texts with peers and adults in small and larger groups. (1-PS4-1),(1-PS4-2),(1-PS4-3)
  - Mathematics  
    - MP.5 Use appropriate tools strategically. (1-PS4-4)
    - 1.MD.1 Order three objects by length; compare the lengths of two objects indirectly by using a third object. (1-PS4-4)
    - 1.MD.2 Express the length of an object as a whole number of length units, by layering multiple copies of a shorter object (the length unit) end to end; understand that the length measurement of an object is the number of same-size length units that span it with no gaps or overlaps. (1-PS4-4)

---

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled “Disciplinary Core Ideas” is reproduced verbatim from A Framework for K–12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.*
# 1. Structure, Function, and Information Processing

Students who demonstrate understanding can:

1-LS1-1. Use materials to design a solution to a human problem by mimicking how plants and/or animals use their external parts to help them survive, grow, and meet their needs.\(^1\) (Clarification Statement: Examples of human problems that can be solved by mimicking plant or animal solutions could include designing clothing or equipment to protect bicyclists by mimicking turtle shells, acorn shells, and animal scales; stabilizing structures by mimicking animal tails and roots on plants; keeping out intruders by mimicking thorns on branches and animal quills; and, detecting intruders by mimicking eyes and ears.)

1-LS1-2. Read texts and use media to determine patterns in behavior of parents and offspring that help offspring survive. (Clarification Statement: Examples of patterns of behaviors could include the signals that offspring make (such as crying, cheeping, and other vocalizations) and responses of the parents (such as feeding, comforting, and protecting the offspring.).)

1-LS3-1. Make observations to construct an evidence-based account that young plants and animals are like, but not exactly like, their parents. (Clarification Statement: Examples of patterns could include features plants or animals share. Examples of observations could include leaves from the same kind of plant are the same shape but can differ in size; and, a particular breed of dog looks like its parents but is not exactly the same.)

1-LT1-2. Use appropriate tools strategically. (1-LT1-2; 1-LT3-1)

1-LT3-1. Structure and Function
- The shape and stability of structures of natural and designed objects are related to their function(s). (1-LT1-1)

**Connections to Other DCIs in First Grade:** N/A

### Disciplinary Core Ideas

<table>
<thead>
<tr>
<th>Science and Engineering Practices</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constructing Explanations and Designing Solutions</td>
<td>Patterns</td>
</tr>
<tr>
<td>Constructing explanations and designing solutions in K–2 builds on prior experiences and progresses to the use of evidence and ideas in constructing evidence-based accounts of natural phenomena and designing solutions.</td>
<td></td>
</tr>
<tr>
<td>- Make observations ( firsthand or from media) to construct an evidence-based account for natural phenomena. (1-LS1-1)</td>
<td></td>
</tr>
<tr>
<td>- Use materials to design a device that solves a specific problem or a solution to a specific problem. (1-LS1-1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Obtaining, Evaluating, and Communicating Information</td>
<td>Connections to Engineering, Technology, and Applications of Science</td>
</tr>
<tr>
<td>Obtaining, evaluating, and communicating information in K–2 builds on prior experiences and uses observations and texts to communicate new information.</td>
<td></td>
</tr>
<tr>
<td>- Read grade-appropriate texts and use media to obtain scientific information to determine patterns in the natural world. (1-LS1-2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Scientific Knowledge is Based on Empirical Evidence</td>
<td>Influence of Engineering, Technology, and Science on Society and the Natural World</td>
</tr>
<tr>
<td>Scientists look for patterns and order when making observations about the world. (1-LS1-2)</td>
<td></td>
</tr>
</tbody>
</table>

### Connections to Other DCIs in Grade Levels:

- **1-LS1-1:** 1-LT1-2; 1-LT3-1
- **1-LS2-D:** 1-LT1-2; 1-LT3-1
- **1-LS3-A:** 1-LT1-2; 1-LT3-1
- **1-LS3-B:** 1-LT1-2; 1-LT3-1
- **1-LS3-C:** 1-LT1-2; 1-LT3-1
- **1-LS3-D:** 1-LT1-2; 1-LT3-1
- **4-LS1-A:** 1-LT1-2; 1-LT3-1
- **4-LS1-D:** 1-LT1-2; 1-LT3-1
- **4-ETS1-A:** 1-LT1-2; 1-LT3-1

---

\(^1\) The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled "Disciplinary Core Ideas" is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.
## 1. Space Systems: Patterns and Cycles

Students who demonstrate understanding can:

**1-ESS1-1. Use observations of the sun, moon, and stars to describe patterns that can be predicted.** [Clarification Statement: Examples of patterns could include that the sun and moon appear to rise in one part of the sky, move across the sky, and set; and stars other than our sun are visible at night but not during the day.] [Assessment Boundary: Assessment of star patterns is limited to stars being seen at night and not during the day.]

**1-ESS1-2. Make observations at different times of year to relate the amount of daylight to the time of year.** [Clarification Statement: Emphasis is on relative comparisons of the amount of daylight in the winter to the amount in the spring or fall.] [Assessment Boundary: Assessment is limited to relative amounts of daylight, not quantifying the hours or time of daylight.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education:*

<table>
<thead>
<tr>
<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Planning and Carrying Out Investigations</strong></td>
<td>ESS1.A: The Universe and Its Stars</td>
<td>Patterns</td>
</tr>
<tr>
<td>Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.</td>
<td>- Patterns of the motion of the sun, moon, and stars in the sky can be observed, described, and predicted. (1-ESS1-1)</td>
<td>- Patterns in the natural world can be observed, used to describe phenomena, and used as evidence. (1-ESS1-1),(1-ESS1-2)</td>
</tr>
<tr>
<td>• Make observations (firsthand or from media) to collect data that can be used to make comparisons. (1-ESS1-2)</td>
<td>ESS1.B: Earth and the Solar System</td>
<td>----------------------------------------------</td>
</tr>
<tr>
<td>Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations.</td>
<td>- Seasonal patterns of sunrise and sunset can be observed, described, and predicted. (1-ESS1-2)</td>
<td><strong>Connections to Nature of Science</strong></td>
</tr>
<tr>
<td>• Use observations (firsthand or from media) to describe patterns in the natural world in order to answer scientific questions. (1-ESS1-1)</td>
<td>Scientific Knowledge Assumes an Order and Consistency in Natural Systems</td>
<td>• Science assumes natural events happen today as they happened in the past. (1-ESS1-1)</td>
</tr>
<tr>
<td>Connections to other DCIs in first grade: N/A</td>
<td></td>
<td>• Many events are repeated. (1-ESS1-1)</td>
</tr>
</tbody>
</table>

**Articulation of DCIs across grade-levels:** 3.PS2.A (1-ESS1-1); 5.PS2.B (1-ESS1-1),(1-ESS1-2) 5-ESS1.B (1-ESS1-1),(1-ESS1-2)

**Kentucky Academic Standards Connections:**

**ELA/Literacy –**

- **W.1.7** Participate in shared research and writing projects (e.g., explore a number of “how-to” books on a given topic and use them to write a sequence of instructions). (1-ESS1-1),(1-ESS1-2)
- **W.1.8** With guidance and support from adults, recall information from experiences or gather information from provided sources to answer a question. (1-ESS1-1),(1-ESS1-2)

**Mathematics –**

- **MP.2** Reason abstractly and quantitatively. (1-ESS1-2)
- **MP.4** Model with mathematics. (1-ESS1-2)
- **MP.5** Use appropriate tools strategically. (1-ESS1-2)
- **1.OA.A.1** Use addition and subtraction within 20 to solve word problems involving situations of adding to, taking from, putting together, taking apart, and comparing, with unknowns in all positions, e.g., by using objects, drawings, and equations to represent the problem. (1-ESS1-2)
- **1.MD.C.4** Organize, represent, and interpret data with up to three categories; ask and answer questions about the total number of data points, how many in each category, and how many more or less are in one category than in another. (1-ESS1-2)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled “Disciplinary Core Ideas” is reproduced verbatim from *A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas.* Integrated and reprinted with permission from the National Academy of Sciences.*
2. Structure and Properties of Matter

Students who demonstrate understanding can:

2-PS1-1. Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties. [Clarification Statement: Observations could include color, texture, hardness, and flexibility. Patterns could include the similar properties that different materials share.]

2-PS1-2. Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose. [Clarification Statement: Examples of properties could include, strength, flexibility, hardness, texture, and absorbency.] [Assessment Boundary: Assessment of quantitative measurements is limited to length.]

2-PS1-3. Make observations to construct an evidence-based account of how an object made of a small set of pieces can be disassembled and made into a new object. [Clarification Statement: Examples of pieces could include blocks, building blocks, or other assorted small objects.]

2-PS1-4. Construct an argument with evidence that some changes caused by heating or cooling can be reversed and some cannot. [Clarification Statement: Examples of reversible changes could include materials such as water and butter at different temperatures. Examples of irreversible changes could include cooking an egg, freezing a plant leaf, and heating paper.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

<table>
<thead>
<tr>
<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning and Carrying Out Investigations</td>
<td>PS1.A: Structure and Properties of Matter</td>
<td>Patterns: Patterns in the natural and human designed world can be observed. (2-PS1-1)</td>
</tr>
<tr>
<td>Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.</td>
<td>Different kinds of matter exist and many of them can be either solid or liquid, depending on temperature. Matter can be described and classified by its observable properties. (2-PS1-1)</td>
<td>Cause and Effect: Events have causes that generate observable patterns. (2-PS1-4)</td>
</tr>
<tr>
<td>Analyzing and Interpreting Data</td>
<td>Different properties are suited to different purposes. (2-PS1-2),(2-PS1-3)</td>
<td>Simple tests can be designed to gather evidence to support or refute student ideas about causes. (2-PS1-2)</td>
</tr>
<tr>
<td>Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations.</td>
<td>A great variety of objects can be built up from a small set of pieces. (2-PS1-3)</td>
<td>Energy and Matter: Objects may break into smaller pieces and be put together into larger pieces, or change shapes. (2-PS1-3)</td>
</tr>
<tr>
<td>Analyze data from tests of an object or tool to determine if it works as intended.</td>
<td></td>
<td>Connections to Engineering, Technology, and Applications of Science</td>
</tr>
<tr>
<td>Constructing Explanations and Designing Solutions</td>
<td>PS1.B: Chemical Reactions</td>
<td>Influence of Engineering, Technology, and Science on Society and the Natural World</td>
</tr>
<tr>
<td>Constructing explanations and designing solutions in K–2 builds on prior experiences and progresses to the use of evidence and ideas in constructing evidence-based accounts of natural phenomena and designing solutions.</td>
<td>Heating or cooling a substance may cause changes that can be observed. Sometimes these changes are reversible, and sometimes they are not. (2-PS1-4)</td>
<td>Every human-made product is designed by applying some knowledge of the natural world and is built by using natural materials. (2-PS1-2)</td>
</tr>
<tr>
<td>Make observations (firsthand or from media) to construct an evidence-based account for natural phenomena. (2-PS1-3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engaging in Argument from Evidence</td>
<td>Connections to other DCIs in second grade: N/A</td>
<td></td>
</tr>
<tr>
<td>Engaging in argument from evidence in K–2 builds on prior experiences and progresses to comparing ideas and representations about the natural and designed world(s).</td>
<td>Articulation of DCIs across grade-levels: 4.ESS2.A (2-PS1-3); 5.PS1.A (2-PS1-1),(2-PS1-2),(2-PS1-3); 5.PS1.B (2-PS1-4); 5.LS2.A (2-PS1-3)</td>
<td></td>
</tr>
<tr>
<td>Construct an argument with evidence to support a claim. (2-PS1-4)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Kentucky Academic Standards Connections:

**ELA/Literacy—**

**RI.2.1** Ask and answer such questions as who, what, where, when, why, and how to demonstrate understanding of key details in a text. (2-PS1-4)

**RI.2.2** Describe the connection between a series of historical events, scientific ideas or concepts, or steps in technical procedures in a text. (2-PS1-4)

**RI.2.8** Describe how reasons support specific points the author makes in a text. (2-PS1-2),(2-PS1-4)

**W.2.1** Write opinion pieces in which they introduce the topic or book they are writing about, state an opinion, supply reasons that support the opinion, use linking words (e.g., because, and, also) to connect opinion and reasons, and provide a concluding statement or section. (2-PS1-4)

**W.2.7** Participate in shared research and writing projects (e.g., read a number of books on a single topic to produce a report; record science observations). (2-PS1-1), (2-PS1-2),(2-PS1-3)

**W.2.8** Recall information from experiences or gather information from provided sources to answer a question. (2-PS1-1),(2-PS1-2),(2-PS1-3)

**Mathematics—**

**MP.2** Reason abstractly and quantitatively. (2-PS1-2)

**MP.4** Model with mathematics. (2-PS1-1),(2-PS1-2)

**MP.5** Use appropriate tools strategically. (2-PS1-2)

**2.MD.D.10** Draw a picture graph and a bar graph (with single-unit scale) to represent a data set with up to four categories. Solve simple put-together, take-apart, and compare problems using information presented in a bar graph. (2-PS1-1),(2-PS1-2)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled “Disciplinary Core Ideas” is reproduced verbatim from *A Framework for K–12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas*. Integrated and reprinted with permission from the National Academy of Sciences.*
### 2. Interdependent Relationships in Ecosystems

Students who demonstrate understanding can:

2-LS2-1. **Plan and conduct an investigation to determine if plants need sunlight and water to grow.** [Assessment Boundary: Assessment is limited to testing one variable at a time.]

2-LS2-2. **Develop a simple model that mimics the function of an animal in dispersing seeds or pollinating plants.*

2-LS4-1. **Make observations of plants and animals to compare the diversity of life in different habitats.** [Clarification Statement: Emphasis is on the diversity of living things in each of a variety of different habitats.] [Assessment Boundary: Assessment does not include specific animal plant names in specific habitats.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

- **LS1** Science and Engineering Practices
- **LS2** Disciplinary Core Ideas
- **LS4** Crosscutting Concepts

### Develop and Using Models
Modeling in K–2 builds on prior experiences and progresses to include using and developing models (i.e., diagram, drawing, physical replica, diorama, dramatization, or storyboard) that represent concrete events or design solutions.

- Develop a simple model based on evidence to represent a proposed object or tool. (2-LS2-2)

### Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.

- Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence to answer a question. (2-LS2-1)
- Make observations (firsthand or from media) to collect data which can be used to make comparisons. (2-LS4-1)

### Scientific Knowledge is Based on Empirical Evidence
Scientists look for patterns and order when making observations about the world. (2-LS4-1)

### Connections to Nature of Science

<table>
<thead>
<tr>
<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LS2.A: Interdependent Relationships in Ecosystems</strong></td>
<td>Plants depend on water and light to grow. (2-LS2-1)</td>
<td>Cause and Effect</td>
</tr>
<tr>
<td></td>
<td>Plants depend on animals for pollination or to move their seeds around. (2-LS2-2)</td>
<td>• Events have causes that generate observable patterns. (2-LS2-1)</td>
</tr>
<tr>
<td><strong>LS4.D: Biodiversity and Humans</strong></td>
<td>There are many different kinds of living things in any area, and they exist in different places on land and in water. (2-LS4-1)</td>
<td>Structure and Function</td>
</tr>
<tr>
<td><strong>ETS1.B: Developing Possible Solutions</strong></td>
<td>Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem’s solutions to other people. (secondary to 2-LS2-2)</td>
<td></td>
</tr>
</tbody>
</table>

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled “Disciplinary Core Ideas” is reproduced verbatim from *A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas*. Integrated and reprinted with permission from the National Academy of Sciences.
2. Earth’s Systems: Processes that Shape the Earth

Students who demonstrate understanding can:

2-ESS1-1. Use information from present sources to provide evidence that Earth events can occur quickly or slowly.

[Clarification Statement: Examples of events and timescales could include volcanic explosions and earthquakes, which happen quickly and erosion of rocks, which occurs slowly.] [Assessment Boundary: Assessment does not include quantitative measurements of timescales.]

2-ESS2-1. Compare multiple solutions designed to slow or prevent wind or water from changing the shape of the land.*

[Clarification Statement: Examples of solutions could include different designs of dikes and windbreaks to hold back wind and water, and different designs for shrubs, grass, and trees to hold back the land.]

2-ESS2-2. Develop a model to represent the shapes and kinds of land and bodies of water in an area. [Assessment Boundary: Assessment does not include quantitative scaling in models.]

2-ESS2-3. Obtain information to identify where water is found on Earth and that it can be solid or liquid.

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:

<table>
<thead>
<tr>
<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developing and Using Models</td>
<td>ESS1.C: The History of Planet Earth</td>
<td>Patterns</td>
</tr>
<tr>
<td></td>
<td>• Some events happen very quickly; others occur very slowly, over a time period much longer than one can observe. (2-ESS1-1)</td>
<td>• Patterns in the natural world can be observed. (2-ESS2-2), (2-ESS2-3)</td>
</tr>
<tr>
<td>Constructing Explanations and Designing Solutions</td>
<td>ESS2.A: Earth Materials and Systems</td>
<td>Stability and Change</td>
</tr>
<tr>
<td></td>
<td>• Wind and water can change the shape of the land. (2-ESS2-1)</td>
<td>• Things may change slowly or rapidly. (2-ESS1-1), (2-ESS2-1)</td>
</tr>
<tr>
<td>Obtaining, Evaluating, and Communicating Information</td>
<td>ESS2.B: Plate Tectonics and Large-Scale System Interactions</td>
<td>Connections to Engineering, Technology, and Applications of Science</td>
</tr>
<tr>
<td></td>
<td>• Maps show where things are located. One can map the shapes and kinds of land and water in any area. (2-ESS2-2)</td>
<td>Influence of Engineering, Technology, and Science on Society and the Natural World</td>
</tr>
<tr>
<td></td>
<td>ESS2.C: The Roles of Water in Earth’s Surface Processes</td>
<td>• Developing and using technology has impacts on the natural world. (2-ESS2-1)</td>
</tr>
<tr>
<td></td>
<td>• Water is found in the ocean, rivers, lakes, and ponds. Water exists as solid ice and in liquid form. (2-ESS2-3)</td>
<td>-----------------------------</td>
</tr>
<tr>
<td></td>
<td>ETS1.C: Optimizing the Design Solution</td>
<td>Connections to Nature of Science</td>
</tr>
<tr>
<td></td>
<td>• Because there is always more than one possible solution to a problem, it is useful to compare and test designs. (secondary to 2-ESS2-1)</td>
<td>Science Addresses Questions About the Natural and Material World</td>
</tr>
<tr>
<td>Connections to other DCIs in second grade: 2.PS1.A (2-ESS2-3)</td>
<td></td>
<td>• Scientists study the natural and material world. (2-ESS2-1)</td>
</tr>
</tbody>
</table>

Articulation of DCIs across grade levels:


Kentucky Academic Standards Connections:

ELA/Literacy –

RI.2.1 Ask and answer such questions as who, what, where, when, why, and how to demonstrate understanding of key details in a text. (2-ESS1-1)

RI.2.3 Describe the connection between a series of historical events, scientific ideas or concepts, or steps in technical procedures in a text. (2-ESS2-1), (2-ESS2-1)

RI.2.9 Compare and contrast the most important points presented by two texts on the same topic. (2-ESS2-1)

W.2.6 With guidance and support from adults, use a variety of digital tools to produce and publish writing, including in collaboration with peers. (2-ESS1-1), (2-ESS2-3)

W.2.7 Participate in shared research and writing projects (e.g., read a number of books on a single topic to produce a report; record science observations). (2-ESS1-1)

W.2.8 Recall information from experiences or gather information from provided sources to answer a question. (2-ESS1-1), (2-ESS2-3)

SL.2.2 Recount or describe key ideas or details from a text read aloud or information presented orally or through other media. (2-ESS1-1)

SL.2.5 Create audio recordings of stories or poems; add drawings or other visual displays to stories or recounts of experiences when appropriate to clarify ideas, thoughts, and feelings. (2-ESS2-2)

Mathematics –

MP.2 Reason abstractly and quantitatively. (2-ESS2-1), (2-ESS2-1), (2-ESS2-2)

MP.4 Model with mathematics. (2-ESS1-1), (2-ESS2-2)

MP.5 Use appropriate tools strategically. (2-ESS2-1)

2.NBT.A Understand place value. (2-ESS1-1)

2.NBT.A.3 Read and write numbers to 1000 using base-ten numerals, number names, and expanded form. (2-ESS2-2)

2.MD.B.5 Use addition and subtraction within 100 to solve word problems involving lengths that are given in the same units, e.g., by using drawings (such as drawings of rulers) and equations with a symbol for the unknown number to represent the problem. (2-ESS2-1)
3. Forces and Interactions

Students who demonstrate understanding can:

3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object. [Clarification Statement: Examples could include an unbalanced force on one side of a ball can make it start moving; and, balanced forces pushing on a box from both sides will not produce any motion at all.] [Assessment Boundary: Assessment is limited to one variable at a time: number, size, or direction of forces. Assessment does not include quantitative force size, only qualitative and relative. Assessment is limited to gravity being addressed as a force that pulls objects down.]

3-PS2-2. Make observations and/or measurements of an object’s motion to provide evidence that a pattern can be used to predict future motion. [Clarification Statement: Examples of motion with a predictable pattern could include a child swinging in a swing, a ball rolling back and forth in a bowl, and two children on a see-saw.] [Assessment Boundary: Assessment does not include technical terms such as period and frequency.]

3-PS2-3. Ask questions to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other. [Clarification Statement: Examples of an electric force could include the force on hair from an electrically charged balloon and the electrical forces between a charged rod and pieces of paper; examples of a magnetic force could include the force between two permanent magnets, the force between an electromagnet and steel paperclips, and the force exerted by one magnet versus the force exerted by two magnets. Examples of cause and effect relationships could include how the distance between objects affects strength of the force and how the orientation of magnets affects the direction of the magnetic force.] [Assessment Boundary: Assessment is limited to forces produced by objects that can be manipulated by students, and electrical interactions are limited to static electricity.]

3-PS2-4. Define a simple design problem that can be solved by applying scientific ideas about magnets.* [Clarification Statement: Examples of problems could include constructing a latch to keep a door shut and creating a device to keep two moving objects from touching each other.]

The performance expectations above were developed using the following elements from the NRC document A Framework for K–12 Science Education:

Science and Engineering Practices

<table>
<thead>
<tr>
<th>Asking Questions and Defining Problems</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asking questions and defining problems in grades 3–5 builds on grades K–2 experiences and progresses to specifying qualitative relationships.</td>
<td>PS2.A: Forces and Motion</td>
<td>Patterns</td>
</tr>
<tr>
<td>• Ask questions that can be investigated based on patterns such as cause and effect relationships. (3-PS2-3)</td>
<td>• Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object’s speed or direction of motion. (Boundary: Qualitative and conceptual, but not quantitative addition of forces are used at this level.) (3-PS2-1)</td>
<td>• Patterns of change can be used to make predictions. (3-PS2-2)</td>
</tr>
<tr>
<td>• Define a simple problem that can be solved through the development of a new or improved object or tool. (3-PS2-4)</td>
<td>• The patterns of an object’s motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it. (Boundary: Technical terms, such as magnitude, velocity, momentum, and vector quantity, are not introduced at this level, but the concept that some quantities need both size and direction to be described is developed.) (3-PS2-2)</td>
<td>• Cause and Effect</td>
</tr>
<tr>
<td>Planning and Carrying Out Investigations</td>
<td>PS2.B: Types of Interactions</td>
<td>Cause and Effect</td>
</tr>
<tr>
<td>Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.</td>
<td>• Objects in contact exert forces on each other. (3-PS2-1)</td>
<td>• Cause and effect relationships are routinely identified. (3-PS2-1)</td>
</tr>
<tr>
<td>• Plan and conduct a simple investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. (3-PS2-1)</td>
<td>• Electric and magnetic forces between a pair of objects do not require that the objects be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other. (3-PS2-3), (3-PS2-4)</td>
<td>• Cause and effect relationships are routinely identified, tested, and used to explain change. (3-PS2-3)</td>
</tr>
<tr>
<td>• Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution. (3-PS2-2)</td>
<td></td>
<td><strong>Connections to Engineering, Technology, and Applications of Science</strong></td>
</tr>
</tbody>
</table>

Science Knowledge is Based on Empirical Evidence

• Science findings are based on recognizing patterns. (3-PS2-2)

Scientific Investigations Use a Variety of Methods

• Science investigations use a variety of methods, tools, and techniques. (3-PS2-1)

Connections to Nature of Science

**Connections to other DCIs in third grade:**

- **MS.ESS1.B (3-PS2-1); MS.ESS2.C (3-PS2-1)**
- **ETS1.A (3-PS2-4); MS.PS2.A (3-PS2-1); MS.PS2.B (3-PS2-2)**
- **ELA/Literacy –**
  - **RI.3.1** Ask and answer questions about a text, referring explicitly to the text as the basis for the answers. (3-PS2-1), (3-PS2-3)
  - **RI.3.3** Describe the relationship between a series of historical events, scientific ideas or concepts, or steps in technical procedures in a text, using language that pertains to time, sequence, and cause/effect. (3-PS2-3)
  - **RI.3.8** Describe the logical connection between particular sentences and paragraphs in a text (e.g., comparison, cause/effect, first/second/third in a sequence). (3-PS2-3) **W.3.7** Conduct short research projects that build knowledge about a topic. (3-PS2-1), (3-PS2-2)
  - **W.3.8** Recall information from experiences or gather information from print and digital sources; take brief notes on sources and sort evidence into provided categories. (3-PS2-1), (3-PS2-3)
  - **SL.3.3** Ask and answer questions about information from a speaker, offering appropriate elaboration and detail. (3-PS2-3)

**Mathematics –**

- **MP.2** Reason abstractly and quantitatively. (3-PS2-1)
- **MP.5** Use appropriate tools strategically. (3-PS2-1)
- **3.MD.A.2** Measure and estimate liquid volumes and masses of objects using standard units of grams (g), kilograms (kg), and liters (l). Add, subtract, multiply, or divide to solve one-step word problems involving masses or volumes that are given in the same units, e.g., by using drawings (such as a beaker with a measurement scale) to represent the problem. (3-PS2-1)

---

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

3. Interdependent Relationships in Ecosystems

Students who demonstrate understanding can:

3.LS2-1. Construct an argument that some animals form groups that help members survive.

3.LS4-1. Analyze and interpret data from fossils to provide evidence of the organisms and the environments in which they lived long ago. [Clarification Statement: Examples of data could include type, size, and distributions of fossil organisms. Examples of fossils and environments could include marine fossils found on dry land, tropical plant fossils found in Arctic areas, and fossils of extinct organisms.] [Assessment Boundary: Assessment does not include identification of specific fossils or present plants and animals. Assessment is limited to major fossil types and relative ages.]

3.LS3-2. Construct an argument that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all. [Clarification Statement: Examples of evidence could include needs and characteristics of the organisms and habitats involved. The organisms and their habitat make up a system in which the parts depend on each other.]

3.LS4-4. Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change. [Clarification Statement: Examples of environmental changes could include changes in land characteristics, water distribution, temperature, food, and other organisms.] [Assessment Boundary: Assessment is limited to a single environmental change. Assessment does not include the greenhouse effect or climate change.]

