**2018 Virginia Science Standards of Learning**

**Curriculum Framework**

Science GRFX.eps

Board of Education

Commonwealth of Virginia

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The *2018 Virginia Science Standards of Learning Curriculum Framework* can be found on the Virginia Department of Education’s website at http://www.doe.virginia.gov/testing/sol/standards\_docs/science/index.shtml.

***2018 Virginia Science Standards of Learning Curriculum Framework***

## Introduction

The *2018 Virginia Science Standards of Learning Curriculum Framework* amplifies the *Science Standards of Learning for Virginia Public Schools* (SOL) and defines the content knowledge, skills, and understandings that provide a foundation in science concepts and practices. The framework provides additional guidance to school divisions and their teachers as they develop an instructional program appropriate for their students. It assists teachers as they plan their lessons by identifying enduring understandings and defining the essential science and engineering practices students need to master. This framework delineates in greater specificity the minimum content requirements that all teachers should teach and all students should learn.

School divisions should use the framework as a resource for developing sound curricular and instructional programs. This framework should not limit the scope of instructional programs. Additional knowledge and skills that can enrich instruction and enhance students’ understanding of the content identified in the SOL should be included in quality learning experiences.

The framework serves as a guide for SOL assessment development. Assessment items may not and should not be a verbatim reflection of the information presented in the framework. Students are expected to continue to apply knowledge and skills from the SOL presented in previous grades as they build scientific expertise.

The Board of Education recognizes that school divisions will adopt a K–12 instructional sequence that best serves their students. The design of the SOL assessment program, however, requires that all Virginia school divisions prepare students to demonstrate achievement of the standards for elementary and middle school by the time they complete the grade levels tested. The high school end-of-course SOL tests, for which students may earn verified units of credit, are administered in a locally determined sequence.

Each topic in the framework is developed around the SOL. The format of the framework facilitates teacher planning by identifying the enduring understandings and the scientific and engineering practices that should be the focus of instruction for each standard. The categories of scientific and engineering practices appear across all grade levels and content areas. Those categories are: asking questions and defining problems; planning and carrying out investigations; interpreting, analyzing, and evaluating data; constructing and critiquing conclusions and explanations; developing and using models; and obtaining, evaluating, and communicating information. These science and engineering practices are embedded in instruction to support the development and application of science content.

### Science and Engineering Practices

Science utilizes observation and experimentation along with existing scientific knowledge, mathematics, and engineering technologies to answer questions about the natural world. Engineering employs existing scientific knowledge, mathematics, and technology to create, design, and develop new devices, objects, or technology to meet the needs of society. By utilizing both scientific and engineering practices in the science classroom, students develop a deeper understanding and competence with techniques at the heart of each discipline.

*Engineering Design Practices*

Engineering design practices are similar to those used in an inquiry cycle; both use a system of problem solving and testing to come to a conclusion. However, unlike the inquiry cycle in which students ask a question and use the scientific method to answer it, in the engineering and design process, students use existing scientific knowledge to solve a problem. Both include research and experimentation; however, the engineering design process has a goal of a solving a societal problem and may have multiple solutions. More information on the engineering and design process can be found at <https://www.eie.org/overview/engineering-design-process>.



Figure 1: Engineering Design Process image based on the National Aeronautics and Space Administration (NASA) engineering design model.

The Engineering Design Process:

1. Define: Define the problem, ask a question
2. Imagine: Brainstorm possible solutions
3. Research: Research the problem to determine the feasibility of possible solutions
4. Plan: Plan a device/model to address the problem or answer the question
5. Build: Build a device/model to address the problem or answer the question
6. Test: Test the device/model in a series of trials
   1. Does the design meet the criteria and constraints defined in the problem?
      1. Yes? Go to Share (#8)
      2. No? Go to Improve (#7)
7. Improve: Using the results of the test, brainstorm improvements to the device/model; return to #3
8. Share: Communicate your results to stakeholders and the public

### Computational Thinking

The term *computational thinking* is used throughout this framework. Computational thinking is a way of solving problems that involves logically organizing and classifying data and using a series of steps (algorithms). Computational thinking is an integral part of Virginia’s computer science standards and is explained as such in the *Computer Science Standards of Learning*:

*Computational thinking is an approach to solving problems that can be implemented with a computer. It involves the use of concepts, such as abstraction, recursion, and iteration, to process and analyze data, and to create real and virtual artifacts. Computational thinking practices such as abstraction, modeling, and decomposition connect with computer science concepts such as algorithms, automation, and data visualization. [Computer Science Teachers Association & Association for Computing Machinery]*

Students engage in computational thinking in the science classroom when using both inquiry and the engineering design process. Computational thinking is used in laboratory experiences as students develop and follow procedures to conduct an investigation.