The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:

Science and Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts
---|---|---
Analyzing and Interpreting Data | LS2.C: Ecosystem Dynamics, Functioning, and Resilience | Cause and Effect
- Analyzing data in 3–5 builds on K–2 experiences and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations. When possible and feasible, digital tools should be used.
  - Analyze and interpret data to make sense of phenomena using logical reasoning. (3.LS4-1)
- Engaging in Argument from Evidence
  - Engaging in argument from evidence in 3–5 builds on K–2 experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed worlds.
  - Construct an argument with evidence, data, and/or a model. (3.LS2-1)
  - Construct an argument with evidence. (3.LS4-3)
  - Make a claim about the merit of a solution to a problem by citing relevant evidence about how it meets the criteria and constraints of the problem. (3.LS4-4)
- LS2.C: Ecosystem Dynamics, Functioning, and Resilience
  - When the environment changes in ways that affect a place’s physical characteristics, temperature, or availability of resources, some organisms survive and reproduce, others move to new locations, yet others move into the transformed environment, and some die. (secondary to 3.LS4-4)
- LS2.D: Social Interactions and Group Behavior
  - Being part of a group helps animals obtain food, defend themselves, and cope with changes. Groups may serve different functions and vary dramatically in size. (Note: Moved from K–2) (3.LS2-1)
  - Some kinds of plants and animals that once lived on Earth are no longer found anywhere. (Note: Moved from K–2) (3.LS4-1)
  - Fossils provide evidence about the types of organisms that lived long ago and also about the nature of their environments. (3.LS4-1)
- LS4.C: Adaptation
  - For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all. (3.LS4-3)
- LS4.D: Biodiversity and Humans
  - Populations live in a variety of habitats, and change in those habitats affects the organisms living there. (3.LS4-4)
- Cause and Effect
  - Cause and effect relationships are routinely identified and used to explain change. (3.LS2-1),(3.LS4-3)
- Scale, Proportion, and Quantity
  - Observable phenomena exist from very short to very long time periods. (3.LS4-1)

Interdependence of Science, Engineering, and Technology
- Knowledge of relevant scientific concepts and research findings is important in engineering. (3.LS4-4)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

Scientific Knowledge Assumes an Order and Consistency in Natural Systems
- Science assumes consistent patterns in natural systems. (3.LS4-1)

Connections to other DCIs in third grade: 3.ESS2.D (3.LS4-3); 3.ESS3.B (3.LS4-4)

Articulation of DCIs across grade-levels: K:ESS3.A (3.LS4-3); (3.LS4-4); 1.KST.1A (3.LS4-4); 1.LS1.B (3.LS2-1); 2.LS2A (3.LS4-3); (3.LS4-4); 2.LS4.D (3.LS4-3); (3.LS4-4); 4.ESS1.A, C (3.LS4-4); 4.ESS2.B (3.LS4-4); 4.ESS1.A, C (3.LS4-4); 4.ESS2.B (3.LS4-4); 4.ESS3.A (3.LS4-3); 4.ESS3.B (3.LS4-4); 4.ESS3.C (3.LS4-4); MS.ESS2 (3.LS4-4); MS.ESS2 (3.LS4-4); MS.ESS2 (3.LS4-4); MS.ESS2 (3.LS4-4); MS.ESS2 (3.LS4-4); MS.ESS2 (3.LS4-4); MS.ESS2 (3.LS4-4); KS.ESS2 (3.LS4-4); KS.ESS3.C (3.LS4-4)

Kentucky Academic Standards Connections:

ELA/Literacy
- RI.3.1 Ask and answer questions to demonstrate understanding of a text, referring explicitly to the text as the basis for the answers. (3.LS2-1),(3.LS4-1),(3.LS4-3),(3.LS4-4)
- RI.3.2 Determine the main idea of a text; recount the key details and explain how they support the main idea. (3.LS4-1),(3.LS4-3),(3.LS4-4)
- RI.3.3 Describe the relationship between a series of historical events, scientific ideas or concepts, or steps in technical procedures in a text, using language that pertains to time, sequence, and cause/effect. (3.LS2-1),(3.LS4-1),(3.LS4-3),(3.LS4-4)
- W.3.1 Write opinion pieces on topics or texts, supporting a point of view with reasons. (3.LS2-1),(3.LS4-1),(3.LS4-3),(3.LS4-4)
- W.3.2 Write informative/explanatory texts to examine a topic and convey ideas and information clearly. (3.LS4-1),(3.LS4-3),(3.LS4-4)
- W.3.9 Recall information from experiences or gather information from print and digital sources; take brief notes on sources and sort evidence into provided categories. (3.LS4-1)
- SL.3.4 Report on a topic or tell a story, or recount an experience with appropriate facts and relevant, descriptive details, speaking clearly at an understandable pace. (3.LS4-1)

Mathematics
- MP.2 Reason abstractly and quantitatively. (3.LS4-1),(3.LS4-4)
- MP.4 Model with mathematics. (3.LS2-1),(3.LS4-3),(3.LS4-4)
- MP.5 Use appropriate tools strategically. (3.LS2-1),(3.LS4-3)
- MP.7 Look for and make use of structure. (3.LS4-1)
- MP.8 Look for and express regularity in repeated reasoning. (3.LS4-1)

3.NBT Number and Operations in Base Ten (3.LS2-1)
3.MD.B.3 Draw a scaled picture graph and a scaled bar graph to represent a data set with several categories. Solve one- and two-step “how many more” and “how many less” problems using information presented in scaled bar graphs. (3.LS4-3)
3.MD.B.4 Generate measurement data by measuring lengths using rulers marked with halves and fourths of an inch. Show the data by making a line plot, where the horizontal scale is marked off in appropriate units—whole numbers, halves, or quarters. (3.LS4-1)

* The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled “Disciplinary Core Ideas” is reproduced verbatim from A Framework for K–12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.
3. Inheritance and Variation of Traits: Life Cycles and Traits

**Students who demonstrate understanding can:**

3-LS1. Develop models to describe that organisms have unique and diverse life cycles but all have in common birth, growth, reproduction, and death. [Clarification Statement: Changes organisms go through during their life form a pattern.] [Assessment Boundary: Assessment of plant life cycles is limited to those of flowering plants. Assessment does not include details of human reproduction.]

3-LS3. Analyze and interpret data to provide evidence that plants and animals have traits inherited from parents and that variation of those traits exists in a group of similar organisms. [Clarification Statement: Patterns are the similarities and differences in traits shared between offspring and their parents, or among siblings. Emphasis is on organisms other than humans.] [Assessment Boundary: Assessment is limited to non-human examples.]

3-LS3. Use evidence to support the explanation that traits can be influenced by the environment. [Clarification Statement: Examples of the environment affecting a trait could include normally tall plants grown with insufficient water are stunted; and, a pet dog that is given too much food and little exercise becomes overweight.]

3-LS4. Use evidence to construct an explanation for how the variations in characteristics among individuals of the same species can provide advantages in surviving, finding mates, and reproducing. [Clarification Statement: Examples of cause and effect relationships could be plants that have larger thorns than other plants may be less likely to be eaten by predators; and, animals that have better camouflage coloration than other animals may be more likely to survive and therefore more likely to leave offspring.]

The performance expectations above were developed using the following elements from the NRC document "A Framework for K-12 Science Education: 2011 Revision of the Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas."

### Science and Engineering Practices

#### Developing and Using Models

Modeling in 3–5 builds on K–2 experiences and progresses to building and revising simple models and using models to represent events and design solutions.

- Develop models to describe phenomena. (3-LS1-1)

#### Analyzing and Interpreting Data

Analyzing data in 3–5 builds on K–2 experiences and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations. When possible and feasible, digital tools should be used.

- Analyze and interpret data to make sense of phenomena using logical reasoning. (3-LS3-1)

#### Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 3–5 builds on K–2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems.

- Use evidence (e.g., observations, patterns) to support an explanation. (3-LS4-2)

- Use evidence (e.g., observations, patterns) to construct an explanation. (3-LS4-2)

### Disciplinary Core Ideas

#### LS1.B: Growth and Development of Organisms

- Reproduction is essential to the continued existence of every kind of organism. Plants and animals have unique and diverse life cycles. (3-LS1-1)

#### LS3.A: Inheritance of Traits

- Many characteristics of organisms are inherited from their parents. (3-LS3-1)

- Other characteristics result from individuals’ interactions with the environment, which can range from diet to learning. Many characteristics involve both inheritance and environment. (3-LS3-2)

#### LS3.B: Variation of Traits

- Different organisms vary in how they look and function because they have different inherited information. (3-LS3-1)

- The environment also affects the traits that an organism develops. (3-LS3-2)

#### LS4.B: Natural Selection

- Sometimes the differences in characteristics between individuals of the same species provide advantages in surviving, finding mates, and reproducing. (3-LS4-2)

### Crosscutting Concepts

#### Patterns

- Similarities and differences in patterns can be used to sort and classify natural phenomena. (3-LS3-1)

- Patterns of change can be used to make predictions. (3-LS3-1)

#### Cause and Effect

- Cause and effect relationships are routinely identified and used to explain change. (3-LS3-2)

### Scientific Knowledge is Based on Empirical Evidence

- Science findings are based on recognizing patterns. (3-LS1-1)

#### Connections to Other DCIs in third grade: 3-LS4.C


---

**Kentucky Academic Standards Connections:**

- ELA/Literacy—RI.3.1: Ask and answer questions to demonstrate understanding of a text, referring explicitly to the text as the basis for the answers. (3-LS3-1), (3-LS3-2)
- RI.3.2: Determine the main idea of a text; recount the key details and explain how they support the main idea. (3-LS3-1), (3-LS3-2)
- RI.3.3: Describe the relationship between a series of historical events, scientific ideas or concepts, or steps in technical procedures in a text, using language that pertains to time, sequence, and cause/effect. (3-LS3-1), (3-LS3-2)
- RI.3.7: Use information gained from illustrations (e.g., maps, photographs) and the words in a text to demonstrate understanding of the text (e.g., where, when, why, and how events occur). (3-LS1-1)
- W.3.2: Write informative/explanatory texts to examine a topic and convey ideas and information clearly. (3-LS3-1), (3-LS3-2)
- SL.3.4: Report on a topic or tell a story, recount an experience with appropriate facts and relevant, descriptive details, speaking clearly at an understandable pace. (3-LS3-1), (3-LS3-2)
- SL.3.5: Create engaging audio recordings of stories or poems that demonstrate fluid reading at an understandable pace; add visual displays when appropriate to emphasize or enhance certain facts or details. (3-LS1-1)

**Mathematics—**

- MP.2: Reason abstractly and quantitatively. (3-LS3-1), (3-LS3-2)
- MP.4: Model with mathematics. (3-LS3-1), (3-LS3-2)
- 3.NBT: Number and Operations in Base Ten (3-LS1-1)
- 3.NF: Number and Operations—Fractions (3-LS1-1)
- 3.MD.B.3: Draw a scaled picture graph and a scaled bar graph to represent a data set with several categories. Solve one- and two-step "how many more" and "how many less" problems using information presented in scaled bar graphs. (3-LS3-1)
- 3.MD.B.4: Generate measurement data by measuring lengths using rulers marked with halves and fourths of an inch. Show the data by making a line plot, where the horizontal scale is marked off in appropriate units—whole numbers, halves, or quarters. (3-LS3-1), (3-LS3-2)

---

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled "Disciplinary Core Ideas" is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.*
### 3. Weather and Climate

**Science and Engineering Practices**

<table>
<thead>
<tr>
<th>Analyzing and Interpreting Data</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
</table>
| Analyzing data in 3–5 builds on K–2 experiences and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations. When possible and feasible, digital tools should be used. | ESS2.D: Weather and Climate
- Scientists record patterns of the weather across different times and areas so that they can make predictions about what kind of weather might happen next. (3-ESS2-1)
- Climate describes a range of an area’s typical weather conditions and the extent to which those conditions vary over years. (3-ESS2-2) | Patterns
- Patterns of change can be used to make predictions. (3-ESS2-1),(3-ESS2-2) |
| Engaging in Argument from Evidence | ESS3.B: Natural Hazards
- A variety of natural hazards result from natural processes. Humans cannot eliminate natural hazards but can take steps to reduce their impacts. (3-ESS3-1) *(Note: This Disciplinary Core Idea is also addressed by 4-ESS3-2.)* | Cause and Effect
- Cause and effect relationships are routinely identified, tested, and used to explain change. (3-ESS3-1) |
| Obtaining, evaluating, and communicating information | | Connections to Engineering, Technology, and Applications of Science |
| Obtaining, evaluating, and communicating information in 3–5 builds on K–2 experiences and progresses to evaluating the merit and accuracy of ideas and methods. | | Influence of Engineering, Technology, and Science on Society and the Natural World
- Engineers improve existing technologies or develop new ones to increase their benefits (e.g., better artificial limbs), decrease known risks (e.g., seatbelts in cars), and meet societal demands (e.g., cell phones). (3-ESS3-1) |

**Connections to other DCIs in third grade:** N/A

**Articulation of DCIs across grade-levels:**
- K.ESS2.D (3-ESS2-1); K.ESS3.B (3-ESS3-1); K.ETS1.A (3-ESS3-1); 4.ESS2.A (3-ESS2-1); 4.ESS3.B (3-ESS3-1); 4.ESS1.A (3-ESS3-1); 5.ESS2.A (3-ESS2-1); 5.ESS2.C (3-ESS2-1),(3-ESS2-2); MS.ESS2.D (3-ESS2-1),(3-ESS2-2); MS.ESS3.B (3-ESS3-1)

**Kentucky Academic Standards Connections:**

<table>
<thead>
<tr>
<th>ELA/Literacy –</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>RI.3.1 Ask and answer questions to demonstrate understanding of a text, referring explicitly to the text as the basis for the answers. (3-ESS2-2)</td>
<td>RI.3.9 Compare and contrast the most important points and key details presented in two texts on the same topic. (3-ESS2-2)</td>
<td></td>
</tr>
<tr>
<td>W.3.1 Write opinion pieces on topics or texts, supporting a point of view with reasons. (3-ESS3-1)</td>
<td>W.3.7 Conduct short research projects that build knowledge about a topic. (3-ESS3-1)</td>
<td></td>
</tr>
<tr>
<td>W.3.9 Recall information from experiences or gather information from print and digital sources; take brief notes on sources and sort evidence into provided categories. (3-ESS2-2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mathematics –</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MP.2 Reason abstractly and quantitatively. (3-ESS2-1),(3-ESS2-2),(3-ESS3-1)</td>
<td>MP.4 Model with mathematics. (3-ESS2-1),(3-ESS2-2),(3-ESS3-1)</td>
<td></td>
</tr>
<tr>
<td>MP.5 Use appropriate tools strategically. (3-ESS2-1)</td>
<td>3.MD.A.2 Measure and estimate liquid volumes and masses of objects using standard units of grams (g), kilograms (kg), and liters (l). Add, subtract, multiply, or divide to solve one-step word problems involving masses or volumes that are given in the same units, e.g., by using drawings (such as a beaker with a measurement scale) to represent the problem. (3-ESS2-1)</td>
<td></td>
</tr>
<tr>
<td>3.MD.B.3 Draw a scaled picture graph and a scaled bar graph to represent a data set with several categories. Solve one- and two-step “how many more” and “how many less” problems using information presented in bar graphs. (3-ESS2-1)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled “Disciplinary Core Ideas” is reproduced verbatim from A Framework for K–12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.*
## K-2. Engineering Design

### Science and Engineering Practices

<table>
<thead>
<tr>
<th>Asking Questions and Defining Problems</th>
<th>ETS1.A: Defining and Delimiting Engineering Problems</th>
<th>Structure and Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asking questions and defining problems in K–2 builds on prior experiences and progresses to simple descriptive questions.</td>
<td>A situation that people want to change or create can be approached as a problem to be solved through engineering. (K-2-ETS1-1)</td>
<td>The shape and stability of structures of natural and designed objects are related to their function(s). (K-2-ETS1-2)</td>
</tr>
<tr>
<td>• Ask questions based on observations to find more information about the natural and/or designed world. (K-2-ETS1-1)</td>
<td>• Asking questions, making observations, and gathering information are useful in thinking about problems. (K-2-ETS1-1)</td>
<td></td>
</tr>
<tr>
<td>• Define a simple problem that can be solved through the development of a new or improved object or tool. (K-2-ETS1-1)</td>
<td>• Before beginning to design a solution, it is important to clearly understand the problem. (K-2-ETS1-1)</td>
<td></td>
</tr>
</tbody>
</table>

### Disciplinary Core Ideas

<table>
<thead>
<tr>
<th>Developing and Using Models</th>
<th>ETS1.B: Developing Possible Solutions</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Modeling in K–2 builds on prior experiences and progresses to include using and developing models (i.e., diagram, drawing, physical replica, diorama, dramatization, or storyboard) that represent concrete events or design solutions.</td>
<td>Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem’s solutions to other people. (K-2-ETS1-2)</td>
<td></td>
</tr>
<tr>
<td>• Develop a simple model based on evidence to represent a proposed object or tool. (K-2-ETS1-2)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Crosscutting Concepts

<table>
<thead>
<tr>
<th>Analyzing and Interpreting Data</th>
<th>ETS1.C: Optimizing the Design Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations.</td>
<td>Because there is always more than one possible solution to a problem, it is useful to compare and test designs. (K-2-ETS1-3)</td>
</tr>
<tr>
<td>• Analyze data from tests of an object or tool to determine if it works as intended. (K-2-ETS1-3)</td>
<td></td>
</tr>
</tbody>
</table>

The performance expectations above were developed using the following elements from the NRC document A Framework for K–12 Science Education:

- Asking Questions and Defining Problems
- Developing and Using Models
- Analyzing and Interpreting Data
- ETS1.A: Defining and Delimiting Engineering Problems
- ETS1.B: Developing Possible Solutions
- ETS1.C: Optimizing the Design Solution

**Connections to K-2-ETS1.A: Defining and Delimiting Engineering Problems include:**

- Kindergarten: K-PS2-2, K-ESS3-2

**Connections to K-2-ETS1.B: Developing Possible Solutions Problems include:**

- Kindergarten: K-ESS3-3, First Grade: 1-PS4-4, Second Grade: 2-LS2-2

**Connections to K-2-ETS1.C: Optimizing the Design Solution include:**

- Second Grade: 2-ESS2-1

**Articulation of DCIs across grade-bands:**

- 3-5.ETS1.A (K-2-ETS1-1),(K-2-ETS1-2),(K-2-ETS1-3); 3-5.ETS1.B (K-2-ETS1-2),(K-2-ETS1-3); 3-5.ETS1.C (K-2-ETS1-1),(K-2-ETS1-2),(K-2-ETS1-3)

**Kentucky Academic Standards Connections:**

- **ELA/Literacy – RI.2.1**
  - Ask and answer such questions as who, what, where, when, why, and how to demonstrate understanding of key details in a text. (K-2-ETS1-1)

- **W.2.6**
  - With guidance and support from adults, use a variety of digital tools to produce and publish writing, including in collaboration with peers. (K-2-ETS1-1),(K-2-ETS1-3)

- **W.2.8**
  - Recall information from experiences or gather information from provided sources to answer a question. (K-2-ETS1-1),(K-2-ETS1-3)

- **SL.2.5**
  - Create audio recordings of stories or poems; add drawings or other visual displays to stories or recounts of experiences when appropriate to clarify ideas, thoughts, and feelings. (K-2-ETS1-2)

- **2.M.D.D.10**
  - Draw a picture graph and a bar graph (with single-unit scale) to represent a data set with up to four categories. Solve simple put-together, take-apart, and compare problems using information presented in a bar graph. (K-2-ETS1-1),(K-2-ETS1-3)

---

## 3-5. Engineering Design

**3-5. Engineering Design**

Students who demonstrate understanding can:

**3-5-ETS1-1.** Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

**3-5-ETS1-2.** Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

**3-5-ETS1-3.** Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education:*

<table>
<thead>
<tr>
<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Asking Questions and Defining Problems</strong></td>
<td><strong>ETS1.A: Defining and Delimiting Engineering Problems</strong></td>
<td><strong>Influence of Science, Engineering, and Technology on Society and the Natural World</strong></td>
</tr>
<tr>
<td>Asking questions and defining problems in 3–5 builds on grades K–2 experiences and progresses to specifying qualitative relationships.</td>
<td>Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. (3-5-ETS1-1)</td>
<td>• People’s needs and wants change over time, as do their demands for new and improved technologies. (3-5-ETS1-1)</td>
</tr>
<tr>
<td><strong>Planning and Carrying Out Investigations</strong></td>
<td><strong>ETS1.B: Developing Possible Solutions</strong></td>
<td>• Engineers improve existing technologies or develop new ones to increase their benefits, decrease known risks, and meet societal demands. (3-5-ETS1-2)</td>
</tr>
<tr>
<td>Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.</td>
<td>Research on a problem should be carried out before beginning to design a solution. Testing a solution involves investigating how well it performs under a range of likely conditions. (3-5-ETS1-2)</td>
<td></td>
</tr>
<tr>
<td>Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. (3-5-ETS1-3)</td>
<td>At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs. (3-5-ETS1-2)</td>
<td></td>
</tr>
<tr>
<td><strong>Constructing Explanations and Designing Solutions</strong></td>
<td><strong>ETS1.C: Optimizing the Design Solution</strong></td>
<td></td>
</tr>
<tr>
<td>Constructing explanations and designing solutions in 3–5 builds on K–2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems.</td>
<td>Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. (3-5-ETS1-3)</td>
<td></td>
</tr>
<tr>
<td>Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design problem. (3-5-ETS1-2)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Connections to 3-5-ETS1.A: Defining and Delimiting Engineering Problems include:**

- **Fourth Grade:** 4-PS3-4

**Connections to 3-5-ETS1.B: Designing Solutions to Engineering Problems include:**

- **Fourth Grade:** 4-ESS3-2

**Connections to 3-5-ETS1.C: Optimizing the Design Solution include:**

- **Fourth Grade:** 4-PS4-3

**Articulation of DCIs across grade-bands: K-2.ETS1.A (3-5-ETS1-1), (3-5-ETS1-2), (3-5-ETS1-3); K-2.ETS1.B (3-5-ETS1-2); K-2.ETS1.C (3-5-ETS1-2), (3-5-ETS1-3); MS.ETS1.A (3-5-ETS1-1); MS.ETS1.B (3-5-ETS1-1), (3-5-ETS1-2), (3-5-ETS1-3); MS.ETS1.C (3-5-ETS1-2), (3-5-ETS1-3)

Kentucky Academic Standards Connections:

- **ELA/Literacy**
  - **RI.5.1** Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from the text. (3-5-ETS-2)
  - **RI.5.2** Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently. (3-5-ETS-2)
  - **RI.5.9** Integrate information from several texts on the same topic in order to write or speak about the subject knowledgeably. (3-5-ETS-2)
  - **W.5.7** Conduct short research projects that use several sources to build knowledge through investigation of different aspects of a topic. (3-5-ETS1-1),(3-5-ETS1-3)
  - **W.5.8** Recall relevant information from experiences or gather relevant information from print and digital sources; summarize or paraphrase information in notes and finished work, and provide a list of sources. (3-5-ETS1-1),(3-5-ETS1-3)
  - **W.5.9** Draw evidence from literary or informational texts to support analysis, reflection, and research. (3-5-ETS1-1),(3-5-ETS1-3)

- **Mathematics**
  - **MP.2** Reason abstractly and quantitatively. (3-5-ETS1-1),(3-5-ETS1-2),(3-5-ETS1-3)
  - **MP.4** Model with mathematics. (3-5-ETS1-1),(3-5-ETS1-2),(3-5-ETS1-3)
  - **MP.5** Use appropriate tools strategically. (3-5-ETS1-1),(3-5-ETS1-2),(3-5-ETS1-3)
  - **3-5.OA** Operations and Algebraic Thinking (3-5-ETS1-1),(3-5-ETS1-2)

The section entitled “Disciplinary Core Ideas” is reproduced verbatim from *A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.*
INTERMEDIATE
SCIENCE
The Kentucky Academic Standards for Science are written as a set of performance expectations that are assessable statements of what students should know and be able to do. An underlying assumption of these standards is that all students should be held accountable for demonstrating their achievement of all performance expectations. A coherent and complete view of what students should be able to do comes when the performance expectations are viewed in tandem with the contents of the foundation boxes that lie just below the performance expectations. These three boxes include the practices, core disciplinary ideas, and crosscutting concepts, derived from the National Research Council's *Framework for K12 Science Education* that were used to construct this set of performance expectations.

**Science and Engineering Practices.** The blue box on the left includes just the science and engineering practices used to construct the performance expectations in the box above. These statements are derived from and grouped by the eight categories detailed in the *Framework* to further explain the science and engineering practices important to emphasize in each grade band. Most sets of performance expectations emphasize only a few of the practice categories; however, all practices are emphasized within a grade band.

**Disciplinary Core Ideas (DCIs).** The orange box in the middle includes statements that are taken from the *Framework* about the most essential ideas in the major science disciplines that all students should understand during 13 years of school. Including these detailed statements was very helpful to the writing team as they analyzed and “unpacked” the disciplinary core ideas and sub-ideas to reach a level that is helpful in describing what each student should understand about each sub-idea at the end of grades 2, 5, 8, and 12. Although they appear in paragraph form in the *Framework*, here they are bulleted to be certain that each statement is distinct.

**Crosscutting Concepts.** The green box on the right includes statements derived from the *Framework*’s list of crosscutting concepts, which apply to one or more of the performance expectations in the box above. Most sets of performance expectations limit the number of crosscutting concepts so as focus on those that are readily apparent when considering the DCIs; however, all are emphasized within a grade band. Aspects of the Nature of Science relevant to the standard are also listed in this box, as are the interdependence of science and engineering, and the influence of engineering, technology, and science on society and the natural world.

**Connection Boxes**
Three Connection Boxes, below the Foundation Boxes, are designed to support a coherent vision of the standards by showing how the performance expectations in each standard connect to other performance expectations in science, as well as to the KAS standards in Mathematics and English/Language Arts. The three boxes include:

- **Connections to other DCIs in this grade level or band.** This box contains the names of science topics in other disciplines that have related disciplinary core ideas at the same grade level. For example, both Physical Science and Life Science performance expectations contain core ideas related to Photosynthesis, and could be taught in relation to one another.

- **Articulation of DCIs across grade levels.** This box contains the names of other science topics that either 1) provide a foundation for student understanding of the core ideas in this set of performance expectations (usually at prior grade levels) or 2) build on the foundation provided by the core ideas in this set of performance expectations (usually at subsequent grade levels).
Connections to the Kentucky Academic Standards in mathematics and English/Language Arts. This box contains the coding and names of pre-requisite or co-requisite Kentucky Academic Standards in English Language Arts & and Literacy and Mathematics that align to the performance expectations. An effort has been made to ensure that the mathematical skills that students need for science were taught in a previous year where possible.
4. Energy

Students who demonstrate understanding can:

4-PS3-1. Use evidence to construct an explanation relating the speed of an object to the energy of that object. [Assessment Boundary: Assessment does not include quantitative measures of changes in the speed of an object or on any precise or quantitative definition of energy.]

4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents. [Assessment Boundary: Assessment does not include quantitative measurements of energy.]

4-PS3-3. Ask questions and predict outcomes about the changes in energy that occur when objects collide. [Clarification Statement: Emphasis is on the change in the energy due to the change in speed, not on the forces, as objects interact.] [Assessment Boundary: Assessment does not include quantitative measurements of energy.]

4-PS3-4. Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.* [Clarification Statement: Examples of devices could include electric circuits that convert electrical energy into motion energy of a vehicle, light, or sound; and, a passive solar heater that converts light into heat. Examples of constraints could include the materials, cost, or time to design the device.] [Assessment Boundary: Devices should be limited to those that convert motion energy to electric energy or use stored energy to cause motion or produce light or sound.]

4-ESS3-1. Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment. [Clarification Statement: Examples of renewable energy resources could include wind energy, water behind dams, and sunlight; nonrenewable energy resources are fossil fuels and emissary materials. Examples of environmental effects could include loss of habitat due to dams, loss of habitat due to surface mining, and air pollution from burning of fossil fuels.]

The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:

<table>
<thead>
<tr>
<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asking Questions and Defining Problems</td>
<td>PS3.A: Definitions of Energy</td>
<td>Cause and Effect</td>
</tr>
<tr>
<td>Asking questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships. (4-PS3-3)</td>
<td>The faster a given object is moving, the more energy it possesses. (4-PS3-1)</td>
<td>*Cause and effect relationships are routinely identified and used to explain change. (4-ESS3-1)</td>
</tr>
<tr>
<td>Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.</td>
<td>Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced. (4-PS3-2)</td>
<td>Energy can be transferred in various ways and between objects. (4-PS3-1), (4-PS3-2), (4-PS3-3), (4-PS3-4)</td>
</tr>
<tr>
<td>Constructing Explanations and Designing Solutions</td>
<td>PS3.D: Energy in Chemical Processes and Everyday Life</td>
<td>Connections to Engineering, Technology, and Applications of Science</td>
</tr>
<tr>
<td>Constructing explanations and designing solutions in 3–5 builds on K–2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems.</td>
<td>The expression &quot;produce energy&quot; typically refers to the conversion of stored energy into a desired form for practical use. (4-PS3-4)</td>
<td>Interdependence of Science, Engineering, and Technology</td>
</tr>
<tr>
<td>Obtaining, Evaluating, and Communicating Information</td>
<td>ETS1.A: Defining Engineering Problems</td>
<td>Knowledge of relevant scientific concepts and research findings is important in engineering. (4-ESS3-1)</td>
</tr>
<tr>
<td>Obtaining, evaluating, and communicating information in 3–5 builds on K–2 experiences and progresses to evaluate the merit and accuracy of ideas and methods.</td>
<td>Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria).</td>
<td>Influence of Engineering, Technology, and Science on Society and the Natural World</td>
</tr>
<tr>
<td>Obtain and combine information from books and other reliable media to explain phenomena. (4-ESS3-1)</td>
<td>Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. (secondary to 4-PS3-4)</td>
<td>Over time, people's needs and wants change, as do their demands for new and improved technologies. (4-ESS3-1)</td>
</tr>
</tbody>
</table>

Connections to other DCLs in fourth grade: N/A

Articulation of DCLs across grade-levels: K.PS2.B (4-PS3-3); K.ETS1.A (4-PS3-4); 2.PS1.A (4-PS3-1); 2.PS1.B (4-PS3-4); 3.PS2.A (4-PS3-3); 3.PS2.B (4-PS3-4); 5.PS3.D (4-PS3-4); 5.LS1.C (4-PS3-3); S.ESS3.C (4-ESS3-1); MS.PS2.A (4-PS3-3); MS.PS2.B (4-PS3-2); MS.PS2.A (4-PS3-1); (4-PS3-2), (4-PS3-3), (4-PS3-4); MS.PS2.B (4-PS3-2), (4-PS3-3), (4-PS3-4); MS.PS3.C (4-PS3-3); MS.PS3.D (4-ESS3-1); MS.PS3.B (4-PS3-2); MS.ESS2.A (4-ESS3-1); MS.ESS3.A (4-ESS3-1); MS.ESS3.C (4-ESS3-1); MS.ESS3.D (4-ESS3-1); MS.ESS1.B (4-PS3-4); MS.ESS1.C (4-PS3-4)

Kentucky Academic Standards Connections:

ELA/Literacy –

RI.4.1 Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text. (4-PS3-1)

RI.4.3 Explain events, procedures, ideas, or concepts in a historical, scientific, or technical text, including what happened and why, based on specific information in the text. (4-PS3-1)

RI.4.9 Integrate information from two texts on the same topic in order to write or speak about the subject knowledgeably. (4-PS3-1)

RI.4.10 Write informative/explanatory texts to examine a topic or convey ideas and information clearly. (4-PS3-1)

W.4.7 Conduct short research projects that build knowledge through investigation of different aspects of a topic. (4-PS3-2), (4-PS3-3), (4-PS3-4), (4-ESS3-1)

W.4.8 Recall relevant information from experiences or gather relevant information from print and digital sources; take notes and categorize information, and provide a list of sources. (4-PS3-1), (4-PS3-2), (4-PS3-3), (4-PS3-4), (4-ESS3-1)

W.4.9 Draw evidence from literary or informational texts to support analysis, reflection, and research. (4-PS3-1), (4-ESS3-1)

Mathematics –

MP.2 Reason abstractly and quantitatively. (4-ESS3-1)

MP.4 Model with mathematics. (4-ESS3-1)

4.OAA.1 Interpret a multiplication equation as a comparison, e.g., interpret 35 = 5 × 7 as a statement that 35 is 5 times as many as 7 and 7 times as many as 5. Represent verbal statements of multiplicative comparisons as multiplication equations. (4-ESS3-1)

4.OAA.3 Solve multistep word problems posed with whole numbers and having whole-number answers using the four operations, including problems in which remainders must be interpreted. Represent these problems using equations with a letter standing for the unknown quantity. Assess the reasonableness of answers using mental computation and estimation strategies including rounding. (4-PS3-4)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

The section entitled "Disciplinary Core Ideas" is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academies of Sciences.
4. Waves: Waves and Information

Students who demonstrate understanding can:

**4-PS4-1.** Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can objects to move. [Clarification Statement: Examples of models could include diagrams, analogies, and physical models using wire to illustrate wavelength and amplitude of waves.] [Assessment Boundary: Assessment does not include interference effects, electromagnetic waves, non-periodic waves, or quantitative models of amplitude and wavelength.]

**4-PS4-3.** Generate and compare multiple solutions that use patterns to transfer information.* [Clarification Statement: Examples of solutions could include drums sending coded information through sound waves, using a grid of 1’s and 0’s representing black and white to send information about a picture, and using Morse code to send text.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education:*

<table>
<thead>
<tr>
<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developing and Using Models</td>
<td>PS4.A: Wave Properties</td>
<td>Patterns</td>
</tr>
<tr>
<td>Modeling in 3–5 builds on K–2 experiences and progresses to building and revising simple models and using models to represent events and design solutions.</td>
<td>• Waves, which are regular patterns of motion, can be made in water by disturbing the surface. When waves move across the surface of deep water, the water goes up and down in place; there is no net motion in the direction of the wave except when the water meets a beach. <em>(Note: This grade band endpoint was moved from K–2).</em> (4-PS4-1)</td>
<td>• Similarities and differences in patterns can be used to sort and classify natural phenomena. (4-PS4-3)</td>
</tr>
<tr>
<td>• Develop a model using an analogy, example, or abstract representation to describe a scientific principle. (4-PS4-1)</td>
<td>• Waves of the same type can differ in amplitude (height of the wave) and wavelength (spacing between wave peaks). (4-PS4-1)</td>
<td>• Similarities and differences in patterns can be used to sort and classify designed products. (4-PS4-3)</td>
</tr>
<tr>
<td>Constructing Explanations and Designing Solutions</td>
<td>PS4.C: Information Technologies and Instrumentation</td>
<td>Connections to Engineering, Technology, and Applications of Science</td>
</tr>
<tr>
<td>Constructing explanations and designing solutions in 3–5 builds on K–2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems.</td>
<td>• Digitized information transmitted over long distances without significant degradation. High-tech devices, such as computers or cell phones, can receive and decode information—convert it from digitized form to voice—and vice versa. (4-PS4-3)</td>
<td>Interdependence of Science, Engineering, and Technology</td>
</tr>
<tr>
<td>• Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution. (4-PS4-3)</td>
<td>ETS1.C: Optimizing The Design Solution</td>
<td>• Knowledge of relevant scientific concepts and research findings is important in engineering. (4-PS4-3)</td>
</tr>
<tr>
<td>Scientific Knowledge is Based on Empirical Evidence</td>
<td>• Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. (secondary to 4-PS4-3)</td>
<td></td>
</tr>
<tr>
<td>• Science findings are based on recognizing patterns. (4-PS4-1)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled “Disciplinary Core Ideas” is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.*
# 4. Structure, Function, and Information Processing

## Students who demonstrate understanding can:

### 4-PS4-2. Develop a model to describe that light reflecting from objects and entering the eye allows objects to be seen.

[Assessment Boundary: Assessment does not include knowledge of specific colors reflected and seen, the cellular mechanisms of vision, or how the works.]

### 4-LS1-1. Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.

[Clarification Statement: Examples of structures could include thorns, stems, roots, petals, heart, stomach, lung, brain, and skin.]

[Assessment Boundary: Assessment is limited to macroscopic structures within plant and animal systems.]

### 4-LS1-2. Use a model to describe that animals receive different types of information through their senses, process the information in their brain, and respond to the information in different ways.

[Clarification Statement: Emphasis is on of information transfer.]

The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:

<table>
<thead>
<tr>
<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Developing and Using Models</strong></td>
<td>PS4.B: Electromagnetic Radiation</td>
<td></td>
</tr>
<tr>
<td>Modeling in 3–5 builds on K–2 experiences and progresses to building and revising simple models and using models to represent events and design solutions.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Develop a model to describe phenomena. (4-PS4-2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Use a model to test interactions concerning the functioning of a natural system. (4-LS1-2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Engaging in Argument from Evidence</strong></td>
<td>LS1:A: Structure and Function</td>
<td></td>
</tr>
<tr>
<td>Engaging in argument from evidence in 3–5 builds on K–2 experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world(s).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Construct an argument with evidence, data, and/or a model. (4-LS1-1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>LS1:D: Information Processing</strong></td>
<td>LS1:D: Information Processing</td>
<td></td>
</tr>
<tr>
<td>• Different sense receptors are specialized for particular kinds of information, which may be then processed by the animal’s brain. Animals are able to use their perceptions and memories to guide their actions. (4-LS1-2)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Connections to other DCIs in this grade-level: N/A

### Articulation of DCIs across grade-levels:

- **1.PS4.B** (4-PS4-2); **1.LS1.A** (4-LS1-1); **1.LS1.D** (4-LS1-2); **3.LS3.B** (4-LS1-1); **MS.PS4.B** (4-PS4-2); **MS.LS1.A** (4-LS1-1), (4-LS1-2); **MS.LS1.D** (4-PS4-2), (4-LS1-2)

### Kentucky Academic Standards Connections:

- **ELA/Literacy – W.4.1** Write opinion pieces on topics or texts, supporting a point of view with reasons and information. (4-LS1-1)
- **SL.4.5** Add audio recordings and visual displays to presentations when appropriate to enhance the development of main ideas or themes. (4-PS4-2), (4-LS1-2)
- **Mathematics – MP.4** Model with mathematics. (4-PS4-2)
- **4.G.A.1** Draw points, lines, line segments, rays, angles (right, acute, obtuse), and perpendicular and parallel lines. Identify these in two-dimensional figures. (4-PS4-2)
- **4.G.A.3** Recognize a line of symmetry for a two-dimensional figure as a line across the figure such that the figure can be folded across the line into matching parts. Identify line symmetric figures and draw lines of symmetry. (4-LS1-1)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled “Disciplinary Core Ideas” is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.*

**Kentucky Academic Standards – Science – Fourth Grade** 238
4. Earth’s Systems: Processes that Shape the Earth

Students who demonstrate understanding can:

4-ESS1-1. Identify evidence from patterns in rock formations and fossils in rock layers to support an explanation for changes in a landscape over time. [Clarification Statement: Examples of evidence from patterns could include rock layers with shell fossils above rock layers with plant fossils and no shells, indicating a change from water to land over time; and, a canyon with different rock layers in the walls and a river in the bottom, indicating that over time a river cut through the rock.] [Assessment Boundary: Assessment does not include specific knowledge of the mechanism of rock formation or memorization of specific rock formations and layers. Assessment is limited to relative time.]

4-ESS2-1. Make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation. [Clarification Statement: Examples of variables to test could include angle of slope in the downhill movement of water, amount of vegetation, speed of wind, relative rate of deposition, cycles of freezing and thawing of water, cycles of heating and cooling, and volume of water flow.] [Assessment Boundary: Assessment is limited to a single form of weathering or erosion.]

4-ESS2-2. Analyze and interpret data from maps to describe patterns of Earth’s features. [Clarification Statement: Maps can include topographic maps of Earth’s land and ocean floor, as well as maps of the locations of mountains, continental boundaries, volcanoes, and earthquakes.]

4-ESS3-2. Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.* [Clarification Statement: Examples of solutions could include designing an earthquake resistant building and improving monitoring of volcanic activity.] [Assessment Boundary: Assessment is limited to earthquakes, floods, tsunamis, and volcanic eruptions.]

The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:

<table>
<thead>
<tr>
<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning and Carrying Out Investigations</td>
<td>ESS1.C: The History of Planet Earth</td>
<td>Patterns</td>
</tr>
<tr>
<td>Constructing Explanations and Designing Solutions</td>
<td>ESS2.A: Earth Materials and Systems</td>
<td>Cause and Effect</td>
</tr>
<tr>
<td>Analyzing Data</td>
<td>ESS2.B: Plate Tectonics and Large-Scale System Interactions</td>
<td>Connections to Engineering, Technology, and Applications of Science</td>
</tr>
<tr>
<td>Interpreting Data</td>
<td>ESS3.B: Natural Hazards</td>
<td>Influence of Engineering, Technology, and Science on Society and the Natural World</td>
</tr>
</tbody>
</table>

Articulation of DCIs across grade-levels: K.ETS1.A (4-ESS1-2); 2.ETS1.C (4-ESS1-1); 5.ETS1.C (4-ESS1-2); 2.ETS2.A (4-ESS2-1); 2.ETS2.B (4-ESS2-2); 2.ETS1.B (4-ESS3-2); 2.ETS1.C (4-ESS3-2); 3.LS4.A (4-ESS1-2); 5.ESS2.A (4-ESS2-2); 5.ESS2.C (4-ESS2-3); 5.ESS2.D (4-ESS2-4); 5.ESS3.B (4-ESS3-2); 2.MS.ESS2.B (4-ESS2-1); 2.MS.ESS3.B (4-ESS3-2); 4.MS.ESS1.B (4-ESS1-2); 4.MS.ESS1.C (4-ESS1-3); 4.MS.ESS2.B (4-ESS2-1); 4.MS.ESS2.B (4-ESS2-2); 4.MS.ESS2.B (4-ESS2-3); 4.MS.ESS2.B (4-ESS2-4); 4.MS.ESS3.B (4-ESS3-2); 4.MS.ESS3.B (4-ESS3-3); 4.MS.ESS3.C (4-ESS3-4)

Kentucky Academic Standards Connections:

ELA/Literacy
RI.4.1 | Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text. (4-ESS1-2)
RI.4.7 | Interpret information presented visually, orally, or quantitatively (e.g., in charts, graphs, diagrams, time lines, animations, or interactive elements on Web pages) and explain how the information contributes to an understanding of the text in which it appears. (4-ESS2-2)
RI.4.9 | Integrate information from two texts on the same topic in order to write or speak about the subject knowledgeably. (4-ESS3-2)
W.4.7 | Conduct short research projects that build knowledge through investigation of different aspects of a topic. (4-ESS1-1), (4-ESS1-2)
W.4.6 | Recall relevant information from experiences or gather relevant information from print and digital sources; take notes and categorize information, and provide a list of sources. (4-ESS1-1), (4-ESS1-2)
W.4.9 | Draw evidence from literary or informational texts to support analysis, reflection, and research. (4-ESS1-1)
Mathematics
MP.2 | Reason abstractly and quantitatively. (4-ESS1-1), (4-ESS1-2), (4-ESS2-1)
MP.4 | Model with mathematics. (4-ESS1-1), (4-ESS1-2), (4-ESS2-1)
MP.5 | Use appropriate tools strategically. (4-ESS1-1)
4.MD.A.1 | For a given set of measurement units or a given sequence of measurement units, compute the measurement of a larger object using the given set of units or sequence of units as a standard. Compute with this standard set of units or sequence of units to solve word problems involving distances, times, liquid volumes, masses of objects, and money, including problems involving simple fractions or decimals, and problems that require expressing measured quantities in a larger unit in terms of a smaller unit. Record measurement equivalents in a two-column table. (4-ESS1-1), (4-ESS2-1)
4.MD.A.2 | Use the four operations to solve word problems involving distributions, intervals of time, liquid volumes, masses of objects, and money, including problems involving simple fractions or decimals, and problems that require expressing measured quantities in a larger unit in terms of a smaller unit. Represent measurement quantities using diagrams such as a line diagram that feature a measurement scale. (4-ESS1-1), (4-ESS2-2)
4.OA.A.1 | Interpret a multiplication equation as a comparison, e.g., interpret 35 = 5 × 7 as a statement that 35 is 5 times as many as 7 and 7 times as many as 5. Represent verbal statements of multiplicative comparisons as multiplication equations. (4-ESS2-3)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

## 5. Structure and Properties of Matter

### Developing and Using Models
Modeling in 3–5 builds on K–2 experiences and progresses to building and revising simple models and using models to represent events and design solutions.
- Develop a model to describe phenomena. (5-PS1-1)

### Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.
- Conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. (5-PS1-4)
- Make observations and measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon. (5-PS1-3)

### Using Mathematics and Computational Thinking
Mathematical and computational thinking in 3–5 builds on K–2 experiences and progresses to extending quantitative measurements to a variety of physical properties and using computation and mathematics to analyze data and compare alternative design solutions.
- Measure and graph quantities such as weight to address scientific and engineering questions and problems. (5-PS1-2)

### PS1.A: Structure and Properties of Matter
- Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means. A model showing that gases are made from matter particles that are too small to see and are moving freely around in space can explain many observations, including the inflation and shape of a balloon; the effects of air on larger particles or objects. (5-PS1-1)
- The amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish. (5-PS1-2)
- Measurements of a variety of properties can be used to identify materials. (Boundary: At this grade level, mass and weight are not distinguished, and no attempt is made to define the unseen particles or explain the atomic-scale mechanism of evaporation and condensation.) (5-PS1-3)

### PS1.B: Chemical Reactions
- When two or more different substances are mixed, a new substance with different properties may be formed. (5-PS1-4)
- No matter what reaction or change in properties occurs, the total weight of the substances does not change. (Boundary: Mass and weight are not distinguished at this grade level.) (5-PS1-2)

### Articulation of DCIs across grade-levels:
- **5-PS1.A** (5-PS1-1), (5-PS1-2), (5-PS1-3), (5-PS1-4); **MS-PS1.A** (5-PS1-1), (5-PS1-2), (5-PS1-3), (5-PS1-4)
- **RI.5.7** Draw from information on multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently. (5-PS1-1)
- **W.5.7** Conduct short research projects that use several sources to build knowledge through investigation of different aspects of a topic. (5-PS1-2), (5-PS1-3), (5-PS1-4)
- **W.9** Draw evidence from literary or informational texts to support analysis, reflection, and research. (5-PS1-2), (5-PS1-3), (5-PS1-4)
- **MP.2** Reason abstractly and quantitatively. (5-PS1-1), (5-PS1-2), (5-PS1-3)

### Crosscutting Concepts
- **Cause and Effect**
  - Cause and effect relationships are routinely identified, tested, and used to explain change. (5-PS1-4)
- **Scale, Proportion, and Quantity**
  - Natural objects exist from the very small to the immensely large. (5-PS1-1)
  - Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume. (5-PS1-2), (5-PS1-3)

### Connections to Nature of Science
- **Scientific Knowledge Assumes an Order and Consistency in Natural Systems**
  - Science assumes consistent patterns in natural systems. (5-PS1-2)

---

*The performance expectations marked with an asterisk integrate traditional scientific content with engineering through a Practice or Disciplinary Core Idea.*

5. Matter and Energy in Organisms and Ecosystems

Students who demonstrate understanding can:

5-PS3-1. Use models to describe that energy in animals' food (used for body repair, growth, motion, and to maintain body warmth) was once energy from the sun. [Clarification Statement: Examples of models could include diagrams, and flow charts.]

5-LS1-1. Support an argument that plants get the materials they need for growth chiefly from air and water. [Clarification Statement: Emphasis is on the idea that plant matter comes mostly from air and water, not from the soil.]

5-LS2-1. Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment. [Clarification Statement: Emphasis is on the idea that matter that is not food (air, water, decomposed materials in soil) is changed by plants into matter that is food. Examples of systems could include organisms, ecosystems, and the Earth.][Assessment Boundary: Assessment does not include molecular explanations.]

The performance expectations 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 3–5 builds on K–2 experiences and progresses to build and revise simple models and using models to represent events and design solutions.
- Use models to describe phenomena. (5-PS3-1)
- Develop a model to describe phenomena. (5-LS2-1)

Engaging in Argument from Evidence
Engaging in argument from evidence in 3–5 builds on K–2 experiences and progresses to critique explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world(s).
- Support an argument with evidence, data, or a model. (5-LS1-1)

Science Models, Laws, Mechanisms, and Theories
Explain Natural Phenomena
- Science explanations describe the mechanisms for natural events. (5-LS2-1)

Disciplinary Core Ideas

PS3.D: Energy in Chemical Processes and Everyday Life
- The energy released from food was once energy from the sun that was captured by plants in the chemical process that forms plant matter (from air and water). (5-PS3-1)

- Food provides animals with the materials they need for body repair and growth and the energy they need to maintain body warmth and for motion. (secondary to 5-PS3-1)
- Plants acquire their material for growth chiefly from air and water. (5-LS1-1)

LS2.A: Interdependent Relationships in Ecosystems
- The food of almost any animal can be traced back to plants. Organisms are related in food webs in which some animals eat plants for food and other animals eat the animals that eat plants. Some organisms, such as fungi and bacteria, break down dead organisms (both plants or plants parts and animals) and therefore operate as “decomposers.” Decomposition eventually restores (recycles) some materials back to the soil. Organisms can survive only in environments in which their particular needs are met. A healthy ecosystem is one in which multiple species of different types are each able to meet their needs in a relatively stable web of life. Newly introduced species can damage the balance of an ecosystem. (5-LS2-1)

LS2.B: Cycles of Matter and Energy Transfer in Ecosystems
- Matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. Organisms obtain gases, and water, from the environment, and release waste matter (gas, liquid, or solid) back into the environment. (5-LS2-1)

Crosscutting Concepts

Connecting to other DCIs in fifth grade: 5.PS1.A, 5-LS1-1, 5-LS2-1, 5-ESS2.A, 5-LS2-1


Kentucky Academic Standards Connections:

ELA/Literacy –
RI.5.1 Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from the text. (5-LS1-1)
RI.5.7 Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently. (5-PS3-1), (5-LS2-1)
RI.5.9 Integrate information from several texts on the same topic in order to write or speak about the subject knowledgeably. (5-LS1-1)
W.5.1 Write opinion pieces on topics or texts, supporting a point of view with reasons and information. (5-LS1-1)
SL.5.5 Include multimedia components (e.g., graphics, sound) and visual displays in presentations when appropriate to enhance the development of main ideas or themes. (5-PS3-1), (5-LS2-1)

Mathematics –
MP.2 Reason abstractly and quantitatively. (5-LS1-1), (5-LS2-1)
MP.4 Model with mathematics. (5-LS1-1), (5-LS2-1)
MP.5 Use appropriate tools strategically. (5-LS1-1)
S.MD.1.A Convert among different-sized standard measurement units within a given measurement system (e.g., convert 5 cm to 0.05 m), and use these conversions in solving multi-step, real-world problems. (5-LS1-1)

The section entitled "Disciplinary Core Ideas" is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.
5. Earth’s Systems

Students who demonstrate understanding can:

5-ESS2-1. Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact. [Clarification Statement: Examples could include the influence of the ocean on ecosystems, landform shape, and climate; the influence of the atmosphere on landforms and ecosystems through weather and climate; and the influence of mountain ranges on winds and clouds in the atmosphere. The geosphere, hydrosphere, atmosphere, and biosphere are each a system.] [Assessment Boundary: Assessment is limited to the interactions of two systems at a time.]

5-ESS2-2. Describe and graph the amounts and percentages of water and fresh water in various reservoirs to provide evidence about the distribution of water on Earth. [Assessment Boundary: Assessment is limited to oceans, lakes, rivers, glaciers, ground water, and polar ice caps, and does not include the atmosphere.]

5-ESS3-1. Obtain and combine information about ways individual communities use science ideas to protect the Earth’s resources and environment.

The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:

<table>
<thead>
<tr>
<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developing and Using Models</td>
<td>ESS2.A: Earth Materials and Systems</td>
<td>Scale, Proportion, and Quantity</td>
</tr>
<tr>
<td>Modeling in 3–5 builds on K–2 experiences and progresses to extending quantitative measurements to a variety of physical properties and using computational thinking in 3–5 builds on K–2 experiences and progresses to extending quantitative measurements to a variety of physical properties and using computational and mathematical thinking to analyze data and compare alternative design solutions.</td>
<td>• Earth’s major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth’s surface materials and processes. The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather. (5-ESS2-1)</td>
<td>• Standard units are used to measure and describe physical quantities such as weight, and volume. (5-ESS2-2)</td>
</tr>
<tr>
<td>Using Mathematics and Computational Thinking</td>
<td>ESS2.C: The Roles of Water in Earth’s Surface Processes</td>
<td>Systems and System Models</td>
</tr>
<tr>
<td>Mathematical and computational thinking in 3–5 builds on K–2 experiences and progresses to evaluating the merit and accuracy of ideas and methods.</td>
<td>• Nearly all of Earth’s available water is in the ocean. Most fresh water is in glaciers or underground; only a tiny fraction is in streams, lakes, wetlands, and the atmosphere. (5-ESS2-2)</td>
<td>• A system can be described in terms of its components and their interactions. (5-ESS2-1)</td>
</tr>
<tr>
<td>Obtaining, Evaluating, and Communicating Information</td>
<td>ESS3.C: Human Impacts on Earth Systems</td>
<td>Connections to Nature of Science</td>
</tr>
<tr>
<td>Obtaining, evaluating, and communicating information in 3–5 builds on K–2 experiences and progresses to evaluating the merit and accuracy of ideas and methods.</td>
<td>• Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth’s resources and environments. (5-ESS3-1)</td>
<td>Science Addresses Questions About the Natural and Material World</td>
</tr>
<tr>
<td>Obtain and combine information from books and/or other reliable media to explain phenomena or solutions to a design problem. (5-ESS3-1)</td>
<td>Connections to other DCIs in fifth grade: N/A</td>
<td></td>
</tr>
</tbody>
</table>

Articulation of DCIs across grade-levels: 2.ESSE.A (5-ESS2-1); 2.ESSE.C (5-ESS2-2); 3.ESSE.D (5-ESS2-1); 4.ESSE.A (5-ESS2-1); MS.ESSE.A (5-ESS2-1); MS.ESSE.C (5-ESS2-1),ESSE.D (5-ESS2-1); MS.ESSE.D (5-ESS2-1); MS.ESSE.A (5-ESS2-2),ESSE.D (5-ESS3-1); MS.ESSE.A (5-ESS3-1); MS.ESSE.D (5-ESS3-1)
5. Space Systems: Stars and the Solar System

Students who demonstrate understanding can:

5-PS2-1. Support an argument that the gravitational force exerted by Earth on objects is directed down. [Clarification Statement: "Down" is a local description of the direction that points toward the center of the spherical Earth.] [Assessment Boundary: Assessment does not include mathematical representation of gravitational force.]

5-ESS1-1. Support an argument that differences in the apparent brightness of the sun compared to other stars is due to relative distances from Earth. [Assessment Boundary: Assessment is limited to relative distances, not sizes, of stars. Assessment does not include causes of seasons.]

5-ESS1-2. Represent data in graphical displays to reveal patterns of daily changes in length and direction of shadows, day and night, and the seasonal appearance of some stars in the night sky. [Clarification Statement: Examples of patterns could include the position and motion of Earth with respect to the sun and selected stars that are visible only in particular months.] [Assessment Boundary: Assessment does not include causes of seasons.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education:*

<table>
<thead>
<tr>
<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analyzing and Interpreting Data</td>
<td>PS2.B: Types of Interactions</td>
<td>Patterns</td>
</tr>
<tr>
<td>Engaging in Argument from Evidence</td>
<td>ESS1.A: The Universe and its Stars</td>
<td>Similarities and differences in patterns can be used to sort, classify, communicate and analyze simple rates of change for natural phenomena. (5-ESS1-2)</td>
</tr>
<tr>
<td></td>
<td>ESS1.B: Earth and the Solar System</td>
<td>Cause and Effect</td>
</tr>
</tbody>
</table>

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled "Disciplinary Core Ideas" is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.*

Kentucky Academic Standards – Science – Fifth Grade

243
3-5. Engineering Design

Students who demonstrate understanding can:

3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:

Science and Engineering Practices

<table>
<thead>
<tr>
<th>Asking Questions and Defining Problems</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asking questions and defining problems in 3–5 builds on grades K–2 experiences and progresses to specifying qualitative relationships.</td>
<td>ETS1.A: Defining and Delimiting Engineering Problems</td>
<td></td>
</tr>
<tr>
<td>• Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost. (3-5-ETS1-1)</td>
<td>• Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. (3-5-ETS1-1)</td>
<td></td>
</tr>
<tr>
<td>Planning and Carrying Out Investigations</td>
<td>ETS1.B: Developing Possible Solutions</td>
<td></td>
</tr>
<tr>
<td>Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.</td>
<td>• Research on a problem should be carried out before beginning to design a solution. Testing a solution involves investigating how well it performs under a range of likely conditions. (3-5-ETS1-2)</td>
<td></td>
</tr>
<tr>
<td>• Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. (3-5-ETS1-3)</td>
<td>• At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs. (3-5-ETS1-2)</td>
<td></td>
</tr>
<tr>
<td>Constructing Explanations and Designing Solutions</td>
<td>ETS1:C: Optimizing the Design Solution</td>
<td></td>
</tr>
<tr>
<td>Constructing explanations and designing solutions in 3–5 builds on K–2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems.</td>
<td>• Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. (3-5-ETS1-3)</td>
<td></td>
</tr>
</tbody>
</table>
| • Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design problem. (3-5-ETS1-2) | Connections to 3-5-ETS1.A: Defining and Delimiting Engineering Problems include:
| Connections to 3-5-ETS1.B: Designing Solutions to Engineering Problems include:
| Connections to 3-5-ETS1.C: Optimizing the Design Solution include:
| Fourth Grade: 4-PS3-4
| Fourth Grade: 4-ESS3-2
| Fourth Grade: 4-PS4-3

Articulation of DCIs across grade-bands: K-2.ETS1.A (3-5-ETS1-1),(3-5-ETS1-2),(3-5-ETS1-3); K-2.ETS1.B (3-5-ETS1-2); K-2.ETS1.C (3-5-ETS1-2),(3-5-ETS1-3); MS.ETS1.A (3-5-ETS1-1); MS.ETS1.B (3-5-ETS1-2),(3-5-ETS1-3); MS.ETS1.C (3-5-ETS1-2),(3-5-ETS1-3)

Kentucky Academic Standards Connections:

ELA/Literacy –
RI.5.1 Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from the text. (3-5-ETS2)
RI.5.7 Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently. (3-5-ETS2)
RI.5.9 Integrate information from several texts on the same topic in order to write or speak about the subject knowledgeably. (3-5-ETS2)
W.5.7 Conduct short research projects that use several sources to build knowledge through investigation of different aspects of a topic. (3-5-ETS1-1),(3-5-ETS1-3)
W.5.8 Recall relevant information from experiences or gather relevant information from print and digital sources; summarize or paraphrase information in notes and finished work, and provide a list of sources. (3-5-ETS1-1),(3-5-ETS1-3)
W.5.9 Draw evidence from literary or informational texts to support analysis, reflection, and research. (3-5-ETS1-1),(3-5-ETS1-3)

Mathematics –
MP.2 Reason abstractly and quantitatively. (3-5-ETS1-1),(3-5-ETS1-2),(3-5-ETS1-3)
MP.4 Model with mathematics. (3-5-ETS1-1),(3-5-ETS1-2),(3-5-ETS1-3)
MP.5 Use appropriate tools strategically. (3-5-ETS1-1),(3-5-ETS1-2),(3-5-ETS1-3)
3-5.OA Operations and Algebraic Thinking (3-5-ETS1-1),(3-5-ETS1-2)

MIDDLE LEVEL SCIENCE
Kentucky Department of Education

The Kentucky Academic Standards for Science are written as a set of performance expectations that are assessable statements of what students should know and be able to do. An underlying assumption of these standards is that all students should be held accountable for demonstrating their achievement of all performance expectations. A coherent and complete view of what students should be able to do comes when the performance expectations are viewed in tandem with the contents of the foundation boxes that lie just below the performance expectations. These three boxes include the practices, core disciplinary ideas, and crosscutting concepts, derived from the National Research Council’s Framework for K12 Science Education that were used to construct this set of performance expectations.