## Structure of the *2018 Virginia Science Standards of Learning Curriculum Framework*

The framework is divided into two columns: Enduring Understandings and Essential Knowledge and Practices. The purpose of each column is explained below.

*Enduring Understandings*

The Enduring Understandings highlight the key concepts and the big ideas of science that are applicable to the standard. These key concepts and big ideas build as students advance in their scientific and engineering understanding. The bullets provide the context of those big ideas at that grade or content level.

*Essential Knowledge and Practices*

Each standard is expanded in the Essential Knowledge and Practices column. What each student should know and be able to do as evidence of understanding of the standard is identified here. This is not meant to be an exhaustive list nor is a list that limits what is taught in the classroom. It is meant to be the key knowledge and practices that define the standard. Science and engineering practices are highlighted with a leaf bullet (see footer).

The *2018 Virginia Science Standards of Learning Curriculum Framework* is informed by the Next Generation Science Standards (<https://www.nextgenscience.org/>).

## Kindergarten

***Using my senses to understand my world***

In science, kindergarten students use their senses to make observations of the characteristics and interactions of objects in their world. Students study the characteristics of water and the basic needs of living things. They also study the relationship between the sun and Earth through shadows and weather. They determine how their actions can change the motion of objects and learn how they can make a difference in their world. Throughout the elementary years, students will develop scientific skills, supported by mathematics and computational thinking, as they learn science content. In kindergarten, students will develop skills in posing simple questions, conducting simple investigations, observing, classifying, and communicating information about the natural world.

### Scientific and Engineering Practices

Engaging in the practices of science and engineering helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the many ways to investigate, model, and explain the world. These scientific and engineering practices include the use of scientific skills and processes to explore the content of science as outlined in the *Science Standards of Learning*. The engineering design practices are the application of science content to solve a problem or design an object, tool, process, or system. These scientific and engineering practices are critical to science instruction and are to be embedded throughout the year.

**K.1 The student will demonstrate an understanding of scientific and engineering practices by**

* 1. **asking questions and defining problems**
     + - **ask questions based on observations**
       - **identify a problem based on need**
       - **make predictions based on observations**

1. **planning and carrying out investigations**

* **make observations to collect data**
* **identify characteristics and properties of objects by observations**
* **measure relative length and weight of common objects**
* **record information from investigation**

1. **interpreting, analyzing, and evaluating data**

* **describe patterns**
* **classify and/or sequence objects based on a single physical characteristic or property**
* **organize and represent data**
* **read and interpret data in object graphs, picture graphs, and tables**

1. **constructing and critiquing conclusions and explanations**

* **make simple conclusions based on data or observations**

1. **developing and using models**

* **distinguish between a model and an actual object**

1. **obtaining, evaluating, and communicating information**

* **communicate comparative measures (e.g., heavier, lighter, longer, shorter, more, less, hotter, colder)**
* **communicate observations using pictures, drawings, and/or speech**

### Kindergarten Science Content

#### Force, Motion, and Energy

**K.2 The student will investigate and understand that pushes and pulls affect the motion of objects. Key ideas include**

* 1. **pushes and pulls can cause an object to move;**
  2. **pushes and pulls can change the direction of an object; and**
  3. **changes in motion are related to the strength of the push or pull.**

**Central Idea:** Pushes and pulls can affect the movement of an object.

**Vertical Alignment:** This standard provides a foundation for the development of the concept of force by introducing the idea that pushes and pulls are required to move objects. The standard does not include non-contact pushes or pulls such as those produced by magnets (2.2).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Forces between objects can cause a change in motion.   * Pushes and pulls (forces) can have different strengths and directions and can cause objects to move (K.2 a, b, c). * Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it (K.2 a, b). * When objects touch or collide, they push one another and can change motion (K.2 b, c). * A bigger push or pull makes things speed up or slow down more quickly (K.2 c). | In order to meet this standard, it is expected that students will   * make and communicate observations about how pushes and pulls affect the motion of everyday objects (K.2 a, b) * predict and test how a push or pull will affect the motion of an object (K.2 a, b) * compare the motion (fast/slow, close/far) of an object after pushing and pulling the same object with different strengths (K.2 c) * plan and conduct an investigation to compare the effects of different strengths or directions of pushes and pulls on the motion of an object (K.2 c) * determine if a design solution works as intended to change the speed or direction of an object with a push or pull (K.2 a, b, c). |