Science and Engineering Practices
The blue box on the left includes just the science and engineering practices used to construct the performance expectations in the box above. These statements are derived from and grouped by the eight categories detailed in the Framework to further explain the science and engineering practices important to emphasize in each grade band. Most sets of performance expectations emphasize only a few of the practice categories; however, all practices are emphasized within a grade band.

Disciplinary Core Ideas (DCIs)
The orange box in the middle includes statements that are taken from the Framework about the most essential ideas in the major science disciplines that all students should understand during 13 years of school. Including these detailed statements was very helpful to the writing team as they analyzed and “unpacked” the disciplinary core ideas and sub-ideas to reach a level that is helpful in describing what each student should understand about each sub-idea at the end of grades 2, 5, 8, and 12. Although they appear in paragraph form in the Framework, here they are bulleted to be certain that each statement is distinct.

Crosscutting Concepts
The green box on the right includes statements derived from the Framework’s list of crosscutting concepts, which apply to one or more of the performance expectations in the box above. Most sets of performance expectations limit the number of crosscutting concepts so as focus on those that are readily apparent when considering the DCIs; however, all are emphasized within a grade band. Aspects of the Nature of Science relevant to the standard are also listed in this box, as are the interdependence of science and engineering, and the influence of engineering, technology, and science on society and the natural world.

Connection Boxes
Three Connection Boxes, below the Foundation Boxes, are designed to support a coherent vision of the standards by showing how the performance expectations in each standard connect to other performance expectations in science, as well as to the KAS standards in Mathematics and English/Language Arts. The three boxes include:

Connections to other DCIs in this grade level or band. This box contains the names of science topics in other disciplines that have related disciplinary core ideas at the same grade level. For example, both Physical Science and Life Science performance expectations contain core ideas related to Photosynthesis, and could be taught in relation to one another.
Articulation of DCIs across grade levels. This box contains the names of other science topics that either 1) provide a foundation for student understanding of the core ideas in this set of performance expectations (usually at prior grade levels) or 2) build on the
foundation provided by the core ideas in this set of performance expectations (usually at subsequent grade levels).

Connections to the Kentucky Academic Standards in mathematics and English/Language Arts. This box contains the coding and names of pre-requisite or co-requisite Kentucky Academic Standards in English Language Arts & and Literacy and Mathematics that align to the performance expectations. An effort has been made to ensure that the mathematical skills that students need for science were taught in a previous year where possible.
### MS. Structure and Properties of Matter

**Students who demonstrate understanding can:**

| 06-PS1-1. | Develop models to describe the atomic composition of simple molecules and extended structures. [Clarification Statement: Emphasis is on developing models of molecules that vary in complexity. Examples of simple molecules could include ammonia and methanol. Examples of extended structures could include sodium chloride or diamonds. Examples of molecular-level models could include drawings, 3D ball and stick structures or computer representations showing different molecules with different types of atoms.] [Assessment Boundary: Assessment does not include valence electrons and bonding energy, discussing the ionic nature of subunits of complex structures, or a complete depiction of all individual atoms in a complex molecule or extended structure.] |
| 06-PS1-3. | Gather and make sense of information to describe that synthetic materials come from natural resources and impact society. [Clarification Statement: Emphasis is on natural resources that undergo a chemical process to form the synthetic material. Examples of new materials could include new medicine, foods, and alternative fuels.] [Assessment Boundary: Assessment is limited to qualitative information.] |
| 06-PS1-4. | Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed. [Clarification Statement: Emphasis is on qualitative molecular-level models of solids, liquids, and gases to show that adding or removing thermal energy increases or decreases kinetic energy of the particles until a change of state occurs. Examples of models could include drawings and diagrams. Examples of particles could include molecules or inert atoms. Examples of pure substances could include water, carbon dioxide, and helium.] |

The performance expectations 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 | **PS1.A:** Structure and Properties of Matter | **Cause and Effect** |
| Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to describe, test, and predict more abstract phenomena and design systems. |
| Develop a model to predict and/or describe phenomena. (06-PS1-1), (06-PS1-4) | Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms (not probable). |
| Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (06-PS1-3) (Note: This Disciplinary Core Idea is also addressed by 07-PS1-2). |
| In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. (06-PS1-4) |
| Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals). (06-PS1-1) |
| The changes of state occur with variations in temperature or pressure can be described and predicted using these models of matter. (06-PS1-4) |
| **PS1.B:** Chemical Reactions |
| Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (06-PS1-3) (Note: This Disciplinary Core Idea is also addressed by 07-PS1-2 and 07-PS1-5) |
| PS1.A: Definitions of Energy |
| The term “heat” as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects. (secondary to 06-PS1-4) |
| The temperature of a system is proportional to the average internal kinetic energy and potential energy per atom or molecule (whichever is the appropriate building block for the system’s material). The details of that relationship depend on the type of atom or molecule and the interactions among the atoms in the material. Temperature is not a direct measure of a system’s total thermal energy. The total thermal energy (sometimes called the total internal energy) of a system depends jointly on the temperature, the total number of atoms in the system, and the state of the material. (secondary to 06-PS1-4) |

Connections to other DCIs in this grade-band: MS.LS2.A (06-PS1-3); MS.LS4.D (06-PS1-3); MS.ESS2.C (06-PS1-1), (06-PS1-4); MS.ESS3.A (06-PS1-3); MS.ESS3.C (06-PS1-3)

Articulation across grade-bands: S.PS1.A (06-PS1-1); HS.PS1.A (06-PS1-1), (06-PS1-3), (06-PS1-4); HS.PS1.B (06-PS1-4); HS.PS3.A (06-PS1-4); HS.LS2.A (06-PS1-3); HS.LS3.A (06-PS1-3); HS.LS4.D (06-PS1-3); HS.ESS1.A (06-PS1-1); HS.ESS3.A (06-PS1-3)

### Kentucky Academic Standards Connections:

<p>| ELA.Literacy – RST.6-8.1 | Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions (06-PS1-3) |
| RST.6-8.7 | Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, graph, or table). (06-PS1-1), (06-PS1-4) |
| WHST.6-8.8 | Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation. (06-PS1-3) |
| Mathematics – MP.2 | Reason abstractly and quantitatively. (06-PS1-1) |</p>
<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MP.4</td>
<td>Model with mathematics. (06-PS1-1)</td>
</tr>
<tr>
<td>6.RP.A.3</td>
<td>Use ratio and rate reasoning to solve real-world and mathematical problems. (06-PS1-1)</td>
</tr>
<tr>
<td>6.NS.C.5</td>
<td>Understand that positive and negative numbers are used together to describe quantities having opposite directions or values (e.g., temperature above/below zero, elevation above/below sea level, credits/debits, positive/negative electric charge); use positive and negative numbers to represent quantities in real-world contexts, explaining the meaning of 0 in each situation. (06-PS1-4)</td>
</tr>
<tr>
<td>8.EE.A.3</td>
<td>Use numbers expressed in the form of a single digit times an integer power of 10 to estimate very large or very small quantities, and to express how many times as much one is than the other. (06-PS1-1)</td>
</tr>
</tbody>
</table>

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled “Disciplinary Core Ideas” is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.*
MS. Chemical Reactions

Students who demonstrate understanding can:

07-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred. [Clarification Statement: Examples of reactions could include burning sugar or steel wool, fat reacting with sodium hydroxide, and mixing zinc with HCl.] [Assessment Boundary: Assessment is limited to analysis of the following properties: density, melting point, boiling point, solubility, flammability, and odor.]

07-PS1-5. Develop a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved. [Clarification Statement: Emphasis is on law of conservation of matter, and on physical models or drawings, including digital forms, that represent atoms.] [Assessment Boundary: Assessment does not include the use of atomic masses, balancing symbolic equations, or intermolecular forces.]

07-PS1-6. Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.* [Clarification Statement: Emphasis is on the design, controlling the transfer of energy to the environment, and modification of a device using factors such as type and concentration of a substance. Examples of designs could involve chemical reactions such as dissolving ammonium chloride or calcium chloride. [Assessment Boundary: Assessment is limited to the criteria of amount, time, and temperature of substance in testing the device.]

The performance expectations 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 6–8 builds on K–5 and progresses to developing, using and revising models to describe, test, and predict more abstract phenomena and design solutions.
  - Develop a model to describe unobservable mechanisms. (07-PS1-5)

- Analyzing and Interpreting Data
  - Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data analysis and error analysis.
  - Analyze and interpret data to determine similarities and differences in findings. (07-PS1-2)

- Constructing Explanations and Designing Solutions
  - Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.
  - Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints. (07-PS1-6)

- Scientific Knowledge is Based on Empirical Evidence
  - Scientific knowledge is based upon logical and conceptual connections between evidence and explanations. (07-PS1-2)

- Science Models, Laws, Mechanisms, and Theories
  - Explain Natural Phenomena
    - Laws are regularities or mathematical descriptions of natural phenomena. (07-PS1-5)

Disciplinary Core Ideas

  - Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (07-PS1-2) (Note: This Disciplinary Core Idea is also addressed by 06-PS1-3.)

- PS1.B: Chemical Reactions
  - Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are reorganized into different molecules, and these new substances have different properties from those of the reactants. (07-PS1-2),(07-PS1-5)
  - The total number of each type of atom is conserved, and thus the mass does not change. (07-PS1-5)
  - Some chemical reactions release energy, others store energy. (07-PS1-6)

- ETS1.B: Developing Possible Solutions
  - A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. (secondary to 07-PS1-6)

- ETS1.C: Optimizing the Design Solution
  - Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of the characteristics may be incorporated into the new design. (secondary to 07-PS1-6)
  - The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. (secondary to 07-PS1-6)

Crosscutting Concepts

- Patterns
  - Macroscopic patterns are related to the nature of microscopic and atomic-level structure. (07-PS1-2)

- Energy and Matter
  - Matter is conserved because atoms are conserved in physical and chemical processes. (07-PS1-5)
  - The transfer of energy can be tracked as energy flows through a designed or natural system. (07-PS1-6)

Connections to other DCIs in this grade-band: MS.PS3.D (07-PS1-2),(07-PS1-6); MS.LS1.C (07-PS1-2),(07-PS1-5); MS.LS2.B (07-PS1-5); MS.ESS2.A (07-PS1-2),(07-PS1-5)

Articulation across grade-bands: 5.PS1.B (07-PS1-2),(07-PS1-5); HS.PS1.A (07-PS1-6); HS.PS1.B (07-PS1-2),(07-PS1-5),(07-PS1-6); HS.PS3.A (07-PS1-6); HS.PS3.B (07-PS1-6); HS.PS3.D (07-PS1-6)

Kentucky Academic Standards Connections:

ELA/Literacy –
- R.I.7.1

Science and Engineering Practices –
- 07-PS1-2

- 07-PS1-5

- 07-PS1-6

- RST.6-8.1

- RST.6-8.3

- RST.6-8.7

- WHST.6-8.7

- MP.2

- 6.RP.A.3

- 6.SP.B.4

- 6.SP.B.5

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled “Disciplinary Core Ideas” is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.
MS. Forces and Interactions

Science and Engineering Practices

| Asking Questions and Defining Problems | PS2.1: For any pair of interacting objects, the force exerted by the first object on the second object is equal in magnitude to the force exerted by the second object on the first object. Assessment does not include the use of trigonometry. |
| Planning and Carrying Out Investigations | PS2.2: Types of Interactions Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. For any given object, a larger force causes a larger change in motion. All positions of objects and the directions of forces and motions must be described in an arbitrary reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared. |
| Constructing Explanations and Designing Solutions | PS2.3: Exerting forces on each other even though the objects are not in contact. Newton's Law of Gravitation and its applications can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively). |

MS. Forces and Interactions

Students who demonstrate understanding can:

06-PS2-1. Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects. [Clarification Statement: Examples of practical problems could include the impact of collisions between two cars, between a car and stationary objects, and between a meteor and a space vehicle.]

06-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object. [Clarification Statement: Emphasis is on balanced (Newton's First Law) and unbalanced forces in a system, qualitative comparisons of forces, mass and changes in motion (Newton's Second Law), frame of reference, and specification of units. Assessment Boundary: Assessment is limited to forces and changes in motion in one-dimension in an inertial reference frame, and to change in one variable at a time. Assessment does not include the use of trigonometry.]

07-PS2-3. Ask questions about data to determine the factors that affect the strength of electric and magnetic forces. [Clarification Statement: Examples of devices that use electric and magnetic forces could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or the speed of an electric motor. Assessment Boundary: Assessment about questions that require quantitative answers is limited to proportional reasoning and algebraic thinking.]

07-PS2-4. Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects. [Clarification Statement: Examples of evidence for arguments could include data generated from simulations or digital tools; and charts displaying mass, strength of interaction, distance from the Sun, and orbital periods of objects within the solar system. Assessment Boundary: Assessment does not include Newton's Law of Gravitation or Kepler's Laws.]

07-PS2-5. Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact. [Clarification Statement: Examples of this phenomenon could include the interactions of magnets, electrically-charged strips of tape, and electrically-charged ping-pong balls. Examples of investigations could include first-hand experiments or simulations.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

- **Cause and Effect**: Cause and effect relationships may be used to predict phenomena in natural or designed systems.
- **Systems and System Models**: Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems. Examples of systems and system models include the interactions of magnets, electrically-charged strips of tape, and electrically-charged ping-pong balls.
- **Stability and Change**: Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales.

**Connections to Engineering, Technology, and Applications of Science**

Influence of Science, Engineering, and Technology on Society and the Natural World

The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions.
### Kentucky Department of Education

#### MS. Forces and Interactions - Continued

<table>
<thead>
<tr>
<th>Kentucky Academic Standards Connections:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ELA/Literacy</strong> –</td>
<td></td>
</tr>
<tr>
<td>RST.6-8.1</td>
<td>Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. (06-PS2-1),(07-PS2-3)</td>
</tr>
<tr>
<td>RST.6-8.3</td>
<td>Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. (06-PS2-1),(06-PS2-2),(07-PS2-3)</td>
</tr>
<tr>
<td>WHST.6-8.1</td>
<td>Write arguments focused on discipline-specific content. (07-PS2-4)</td>
</tr>
<tr>
<td>WHST.6-8.7</td>
<td>Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. (06-PS2-1),(06-PS2-2),(07-PS2-5)</td>
</tr>
<tr>
<td><strong>Mathematics –</strong></td>
<td></td>
</tr>
<tr>
<td>MP.2</td>
<td>Reason abstractly and quantitatively. (06-PS2-1),(06-PS2-2),(07-PS2-3)</td>
</tr>
<tr>
<td>6.NS.C.5</td>
<td>Understand that positive and negative numbers are used together to describe quantities having opposite directions or values; use positive and negative numbers to represent quantities in real-world contexts, explaining the meaning of 0 in each situation. (06-PS2-1)</td>
</tr>
<tr>
<td>6.EE.A.2</td>
<td>Write, read, and evaluate expressions in which letters stand for numbers. (06-PS2-1),(06-PS2-2)</td>
</tr>
<tr>
<td>7.EE.B.3</td>
<td>Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form, using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies. (06-PS2-1),(06-PS2-2)</td>
</tr>
<tr>
<td>7.EE.B.4</td>
<td>Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities. (06-PS2-1),(06-PS2-2)</td>
</tr>
</tbody>
</table>

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled “Disciplinary Core Ideas” is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.*
Students who demonstrate understanding can:

08-PS3-1. Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object. [Clarification Statement: Emphasis is on descriptive relationships between kinetic energy and mass separately from kinetic energy and speed. Examples could include riding a bicycle at different speeds, rolling different sizes of rocks downhill, and getting hit by a wiffle ball versus a tennis ball.]

07-PS3-2. Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system. [Clarification Statement: Emphasis is on relative amounts of potential energy, not on calculations of potential energy. Examples of objects within systems interacting at varying distances could include: the Earth and either a roller coaster cart at varying positions on a hill or at varying heights on shelves, changing the direction/orientation of a magnet, and a balloon with static electrical charge being brought closer to a classmate’s hair. Examples of models could include representations, diagrams, pictures, and written descriptions of systems.] [Assessment Boundary: Assessment is limited to two and electric, magnetic, and gravitational interactions.]

07-PS3-3. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.* [Clarification Statement: Examples of devices could include an insulated box, a solar cooker, and a Styrofoam cup.] [Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.]

07-PS3-4. Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample. [Clarification Statement: Examples of experiments could include comparing final water temperatures after different masses of ice melted in the same volume of water with the same initial temperature, the temperature change of samples of different materials with the same mass as they cool or heat in the environment, or the same material with different masses when a specific amount of energy is added.] [Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.]

07-PS3-5. Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object. [Clarification Statement: Examples of empirical evidence used in arguments could include an inventory or other representation of the energy before and after the transfer in the form of temperature changes or motion of object.] [Assessment Boundary: Assessment does not include calculations of energy.]

The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:

<table>
<thead>
<tr>
<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developing and Using Models</td>
<td>PS3.A: Definitions of Energy</td>
<td>Scale, Proportion, and Quantity</td>
</tr>
<tr>
<td>Planning and Carrying Out Investigations</td>
<td>Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed. (08-PS3-1)</td>
<td>Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes. (08-PS3-1), (07-PS3-4)</td>
</tr>
<tr>
<td>Analyzing and Interpreting Data</td>
<td>A system of objects may also contain stored (potential) energy, depending on their relative positions. (07-PS3-2)</td>
<td>Systems and System Models</td>
</tr>
<tr>
<td>Constructing Explanations and Designing Solutions</td>
<td>Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. (07-PS3-3), (07-PS3-4)</td>
<td>Models can be used to represent systems and their interactions – such as inputs, processes, and outputs – and energy and matter flows within systems. (07-PS3-2)</td>
</tr>
<tr>
<td>Engaging in Argument from Evidence</td>
<td>When the motion energy of an object changes, there is inevitably some other change in energy at the same time. (07-PS3-5)</td>
<td>Energy and Matter</td>
</tr>
<tr>
<td>Connections to Nature of Science</td>
<td>The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment. (07-PS3-4)</td>
<td>Energy can take different forms (e.g. energy in fields, thermal energy, energy of motion). (07-PS3-5)</td>
</tr>
</tbody>
</table>

The transfer of energy can be tracked as energy flows through a designed or natural system. (07-PS3-3)
Kentucky Department of Education

MS. Energy - Continued

Kentucky Academic Standards Connections:

ELA/Literacy –

RST.6-8.1  Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. (08-PS3-1),(07-PS3-5)

RST.6-8.3  Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. (07-PS3-3),(07-PS3-4)

RST.6-8.7  Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, or table). (08-PS3-1)

WHST.6-8.1  Write arguments focused on discipline content. (07-PS3-5)

WHST.6-8.7  Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. (07-PS3-3),(07-PS3-4)

SL.8.5  Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. (07-PS3-2)

Mathematics –

MP.2  Reason abstractly and quantitatively. (08-PS3-1),(07-PS3-4),(07-PS3-5)

6.RP.A.1  Understand the concept of ratio and use ratio language to describe a ratio relationship between two quantities. (08-PS3-1),(07-PS3-5)

6.RP.A.2  Understand the concept of a unit rate a/b associated with a ratio a:b with b ≠ 0, and use rate language in the context of a ratio relationship. (08-PS3-1)

7.RP.A.2  Recognize and represent proportional relationships between quantities. (08-PS3-1),(07-PS3-5)

8.EE.A.1  Know and apply the properties of integer exponents to generate equivalent numerical expressions. (08-PS3-1)

8.EE.A.2  Use square root and cube root symbols to represent solutions to equations of the form x² = p and x³ = p, where p is a positive rational number. Evaluate square roots of small perfect squares and cube roots of small perfect cubes. Know that √2 is irrational. (08-PS3-1)

8.F.A.3  Interpret the equation y = mx + b as defining a linear function, whose graph is a straight line; give examples of functions that are not linear. (08-PS3-1),(07-PS3-5)

6.SP.B.5  Summarize numerical data sets in relation to their context. (07-PS3-4)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled "Disciplinary Core Ideas" is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences."
## MS. Waves and Electromagnetic Radiation

### Science and Engineering Practices

**Developing and Using Models**
- Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.
- Develop and use a model to describe phenomena. (07-PS4-2)

**Using Mathematics and Computational Thinking**
- Mathematical and computational thinking at the 6–8 level builds on K–5 and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments.
- Use mathematical representations to describe and support mathematical conclusions and design solutions. (07-PS4-1)

**Obtaining, Evaluating, and Communicating Information**
- Obtaining, evaluating, and communicating information in 6–8 builds on K–5 and progresses to evaluating the merit and validity of ideas and methods.
- Integrate qualitative scientific and technical information in written text with that contained in media and visual displays to clarify claims and findings. (07-PS4-3)

### Disciplinary Core Ideas

**PS4.A: Wave Properties**
- A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. (07-PS4-1) [Clarification Statement: Emphasis is on describing waves with both qualitative and quantitative thinking.] [Assessment Boundary: Assessment does not include electromagnetic waves and is limited to standard repeating waves.]
- A sound wave needs a medium through which it is transmitted. (07-PS4-2)

**PS4.B: Electromagnetic Radiation**
- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object’s material and the frequency (color) of the light. (07-PS4-2) [Clarification Statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, simulations, and written descriptions.] [Assessment Boundary: Assessment is limited to qualitative applications pertaining to light and mechanical waves.]
- The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends. (07-PS4-2) [Clarification Statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, simulations, and written descriptions.] [Assessment Boundary: Assessment is limited to qualitative applications pertaining to light and mechanical waves.]
- Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals. (07-PS4-3)

### Crosscutting Concepts

**Patterns**
- Graphs and charts can be used to identify patterns in data. (07-PS4-1)

**Structure and Function**
- Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (07-PS4-2)
- Structures can be designed to serve particular functions. (07-PS4-3)

**Connections to Nature of Science**
- Science is a Human Endeavor
  - Advances in technology influence the progression of science and science has influenced advances in technology. (07-PS4-3)

### Connections to other DCIs in this grade-band: MS.LS.1.D (07-PS4-2)

### Articulation across grade-bands: 4.PS.3.A (07-PS4-1); 4.PS.3.B (07-PS4-1); 4.PS.4.A (07-PS4-1); 4.PS.4.B (07-PS4-2); 4.PS.4.C (07-PS4-3); HS.PS.4.A (07-PS4-1),(07-PS4-2),(07-PS4-3); HS.PS.4.B (07-PS4-1),(07-PS4-2); HS.PS.4.C (07-PS4-3); HS.ESS.1.A (07-PS4-2); HS.ESS.2.A (07-PS4-2); HS.ESS.2.C (07-PS4-2); HS.ESS.2.D (07-PS4-2)

### Kentucky Academic Standards Connections:

**ELA/Literacy –**
- Cite specific textual evidence to support analysis of science and technical texts. (07-PS4-3)
- Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions. (07-PS4-3)
- Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. (07-PS4-3)
- Draw evidence from informational texts to support analysis, reflection, and research. (07-PS4-3)

**RST.6-8.5**
- Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. (07-PS4-1),(07-PS4-2)

**RST.6-8.9**
- Reason abstractly and quantitatively. (07-PS4-1)
- Model with mathematics. (07-PS4-1)
- Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. (07-PS4-1)
- Use ratio and rate reasoning to solve real-world and mathematical problems. (07-PS4-1)
- Recognize and represent proportional relationships between quantities. (07-PS4-1)

**WHST.6-8.9**
- Interpret the equation y = mx + b as defining a linear function, whose graph is a straight line; give examples of functions that are not linear. (07-PS4-1)

---

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.*
MS. Structure, Function, and Information Processing

Students who demonstrate understanding can:

07-LS1.1. Conduct an investigation to provide evidence that living things are made of cells, either one cell or many different numbers and types of cells. [Clarification Statement: Emphasis is on developing evidence that living things are made of cells, distinguishing between living and non-living cells, and understanding that living things may be made of one cell or many and varied cells.]

07-LS1.2. Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function. [Clarification Statement: Emphasis is on the cell functioning as a whole system and the primary role of identified parts of the cell, specifically the nucleus, chloroplasts, mitochondria, cell membrane, and cell wall.] [Assessment Boundary: Assessment of organelle structure/function relationships is limited to the cell wall and cell membrane. Assessment of the function of the other organelles is limited to their relationship to the whole cell. Assessment does not include the biochemical function of cells or cell parts.]

07-LS1.3. Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells. [Clarification Statement: Emphasis is on the conceptual understanding that cells form tissues and tissues form organs specialized for particular body functions. Examples could include the interaction of subsystems within a system and the normal functioning of those systems.] [Assessment Boundary: Assessment does not include the mechanism of one body system independent of others. Assessment is limited to the circulatory, excretory, digestive, respiratory, muscular, and nervous systems.]

08-LS1.8. Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories. [Assessment Boundary: Assessment does not include mechanisms for the transmission of this information.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

<table>
<thead>
<tr>
<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developing and Using Models</td>
<td>LS1.A: Structure and Function</td>
<td>Cause and Effect</td>
</tr>
<tr>
<td>Planning and Carrying Out</td>
<td>All living things are made up of cells, which is the smallest unit that can be said to be alive.</td>
<td>Cause and effect relationships may be used to predict phenomena in natural systems. (08-LS1.8)</td>
</tr>
<tr>
<td>Investigations</td>
<td>An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular). (07-LS1.1)</td>
<td>Scale, Proportion, and Quantity</td>
</tr>
<tr>
<td>Engaging in Argument from</td>
<td>Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell. (07-LS1.2)</td>
<td>Phenomena that can be observed at one scale may not be observable at another scale. (07-LS1.1)</td>
</tr>
<tr>
<td>Evidence</td>
<td>In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions. (07-LS1.3)</td>
<td>Systems and System Models</td>
</tr>
<tr>
<td>Obtaining, Evaluating, and</td>
<td>LS1.D: Information Processing</td>
<td>Structure and Function</td>
</tr>
<tr>
<td>Communicating Information</td>
<td>Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain.</td>
<td>Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the relationships among its parts, therefore complex natural and designed structures/systems can be analyzed to determine how they function. (07-LS1.2)</td>
</tr>
<tr>
<td>Connections to Other DCIs in the</td>
<td>Connections to Engineering, Technology, and Applications of Science</td>
<td></td>
</tr>
<tr>
<td>Articulation to DCIs across</td>
<td>Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems. (07-LS1.1)</td>
<td></td>
</tr>
<tr>
<td>LS1.A 4.LS1.D 8.LS1.1 07-LS1.2 07-LS1.3 08-LS1.8)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Kentucky Academic Standards Connections:

| ELA/Literacy – RST.5-8.1 | Cite specific textual evidence to support analysis of science and technical texts. (07-LS1.3) |
| RST.6.8 | Trace and evaluate the argument and specific claims in a text, distinguishing claims that are supported by reasons and evidence from claims that are not. (07-LS1.3) |
| WHST.6-8.1 | Write arguments focused on discipline content. (07-LS1.3) |
| WHST.6-8.7 | Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. (07-LS1.1) |
| WHST.6-8.8 | Gather relevant information from multiple print and digital sources; assess the credibility of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and providing basic bibliographic information for sources. (08-LS1.8) |
| SL.8.5 | Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. (07-LS1.2) |
| Mathematics – 6.EE.C.9 | Use variables to represent two quantities in a real-world problem that change in relationship to one another; write an equation to express one quantity, thought of as the dependent variable, in terms of the other quantity, thought of as the independent variable. Analyze the relationship between the dependent and independent variables using graphs and tables, and relate these to the equation. (07-LS1.1, 07-LS1.2, 07-LS1.3) |

The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

The section entitled “Disciplinary Core Ideas” is reproduced with permission from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.
**MS. Matter and Energy in Organisms and Ecosystems**

### Students who demonstrate understanding can:

**07-LS1-6.** Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms. [Clarification Statement: Emphasis is on tracing movement of matter and flow of energy.] [Assessment Boundary: does not include the biochemical mechanisms of photosynthesis.]

**07-LS1-7.** Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism. [Clarification Statement: Emphasis is on describing that molecules are broken apart and put back together and that in this process, energy is released.] [Assessment Boundary: Assessment does not include details of the chemical reactions for photosynthesis or respiration.]

**06-LS2-1.** Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem. [Clarification Statement: Emphasis is on cause and effect relationships between resources and growth of individual organisms and the numbers of organisms in ecosystems during periods of abundant and scarce resources.]

**06-LS2-3.** Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem. [Clarification Statement: Emphasis is on describing the conservation of matter and flow of energy into and out of various ecosystems, and on defining the boundaries of the system.] [Assessment Boundary: Assessment does not include the use of chemical reactions to describe the processes.]

**08-LS2-4.** Construct an argument supported by empirical evidence that changes to physical or biological components of an affect populations. [Clarification Statement: Emphasis is on recognizing patterns in data and making warranted inferences about changes in populations, and on evaluating empirical evidence supporting arguments about changes to ecosystems.]

---

### Science and Engineering Practices

<table>
<thead>
<tr>
<th>Developing and Using Models</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems. Develop a model to describe phenomena.</td>
<td>PS3.D: Energy in Chemical Processes and Everyday Life</td>
<td>Cause and Effect</td>
</tr>
<tr>
<td>Develop a model to describe unobservable mechanisms.</td>
<td>The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen. (secondary to 07-LS1-6) Cellular respiration in plants and animals involves chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials. (secondary to 07-LS1-7)</td>
<td>Cause and effect relationships may be used to predict phenomena in natural or designed systems.</td>
</tr>
<tr>
<td>Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. Analyze and interpret data to provide evidence for phenomena.</td>
<td>Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use. (07-LS1-6)</td>
<td>Matter is conserved because atoms are conserved in physical and chemical processes.</td>
</tr>
<tr>
<td><strong>Constructing Explanations and Designing Solutions</strong></td>
<td>LS2: Interdependent Relationships in Ecosystems</td>
<td>Stability and Change</td>
</tr>
<tr>
<td>Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories. Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students’ own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.</td>
<td>In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. (06-LS2-1)</td>
<td>Small changes in one part of a system might cause large changes in another part.</td>
</tr>
<tr>
<td><strong>Engaging in Argument from Evidence</strong></td>
<td>LS2: The Cycle of Matter and Energy Transfer in Ecosystems</td>
<td></td>
</tr>
<tr>
<td>Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world(s). Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.</td>
<td>Food webs are models that demonstrate how matter and energy is transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem.</td>
<td></td>
</tr>
<tr>
<td><strong>Connections to Nature of Science</strong></td>
<td>LS2: Ecosystem Dynamics, Functioning, and Resilience</td>
<td></td>
</tr>
<tr>
<td><strong>Scientific Knowledge is Based on Empirical Evidence</strong></td>
<td>Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. (08-LS2-4)</td>
<td></td>
</tr>
</tbody>
</table>

**Connections to other DCl's in this grade-band:** MS.PS1.B (07-LS1-6), (07-LS1-7), (06-LS2-3); MS.LS4.C (08-LS2-4); MS.LS4.D (08-LS2-4); MS.ESS2.A (07-LS1-6), (06-LS2-3), (08-LS2-4); MS.ESS3.A (08-LS2-1), (08-LS2-4); MS.ESS3.B (08-LS2-1), (08-LS2-4).

**Articulation across grade-bands:** 3.LS2.C (06-LS2-1), (08-LS2-4); 3.LS4.D (06-LS2-1), (08-LS2-4); 5.PS3.D (07-LS1-6), (07-LS1-7); 5.LS1.C (07-LS1-6), (07-LS1-7); 5.LS2.A (07-LS1-6), (06-LS2-1), (06-LS2-3); 5.LS2.B (07-LS1-6), (07-LS1-7), (06-LS2-1), (06-LS2-3); 6.LS1.C (07-LS1-6), (07-LS1-7); 6.LS2.A (06-LS2-3); 6.LS2.B (07-LS1-6), (07-LS1-7), (06-LS2-3); 6.LS2.C (08-LS2-4); 6.LS4.C (06-LS2-1), (08-LS2-4); 6.LS4.D (06-LS2-1), (08-LS2-4); 6.ESS2.A (08-LS2-3); 6.ESS2.D (07-LS1-6); 6.ESS2.E (08-LS2-4); 6.ESS3.A (08-LS2-1); 6.ESS3.B (08-LS2-4); 6.ESS3.C (08-LS2-4)
Kentucky Department of Education

**MS. Matter and Energy in Organisms and Ecosystems - Continued**

<table>
<thead>
<tr>
<th>Kentucky Academic Standards Connections:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ELA/Literacy –</strong></td>
</tr>
<tr>
<td>RST.6-8.1</td>
</tr>
<tr>
<td>RST.6-8.2</td>
</tr>
<tr>
<td>RI.8.8</td>
</tr>
<tr>
<td>WHST.6-8.1</td>
</tr>
<tr>
<td>WHST.6-8.2</td>
</tr>
<tr>
<td>WHST.6-8.9</td>
</tr>
<tr>
<td>SL.8.5</td>
</tr>
<tr>
<td>Mathematics –</td>
</tr>
<tr>
<td>6.EE.C.9</td>
</tr>
</tbody>
</table>

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled “Disciplinary Core Ideas” is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.*

Kentucky Academic Standards – Science – Middle Level 425
## MS. Interdependent Relationships in Ecosystems

### Students who demonstrate understanding can:

| 06-LS2. | Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems. [Clarification Statement: Emphasis is on predicting consistent patterns of interactions in different ecosystems in terms of the relationships among and between organisms and abiotic components of ecosystems. Examples of types of interactions could include competitive, predatory, and mutually beneficial.] |
| 08-LS2.5. | Evaluate competing design solutions for maintaining biodiversity and ecosystem services.* [Clarification Statement: Examples of ecosystem services could include water purification, nutrient recycling, and prevention of soil erosion. Examples of design solution constraints could include scientific, economic, and social considerations.] |

### The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:

### Crosscutting Concepts

| Patterns | Patterns can be used to identify cause and effect relationships. (06-LS2-2) |
| Stability and Change | Small changes in one part of a system might cause large changes in another part. (08-LS2-5) |

### Connections to Engineering, Technology, and Applications of Science

| Influence of Science, Engineering, and Technology on Society and the Natural World |
| The use of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time. (08-LS2-5) |

### Connections to Nature of Science

| Science Addresses Questions About the Natural and Material World |
| Scientific knowledge can describe the consequence of actions but does not necessarily prescribe the decisions that society takes. (08-LS2-5) |

---

### Connections to other DCIs in this grade-band:

| MS.LS1.B | (06-LS2-2); MS.ESS3.C | (08-LS2-5) |

### Articulation across grade-band:

| LS1.B | (06-LS2-2); HS.LS2.A | (06-LS2-2), (08-LS2-5); HS.LS2.B | (06-LS2-2); HS.LS2.C | (08-LS2-5); HS.LS2.D | (06-LS2-2); LS4.D | (08-LS2-5); HS.ESS3.A | (08-LS2-5); HS.ESS3.C | (08-LS2-5); HS.ESS3.D | (08-LS2-5) |

---

### Kentucky Academic Standards Connections:

| ELA/Literacy – RST.6.8 | Trace and evaluate the argument and specific claims in a text, assessing whether the reasoning is sound and the evidence is relevant and sufficient to support the claims. (08-LS2-5) |
| RST.6.8 | Distinguish among facts, reasoned judgment based on research findings, and speculation in a text. (08-LS2-5) |
| RI.8.8 | Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content. (06-LS2-2) |
| WHST.6.8-2 | Draw evidence from literary or informational texts to support analysis, reflection, and research. (06-LS2-2) |
| WHST.6.8-9 | on SL.8.1 | Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. (06-LS2-2) |
| Concepts | SL.4 | Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 8 topics, texts, and issues, building others’ ideas and expressing their own clearly. (06-LS2-2) |
| Mathematics – MP.4 | Model with mathematics. (08-LS2-5) |
| 6.RP.A.3 | Use ratio and rate reasoning to solve real-world and mathematical problems. (08-LS2-5) |
| 6.SP.B.5 | Summarize numerical data sets in relation to their context. (08-LS2-2) |

---

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled "Disciplinary Core Ideas" is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.*
Students who demonstrate understanding can:

07-LS1.4. Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively. [Clarification Statement: Examples of behaviors that affect the probability of animal reproduction could include nest building to protect young from cold, herding of animals to protect young from predators, and vocalization of animals and colorful plumage to attract mates for breeding. Examples of animal behaviors that affect the probability of plant reproduction could include transferring pollen or seeds, and creating conditions for seed germination and growth. Examples of plant structures could include bright flowers attracting butterflies that transfer pollen, flower nectar and odors that attract insects that transfer pollen, and hard shells on nuts that squirrels bury.]

07-LS1.5. Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms. [Clarification Statement: Examples of local environmental conditions could include availability of food, light, space, and water. Examples of genetic factors could include large breed cattle and species of grass affecting growth of organisms. Examples of evidence could include drought decreasing plant growth, fertilizer increasing plant growth, different varieties of plant seeds growing at different rates in different conditions, and fish growing larger in large ponds than they do in small ponds.]

08-LS3.1. Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism. [Clarification Statement: Emphasis is on conceptual understanding of how changes in genetic material may result in making different proteins. [Assessment Boundary: Assessment does not include specific changes at the molecular level, mechanisms for protein synthesis, or specific types of mutations.]

08-LS3.2. Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation. [Clarification Statement: Emphasis is on using models such as Punnett squares, diagrams, and simulations to describe the cause and effect relationship of gene transmission from parent(s) to offspring and resulting genetic variation.]

08-LS4.5. Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms. [Clarification Statement: Emphasis is on synthesizing information from reliable sources about the influence of humans on genetic outcomes in artificial selection (such as genetic modification, animal husbandry, gene therapy); and, on the impacts these technologies have on society as well as the technologies leading to these scientific discoveries.]

The performance expectations 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 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.
  - Develop and use a model to describe phenomena. (08-LS3-1), (08-LS3-2)
- Constructing Explanations and Designing Solutions
  - Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.
  - Construct a scientific explanation and/or design a solution that supports claims for either explanations or solutions about the natural and designed world(s).
  - Use an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. (07-LS1-4)
- Obtaining, Evaluating, and Communicating Information
  - Obtaining, evaluating, and communicating information in 6–8 builds on K–5 experiences and progresses to evaluating the merit and validity of ideas and methods.
  - Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence. (08-LS4-5)
  - Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively. (07-LS1-4)
  - Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms. (07-LS1-5)

**Disciplinary Core Ideas**
- LS1.B: Growth and Development of Organisms
  - Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. (secondary to 08-LS3-2)
  - Animals engage in characteristic behaviors that increase the odds of reproduction. (07-LS1-4)
  - Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction. (07-LS1-4)
  - Genetic factors as well as local conditions affect the growth of the adult plant. (07-LS1-5)
- LS3.A: Inheritance of Traits
  - Genetics are located in the chromosomes of cells, with each chromosome containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits. (08-LS3-1)
  - Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited. (08-LS3-2)
- LS3.B: Variation of Traits
  - In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other. (08-LS3-2)
  - In addition to variations that arise from sexual reproduction, genetic information can be altered because of mutations. Though rare, mutations may result in changes to the structure and function of proteins. Some changes are beneficial, others harmful, and some neutral to the organism. (08-LS3-1)
- LS4.B: Natural Selection
  - In artificial selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring. (08-LS4-5)

**Crosscutting Concepts**
- Cause and Effect
  - Cause and effect relationships may be used to predict phenomena in natural systems. (08-LS3-2)
  - Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (07-LS1-4), (07-LS1-5), (08-LS4-5)
- Structure and Function
  - Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts, therefore complex natural and designed structures/systems can be analyzed to determine how they function. (08-LS3-1)

**Connections to Engineering, Technology, and Applications of Science**
- Interdependence of Science, Engineering, and Technology
  - Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems. (08-LS4-5)

**Connections to Nature of Science**
- Science Addresses Questions About the Natural and Material World
  - Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the actions that society takes. (08-LS4-5)
Kentucky Academic Standards Connections:

**ELA/Literacy** –

**RST.6-8.1** Cite specific textual evidence to support analysis of science and technical texts. (07-LS1-4),(07-LS1-5),(08-LS3-1),(08-LS3-2),(08-LS4-5)

**RST.6-8.4** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics. (08-LS3-1),(08-LS3-2)

**RST.6-8.7** Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, or table). (08-LS3-1),(08-LS3-2)

**RI.6.8** Trace and evaluate the argument and specific claims in a text, distinguishing claims that are supported by reasons and evidence from claims that are not. (07-LS1-4)

**WST.6-8.1** Write arguments focused on discipline content. (07-LS1-4)

**WHST.6-8.2** Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content. (07-LS1-5)

**WHST.6-8.8** Gather relevant information from multiple print and digital sources; assess the credibility of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and providing basic bibliographic information for sources. (08-LS4-5)

**WHST.6-8.9** Draw evidence from informational texts to support analysis, reflection, and research. (07-LS1-5)

**MP.4** Model with mathematics. (08-LS3-2)

**6.SP.A.2** Understand that a set of data collected to answer a statistical question has a distribution which can be described by its center, spread, and overall shape. (07-LS1-4), (07-LS1-5)

**6.SP.B.4** Summarize numerical data sets in relation to their context. (07-LS1-4),(07-LS1-5)

**6.SP.B.5** Summarize numerical data sets in relation to their context. (08-LS3-2)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled “Disciplinary Core Ideas” is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.*
### MS. Natural Selection and Adaptations

Students who demonstrate understanding can:

**08-LS4-1.** Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.  

[Clarification Statement: Emphasis is on finding patterns of changes in the level of complexity of anatomical structures in organisms and the chronological order of fossil appearance in the rock layers.] [Assessment Boundary: Assessment does not include the names of individual species or geological eras in the fossil record.]

**08-LS4-2.** Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.  

[Clarification Statement: Emphasis is on explanations of the evolutionary relationships among organisms in terms of similarity or differences of the gross appearance of anatomical structures.]

**08-LS4-3.** Analyze displays of pictorial data to compare patterns of similarities in the embryological development across multiple species to identify relationships not evident in the fully formed anatomy.  

[Clarification Statement: Emphasis is on inferring general patterns of relatedness among embryos of different organisms by comparing the macroscopic appearance of diagrams or pictures.] [Assessment Boundary: Assessment of comparisons is limited to gross appearance of anatomical structures in embryological development.]

**08-LS4-4.** Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals’ probability of surviving and reproducing in a specific environment.  

[Clarification Statement: Emphasis is on using simple probability statements and proportional reasoning to construct explanations.]

**08-LS4-6.** Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.  

[Clarification Statement: Emphasis is on using mathematical models, probability statements, and proportional reasoning to support explanations of trends in changes to populations over time.] [Assessment Boundary: Assessment does not include Hardy Weinberg calculations.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

<table>
<thead>
<tr>
<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analyzing and Interpreting Data</td>
<td>LS4.A: Evidence of Common Ancestry and Diversity</td>
<td>Patterns</td>
</tr>
<tr>
<td>Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. Analyze displays of data to identify linear and nonlinear relationships. Analyze and interpret data to determine similarities and differences in findings. (08-LS4-1)</td>
<td>The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found or through radioactive dating) is known as the fossil record. It documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth. (08-LS4-1) Anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent. (08-LS4-2) Comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully-formed anatomy. (08-LS4-3)</td>
<td>Patterns can be used to identify cause and effect relationships. (08-LS4-2) Graphs, charts, and images can be used to identify patterns in data. (08-LS4-1), (08-LS4-3)</td>
</tr>
<tr>
<td>Using Mathematics and Computational Thinking</td>
<td>LS4.B: Natural Selection</td>
<td>Cause and Effect</td>
</tr>
<tr>
<td>Mathematical and computational thinking in 6–8 builds on K–5 experiences and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments. Use mathematical representations to support scientific conclusions and design solutions. (08-LS4-6)</td>
<td>Natural selection leads to the predominance of certain traits in a population, and the suppression of others. (08-LS4-4)</td>
<td>Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (08-LS4-4), (08-LS4-6)</td>
</tr>
<tr>
<td>Constructing Explanations and Designing Solutions</td>
<td>LS4.C: Adaptation</td>
<td>Connections to Nature of Science</td>
</tr>
<tr>
<td>Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories. Apply scientific ideas to construct an explanation for real-world phenomena, examples, or events. (08-LS4-2) Construct an explanation that includes qualitative or quantitative relationships between variables that describe phenomena. (08-LS4-4)</td>
<td>Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes. (08-LS4-6)</td>
<td>Scientific Knowledge Assumes an Order and Consistency in Natural Systems</td>
</tr>
<tr>
<td>Scientific Knowledge is Based on Empirical Evidence</td>
<td>Connections to Other Disciplines in this grade-band: MS.LS2.A (08-LS4-4), (08-LS4-6); MS.LS2.C (08-LS4-6); MS.LS3.A (08-LS4-2),(08-LS4-4); MS.LS3.B (08-LS4-2),(08-LS4-4),(08-LS4-6); MS.ESS1.C (08-LS4-1); (08-LS4-2),(08-LS4-6); MS.ESS2.B (08-LS4-1)</td>
<td>Articulation across grade-bands: 3.LS3.B (08-LS4-4); 3.LS4.A (08-LS4-1),(08-LS4-2); 3.LS4.B (08-LS4-4); 3.LS4.C (08-LS4-6); HS.LS2.A (08-LS4-4),(08-LS4-6); HS.LS2.C (08-LS4-6); HS.LS3.B (08-LS4-4),(08-LS4-6); HS.LS4.A (08-LS4-1),(08-LS4-2),(08-LS4-3); HS.LS4.B (08-LS4-4),(08-LS4-6); HS.LS4.C (08-LS4-4),(08-LS4-6); HS.ESS1.C (08-LS4-1),(08-LS4-2)</td>
</tr>
</tbody>
</table>
Kentucky Department of Education

**MS. Natural Selection and Adaptations - Continued**

<table>
<thead>
<tr>
<th>Kentucky Academic Standards Connections:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ELA/Literacy</strong></td>
<td><strong>Mathematics</strong></td>
</tr>
<tr>
<td>RST.6-8.1</td>
<td>MP.4</td>
</tr>
<tr>
<td>Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions (08-LS4-1), (08-LS4-2), (08-LS4-3), (08-LS4-4)</td>
<td>Model with mathematics. (08-LS4-6)</td>
</tr>
<tr>
<td>RST.6-8.7</td>
<td>6.RP.A.1</td>
</tr>
<tr>
<td>Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, or table). (08-LS4-1), (08-LS4-3)</td>
<td>Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. (08-LS4-4), (08-LS4-6)</td>
</tr>
<tr>
<td>RST.6-8.9</td>
<td>6.SP.B.5</td>
</tr>
<tr>
<td>Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. (08-LS4-3), (08-LS4-4)</td>
<td>Summarize numerical data sets in relation to their context. (08-LS4-4), (08-LS4-6)</td>
</tr>
<tr>
<td>WHST.6-8.2</td>
<td>6.EE.B.6</td>
</tr>
<tr>
<td>Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content. (08-LS4-2), (08-LS4-4)</td>
<td>Use variables to represent numbers and write expressions when solving a real-world or mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified set. (08-LS4-1), (08-LS4-2)</td>
</tr>
<tr>
<td>WHST.6-8.9</td>
<td>7.RP.A.2</td>
</tr>
<tr>
<td>Draw evidence from informational texts to support analysis, reflection, and research. (08-LS4-2), (08-LS4-4)</td>
<td>Recognize and represent proportional relationships between quantities. (08-LS4-4), (08-LS4-6)</td>
</tr>
<tr>
<td>SL.8.1</td>
<td></td>
</tr>
<tr>
<td>Engage effectively in a range of collaborative discussions [one-on-one, in groups, teacher-led] with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly. (08-LS4-2), (08-LS4-4)</td>
<td></td>
</tr>
<tr>
<td>SL.8.4</td>
<td></td>
</tr>
<tr>
<td>Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. (08-LS4-2), (08-LS4-4)</td>
<td></td>
</tr>
</tbody>
</table>

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled “Disciplinary Core Ideas” is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.*
## MS. Space Systems

### Science and Engineering Practices

<table>
<thead>
<tr>
<th>Developing and Using Models</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems. Develop and use a model to describe phenomena. (06-ESS1-1),(06-ESS1-2)</td>
<td>ESS1.A: The Universe and Its Stars</td>
<td>Patterns Patterns can be used to identify cause and effect relationships. (06-ESS1-1)</td>
</tr>
<tr>
<td>Analyzing and Interpreting Data</td>
<td>ESS1.B: Earth and the Solar System</td>
<td>Scale, Proportion, and Quantity</td>
</tr>
<tr>
<td>Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. Analyze and interpret data to determine similarities and differences in findings. (06-ESS1-3)</td>
<td>The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. (06-ESS1-2),(06-ESS1-3) This model of the solar system can explain eclipses of the sun and the moon. Earth’s spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year. (06-ESS1-1) The solar system appears to have formed from a disk of dust and gas, drawn together by gravity. (06-ESS1-2)</td>
<td>Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (06-ESS1-3)</td>
</tr>
</tbody>
</table>

### ESS1: The Universe and Its Stars

- **Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models. (06-ESS1-1)**
- **Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe. (06-ESS1-2)**
- **The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. (06-ESS1-2),(06-ESS1-3)**
- **This model of the solar system can explain eclipses of the sun and the moon. Earth’s spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year. (06-ESS1-1)**
- **The solar system appears to have formed from a disk of dust and gas, drawn together by gravity. (06-ESS1-2)**

### Crosscutting Concepts

- **Scale, Proportion, and Quantity**
  - Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (06-ESS1-3)

### Systems and System Models

- **Models can be used to represent systems and their interactions. (06-ESS1-2)**

### Connections to Engineering, Technology, and Applications of Science

- **Connections to Nature of Science**
  - Scientific Knowledge Assumes an Order and Consistency in Natural Systems

- **Interdependence of Science, Engineering, and Technology**
  - Engineering advances have led to important discoveries in virtually every field of science and scientific discoveries have led to the development of entire industries and engineered systems. (06-ESS1-3)

### Kentucky Academic Standards Connections

<table>
<thead>
<tr>
<th>ELA/Literacy – RST.6-8.1</th>
<th>Cite specific textual evidence to support analysis of science and technical texts. (06-ESS1-3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RST.6-8.7</td>
<td>Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, or table). (06-ESS1-3)</td>
</tr>
<tr>
<td>SL.7.5</td>
<td>Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points. (06-ESS1-1),(06-ESS1-2)</td>
</tr>
<tr>
<td>Mathematics – MP.2</td>
<td>Reason abstractly and quantitatively. (06-ESS1-3)</td>
</tr>
<tr>
<td>MP.4</td>
<td>Model with mathematics. (06-ESS1-1),(06-ESS1-2)</td>
</tr>
<tr>
<td>6.RP.A.1</td>
<td>Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. (06-ESS1-1),(06-ESS1-2),(06-ESS1-3)</td>
</tr>
<tr>
<td>7.RP.A.2</td>
<td>Recognize and represent proportional relationships between quantities. (06-ESS1-1),(06-ESS1-2),(06-ESS1-3)</td>
</tr>
<tr>
<td>6.EE.B.6</td>
<td>Use variables to represent numbers and write expressions when solving a real-world or mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified set. (06-ESS1-2)</td>
</tr>
<tr>
<td>7.EE.B.4</td>
<td>Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities. (06-ESS1-2)</td>
</tr>
</tbody>
</table>

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled “Disciplinary Core Ideas” is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.*
**MS. History of Earth**

**Students who demonstrate understanding can:**

**08-ESS1-4.** Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth’s 4.6-billion-year-old history. [Clarification Statement: Emphasis is on how analyses of rock formations and the fossils they contain are used to establish relative ages of major events in Earth’s history. Examples of Earth’s major events could range from being very recent (such as the last Ice Age or the earliest fossils of hominins) to very old (such as the formation of Earth or the earliest evidence of life). Examples can include the formation of mountain chains and ocean basins, the evolution of particular living organisms, or significant volcanic eruptions.] [Assessment Boundary: Assessment does not include recalling the names of specific periods or epochs and events within them.]

**06-ESS2-2.** Construct an explanation based on evidence for how geoscience processes have changed Earth’s surface at varying time and spatial scales. [Clarification Statement: Emphasis is on how processes change Earth’s surface at time and spatial scales that can be large (such as slow plate motions or the uplift of large mountain ranges) or small (such as rapid landslides or microscopic geochemical reactions), and how many geoscience processes (such as earthquakes, volcanoes, and meteor impacts) usually behave gradually but are punctuated by catastrophic events. Examples of geoscience processes include surface weathering and deposition by the movements of water, ice, and wind. Emphasis is on geoscience processes that shape local geographic features, where appropriate.]

**06-ESS2-3.** Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions. [Clarification Statement: Examples of data include similarities of rock and fossil types on different continents, the shapes of the continents (including continental shelves), and the locations of ocean structures (such as ridges, fracture zones, and trenches).] [Assessment Boundary: Paleomagnetic anomalies in oceanic and continental crust are not assessed.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

<table>
<thead>
<tr>
<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analyzing and Interpreting Data</td>
<td>ESS1.C: The History of Planet Earth</td>
<td>Patterns</td>
</tr>
<tr>
<td>Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. Analyze and interpret data to provide evidence for phenomena. (06-ESS2-3)</td>
<td>Tectonic processes continually generate new ocean sea floor at ridges and destroy old sea floor at trenches. (HS.ESS1.C.GBE) (secondary to 06-ESS2-3)</td>
<td>Patterns in rates of change and other numerical relationships can provide information about natural systems. (06-ESS2-3)</td>
</tr>
<tr>
<td>Constructing Explanations and Designing Solutions</td>
<td>ESS2.A: Earth’s Materials and Systems</td>
<td>Scale Proportion and Quantity</td>
</tr>
<tr>
<td>Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories. Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students’ own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (06-ESS1-4), (06-ESS2-2)</td>
<td>The planet’s systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth’s history and will determine its future. (06-ESS2-2)</td>
<td>Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (06-ESS1-4), (06-ESS2-2)</td>
</tr>
<tr>
<td>Scientific Knowledge is Open to Revision in Light of New Evidence</td>
<td>ESS2.B: Plate Tectonics and Large-Scale System Interactions</td>
<td></td>
</tr>
<tr>
<td>Science findings are frequently revised and/or reinterpreted based on new evidence. (06-ESS2-3)</td>
<td>Maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth’s plates have moved great distances, collided, and spread apart. (06-ESS2-3)</td>
<td></td>
</tr>
<tr>
<td><strong>Connections to Nature of Science</strong></td>
<td>ESS2.C: The Roles of Water in Earth’s Surface Processes</td>
<td></td>
</tr>
<tr>
<td><strong>Connections to other DCIs in this grade-band:</strong> MS.PS.1.B (06-ESS2-2), MS.LS.2.B (06-ESS2-2), MS.LS.4.A (08-ESS1-4), (06-ESS2-3); MS.LS.4.C (08-ESS1-4), (06-ESS2-3)</td>
<td>Water’s movements—both on the land and underground—cause weathering and erosion, which change the land’s surface features and create underground formations. (06-ESS2-2)</td>
<td></td>
</tr>
</tbody>
</table>


**Kentucky Academic Standards Connections:**

**ELA/Literacy – RST.6-8.1** Cite specific textual evidence to support analysis of science and technical texts. (06-ESS1-4), (06-ESS2-3)

**RST.6-8.7** Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, or table). (06-ESS2-3)

**RST.6-8.9** Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. (06-ESS2-3)

**WHST.6-8.2** Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content. (06-ESS1-4), (06-ESS2-2)

**SL.8.5** Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points. (06-ESS2-2)

**Mathematics – MP.2** Reason abstractly and quantitatively. (06-ESS2-2), (06-ESS2-3)

**6.EE.6** Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities. (06-ESS1-4), (06-ESS2-2), (06-ESS2-3)

**7.EE.4** Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities. (06-ESS1-4), (06-ESS2-2), (06-ESS2-3)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled “Disciplinary Core Ideas” is reproduced verbatim from *A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas*. Integrated and reprinted with permission from the National Academy of Sciences.*
# MS. Earth’s Systems

**Students who demonstrate understanding can:**

06-ESS2-1. Develop a model to describe the cycling of Earth’s materials and the flow of energy that drives this process. [Clarification Statement: Emphasis is on the processes of melting, crystallization, weathering, deformation, and sedimentation, which act together to form minerals and rocks through the cycling of Earth’s materials.] [Assessment Boundary: Assessment does not include the identification and naming of minerals.]

06-ESS2-4. Develop a model to describe the cycling of water through Earth’s systems driven by energy from the sun and the force of gravity. [Clarification Statement: Emphasis is on the ways water changes its state as it moves through the multiple pathways of the hydrologic cycle. Examples of models can be conceptual or physical.] [Assessment Boundary: A quantitative understanding of the latent heats of vaporization and fusion is not assessed.]