#### Matter

**K.3** **The student will investigate and understand that physical properties of an object can be described. Properties include**

* 1. **colors;**
  2. **shapes and forms;**
  3. **textures and feel; and**
  4. **relative sizes and weights of objects.**

**Central Idea:** All objects have physical properties, which include color, shape or form, texture, and size. Properties are independent of each other.

**Vertical Alignment:** This is an introduction to physical properties of objects; it is elaborated upon in first grade to show that materials retain most physical properties regardless of the size of the material (1.3).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Objects can be described and compared by their properties.   * Objects have properties that can be observed and described. These properties include color, shape, form, texture, feel, size, and weight (K.3 a, b, c, d). * Two different objects can have some of the same physical properties and some different physical properties (K.3 a, b, c,-d). | In order to meet this standard, it is expected that students will   * observe objects and describe their basic properties to include color, shape, texture, and relative size and weight (K.3 a, b, c, d) * arrange a set of objects in sequence according to size (K.3 d) * compare objects based on a single physical property (K.3 a, b, c, d) * describe the physical properties of objects both pictorially and verbally (K.3 a, b, c, d) |

**K.4 The student will investigate and understand that water is important in our daily lives and has properties. Key ideas include**

* 1. **water has many uses;**
  2. **water can be found in many places;**
  3. **water occurs in different phases; and**
  4. **water flows downhill.**

**Central Idea:** Water is an important resource for our daily lives and has specific properties.

**Vertical Alignment:** This standard is an introduction to water, one of the essential resources for all organisms’ survival. The importance of water is revisited in other grade levels.

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Energy and matter are required for all organisms to survive. Water is an important resource for our daily lives and has specific properties.   * Water is a very important resource and we use it for many things (K.4 a). * There are many places where we find water, including streams, rivers, lakes, oceans, and underground (e.g., wells) (K.4 b). * Water can be a solid (ice), liquid (liquid water), or gas (water vapor) (K.4 c). *Students are not responsible for understanding water as a gas.* * The phases of water can be changed by heating or cooling (K.4 c). * The natural flow of water is from a higher to a lower level. An example is seen as water in streams flows from higher elevations to lower elevations (K.4 d). | In order to meet this standard, it is expected that students will   * describe several uses of water at school and at home (K.4 a) * identify several natural sources of water (K.4 b) * classify examples of water as a solid or a liquid (K.4 c) * conduct an investigation to determine how water flows (K.4 d) * predict where a stream of water will flow (K.4 d) * find examples of how water flows in the classroom, school, or community (K.4 d). |

#### Living Systems and Processes

**K.5 The students will investigate and understand that senses allow humans to seek, find, take in, and react or respond to different information. Key ideas include**

**a) the five basic senses correspond to specific human body structures; and**

**b) senses are used in our daily lives.**

**Central Idea:** Organisms possess physical features, including the five senses, which enable them to survive in their environment and obtain resources to meet their basic needs.

**Vertical Alignment:** The use of senses is important to an organism’s survival. The use of our senses for observing and collecting data is critical to the development of science and engineering practices.

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Organisms possess physical features that enable them to survive in their environment and obtain resources to meet their basic needs.   * Humans have five basic senses: taste, touch, smell, hearing, and sight (K.5 a). * In humans, body structures are associated with particular senses: eye–sight, ear–hearing, nose–smell, tongue–taste, and skin–touch (K.5 a). * There are sensory descriptors that are associated with the senses that include, but are not limited to, the following**:** taste–sweet, sour, bitter, salty; touch–rough, smooth, hard, soft, cold, warm, hot; hearing–loud, soft, high, low; sight–bright, dull, color; smell–strong, faint, and pleasant (K.5 b). | In order to meet this standard, it is expected that students will   * identify and describe the five basic senses (K.5 a) * match each human body structure with its associated sense (K.5 a) * provide examples of how the five senses are used to make observations (K.5 b) * classify sensory descriptors with the senses (K.5 b). |

**K.6 The student will investigate and understand that there are differences between living organisms and nonliving objects. Key ideas include**

* 1. **all things can be classified as living or nonliving; and**
  2. **living organisms have certain characteristics that distinguish them from nonliving objects.**

**Central Idea:** Living and nonliving things have differences; recognition of these differences is essential to developing a deeper understanding of living systems.