08-ESS3-1. Construct a scientific explanation based on evidence for how the uneven distributions of Earth’s mineral, energy, and groundwater resources are the result of past and current geoscience processes. [Clarification Statement: Emphasis is on how these resources are limited and typically non-renewable, and how their distributions are significantly changing as a result of removal by humans. Examples of uneven distributions of resources as a result of past processes include but are not limited to petroleum (locations of the burial of organic marine sediments and subsequent geologic traps), metal ores (locations of past volcanic and hydrothermal activity associated with Subduction Zones), and soil (locations of active weathering and/or deposition of rocks).]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education:*

### Disciplinary Core Ideas

<table>
<thead>
<tr>
<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Developing and Using Models</strong></td>
<td><strong>ESS2.A: Earth’s Materials and Systems</strong></td>
<td><strong>Cause and Effect</strong></td>
</tr>
<tr>
<td>Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems. Develop and use a model to describe phenomena. (06-ESS2-1)</td>
<td>All Earth processes are the result of energy flowing and matter cycling within and among the planet’s systems. This energy is derived from the sun and Earth’s hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth’s materials and living organisms. (06-ESS2-1)</td>
<td>Cause and effect relationships may be used to predict phenomena in natural or designed systems. (08-ESS3-1)</td>
</tr>
<tr>
<td>Develop a model to describe unobservable mechanisms. (06-ESS2-4)</td>
<td><strong>ESS2.C: The Roles of Water in Earth’s Surface Processes</strong></td>
<td><strong>Energy and Matter</strong></td>
</tr>
<tr>
<td>Constructing Explanations and Designing Solutions</td>
<td>Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downwind flows on land. (06-ESS2-4)</td>
<td>Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. (08-ESS2-4)</td>
</tr>
<tr>
<td><strong>Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.</strong></td>
<td><strong>ESS3.A: Natural Resources</strong></td>
<td><strong>Stability and Change</strong></td>
</tr>
<tr>
<td>Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students’ own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (08-ESS3-1)</td>
<td>Humans depend on Earth’s land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes. (08-ESS3-1)</td>
<td>Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and processes at different scales, including the atomic scale. (08-ESS2-1)</td>
</tr>
</tbody>
</table>

### Crosscutting Concepts

**Connections to Engineering, Technology, and Applications of Science**

**Influence of Science, Engineering, and Technology on Society and the Natural World**

All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. (08-ESS3-1)

---

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled “Disciplinary Core Ideas” is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.*
### MS. Weather and Climate

**Students who demonstrate understanding can:**

**06-ESS2-5.** Collect data to provide evidence for how the motions and complex interactions of air masses results in changes in weather conditions. [Clarification Statement: Emphasis is on how air masses flow from regions of high pressure to low pressure, causing weather (defined by temperature, pressure, humidity, precipitation, and wind) at a fixed location to change over time, and how sudden changes in weather can result when different air masses collide. Emphasis is on how weather can be predicted within probabilistic ranges. Examples of data can be provided to students (such as weather maps, diagrams, and visualizations) or obtained through laboratory experiments (such as with condensation).] [Assessment Boundary: Assessment does not include the names of cloud types or weather symbols used on weather maps or the reported diagrams from weather stations.]

**06-ESS2-6.** Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates. [Clarification Statement: Emphasis is on how patterns vary by latitude, altitude, and geographic land distribution. Emphasis of atmospheric circulation is on the sunlight-driven latitudinal banding, the Coriolis effect, and resulting prevailing winds; emphasis of ocean circulation is on the transfer of heat by the global ocean convection cycle, which is constrained by the Coriolis effect and the outlines of continents. Examples of models can be diagrams, maps and globes, or digital representations.] [Assessment Boundary: Assessment does not include the dynamics of the Coriolis effect.]

**08-ESS3-5.** Ask students to clarify evidence of the factors that have caused the rise in global temperatures over the past century. [Clarification Statement: Examples of factors include human activities (such as fossil fuel combustion, cement production, and agricultural activity) and natural processes (such as changes in incoming solar radiation or volcanic activity). Examples of evidence can include tables, graphs, and maps of global and regional temperatures, atmospheric levels of gases such as carbon dioxide and methane, and the rates of human activities. Emphasis is on the major role that human activities play in causing the rise in current global temperatures.]

---

<table>
<thead>
<tr>
<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asking Questions and Defining Problems</td>
<td>ESS2.C: The Roles of Water in Earth’s Surface Processes</td>
<td>Cause and Effect</td>
</tr>
<tr>
<td>Developing and Using Models</td>
<td>The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns. (06-ESS2-5)</td>
<td>Cause and Effect relationships may be used to predict phenomena in natural or designed systems. (06-ESS2-5)</td>
</tr>
<tr>
<td>Planning and Carrying Out Investigations</td>
<td>Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents. (06-ESS2-6)</td>
<td>Systems and System Models</td>
</tr>
<tr>
<td>Modeling in 6–8 builds on K–5 experiences and progresses to develop models that describe, test, and predict more abstract phenomena and design systems. Develop and use a model to describe phenomena. (06-ESS2-6)</td>
<td>ESS2.D: Weather and Climate</td>
<td>Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. (06-ESS2-6)</td>
</tr>
<tr>
<td>Planning and carrying out investigations in 6-8 builds on K-5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or solutions. Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions. (06-ESS2-5)</td>
<td>ESS3.D: Global Climate Change</td>
<td>Stability and Change</td>
</tr>
<tr>
<td>Articulation of DCIs across grade bands: 3.PS2.A (06-ESS2-6); 4.ESS2.D (06-ESS2-6); 5.ESS2.D (06-ESS2-5), (06-ESS2-6); 5.ESS2.A (06-ESS2-5), (06-ESS2-6); HS.PS2.A (06-ESS2-6); HS.PS3.B (06-ESS2-6); HS.PS3.D (06-ESS2-6); HS.PS4.B (06-ESS2-5), (06-ESS2-6); HS.ESS1.B (06-ESS2-6); HS.ESS2.A (06-ESS2-6), (06-ESS2-5); HS.ESS2.C (06-ESS2-5); HS.ESS2.D (06-ESS2-6), (06-ESS2-5); HS.ESS3.C (06-ESS3-5); HS.ESS3.D (06-ESS3-5)</td>
<td>Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth’s mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities. (08-ESS3-5)</td>
<td>Stability might be disturbed either by sudden events or gradual changes that accumulate over time. (08-ESS3-5)</td>
</tr>
</tbody>
</table>

---

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.*

The section entitled “Disciplinary Core Ideas” is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and **connections to other DCIs in this grade-band:** MS.PS1.A (06-ESS2-5); MS.PS2.A (06-ESS2-5); MS.PS3.A (06-ESS2-5), (06-ESS3-5); MS.PS3.B (06-ESS2-5), (06-ESS3-5); MS.PS4.B (06-ESS2-6); MS.PS4.D (06-ESS2-5).

---

**Kentucky Academic Standards Connections:**

**ELA/Literacy –**

- RST.6-8.1
- RST.6-8.9
- WHST.6-8.8
- SL.8.5
- **Mathematics –**
- **MP.2**
- **6.NS.C.5**
- **6.EE.B.6**
- **6.EE.B.4**
- **7.EE.B.4**

- Cite specific textual evidence to support analysis of science and technical texts. (06-ESS2-5),(08-ESS3-5)
- Compare and contrast the information gained from experiments, simulations, video or multimedia sources with that gained from reading a text on the same topic. (06-ESS2-5)
- Gather relevant information from multiple print and digital sources; assess the credibility of each source; and quote or paraphrase the data and conclusions of others avoiding plagiarism and providing basic bibliographic information for sources. (06-ESS2-5)
- Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points. (06-ESS2-6)
- Reason abstractly and quantitatively. (06-ESS2-5),(08-ESS3-5)
- Understand that positive and negative numbers are used together to describe quantities having opposite directions or values (e.g., temperature above/below zero, elevation above/below sea level, credits/debits, positive/negative electric charge); use positive and negative numbers to represent quantities in real-world contexts, explaining the meaning of 0 in each situation. (06-ESS2-5)
- Use variables to represent numbers and write expressions when solving a real-world or mathematical problem; understand that a variable can represent an unknown number; or, depending on the purpose at hand, any number in a specified set. (06-ESS3-5)
- Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities. (08-ESS3-5)
MS. Human Impacts

Students who demonstrate understanding can:

08-ESS3-2. Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects. [Clarification Statement: Emphasis is on how some natural hazards, such as volcanic eruptions and severe weather, are preceded by phenomena that allow for reliable predictions, but others, such as earthquakes, occur suddenly and with no notice, and thus are not yet predictable. Examples of natural hazards can be taken from interior processes (such as earthquakes and volcanic eruptions), surface processes (such as mass wasting and tsunamis), or severe weather events (such as hurricanes, tornadoes, and floods). Examples of data can include the locations, magnitudes, and frequencies of the natural hazards. Examples of technologies can be global (such as satellite systems to monitor hurricanes or forest fires) or local (such as building basements in tornado-prone regions or reservoirs to mitigate droughts).]

08-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.* [Clarification Statement: Examples of the design process include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact. Examples of human impacts can include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as of air, water, or land).]

08-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth’s systems. [Clarification Statement: Examples of evidence include grade-appropriate databases on human populations and the rates of consumption of food and natural resources (such as freshwater, mineral, and energy). Examples of impacts can include changes to the appearance, and structure of Earth’s systems as well as the rates at which they change. The consequences of increases in human populations and consumption of natural resources are described by science, but science does not make the decisions for the actions society takes.]

The performance expectations above were developed using the following elements from the NRC document A Framework for K–12 Science Education:

<table>
<thead>
<tr>
<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analyzing and Interpreting Data</td>
<td>ESS3:B: Natural Hazards Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events. (08-ESS3-2)</td>
<td>Patterns Graphs, charts, and images can be used to identify patterns in data. (08-ESS3-2)</td>
</tr>
<tr>
<td>Constructing Explanations and Designing Solutions</td>
<td>ESS3:C: Human Impacts on Earth Systems Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth’s environments can have different impacts (negative and positive) for different living things. (08-ESS3-3)</td>
<td>Cause and Effect Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. (08-ESS3-4)</td>
</tr>
<tr>
<td>Engaging in Argument from Evidence</td>
<td>ESS3:D: Ecosystems are engineered by multiple sources of evidence consistent with scientific ideas, principles, and theories. Apply scientific principles to design an object, tool, process or system. (08-ESS3-3)</td>
<td>Connections to Engineering, Technology, and Applications of Science Influence of Science, Engineering, and Technology on Society and the Natural World All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. (08-ESS3-4) The uses of technologies and limitations on their use are driven by people’s needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time. (08-ESS3-2),(08-ESS3-3)</td>
</tr>
<tr>
<td>Connections to other DCIs in this grade-band: MS.PS3.C (08-ESS3-2); MS.LS2.A (08-ESS3-3),(08-ESS3-4); MS.LS2.C (08-ESS3-3),(08-ESS3-4); MS.LS4.D (08-ESS3-3),(08-ESS3-4)</td>
<td>Articulation of DCIs across grade-bands: 3.LS2.C (08-ESS3-3),(08-ESS3-4); 3.LS4.D (08-ESS3-3),(08-ESS3-4); 3.ESS3.B (08-ESS3-2); 4.ESS3.B (08-ESS3-2); 5.ESS3.C (08-ESS3-3),(08-ESS3-4); HS.LS2.A (08-ESS3-4); HS.LS2.C (08-ESS3-3),(08-ESS3-4); HS.LS4.C (08-ESS3-3),(08-ESS3-4); HS.LS4.D (08-ESS3-3),(08-ESS3-4); HS.ESS2.B (08-ESS3-2); HS.ESS2.C (08-ESS3-3); HS.ESS2.D (08-ESS3-2),(08-ESS3-3); HS.ESS2.E (08-ESS3-3),(08-ESS3-4); HS.ESS3.A (08-ESS3-4); HS.ESS3.B (08-ESS3-2); HS.ESS3.C (08-ESS3-3),(08-ESS3-4); HS.ESS3.D (08-ESS3-2),(08-ESS3-3)</td>
<td>Connections to Nature of Science Science Addresses Questions About the Natural and Material World Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes. (08-ESS3-4)</td>
</tr>
</tbody>
</table>
Kentucky Department of Education

MS. Human Impacts - Continued

<table>
<thead>
<tr>
<th>Subject</th>
<th>Standard</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELA/Literacy</td>
<td>RST.6-8.1</td>
<td>Cite specific textual evidence to support analysis of science and technical texts. <em>(08-ESS3-2),(08-ESS3-4)</em></td>
</tr>
<tr>
<td></td>
<td>RST.6-8.7</td>
<td>Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). <em>(08-ESS3-2)</em></td>
</tr>
<tr>
<td></td>
<td>WHST.6-8.1</td>
<td>Write arguments focused on discipline content. <em>(08-ESS3-4)</em></td>
</tr>
<tr>
<td></td>
<td>WHST.6-8.7</td>
<td>Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. <em>(08-ESS3-3)</em></td>
</tr>
<tr>
<td></td>
<td>WHST.6-8.8</td>
<td>Gather relevant information from multiple print and digital sources; assess the credibility of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and providing basic bibliographic information for sources. <em>(08-ESS3-3)</em></td>
</tr>
<tr>
<td></td>
<td>WHST.6-8.9</td>
<td>Draw evidence from informational texts to support analysis, reflection, and research. <em>(08-ESS3-4)</em></td>
</tr>
<tr>
<td>Mathematics</td>
<td>MP.2</td>
<td>Reason abstractly and quantitatively. <em>(08-ESS3-2)</em></td>
</tr>
<tr>
<td></td>
<td>6.RP.A.1</td>
<td>Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. <em>(08-ESS3-3),(08-ESS3-4)</em></td>
</tr>
<tr>
<td></td>
<td>7.RP.A.2</td>
<td>Recognize and represent proportional relationships between quantities. <em>(08-ESS3-3),(08-ESS3-4)</em></td>
</tr>
<tr>
<td></td>
<td>6.EE.B.6</td>
<td>Use variables to represent numbers and write expressions when solving a real-world or mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified set. <em>(08-ESS3-2),(08-ESS3-3),(08-ESS3-4)</em></td>
</tr>
<tr>
<td></td>
<td>7.EE.B.4</td>
<td>Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities. <em>(08-ESS3-2),(08-ESS3-3),(08-ESS3-4)</em></td>
</tr>
</tbody>
</table>

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled "Disciplinary Core Ideas" is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.*
**MS. Engineering Design**

**Science and Engineering Practices**

**ETSI.C: Optimizing the Design Solution**

- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. (MS-ETS1-4)

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

- The more precisely a design task’s criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions. (MS-ETS1-1)

**ETSI.B: Developing Possible Solutions**

- A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. (MS-ETS1-4)

**ETSI.D: Evaluating Design Solutions**

- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (MS-ETS1-2, MS-ETS1-3)

**ETSI.E: Designing and Building Solutions**

- Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. (MS-ETS1-3)

**ETSI.F: Testing and Refining Solutions**

- Models of all kinds are important for testing solutions. (MSET5-1-4)

**ETSI.G: Communicating and Evaluating Design Solutions**

- Engaging in argument from evidence—engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world. Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. (MS-ETS1-2)

**Disciplinary Core Ideas**

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

- **ETS1.B: Developing Possible Solutions**

- **ETS1.C: Optimizing the Design Solution**

- **ETS1.D: Evaluating Design Solutions**

- **ETS1.E: Designing and Building Solutions**

- **ETS1.F: Testing and Refining Solutions**

- **ETS1.G: Communicating and Evaluating Design Solutions**

**Crosscutting Concepts**

- **Influence of Science, Engineering, and Technology on Society and the Natural World**

- All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. (MS-ETS1-1)

- The uses of technologies and limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. (MS-ETS1-1)

**Connections to MS-ETS1.A: Defining and Delimiting Engineering Problems include:**

- Physical Science: MS-PS3-3

**Connections to MS-ETS1.B: Developing Possible Solutions Problems include:**

- Physical Science: MS-PS1-6, MS-PS3-3, Life Science: MS-LS2-5

**Connections to MS-ETS1.C: Optimizing the Design Solution include:**

- Physical Science: MS-PS1-6

**Articulation of DCIs across grade-bands**: 3-5.ETS1.A (MS-ETS1-1), (MS-ETS1-2), (MS-ETS1-3), 3-5.ETS1.B (MS-ETS1-2), (MS-ETS1-3), (MS-ETS1-4), 3-5.ETS1.C (MS-ETS1-1), (MS-ETS1-2), (MS-ETS1-3), (MS-ETS1-4), HS.ETS1.A (MS-ETS1-1), (MS-ETS1-2), HS.ETS1.B (MS-ETS1-1), (MS-ETS1-2), (MS-ETS1-3), (MS-ETS1-4), HS.ETS1.C (MS-ETS1-3), (MS-ETS1-4)
Kentucky Department of Education

**MS. Engineering Design - Continued**

<table>
<thead>
<tr>
<th>Kentucky Academic Standards Connections:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ELA/Literacy –</strong></td>
</tr>
<tr>
<td><strong>RST.6-8.1</strong> Cite specific textual evidence to support analysis of science and technical texts. (MS-ETS1-1), (MS-ETS1-2), (MS-ETS1-3)</td>
</tr>
<tr>
<td><strong>RST.6-8.7</strong> Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, or table). (MS-ETS1-3)</td>
</tr>
<tr>
<td><strong>RST.6-8.9</strong> Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. (MS-ETS1-2), (MS-ETS1-3)</td>
</tr>
<tr>
<td><strong>WHST.6-8.7</strong> Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. (MS-ETS1-2)</td>
</tr>
<tr>
<td><strong>WHST.6-8.8</strong> Gather relevant information from multiple print and digital sources; assess the credibility of each source; and quote or paraphrase the data and conclusions of others avoiding plagiarism and providing basic bibliographic information for sources. (MS-ETS1-1)</td>
</tr>
<tr>
<td><strong>WHST.6-8.9</strong> Draw evidence from informational texts to support analysis, reflection, and research. (MS-ETS1-2)</td>
</tr>
<tr>
<td><strong>SL.8.5</strong> Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points. (MS-ETS1-4)</td>
</tr>
<tr>
<td><strong>Mathematics –</strong></td>
</tr>
<tr>
<td><strong>MP.2</strong> Reason abstractly and quantitatively. (MS-ETS1-1), (MS-ETS1-2), (MS-ETS1-3), (MS-ETS1-4)</td>
</tr>
<tr>
<td><strong>7.EE.3</strong> Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals) using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies. (MS-ETS1-1), (MS-ETS1-2), (MS-ETS1-3)</td>
</tr>
<tr>
<td><strong>7.SP</strong> Develop a probability model and use it to find probabilities of events. Compare probabilities from a model to observed frequencies; if the agreement is not good, explain possible sources of the discrepancy. (MS-ETS1-4)</td>
</tr>
</tbody>
</table>

HIGH SCHOOL SCIENCE
The Kentucky Academic Standards for Science are written as a set of performance expectations that are assessable statements of what students should know and be able to do. An underlying assumption of these standards is that all students should be held accountable for demonstrating their achievement of all performance expectations. A coherent and complete view of what students should be able to do comes when the performance expectations are viewed in tandem with the contents of the foundation boxes that lie just below the performance expectations. These three boxes include the practices, core disciplinary ideas, and crosscutting concepts, derived from the National Research Council’s Framework for K12 Science Education that were used to construct this set of performance expectations.

**Science and Engineering Practices.** The blue box on the left includes just the science and engineering practices used to construct the performance expectations in the box above. These statements are derived from and grouped by the eight categories detailed in the Framework to further explain the science and engineering practices important to emphasize in each grade band. Most sets of performance expectations emphasize only a few of the practice categories; however, all practices are emphasized within a grade band.

**Disciplinary Core Ideas (DCIs).** The orange box in the middle includes statements that are taken from the Framework about the most essential ideas in the major science disciplines that all students should understand during 13 years of school. Including these detailed statements was very helpful to the writing team as they analyzed and "unpacked" the disciplinary core ideas and sub-ideas to reach a level that is helpful in describing what each student should understand about each sub-idea at the end of grades 2, 5, 8, and 12. Although they appear in paragraph form in the Framework, here they are bulleted to be certain that each statement is distinct.

**Crosscutting Concepts.** The green box on the right includes statements derived from the Framework’s list of crosscutting concepts, which apply to one or more of the performance expectations in the box above. Most sets of performance expectations limit the number of crosscutting concepts so as focus on those that are readily apparent when considering the DCIs; however, all are emphasized within a grade band. Aspects of the Nature of Science relevant to the standard are also listed in this box, as are the interdependence of science and engineering, and the influence of engineering, technology, and science on society and the natural world.

**Connection Boxes**

Three Connection Boxes, below the Foundation Boxes, are designed to support a coherent vision of the standards by showing how the performance expectations in each standard connect to other performance expectations in science, as well as to the KAS standards in Mathematics and English/Language Arts. The three boxes include:

- Connections to other DCIs in this grade level or band. This box contains the names of science topics in other disciplines that have related disciplinary core ideas at the same grade level. For example, both Physical Science and Life Science performance expectations contain core ideas related to Photosynthesis, and could be taught in relation to one another.

- Articulation of DCIs across grade levels. This box contains the names of other science topics that either 1) provide a foundation for student understanding of the core ideas in this set of performance expectations (usually at prior grade levels) or 2) build on the
foundation provided by the core ideas in this set of performance expectations (usually at subsequent grade levels).

- Connections to the Kentucky Academic Standards in mathematics and English/Language Arts. This box contains the coding and names of pre-requisite or co-requisite Kentucky Academic Standards in English Language Arts & Literacy and Mathematics that align to the performance expectations. An effort has been made to ensure that the mathematical skills that students need for science were taught in a previous year where possible.
HS. Structure and Properties of Matter

Students who demonstrate understanding can:

**HS-PS1:** 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. [Clarification Statement: 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 Boundary: Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.]

**HS-PS1-3:** Plan and conduct an investigation to gather evidence to compare the strength of electrical forces between particles. [Clarification Statement: Emphasis is on understanding the strengths of forces between particles, and 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 Boundary: Assessment does not include Raoult's law calculations of vapor pressure.]

**HS-PS1-8:** Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during processes of fission, fusion, and radioactive decay. [Clarification Statement: 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 Boundary: Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.]

**HS-PS2:** Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials. [Clarification Statement: 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 Boundary: Assessment is limited to provided molecular structures of specific designed materials.]

<table>
<thead>
<tr>
<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
<td>Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. (HS-PS1-1)</td>
<td>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-PS1-1), (HS-PS1-3)</td>
</tr>
<tr>
<td>Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS1-1)</td>
<td>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-PS1-1)</td>
<td>Energy and Matter</td>
</tr>
<tr>
<td>Use a model to predict the relationships between systems or between components of a system. (HS-PS1-1)</td>
<td>The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (HS-PS1-3), (secondary to HS-PS2-6)</td>
<td>In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HS-PS1-8)</td>
</tr>
<tr>
<td>Planning and Carrying Out Investigations</td>
<td>PS1.C: Nuclear Processes</td>
<td>Structure and Function</td>
</tr>
<tr>
<td>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.</td>
<td>Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process. (HS-PS1-8)</td>
<td>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-PS2-6)</td>
</tr>
<tr>
<td>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-PS1-3)</td>
<td>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. (HS-PS1-3), (HS-PS2-6)</td>
<td></td>
</tr>
<tr>
<td>Obtaining, Evaluating, and Communicating Information</td>
<td>PS2.B: Types of Interactions</td>
<td></td>
</tr>
<tr>
<td>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.</td>
<td>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. (HS-PS1-3), (HS-PS2-6)</td>
<td></td>
</tr>
<tr>
<td>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-PS2-6)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Connections to other DCIs in this grade-band: HS-PS3.A (HS-PS1-8); HS-PS3.B (HS-PS1-8); HS-PS3.C (HS-PS1-8); HS-PS3.D (HS-PS1-8); HS.LS1.C (HS-PS1-1); HS.ESS1.A (HS-PS1-8); HS.ESS1.B (HS-PS1-8); HS.ESS2.C (HS-PS1-3)

Articulation to DCIs across grade-bands: MS-PS1.A (HS-PS1-1), (HS-PS1-3), (HS-PS1-8), (HS-PS2-6); MS-PS1.B (HS-PS1-1), (HS-PS1-8); MS-PS1.C (HS-PS1-8); MS-PS2.B (HS-PS1-8); MS-ESS2.A (HS-PS1-8)
Kentucky Department of Education

HS. Structure and Properties of Matter - Continued

<table>
<thead>
<tr>
<th>Kentucky Academic Standards Connections:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ELA/Literacy –</strong></td>
</tr>
<tr>
<td><strong>RST.9-10.7</strong> Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. (HS-PS1-1)</td>
</tr>
<tr>
<td><strong>RST.11-12.1</strong> Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS1-3),(HS-PS2-6)</td>
</tr>
<tr>
<td><strong>WHST.9-12.7</strong> Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HSPS1-3)</td>
</tr>
<tr>
<td><strong>WHST.11-12.8</strong> Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS1-3)</td>
</tr>
<tr>
<td><strong>WHST.9-12.9</strong> Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS1-3)</td>
</tr>
<tr>
<td><strong>Mathematics –</strong></td>
</tr>
<tr>
<td><strong>MP.4</strong> Model with mathematics. (HS-PS1-8)</td>
</tr>
<tr>
<td><strong>HSN-Q.A.1</strong> Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS1-3),(HS-PS1-8),(HS-PS2-6)</td>
</tr>
<tr>
<td><strong>HSN-Q.A.2</strong> Define appropriate quantities for the purpose of descriptive modeling. (HS-PS1-8),(HS-PS2-6)</td>
</tr>
<tr>
<td><strong>HSN-Q.A.3</strong> Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS1-3),(HS-PS1-8),(HS-PS2-6)</td>
</tr>
</tbody>
</table>

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

## HS. Chemical Reactions

**HS-PS1.2.** 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. [Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.] [Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.]

**HS-PS1.4.** Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon changes in total bond energy. [Clarification Statement: 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 Boundary: Assessment does not include calculating total bond energy changes during a chemical reaction from the bond energies of reactants and products.]

**HS-PS1.5.** 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. [Clarification Statement: Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules.] [Assessment Boundary: Assessment is limited to simple reactions in which there are only reactants; evidence from temperature, concentration, and rate data; and qualitative relationships between rate and temperature.]

**HS-PS1.6.** Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of product at equilibrium.* [Clarification Statement: 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 Boundary: Assessment is limited to specifying the change in only one variable at a time. Assessment does not include calculating equilibrium constants and concentrations.]

**HS-PS1.7.** Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. [Clarification Statement: 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. Emphasis is on assessing students’ use of mathematical thinking and not on memorization and rote application of problem-solving techniques.] [Assessment Boundary: Assessment does not include complex chemical reactions.]

---

### The performance expectations above were developed using the following elements from the NRC document *A Framework for K–12 Science Education*:

<table>
<thead>
<tr>
<th>Developing and Using Models</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Science and Engineering Practices</strong></td>
<td><strong>PS1.A: Structure and Properties of Matter</strong></td>
<td><strong>Patterns</strong></td>
</tr>
<tr>
<td>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.</td>
<td>• 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-PS1-2) <strong>(Note: This Disciplinary Core Idea is also addressed by HS-PS1-1)</strong></td>
<td>• 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-PS1-2),(HS-PS1-5)</td>
</tr>
<tr>
<td>Developing a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS1-4)</td>
<td>• A 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-PS1-4)</td>
<td><strong>Energy and Matter</strong></td>
</tr>
<tr>
<td>Using Mathematics and Computational Thinking</td>
<td><strong>PS1.B: Chemical Reactions</strong></td>
<td>• The total amount of energy and matter in closed systems is conserved. (HS-PS1-7)</td>
</tr>
<tr>
<td>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.</td>
<td>• 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. (HSPS1-4),(HS-PS1-5)</td>
<td>• 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-PS1-4)</td>
</tr>
<tr>
<td>Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS1-4)</td>
<td>• 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-PS1-6)</td>
<td><strong>Stability and Change</strong></td>
</tr>
<tr>
<td>Use the mathematical representations of phenomena to support claims. (HS-PS1-7)</td>
<td>• 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-PS1-2),(HS-PS1-7)</td>
<td>• Much of science deals with constructing explanations of how things change and how they remain stable. (HS-PS1-6)</td>
</tr>
<tr>
<td><strong>Constructing Explanations and Designing Solutions</strong></td>
<td><strong>ETS1.C: Optimizing the Design Solution</strong></td>
<td><strong>Connections to Nature of Science</strong></td>
</tr>
<tr>
<td>Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple independent and/or converging lines of evidence from 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-PS1-2)</td>
<td>• 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 (tradeoffs) may be needed. (secondary to HS-PS1-6)</td>
<td><strong>Scientific Knowledge Assumes an Order and Consistency in Natural Systems</strong></td>
</tr>
<tr>
<td>Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-PS1-6)</td>
<td></td>
<td>• Science assumes the universe is a vast single system in which basic laws are consistent. (HS-PS1-7)</td>
</tr>
</tbody>
</table>

*Clarification Statement: 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. Emphasis is on assessing students’ use of mathematical thinking and not on memorization and rote application of problem-solving techniques. [Assessment Boundary: Assessment does not include complex chemical reactions.]

---

Connections to other DCIs in this grade-band: HS.PS3.A (HS-PS1-4),(HS-PS1-5); HS.PS3.B (HS-PS1-4),(HS-PS1-6),(HS-PS1-7); HS.PS3.D (HS-PS1-4); HS.LS1.C (HS-PS1-2),(HS-PS1-4),(HS-PS1-7); HS.LS2.B (HS-PS1-7); HS.ESS2.C (HS-PS1-2)

Articulation to DCIs across grade-bands: MS.PS1.A (HS-PS1-2),(HS-PS1-4),(HS-PS1-5),(HS-PS1-7); HS.PS1.B (HS-PS1-2),(HS-PS1-4),(HS-PS1-5),(HS-PS1-6),(HS-PS1-7); MS.PS2.B (HS-PS1-3),(HS-PS1-4),(HS-PS1-5); MS.PS3.A (HS-PS1-5); MS.PS3.B (HS-PS1-5); MS.PS3.D (HS-PS1-4); MS.LS1.C (HS-PS1-4),(HS-PS1-7); MS.LS2.B (HS-PS1-7); MS.ESS2.A (HS-PS1-7)
Kentucky Academic Standards Connections:

<table>
<thead>
<tr>
<th>ELA/Literacy – RST.11-12.1</th>
<th>Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS1-5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHST.9-12.2</td>
<td>Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS1-2),(HS-PS1-5)</td>
</tr>
<tr>
<td>WHST.9-12.5</td>
<td>Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for specific purpose and audience. (HS-PS1-2)</td>
</tr>
<tr>
<td>SL.11-12.5</td>
<td>Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-PS1-4)</td>
</tr>
</tbody>
</table>

Mathematics –

| MP.2                      | Reason abstractly and quantitatively. (HS-PS1-5),(HS-PS1-7) |
| MP.4                      | Model with mathematics. (HS-PS1-4) |
| HSN-Q.A.1                 | Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS1-2),(HS-PS1-4),(HS-PS1-5),(HS-PS1-7) |
| HSN-Q.A.2                 | Define appropriate quantities for the purpose of descriptive modeling. (HS-PS1-4),(HS-PS1-7) |
| HSN-Q.A.3                 | Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS1-2),(HS-PS1-4),(HS-PS1-5),(HS-PS1-7) |

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled “Disciplinary Core Ideas” is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.*
HS. Forces and Interactions

Students who demonstrate understanding can:

**HS-PS2-1.** Analyze data to support the claim that Newton’s second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. [Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.] [Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.]

**HS-PS2-2.** Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. [Clarification Statement: Emphasis is on the quantitative conservation of momentum in the and the qualitative meaning of this principle.] [Assessment Boundary: Assessment is limited to systems of two macroscopic bodies moving in one dimension.]

**HS-PS2-3.** Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision. [Clarification Statement: Examples of evaluation and refinement could include determining the success of a device at protecting an object from impact and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.] [Assessment Boundary: Assessment is limited to qualitative evaluations and/or algebraic manipulations.]

**HS-PS2-4.** Use mathematical representations of Newton’s Law of Gravitation and Coulomb’s Law to describe and predict the gravitational and electrostatic forces between objects. [Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.] [Assessment Boundary: Assessment is limited to systems with two objects.]

**HS-PS2-5.** Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current. [Assessment Boundary: Assessment is limited to designing and conducting investigations with provided materials and tools.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

**Science and Engineering Practices**
Plan 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-PS2-5)
- 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-PS2-1)

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-PS2-2),(HS-PS2-4)

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-PS2-3)

**Disciplinary Core Ideas**

**PS2.A: Forces and Motion**
- Newton’s second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1)
- Momentum is defined for a particular frame of reference: it is the mass times the velocity of the object. (HS-PS2-2)
- 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-PS2-2),(HS-PS2-3)

**PS2.B: Types of Interactions**
- Newton’s law of universal gravitation and Coulomb’s law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (HS-PS2-4)
- Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents can cause magnetic fields; electric charges or changing magnetic fields cause electric fields. (HS-PS2-4),(HS-PS2-5)

**PS3.A: Definitions of Energy**
- …and “electrical energy” may mean energy stored in a battery or energy transmitted by electric currents. (secondary to HS-PS2-5)

**ETS1.A: Defining and Delimiting Engineering Problems**
- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary to HS-PS2-3)

**ETS1.C: Optimizing the Design Solution**
- Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed. (secondary to HS-PS2-3)

**Connections to Nature of Science**

Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena
- Theories and laws provide explanations in science. (HS-PS2-1),(HS-PS2-4)
- Laws are statements or descriptions of the relationships among observable phenomena. (HS-PS2-1),(HS-PS2-4)

Connections to other DCIs in this grade-band: HS.PS3.A (HS-PS2-4),(HS-PS2-5); HS.PS3.C (HS-PS2-1); HS.PS4.B (HS-PS2-5); HS.ESS1.A (HS-PS2-1),(HS-PS2-2),(HS-PS2-4); HS.ESS1.B (HS-PS2-4); HS.ESS2.A (HS-PS2-5); HS.ESS1.C (HS-PS2-1),(HS-PS2-2),(HS-PS2-4); HS.ESS2.C (HS-PS2-1),(HS-PS2-4); HS.ESS3.A (HS-PS2-4),(HS-PS2-5)

Articulation to DCIs across grade-bands: MS.PS2.A (HS-PS2-1),(HS-PS2-2),(HS-PS2-3); MS.PS2.B (HS-PS2-4),(HS-PS2-5); MS.PS3.C (HS-PS2-1),(HS-PS2-2),(HS-PS2-3); MS.ESS1.B (HS-PS2-4),(HS-PS2-5)
Kentucky Department of Education

HS. Forces and Interactions - Continued

Kentucky Academic Standards Connections:

ELA Literacy –
RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS2-1)
RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-PS2-1)
WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS2-3),(HSSPS2-5)

WHST.11-12.6 Each

WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS2-1),(HS-PS2-5)

Mathematics –
MP.2 Reason abstractly and quantitatively. (HS-PS2-1),(HS-PS2-2),(HS-PS2-4)

HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS2-1),(HS-PS2-2),(HS-PS2-4),(HS-PS2-5)

HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-PS2-1),(HS-PS2-2),(HS-PS2-4),(HS-PS2-5)

HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS2-1),(HS-PS2-2),(HS-PS2-4),(HS-PS2-5)

HSA-SSE.A.1 Interpret expressions that represent a quantity in terms of its context. (HS-PS2-1),(HS-PS2-4)

HSA-SSE.B.3 Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS2-1),(HS-PS2-4)

HSA-CED.A.1 Create equations and inequalities in one variable and use them to solve problems. (HS-PS2-1),(HS-PS2-2)

HSA-CED.A.2 Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. (HS-PS2-2)

HSA-CED.A.4 Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-PS2-1),(HS-PS2-2)

HSF-IF.C.7 Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases. (HS-PS2-1)

HSS-ID.A.1 Represent data with plots on the real number line (dot plots, histograms, and box plots). (HS-PS2-1)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

### HS. Energy

Students who demonstrate understanding can:

**HS-PS3-1. Energy**

Create a computational model to calculate the change in the energy of one component in a system when the change in one of the other component(s) and energy flows in and out of the system are known. [Clarification Statement: Emphasis is on explaining the mathematical expressions used in the model.] [Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.]

**HS-PS3-2.** Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects). [Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically-charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.]

**HS-PS3-3.** Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.* [Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency.] [Assessment Boundary: Assessment is limited to devices constructed with materials provided to students.]

**HS-PS3-4.** 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). [Clarification Statement: 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 Boundary: Assessment is limited to investigations based on materials and tools provided to students.]

**HS-PS3-5.** Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between the objects and the changes in energy of the objects due to the interaction. [Clarification Statement: Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.] [Assessment Boundary: Assessment is limited to systems containing two objects.]

---

### Disciplinary Core Ideas

**PS3.A: Definitions of Energy**

- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system’s total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (HS-PS3-2), (HS-PS3-3)
- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HS-PS3-2) (HS-PS3-3)
- These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. (HS-PS3-2)

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

- Conservation of energy means that the total change of energy in one system is always equal to the total energy transferred into or out of the system. (HS-PS3-1)
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-1), (HS-PS3-2), (HS-PS3-3), (HS-PS3-4)
- Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (HS-PS3-1)
- The availability of energy limits what can occur in any system. (HS-PS3-1)
- Uncontrolled systems move 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-PS3-4)

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

- When two objects interacting through a field change relative position, the energy stored in the field is changed. (HS-PS3-3)

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

- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. (HS-PS3-3), (HS-PS3-4)

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

- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary to HS-PS3-3)

<table>
<thead>
<tr>
<th>Connections to other DCIs in this grade-band: <strong>HS.PS1.A</strong> (HS-PS3-2); <strong>HS.PS1.B</strong> (HS-PS3-1),(HS-PS3-2); <strong>HS.PS2.B</strong> (HS-PS3-2),(HS-PS3-5); <strong>HS.LS2.B</strong> (HS-PS3-1); <strong>HS.ESS1.A</strong> (HS-PS3-1),(HS-PS3-4); <strong>HS.ESS2.A</strong> (HS-PS3-1),(HS-PS3-2),(HS-PS3-4); <strong>HS.ESS2.D</strong> (HS-PS3-4); <strong>HS.ESS3.A</strong> (HS-PS3-3); <strong>MS.PS1.C</strong> (HS-PS3-2),(HS-PS3-5); <strong>MS.ESS2.A</strong> (HS-PS3-1),(HS-PS3-3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Articulation to DCIs across grade-bands: <strong>MS.PS1.A</strong> (HS-PS3-2); <strong>MS.PS2.B</strong> (HS-PS3-2),(HS-PS3-5); <strong>MS.PS3.A</strong> (HS-PS3-1),(HS-PS3-2),(HS-PS3-3); <strong>MS.PS3.B</strong> (HS-PS3-1),(HS-PS3-3),(HS-PS3-4); <strong>MS.PS3.C</strong> (HS-PS3-2),(HS-PS3-5), <strong>MS.ESS2.A</strong> (HS-PS3-1),(HS-PS3-3)</td>
</tr>
</tbody>
</table>

| **Kentucky Academic Standards Connections:** |
| ELA/Literacy – |
| **RST.11-12.1** | Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS3-4) |
| **WHST.9-12.7** | Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS3-3),(HSPS3-4),(HS-PS3-5) |
| **WHST.11-12.8** | Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on one source and following a standard format for citation. (HS-PS3-4),(HS-PS3-5) |
| **WHST.9-12.9** | Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS3-4),(HS-PS3-5) |
| **SL.11-12.5** and **Mathematics –** |
| **MP.2** | Reason abstractly and quantitatively. (HS-PS3-1),(HS-PS3-2),(HS-PS3-3),(HS-PS3-4),(HS-PS3-5) |
| **MP.4** | Model with mathematics. (HS-PS3-1),(HS-PS3-2),(HS-PS3-3),(HS-PS3-4),(HS-PS3-5) |
| **HSN.Q.A.1** | Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS3-1),(HS-PS3-3) |
| **HSN.Q.A.2** | Define appropriate quantities for the purpose of descriptive modeling. (HS-PS3-1),(HS-PS3-3) |
| **HSN.Q.A.3** | Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS3-1),(HS-PS3-3) |

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.*
HS. Waves and Electromagnetic Radiation

Students who demonstrate understanding can:

HS-PS4-1. **Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.** [Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.] [Assessment Boundary: Assessment is limited to algebraic relationships and those relationships qualitatively.]

**Examples**
- Obtaining, evaluating, and communicating information in 9th grade progresses to using appropriate tools in 10th grade.
- Engaging in Argument from Evidence in 11th grade.
- Using Mathematics and Computational Thinking in 12th grade.

---

**Connections to Nature of Science**

**Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena**
- A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. (HS-PS4-3)

---

**Science and Engineering Practices**

**Disciplinary Core Ideas**

**Cause and Effect**
- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS4-1)
- 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-PS4-4)
- Systems can be designed to cause a desired effect. (HS-PS4-5)

**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-PS4-3)

---

**Crosscutting Concepts**

**Connections to Engineering, Technology, and Applications of Science**

**Interdependence of Science, Engineering, and Technology**
- Science and engineering complement each other in the cycle known as research and development (R&D). (HS-PS4-5)
- Influence of Engineering, Technology, and Science on Society and the Natural World
  - Modern civilization depends on major technological systems. (HS-PS4-2)
  - Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HS-PS4-2)
Connections to other DCIs in this grade-band: HS.PS1.C (HS-PS4-4); HS.PS3.A (HS-PS4-4),(HS-PS4-5); HS.PS3.D (HS-PS4-3),(HS-PS4-4); HS.LS1.C (HS-PS4-4); HS.ESS1.A (HS-PS4-3); HS.ESS2.A (HS-PS4-1); HS.ESS2.D (HS-PS4-3)

Articulation to DCIs across grade-bands: MS.PS3.D (HS-PS4-4); MS.PS4.A (HS-PS4-1),(HS-PS4-2),(HS-PS4-5); MS.PS4.B (HS-PS4-1),(HS-PS4-2),(HS-PS4-3),(HS-PS4-4),(HS-PS4-5); MS.PS4.C (HS-PS4-2),(HS-PS4-5); MS.LS1.C (HS-PS4-4); MS.ESS2.D (HS-PS4-4)

Kentucky Academic Standards Connections:

### ELA/Literacy – RST.9-10.8
Assess the extent to which the reasoning and evidence in a text support the author’s claim or a recommendation for solving a scientific or technical problem. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4)

### RST.11-12.1
Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4)

### RST.11-12.7
Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-PS4-1),(HS-PS4-4)

### RST.11-12.8
Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4)

### WHST.9-12.2
Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS4-5)

### WHST.11-12.8
Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS4-4)

### Mathematics – MP.2
Reason abstractly and quantitatively. (HS-PS4-1),(HS-PS4-3)

### MP.4
Model with mathematics. (HS-PS4-1)

### HSA-SSE.A.1
Interpret expressions that represent a quantity in terms of its context. (HS-PS4-1),(HS-PS4-3)

### HSA-SSE.B.3
Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS4-1),(HS-PS4-3)

### HSA.CED.A.4
Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-PS4-1),(HS-PS4-3)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled “Disciplinary Core Ideas” is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.*
HS. Structure and Function

Students who demonstrate understanding can:

HS-LS1.1. Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells. [Assessment Boundary: Assessment does not include identification of specific cell or tissue types, whole body systems, specific protein structures and functions, or the biochemistry of protein synthesis.]

HS-LS1.2. Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. [Clarification Statement: Emphasis is on functions at the organism system level such as nutrient uptake, water delivery, and organism movement in response to neural stimuli. An example of an interacting system could be an artery depending on the proper function of elastic tissue and smooth muscle to regulate and deliver the proper amount of blood within the circulatory system.] [Assessment Boundary: Assessment does not include interactions and functions at the molecular or chemical reaction level.]

HS-LS1.3. Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis. [Clarification Statement: Examples of investigations could include heart rate response to exercise, stomate response to moisture and temperature, and root development in response to water levels.] [Assessment Boundary: Assessment does not include the cellular processes involved in the feedback mechanism.]

The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:

### Developing and Using Models

**Modeling** in K–8 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 world.

- Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-LS1.2)

**Planning and Carrying Out Investigations**

Planning and carrying out 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-LS1.3)

### 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.

- Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students’ own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-LS1.1)

### Scientific Investigations Use a Variety of Methods

Scientific inquiry is characterized by a common set of values that include: logical thinking, precision, open-mindedness, objectivity, skepticism, replicability of results, and honest and ethical reporting of findings. (HS-LS1.3)

### Crosscutting Concepts

**Connections to Nature of Science**

#### LS1.A: Structure and Function

- Systems of specialized cells within organisms help them perform the essential functions of life. (HS-LS1.1)
- All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells. (HS-LS1.1) (Note: This Disciplinary Core Idea is also addressed by HS-LS3.1.)
- Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. (HS-LS1.2)
- Feedback mechanisms maintain a living system’s internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system. (HS-LS1.3)

**Connections to other DCIs in this grade-band:** HS.LS3.A (HS-LS1.1)

### Articulation across grade-bands:

- **MS.LS1.A** (HS-LS1.1), (HS-LS1.2), (HS-LS1.3); **MS.LS3.A** (HS-LS1.1), **MS.LS3.B** (HS-LS1.1)

### Kentucky Academic Standards Connections:

- **ELA/Literacy – RST.11-12.1** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-LS1.1)
- **WHST.9-12.2** Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-LS1.1)
- **WHST.9-12.7** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-LS1.3)
- **WHST.11-12.8** Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-LS1.3)
- **WHST.9-12.9** Draw evidence from informational texts to support analysis, reflection, and research. (HS-LS1.1)
- **SL.11-12.5** Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-LS1.2)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled “Disciplinary Core Ideas” is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.*
HS. Matter and Energy in Organisms and Ecosystems

Students who demonstrate understanding can:

**HS-LS1-5.** Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy. [Clarification Statement: Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models.] [Assessment Boundary: Does not include specific biochemical steps.]

**HS-LS1-6.** Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules. [Clarification Statement: Emphasis is on using evidence from models and simulations to support explanations.] [Assessment Boundary: Does not include the details of the specific chemical reactions or identification of macromolecules.]

**HS-LS1-7.** Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy. [Clarification Statement: Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.] [Assessment Boundary: Should not include identification of the steps or specific processes involved in cellular respiration.]

**HS-LS2-3.** An aerobic conditions. [Clarification Statement: Emphasis is on using a mathematical model of stored energy in biomass to describe the transfer of energy from one trophic level to another and that matter and energy are conserved as matter cycles and energy flows through ecosystems. Emphasis is on atoms and molecules such as carbon, oxygen, hydrogen and nitrogen being conserved as they move through an ecosystem.] [Assessment Boundary: Is limited to proportional reasoning to describe the cycling of matter and flow of energy.]

**HS-LS2-4.** Use a mathematical representation to support claims for the cycling of matter and flow of energy among organisms in an ecosystem. [Clarification Statement: Emphasis is on using a mathematical model of stored energy in biomass to describe the transfer of energy from one trophic level to another and that matter and energy are conserved as matter cycles and energy flows through ecosystems. Emphasis is on atoms and molecules such as carbon, oxygen, hydrogen and nitrogen being conserved as they move through an ecosystem.] [Assessment Boundary: Does not include the specific chemical processes of either aerobic or anaerobic respiration.]

**HS-LS2-5.** Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere. [Clarification Statement: Examples of models could include simulations and mathematical models.] [Assessment Boundary: Does not include the specific chemical steps of photosynthesis and respiration.]

The performance expectations 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 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 based on evidence to illustrate the relationships between systems or between components of a system. (HS-LS1-5), (HS-LS1-7)
- Develop a model based on evidence to illustrate the relationships between systems or components of a system. (HS-LS2-5)

**Using Mathematics and Computational Thinking**
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.
- Use mathematical representations of phenomena or design solutions to support claims. (HS-LS2-4)

**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.
- 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-LS1-6), (HS-LS2-3)

### Disciplinary Core Ideas

**LS1.C: Organization for Matter and Energy Flow in Organisms**
- The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. (HS-LS1-5)
- The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. (HS-LS1-6)
- As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different forms to form different products. (HS-LS1-6), (HS-LS1-7)
- As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another and release energy to the surrounding environment and to maintain body temperature. Cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. (HS-LS1-7)

**LS2.B: Cycles of Matter and Energy Transfer in Ecosystems**
- Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. (HS-LS2-3)
- Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved. (HS-LS2-4)
- Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes. (HS-LS2-5)

**PS3.D: Energy in Chemical Processes**
- The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. (secondary to HS-LS2-5)
### Kentucky Department of Education

**HS. Matter and Energy in Organisms and Ecosystems – Continued**

<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Articulation across grade-bands: MS.PS1.A (HS-LS1-6); MS.PS1.B (HS-LS1-5), (HS-LS1-6), (HS-LS1-7), (HS-LS2-3); MS.PS3.D (HS-LS1-5), (HS-LS1-6), (HS-LS1-7), (HS-LS2-3), (HS-LS2-4), (HS-LS2-5); MS.LS1.C (HS-LS1-5), (HS-LS1-6), (HS-LS1-7), (HS-LS2-3), (HS-LS2-4); MS.LS2.B (HS-LS1-5), (HS-LS1-7), (HS-LS2-3), (HS-LS2-4), (HS-LS2-6); MS.ESS2.A (HS-LS2-5); MS.ESS2.E (HS-LS1-6)</td>
</tr>
</tbody>
</table>

**Kentucky Academic Standards Connections:**

<table>
<thead>
<tr>
<th>ELA/Literacy – RST.11-12.1</th>
<th>Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-LS1-6), (HS-LS2-3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHST.9-12.2</td>
<td>Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes. (HS-LS1-6), (HS-LS2-3)</td>
</tr>
<tr>
<td>WHST.9-12.5</td>
<td>Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-LS1-6), (HS-LS2-3)</td>
</tr>
<tr>
<td>WHST.9-12.9</td>
<td>Draw evidence from informational texts to support analysis, reflection, and research. (HS-LS1-6)</td>
</tr>
<tr>
<td>SL.11-12.5</td>
<td>Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-LS1-5), (HS-LS1-7)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mathematics – MP.2</th>
<th>Reason abstractly and quantitatively. (HS-LS2-4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MP.4</td>
<td>Model with mathematics. (HS-LS2-4)</td>
</tr>
<tr>
<td>HSN.Q.A.1</td>
<td>Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-LS2-4)</td>
</tr>
<tr>
<td>HSN.Q.A.2</td>
<td>Define appropriate quantities for the purpose of descriptive modeling. (HS-LS2-4)</td>
</tr>
<tr>
<td>HSN.Q.A.3</td>
<td>Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-LS2-4)</td>
</tr>
</tbody>
</table>

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled “Disciplinary Core Ideas” is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.*
HS. Interdependent Relationships in Ecosystems

Students who demonstrate understanding can:

HS-LS2-1. Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales. [Clarification Statement: Emphasis is on quantitative analysis and comparison of the relationships among interdependent factors including boundaries, resources, climate and competition. Examples of mathematical comparisons could include graphs, charts, histograms, or population changes from simulations or historical data sets. [Assessment Boundary: Assessment does not include deriving mathematical equations to make comparisons.]

HS-LS2-2. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems at different scales. [Clarification Statement: Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.] [Assessment Boundary: Assessment is limited to provided data.]

HS-LS2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem. [Clarification Statement: Examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a seasonal flood; and extreme changes, such as volcanic eruption or sea level rise.]

HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity. [Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species.]

HS-LS2-8. Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce. [Clarification Statement: Emphasis is on: (1) distinguishing between group and individual behavior; (2) identifying evidence supporting the outcomes of group behavior, and (3) developing logical and reasonable arguments based on evidence. Examples of group behaviors could include flocking, schooling, herding, and cooperative behaviors such as hunting, migrating, and swarming.]

HS-LS4-6. Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity. [Clarification Statement: Emphasis is on designing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.]

The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:

Using Mathematics and Computational Thinking
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.

• Use mathematical and/or computational representations of phenomena or design solutions to support explanations. (HSL2-1)
• Use mathematical representations of phenomena or design solutions to support and revise explanations. (HSL2-2)
• Create or revise a simulation of a phenomenon, designed device, process, or system. (HLS4-6)

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 refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HSL2-7)

Engaging in Argument from Evidence
Engaging in argument from evidence in 9–12 builds from 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 the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (HSL2-8)

Connections to Nature of Science
Scientific Knowledge is Open to Revision in Light of New Evidence

• Most scientific knowledge is quite durable, but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence. (HSL2-2)

LS2.A: Interdependent Relationships in Ecosystems
• Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. (HS-LS2-1), (HSL2-2)

LS2.C: Ecosystem Dynamics, Functioning, and Resilience
• A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. (HS-LS2-2), (HLS2-6)
• Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species. (HSL2-7)

LS2.D: Social Interactions and Group Behavior
• Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives. (HSL2-8)

LS4.C: Adaptation
• Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline—and sometimes the extinction—of some species. (HLS4-6)

LS4.D: Biodiversity and Humans
• Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). (secondary to HS-LS2-7)
Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation. (HSLS2-6), (HS-LS2-8)

Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. (secondary to HS-LS2-7), (HS-LS4-6)

ETSI.B: Developing Possible Solutions

- When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (secondary to HSLS2-7), (secondary to HS-LS4-6)
- Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (secondary to HS-LS4-6)

Connections to other DCIs in this grade-band: HS.ESS2.D (HS-LS2-7), (HS-LS4-6); HS.ESS2.E (HS-LS2-2),(HS-LS2-6),(HS-LS2-7),(HS-LS4-6); HS.ESS2.A (HS-LS2-2),(HS-LS2-7), (HS-LS4-6); HS.ESS3.C (HS-LS2-2),(HS-LS2-7),(HS-LS4-6); HS.ESS3.D (HS-LS2-2),(HS-LS4-6)

Articulation across grade-bands: MS.LS1.B (HS-LS2-8); MS.LS2.A (HS-LS2-1),(HS-LS2-2),(HS-LS2-6); MS.LS2.C (HS-LS2-1),(HS-LS2-2),(HS-LS2-6),(HS-LS2-7),(HS-LS4-6); MS.ESS2.E (HS-LS2-6); MS.ESS3.A (HS-LS2-1); MS.ESS3.C (HS-LS2-1),(HS-LS2-2),(HS-LS2-6),(HS-LS2-7),(HS-LS4-6); MS.ESS3.D (HS-LS2-7)

Kentucky Academic Standards Connections:

ELA/Literacy – RST.9-10.8 Assess the extent to which the reasoning and evidence in a text support the author’s claim or a recommendation for solving a scientific or technical problem. (HS-LS2-6),(HS-LS2-7),(HS-LS2-8)

RST.11-12.1 Cite specific textual evidence to support analysis of scientific and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-LS2-1),(HS-LS2-2),(HS-LS2-6),(HS-LS2-8)

RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-LS2-6),(HS-LS2-7),(HS-LS2-8)

RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-LS2-6),(HS-LS2-7),(HS-LS2-8)

WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes. (HS-LS2-2), (HS-LS2-7)

WHST.9-12.5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-LS4-6)

WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem: narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HSLS2-7),(HS-LS4-6)

Mathematics –

MP.2 Reason abstractly and quantitatively. (HS-LS2-1),(HS-LS2-2),(HS-LS2-6),(HS-LS2-7)

MP.4 Model with mathematics. (HS-LS2-1),(HS-LS2-2)

HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-LS2-1),(HS-LS2-2),(HS-LS2-7)

HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-LS2-1),(HS-LS2-2),(HS-LS2-7)

HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-LS2-1),(HS-LS2-2),(HS-LS2-7)

HSS-IA.A.1 Represent data with plots on the real number line. (HS-LS2-6)

HSS-IC.B.6 Evaluate reports based on data. (HS-LS2-6)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled “Disciplinary Core Ideas” is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.
HS. Inheritance and Variation of Traits

Science and Engineering Practices

**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.
- Ask questions that arise from examining models or a theory to clarify relationships. (HS–LS3–1)

**Developing and Using Models**
- Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.
- Use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS–LS1–4)

**Analyzing and Interpreting Data**
- Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more complex data analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.
- 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. (HS–LS3–3)

**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.
- Make and defend a claim based on evidence about the natural world that reflects scientific knowledge, and student-generated evidence. (HS–LS3–2)

**Disciplinary Core Ideas**

**LS1.A: Structure and Function**
- All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins. (secondary to HS–LS3–1) (Note: This Disciplinary Core Idea is also addressed by HS–LS1–1.)

**LS1.B: Growth and Development of Organisms**
- In multicellular organisms, individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism. (HS–LS1–4)

**LS3.A: Inheritance of Traits**
- Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a segment of that DNA. The instructions for forming species’ characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet-known function. (HS–LS3–1)

**LS3.B: Variation of Traits**
- In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited. (HS–LS3–2)
- Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors. (HS–LS3–2),(HS–LS3–3)

**Crosscutting Concepts**

**Cause and Effect**
- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS–LS3–1),(HS–LS3–2)

**Scale, Proportion, and Quantity**
- 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). (HS–LS3–3)

**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–LS1–4)

Connections to Nature of Science

Science is a Human Endeavor
- Technological advances have influenced the progress of science and science has influenced advances in technology. (HS–LS3–3)
- Science and engineering are influenced by society and society is influenced by science and engineering. (HS–LS3–3)

Articulation across grade-bands:

Kentucky Academic Standards Connections:
- **ELA/Literacy – RST.11–12.1**
  - Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS–LS3–1),(HS–LS3–2)
- **RST.11–12.9**
  - Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (HS–LS3–1)
- **WHST.9–12.1**
  - Write arguments focused on discipline-specific content. (HS–LS3–2)
  - Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, evidence and to add interest. (HS–LS1–4)
- **MP.2**
HS. Inheritance and Variation of Traits – Continued

<table>
<thead>
<tr>
<th>MP.4</th>
<th>Model with mathematics. (HS-LS1-4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HSF-IF.C.7</td>
<td>Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases. (HSLS1-4)</td>
</tr>
<tr>
<td>HSF-BF.A.1</td>
<td>Write a function that describes a relationship between two quantities. (HS-LS1-4)</td>
</tr>
</tbody>
</table>

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled “Disciplinary Core Ideas” is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.
HS. Natural Selection and Evolution

Students who demonstrate understanding can:

HS-LS4-1. Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence. [Clarification Statement: Emphasis is on a conceptual understanding of the role each line of evidence has relating to common ancestry and biological evolution. Examples of evidence could include similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development.]

HS-LS4-2. Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment. [Clarification Statement: Emphasis is on using evidence to explain the influence each of the four factors has on number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning.] [Assessment Boundary: Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.]

HS-LS4-3. Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait. [Clarification Statement: Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.] [Assessment Boundary: Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.]

HS-LS4-4. Construct an explanation based on evidence for how natural selection leads to adaptation of populations. [Clarification Statement: Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.]

HS-LS4-5. Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species. [Clarification Statement: Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species.]

The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:

<table>
<thead>
<tr>
<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analyzing and Interpreting Data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>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. • 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. (HS-LS4-3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constructing Explanations and Designing Solutions</td>
<td>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. • Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students’ own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-LS4-2), (HS-LS4-4)</td>
<td></td>
</tr>
<tr>
<td>Engaging in Argument from Evidence</td>
<td>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 or historical episodes in science. • Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments. (HS-LS4-5)</td>
<td></td>
</tr>
<tr>
<td>Obtaining, Evaluating, and Communicating Information</td>
<td>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. • Communicate scientific information (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-LS4-1)</td>
<td></td>
</tr>
</tbody>
</table>

**Connections to Nature of Science**

**Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena**

- A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community values 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-LS4-1)

---

Kentucky Department of Education

**HS. Natural Selection and Evolution**

679

Kentucky Academic Standards – Science – High School
Connections to other DCIs in this grade-band: HS.LS2.A (HS-LS4-2),(HS-LS4-3),(HS-LS4-4),(HS-LS4-5); HS.LS2.D (HS-LS4-2),(HS-LS4-3),(HS-LS4-4),(HS-LS4-5); HS.LS3.A (HS-LS4-1); HS.LS3.B (HS-LS4-1),(HS-LS4-2),(HS-LS4-3),(HS-LS4-5); HS.ESS1.C (HS-LS4-1); HS.ESS2.E (HS-LS4-2),(HS-LS4-5); HS.ESS3.A (HS-LS4-2),(HS-LS4-5)

Articulation across grade-bands: MS.LS2.A (HS-LS4-2),(HS-LS4-3),(HS-LS4-5); MS.LS2.C (HS-LS4-5); MS.LS3.A (HS-LS4-1); MS.LS4.B (HS-LS4-2),(HS-LS4-3),(HS-LS4-4); MS.LS4.C (HS-LS4-2),(HS-LS4-3),(HS-LS4-4),(HS-LS4-5); MS.ESS1.C (HS-LS4-1); MS.ESS3.C (HS-LS4-5)

Kentucky Academic Standards Connections:

ELA/Literacy –

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-LS4-1),(HS-LS4-2),(HS-LS4-3),(HS-LS4-4)

RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-LS4-5)

WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-LS4-1),(HS-LS4-2),(HS-LS4-3),(HS-LS4-4)

WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research. (HS-LS4-1),(HS-LS4-2),(HS-LS4-3),(HS-LS4-4),(HS-LS4-5)

SL.11-12.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. (HS-LS4-1),(HS-LS4-2)

Mathematics –

MP.2 Reason abstractly and quantitatively. (HS-LS4-1),(HS-LS4-2),(HS-LS4-3),(HS-LS4-4),(HS-LS4-5)

MP.4 Model with mathematics. (HS-LS4-2)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled “Disciplinary Core Ideas” is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.
### HS. Space Systems

**Students who demonstrate understanding can:**

**HS-ESS1-1.** Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun’s core to release energy that eventually reaches Earth in the form of radiation. [Clarification Statement: Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun’s core to reach Earth. Examples of evidence for the model include observations of the masses and lifetimes of other stars, as well as the ways that the sun’s radiation varies due to sudden solar flares (“space weather”), the 11-year sunspot cycle, and non-cyclic variations over centuries.] [Assessment Boundary: Does not include details of the atomic and sub-atomic processes involved with the sun’s nuclear fusion.]

**HS-ESS1-2.** Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe. [Clarification Statement: Emphasis is on the astronomical evidence of the red shift of light from galaxies as an indication that the universe is currently expanding, the cosmic microwave background as the remnant radiation from the Big Bang, and the observed composition of ordinary matter of the universe, primarily found in stars and interstellar gases (from the spectra of electromagnetic radiation from stars), which matches that predicted by the Big Bang theory (3/4 hydrogen and 1/4 helium).]

**HS-ESS1-3.** Communicate scientific ideas about the way stars, over their life cycle, produce elements. [Clarification Statement: Emphasis is on the nucleosynthesis, and therefore the different elements created, varies as a function of the mass of a star and the stage of its lifetime.] [Assessment Boundary: Details of the many different nucleosynthesis pathways for stars of differing masses are not assessed.]

**HS-ESS1-4.** Use mathematical or computational representations to predict the motion of orbiting objects in the solar system. [Clarification Statement: Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets and moons.] [Assessment Boundary: Mathematical representations for the gravitational attraction of bodies and Kepler’s Laws of orbital motions should not deal with more than two bodies, nor involve calculus.]

<table>
<thead>
<tr>
<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developing and Using Models</td>
<td><strong>ESS1.A: The Universe and Its Stars</strong></td>
<td>Scale, Proportion, and Quantity</td>
</tr>
<tr>
<td>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 world(s).</td>
<td>- The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. (HSESS1-1)</td>
<td>- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. (HS-ESS1-1)</td>
</tr>
<tr>
<td>Using Mathematical and Computational Thinking</td>
<td>- The study of stars’ light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. (HS-ESS1-2), (HS-ESS1-3)</td>
<td>- 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). (HS-ESS1-4)</td>
</tr>
<tr>
<td>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.</td>
<td>- The Big Bang theory is supported by observations of distant galaxies reaching from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. (HS-ESS1-2)</td>
<td>- Energy cannot be created or destroyed—only moved between one place and another place, between objects and/or fields, or between systems. (HS-ESS1-2)</td>
</tr>
<tr>
<td>Constructing Explanations and Designing Solutions</td>
<td>- Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode. (HS-ESS1-2), (HS-ESS1-3)</td>
<td>- In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HSESS1-3)</td>
</tr>
<tr>
<td>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.</td>
<td><strong>ESS1.B: Earth and the Solar System</strong></td>
<td>- <strong>Connection to Engineering, Technology, and Applications of Science</strong></td>
</tr>
<tr>
<td>- Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students’ own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-ESS1-2)</td>
<td>- Kepler’s laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. (HS-ESS1-4)</td>
<td>- Interdependence of Science, Engineering, and Technology</td>
</tr>
<tr>
<td>Obtaining, Evaluating, and Communicating Information</td>
<td><strong>PS3.D: Energy in Chemical Processes and Everyday Life</strong></td>
<td>- Science and engineering complement each other in the cycle known as research and development (R&amp;D). Many R&amp;D projects may involve scientists, engineers, and others with wide ranges of expertise. (HSESS1-2), (HS-ESS1-4)</td>
</tr>
<tr>
<td>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.</td>
<td>- Nuclear fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. (secondary to HS-ESS1-1)</td>
<td>- <strong>Connection to Nature of Science</strong></td>
</tr>
<tr>
<td>- Communicate scientific 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-ESS1-3)</td>
<td><strong>PS4.B Electromagnetic Radiation</strong></td>
<td>- Scientific Knowledge Assumes an Order and Consistency in Natural Systems</td>
</tr>
<tr>
<td><strong>Connections to Nature of Science</strong></td>
<td>- Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities. (secondary to HS-ESS1-2)</td>
<td>- Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. (HS-ESS1-2)</td>
</tr>
<tr>
<td><strong>Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena</strong></td>
<td>- Connections to other DCIs in this grade-band: HS.PS1.A (HS-ESS1-1),(HS-ESS1-2),(HS-ESS1-3); HS.PS1.C (HS-ESS1-1),(HS-ESS1-2),(HS-ESS1-3); HS.PS2.B (HS-ESS1-1); HS.PS3.A (HS-ESS1-1),(HS-ESS1-2); HS.PS4.A (HS-ESS1-2)</td>
<td></td>
</tr>
<tr>
<td>- 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-ESS1-2)</td>
<td><strong>Articulation of DCIs across grade-bands:</strong> MS.PS1.A (HS-ESS1-1),(HS-ESS1-2),(HS-ESS1-3); MS.PS2.A (HS-ESS1-1),(HS-ESS1-2); MS.PS2.B (HS-ESS1-1),(HS-ESS1-2); MS.PS4.A (HS-ESS1-1),(HS-ESS1-2); MS.ESS1.A (HS-ESS1-1),(HS-ESS1-2),(HS-ESS1-3),(HS-ESS1-4); MS.ESS1.B (HS-ESS1-1),(HS-ESS1-2); MS.ESS2.A (HS-ESS1-1); MS.ESS2.D (HS-ESS1-1)</td>
<td>- <strong>Scientific Knowledge Assumes an Order and Consistency in Natural Systems</strong></td>
</tr>
</tbody>
</table>

Kentucky Academic Standards – Science – High School
# HS. Space Systems – Continued

## Kentucky Academic Standards Connections:

### ELA/Literacy –

<table>
<thead>
<tr>
<th>RST.11-12.1</th>
<th>Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. ([HS-ESS1-1], [HS-ESS1-2])</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHST.9-12.2</td>
<td>Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes. ([HS-ESS1-2], [HSESS1-3])</td>
</tr>
<tr>
<td>SL.11-12.4</td>
<td>Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. ([HS-ESS1-3])</td>
</tr>
</tbody>
</table>

### Mathematics –

<table>
<thead>
<tr>
<th>MP.2</th>
<th>Reason abstractly and quantitatively. ([HS-ESS1-1], [HS-ESS1-2], [HS-ESS1-3], [HS-ESS1-4])</th>
</tr>
</thead>
<tbody>
<tr>
<td>MP.4</td>
<td>Model with mathematics. ([HS-ESS1-1], [HS-ESS1-4])</td>
</tr>
<tr>
<td>HSN-Q.A.1</td>
<td>Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. ([HS-ESS1-1], [HS-ESS1-2], [HS-ESS1-4])</td>
</tr>
<tr>
<td>HSN-Q.A.2</td>
<td>Define appropriate quantities for the purpose of descriptive modeling. ([HS-ESS1-1], [HS-ESS1-2], [HS-ESS1-4])</td>
</tr>
<tr>
<td>HSN-Q.A.3</td>
<td>Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. ([HS-ESS1-1], [HS-ESS1-2], [HS-ESS1-4])</td>
</tr>
<tr>
<td>HSA-SSE.A.1</td>
<td>Interpret expressions that represent a quantity in terms of its context. ([HS-ESS1-1], [HS-ESS1-2], [HS-ESS1-4])</td>
</tr>
<tr>
<td>HSA-CED.A.2</td>
<td>Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. ([HS-ESS1-1], [HS-ESS1-2], [HS-ESS1-4])</td>
</tr>
<tr>
<td>HSA-CED.A.4</td>
<td>Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. ([HS-ESS1-1], [HS-ESS1-2], [HS-ESS1-4])</td>
</tr>
</tbody>
</table>

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

HS. History of Earth

Students who demonstrate understanding can:

HS-ESS1-5. **Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks.** [Clarification Statement: Emphasis is on the ability of plate tectonics to explain the ages of crustal rocks. Examples include evidence of the ages of oceanic crust increasing with distance from mid-ocean ridges (a result of plate spreading) and the ages of North American continental crust increasing with distance away from a central ancient core (a result of past plate interactions).]

HS-ESS1-6. **Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth’s formation and early history.** [Clarification Statement: Emphasis is on using available evidence within the solar system to reconstruct the early history of Earth, which formed along with the rest of the solar system 4.6 billion years ago. Examples of evidence include the absolute ages of ancient materials (obtained by radiometric dating of meteorites, moon rocks, and Earth’s oldest minerals), the sizes and compositions of solar system objects, and the impact cratering record of planetary surfaces.]

HS-ESS2-1. **Develop a model to illustrate how Earth’s internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.** [Clarification Statement: Emphasis is on how the appearance of land features (such as mountains, and plateaus) and sea-floor features (such as trenches, ridges, and seamounts) are a result of both constructive forces (such as volcanism, tectonic uplift, and orogeny) and destructive mechanisms (such as weathering, mass wasting, and coastal erosion).] [Assessment Boundary: Assessment does not include memorization of the formation of specific geographic features of Earth’s surface.]

### Science and Engineering Practices

- **Developing and Using Models**
  - Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s).
  - Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-ESS2-1)
- **Constructing Explanations and Designing Solutions**
  - Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.
  - Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. (HS-ESS1-6)
- **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 evidence behind currently accepted explanations or solutions to determine the merits of arguments. (HS-ESS1-6)

### Disciplinary Core Ideas

- **ESS1.C: The History of Planet Earth**
  - Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are thousands of million years old. (HS-ESS1-5)
  - Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth’s formation and early history. (HS-ESS1-6)
- **ESS2.A: Earth Materials and Systems**
  - Earth’s systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. A deep knowledge of how feedbacks work within and among Earth’s systems is still lacking, thus limiting scientists’ ability to predict some changes and their impacts. (HS-ESS2-1) (Note: This Disciplinary Core Idea is also addressed by HS-ESS2-2.)
- **ESS2.B: Plate Tectonics and Large-Scale System Interactions**
  - Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth’s surface and provides a framework for understanding its geologic history. (ESS2.B Grade 8 GBE) (secondary to HS-ESS1-5),(HS-ESS2-1)
  - Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth’s crust, (ESS2.B Grade 8 GBE) (HS-ESS2-1)
- **PS1.C: Nuclear Processes**
  - Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials. (secondary to HS-ESS1-5),(secondary to HS-ESS1-6)

### Crosscutting Concepts

- **Patterns**
  - Empirical evidence is needed to identify patterns. (HS-ESS1-5)
  - Stability and Change
  - Much of science deals with constructing explanations of how things change and how they remain stable. (HS-ESS1-6)
  - Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. (HS-ESS2-1)

---

**Connections to other DCIs in this grade band:**

- HS.PS2.A (HS-ESS1-6); HS.PS2.B (HS-ESS1-6),(HS-ESS2-1); HS.PS3.B (HS-ESS1-5); HS.ESS2.A (HS-ESS1-5)

**Articulation of DCIs across grade bands:**

- MS.PS2.B (HS-ESS1-6),(HS-ESS2-1); MS.SL2.B (HS-ESS2-1); MS.ESS1.B (HS-ESS1-6); MS.ESS1.C (HS-ESS1-5),(HS-ESS1-6),(HS-ESS2-1); MS.ESS2.A (HS-ESS1-5),(HS-ESS1-6),(HS-ESS2-1); MS.ESS2.B (HS-ESS1-5),(HS-ESS2-1); MS.ESS2.C (HS-ESS1-6),(HS-ESS2-1); MS.ESS2.D (HS-ESS2-1)

---

**Kentucky Academic Standards Connections:**

- **ELA/Literacy – RST.11-12.1** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-ESS1-5),(HS-ESS1-6)
- **RST.11-12.8** Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with sources of information. (HS-ESS1-5),(HS-ESS1-6)
- **WHST.9-12.1** Write arguments focused on discipline-specific content. (HS-ESS1-6)
- **WHST.9-12.2** Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-ESS1-5)
- **SL.11-12.5** Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-ESS2-1)

**Mathematics –**

- **MP.2** Reason abstractly and quantitatively. (HS-ESS1-5),(HS-ESS1-6),(HS-ESS2-1)
- **MP.4** Model with mathematics. (HS-ESS2-1)

- **HSN.Q.A.1** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and...
**HS. History of Earth – Continued**

<table>
<thead>
<tr>
<th>Standard</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HSN-O.A.2</td>
<td>Interpret the scale and the origin in graphs and data displays. (HS-ESS1-5),(HS-ESS1-6),(HS-ESS2-1)</td>
</tr>
<tr>
<td>HSN-O.A.3</td>
<td>Define appropriate quantities for the purpose of descriptive modeling. (HS-ESS1-5),(HS-ESS1-6),(HS-ESS2-1)</td>
</tr>
<tr>
<td>HSF-IF.B.5</td>
<td>Choose a level of accuracy appropriate to limitations on measurement when reporting quantities (HS-ESS1-5),(HS-ESS1-6),(HS-ESS2-1)</td>
</tr>
<tr>
<td>HSS-ID.B.6</td>
<td>Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes. (HS-ESS1-6)</td>
</tr>
</tbody>
</table>

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled "Disciplinary Core Ideas” is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.*
Kentucky Department of Education

HS. Earth’s Systems – Continued

HS-Ess2-2. Analyze geoscience data to make the claim that one change to Earth’s surface can create feedbacks that cause changes to other Earth systems. [Clarification Statement: Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth’s surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.]

HS-Ess2-3. Develop a model based on evidence of Earth’s interior to describe the cycling of matter by thermal convection. [Clarification Statement: Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Examples of evidence include maps of Earth’s three-dimensional structure obtained from seismic waves, records of the rate of change of Earth’s magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth’s layers from high-pressure laboratory experiments.]

HS-Ess2-5. Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes. [Clarification Statement: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions common to the surface. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids.).]

HS-Ess2-6. Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere. [Clarification Statement: Emphasis is on modeling biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere (including humans), providing the foundation for living organisms.]

HS-Ess2-7. Construct an argument based on evidence about the simultaneous coevolution of Earth systems and life on Earth. [Clarification Statement: Emphasis is on the dynamic causes, effects, and feedbacks between the biosphere and Earth’s other systems, whereby geoscience factors control the evolution of life, which in turn continuously alters Earth’s surface. Examples of include how photosynthetic life altered the atmosphere through the production of oxygen, which in turn increased weathering rates and allowed for the evolution of animal life; how microbial life on land increased the formation of soil, which in turn allowed for the evolution of plants; or how the evolution of corals created reefs that altered patterns of erosion and deposition along coastlines and provided habitats for the evolution of new life forms.]

The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:

Science and Engineering Practices
Disciplinary Core Ideas
Crosscutting Concepts

Developing and Using Models
Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s).
- Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-Ess2-3, HS-Ess2-6)

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-Ess2-5)

Analyzing and Interpreting Data
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. (HS-Ess2-2)

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.
- Construct an oral and written argument or counterargument based on data and evidence. (HS-Ess2-7)

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence

ESS2A: Earth Materials and Systems
- Earth’s systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes (HSESS2-2)
- Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth’s surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a solid outer core, a solid mantle and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth’s interior and gravitational movement of denser materials toward the interior. (HS-Ess2-3)

ESS2B: Plate Tectonics and Large-Scale System Interactions
- The radioactive decay of unstable isotopes continually generates new energy within Earth’s crust and mantle, providing the primary source of the heat that drives mantle convection. Plate tectonics can be visualized as the surface expression of mantle convection. (HS-Ess2-3)

ESS2C: The Roles of Water in Earth’s Surface Processes
- The abundance of liquid water on Earth’s surface and its unique combination of physical and chemical properties are central to the planet’s dynamics. These properties include water’s exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks. (HS-Ess2-5)

ESS2D: Weather and Climate
- The foundation for Earth’s global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy’s re-radiation into space. (HS-Ess2-2)
- Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. (HS-Ess2-6)
- Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (HS-Ess2-6)

ESS2E: Biogeology
- The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth’s
Kentucky Department of Education

HS. Earth’s Systems – Continued

- Science knowledge is based on empirical evidence. (HS-ESS2-3)
- Science disciplines share common rules of evidence used to evaluate explanations about natural systems. (HS-ESS2-3)
- Science includes the process of coordinating patterns of evidence with current theory. (HS-ESS2-3)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.*

Kentucky Department of Education

HS. Weather and Climate – Continued

**HS. Weather and Climate**

**Students who demonstrate understanding can:**

- **Use a model to describe how variations in the flow of energy into and out of Earth systems result in changes in surface temperature, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.** (HS-ESS2-4)

- **Analyze and interpret data**
  - **Analyzing and Interpreting Data**
    - 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 computational models in order to make valid and reliable scientific claims. (HS-ESS3-5)
  - **Scientific Knowledge is Based on Empirical Evidence**
    - Science knowledge is based on empirical evidence. (HS-ESS3-5)
    - Science arguments are strengthened by multiple lines of evidence supporting a single explanation. (HS-ESS2-4, HS-ESS3-5)

**Disciplinary Core Ideas**

**ESS1.B: Earth and the Solar System**
- Cyclical changes in the shape of Earth’s orbit around the sun, together with changes in the tilt of the planet’s axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes. (secondary to HS-ESS2-4)

**ESS2.A: Earth Materials and Systems**
- The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun’s energy output or Earth’s orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles. (HS-ESS2-4)

**ESS2.D: Weather and Climate**
- The foundation for Earth’s global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy’s re-radiation into space. (HS-ESS2-4), (secondary to HS-ESS2-2)
- Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (HS-ESS2-4)

**ESS3.D: Global Climate Change**
- Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. (HS-ESS3-5)

**Practice Connections**

- **Developing and Using Models**
- **Analyzing and Interpreting Data**
- **Scientific Knowledge is Based on Empirical Evidence**

**Science and Engineering Practices**

**Crosscutting Concepts**

**Cause and Effect**
- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-ESS2-4)
- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. (HS-ESS3-5)

**Kentucky Academic Standards Connections:**

- **ELA/Literacy – RST.11-12.1** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-ESS3-5)
- **RST.11-12.2** Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but accurate terms. (HS-ESS3-5)
- **RST.11-12.7** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-ESS3-5)
- **SL.11-12.5** Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, evidence and to add interest. (HS-ESS2-4)
- **Mathematics – MP.2** Reason abstractly and quantitatively. (HS-ESS2-4, HS-ESS3-5)
- **MP.4** Model with mathematics. (HS-ESS2-4)
- **HSN.Q.A.1** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret scale and the origin in graphs and data displays. (HS-ESS2-4, HS-ESS3-5)
- **HSN.Q.A.2** Define appropriate quantities for the purpose of descriptive modeling. (HS-ESS2-4, HS-ESS3-5)
- **HSN.Q.A.3** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS2-4, HS-ESS3-5)
HS. Human Impacts

**HS-ESS3-1.** Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, changes in climate have influenced human activity. [Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), superficial processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.]

**HS-ESS3-2.** Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on benefit ratios. [Clarification Statement: Emphasis is on the conservation, recycling, and reuse of resources (such as minerals and metals) where possible, and on minimizing impacts where it is not. Examples include developing best practices for agricultural soil use, mining (for coal, tar sands, and oil shales), and pumping (for petroleum and natural gas). Science knowledge indicates what can happen in natural systems—not what should happen.]

**HS-ESS3-3.** Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity. [Clarification Statement: Examples of factors that affect the management of natural resources include costs of resource extraction and waste management, per-capita consumption, and the development of new technologies. Examples of factors that affect human sustainability include agricultural efficiency, levels of conservation, and urban planning.][Assessment Boundary: Assessment for computational simulations is limited to simple computational models of computer programs or construction of simple parameter programs or constructing宾馆 simulations.]

**HS-ESS3-4.** Evaluate or refine a technological solution that reduces impacts of human activities on natural systems. [Clarification Statement: Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoenvironmental design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).]

**HS-ESS3-6.** Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. [Clarification Statement: Examples of Earth systems to be considered are the hydrosphere, atmosphere, geosphere, and/or biosphere. An example of the far-reaching impacts from a human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations.][Assessment Boundary: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.]

---

The performance expectations above were developed using the following elements from the NRC document _A Framework for K-12 Science Education:_

**Science and Engineering Practices**

- Using Mathematics and Computational Thinking
  - 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 a computational model or simulation of a phenomenon, designed device, process, or system. (HS-ESS3-3)
  - Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations. (HS-ESS3-6)

**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 knowledge, principles, and theories.
- Construct an explanation based on the evaluation of multiple, relevant sources of 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-ESS3-1)
- Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ESS3-4)

**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 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 logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations). (HS-ESS3-2)

**Disciplinary Core Ideas**

- **ESS2.D:** Weather and Climate
  - Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere. (secondary to HS-ESS3-6)

- **ESS3.A:** Natural Resources
  - Resource availability has guided the development of human society. (HS-ESS3-1)
  - All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors. (HS-ESS3-2)

- **ESS3.B:** Natural Hazards
  - Natural hazards and other geologic events have shaped the course of human history; they have significantly altered the sizes of human populations and have driven human migrations. (HS-ESS3-1)

- **ESS3.C:** Human Impacts on Earth Systems
  - The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. (HS-ESS3-3)
  - Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (HS-ESS3-4)

- **ESS3.D:** Global Climate Change
  - Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities. (HS-ESS3-6)

- **ETS1.B:** Designing Solutions to Engineering Problems
  - When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (secondary to HS-ESS3-2, secondary to HS-ESS3-4)

**Crosscutting Concepts**

- **Cause and Effect**
  - Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-ESS3-1)

- **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-ESS3-6)

- **Stability and Change**
  - Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. (HS-ESS3-3)
  - Feedback (negative or positive) can stabilize or destabilize a system. (HSESS3-4)

**Connections to Engineering, Technology, and Applications of Science**

- **Influence of Engineering, Technology, and Science on Society and the Natural World**
  - Modern civilization depends on major technological systems. (HS-ESS3-1, HSESS3-3)
  - Engineers continuously modify these systems to increase benefits while decreasing costs and risks. (HS-ESS3-2, HSESS3-4)
  - New technologies can have deep impacts on society and the environment, including some that were not anticipated. (HS-ESS3-3)
  - Analysis of costs and benefits is a critical aspect of decisions about technology. (HSESS3-2)
Connections to other DCIs in this grade-band: HS.PS1.B (HS-ESS3-3); HS.PS3.B (HS-ESS3-2); HS.PS3.D (HS-ESS3-2); HS.LS2.A (HS-ESS3-2),(HS-ESS3-3),(HS-ESS3-6); HS.LS2.C (HS-ESS3-3),(HS-ESS3-4),(HS-ESS3-6); HS.LS4.D (HS-ESS3-2),(HS-ESS3-3),(HS-ESS3-4),(HS-ESS3-6); HS.ESS2.A (HS-ESS3-2); HS.ESS3-3),(HS-ESS3-6); HS.ESS3.2 (HS-ESS3-3)

Articulation of DCIs across grade-bands: MS.PS1.B (HS-ESS3-3); MS.PS3.D (HS-ESS3-2); MS.LS2.A (HS-ESS3-1),(HS-ESS3-2),(HS-ESS3-3); MS.LS2.B (HS-ESS3-2),(HS-ESS3-3); MS.LS2.C (HS-ESS3-3),(HS-ESS3-4),(HS-ESS3-6); MS.LS4.C (HS-ESS3-3); MS.LS4.D (HS-ESS3-1),(HS-ESS3-2),(HS-ESS3-3); MS.ESS2.A (HS-ESS3-1),(HS-ESS3-3),(HS-ESS3-4),(HS-ESS3-6); MS.ESS2.C (HS-ESS3-6); MS.ESS3.A (HS-ESS3-1),(HS-ESS3-2),(HS-ESS3-3); MS.ESS3.B (HS-ESS3-1),(HS-ESS3-4); MS.ESS3.C (HS-ESS3-2),(HS-ESS3-3), (HS-ESS3-4),(HS-ESS3-6); MS.ESS3.D (HS-ESS3-4),(HS-ESS3-6)

Kentucky Academic Standards Connections:
ELA/Literacy –
RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-ESS3-1),(HS-ESS3-2),(HS-ESS3-4)
RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-ESS3-2),(HS-ESS3-4)
WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-ESS3-1)
Mathematics –
MP.2 Model with mathematics. (HS-ESS3-3),(HS-ESS3-6)
HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-ESS3-1),(HS-ESS3-4),(HS-ESS3-6)
HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-ESS3-1),(HS-ESS3-4),(HS-ESS3-6)
HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS3-1),(HS-ESS3-4),(HS-ESS3-6)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled “Disciplinary Core Ideas” is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.
HS. Engineering Design

Students who demonstrate understanding can:

HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

HS-ETS1-4. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:

<table>
<thead>
<tr>
<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asking Questions and Defining Problems</td>
<td>ETS1.A: Defining and Delimiting Engineering Problems</td>
<td>Systems and System Models</td>
</tr>
<tr>
<td>Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (HS-ETS1-1)</td>
<td>• Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (HS-ETS1-1)</td>
<td>• 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-ETS1-4)</td>
</tr>
<tr>
<td>Using Mathematics and Computational Thinking</td>
<td>ETS1.B: Developing Possible Solutions</td>
<td>Connections to Engineering, Technology, and Applications of Science</td>
</tr>
<tr>
<td>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.</td>
<td>• When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)</td>
<td>• New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ETS1-1) (HSETS1-3)</td>
</tr>
<tr>
<td>Constructing Explanations and Designing Solutions</td>
<td>ETS1.C: Optimizing the Design Solution</td>
<td>Articulation of DCl's across grade-bands: MS.ETS1.A (HS-ETS1-1),(HS-ETS1-2),(HS-ETS1-3),(HS-ETS1-4); MS.ETS1.B (HS-ETS1-2),(HS-ETS1-3),(HS-ETS1-4); MS.ETS1.C (HSETS1-2),(HSETS1-3),(HSETS1-4)</td>
</tr>
<tr>
<td>Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-2)</td>
<td>• Criteria 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. (HSETS1-2)</td>
<td></td>
</tr>
<tr>
<td>Using mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (HS-ETS1-3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mathematically and computationally thinking in 9–12 builds on 9–8 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.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>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.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (HS-ETS1-1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (HS-ETS1-3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-3)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Connections to HS-ETS1.A: Defining and Delimiting Engineering Problems include:

Physical Science: HS-PS2-3, HS-PS3-3
Connections to HS-ETS1.B: Designing Solutions to Engineering Problems include:

Earth and Space Science: HS-ESS3-2, HS-ESS3-4, Life Science: HS-LS2-7, HS-LS4-6
Connections to HS-ETS1.C: Optimizing the Design Solution include:

Physical Science: HS-PS1-6, HS-PS2-3

Articulation of DCl's across grade-bands: MS.ETS1.A (HS-ETS1-1),(HS-ETS1-2),(HS-ETS1-3),(HS-ETS1-4); MS.ETS1.B (HS-ETS1-2),(HS-ETS1-3),(HS-ETS1-4); MS.ETS1.C (HSETS1-2),(HSETS1-3),(HSETS1-4)

Kentucky Academic Standards Connections:

ELA/Literacy –

RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-ETS1-1),(HS-ETS1-3)

RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-ETS1-1),(HS-ETS1-3)

RST.12-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (HS-ETS1-1),(HS-ETS1-3)

Mathematics –

MP.2 Reason abstractly and quantitatively. (HS-ETS1-1),(HS-ETS1-3),(HS-ETS1-4)

MP.4 Model with mathematics. (HS-ETS1-1),(HS-ETS1-2),(HS-ETS1-3),(HS-ETS1-4)