**Vertical Alignment:** The understanding of what is living and what is nonliving is a precursor to understanding what affects living systems.

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Classification relies on careful observation of patterns and similarities and differences. These similarities and differences can be used to sort living organisms from nonliving objects.   * The term *living* is used to describe anything that is or has ever been alive (e.g., dog, flower, seed, log). The term *nonliving* is used to describe anything that is not now nor has ever been alive(e.g., rock, mountain, glass) (K.6 a). * Organisms have needs and life processes, which distinguish them from nonliving objects (K.6 b). * Some important life process of living organisms include growth, responding to the environment, and having offspring (K.6 b). | In order to meet this standard, it is expected that students will   * identify living organisms and nonliving objects found at home and at school (K.6 a) * classify objects as living or nonliving (K.6 a) * identify and describe the basic characteristics of living organisms (K.6 b). |

**K.7 The student will investigate and understand that plants and animals have basic needs and life processes. Key ideas include**

* 1. **living things need adequate food, water, shelter, air, and space to survive;**
  2. **plants and animals have life cycles; and**
  3. **offspring of plants and animals are similar but not identical to their parents or to one another.**

**Central Idea:** Energy and matter are required for all organisms to carry out life process. Organisms have basic needsto carry out those life processes. These processes vary between plants and animals.

**Vertical Alignment:** The concept that plants and animals have basic needs to conduct life processes is introduced in kindergarten. The specific life processes are introduced in later grades.

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Energy and matter are required for all organisms to survive. Organisms have basic needs, both in terms of energy and matter, which are used to carry out life processes.   * Animals need adequate food, water, shelter, air, and space to survive (K.7 a). * To survive, plants need water, air, light, and a place that has adequate space for them to grow (K.7 a). * If animals’ needs are not met, they move to an area that does meet their life needs. If they cannot move, they will not survive. If a plant’s needs are not met it will not survive (K.7 a). * Simple changes animals undergo during their life cycles may include changes in their body size, color, covering, or shape (K.7 b). *Students are not expected to recognize the different stages or sequences of specific life cycles.* * Simple changes plants undergo during their life cycles may include size, presence of leaves and branches, fruits, and seeds (K.7 b). *Students are not expected to recognize the different stages or sequences of specific life cycles.* * Many offspring of plants and animals are like their parents but not identical to them or to one another. Other offspring look very different from their parents (K.7 c). | In order to meet this standard, it is expected that students will   * compare the basic life needs of plants and animals (K.7 a) * use observations to describe what plants and animals need to survive (K.7 a) * predict what will happen to animals and plants if life needs are not met (K.7 a) * describe some simple changes that animals and plants undergo during their life cycles (K.7 b) * recognize similarities and differences between offspring and parents (K.7 c). |

#### Earth and Space Systems

**K.8 The student will investigate and understand that light influences temperature on Earth’s surfaces and can cause shadows. Key ideas include**

* 1. **the sun provides light and warms Earth’s surface;**
  2. **shadows can be produced when sunlight or artificial light is blocked by an object; and**
  3. **objects in shadows and objects in sunlight have different temperatures.**

**Central Idea:** Repeating patterns in nature, or events that occur together with regularity, are clues to cause-and-effect relationships.

**Vertical Alignment:** Looking for patterns is an important tool in understanding and making predictions. This is an opportunity for students to start developing that skill, and to make observations about how light interacts with objects, both in terms of heating an object and in forming shadows.

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Energy can be transferred in various ways and between objects.These energy transfers can be observed and form patterns. *Students are not responsible for the term* energy*.*   * Sunlight warms Earth’s surface. Components of Earth’s surface, such as sand, soil, rocks, and water, become relatively warmer when exposed to sunlight (K.8 a). *Students should measure temperature in relative measures such as warmer/cooler only.* * A shadow is an image of an object created when light is blocked by that object. Shadows can occur whenever light is present (K.8 b). * Both natural (sun) and artificial (electric light, flashlight) sources of light can create shadows (K.8 b). * Objects in a shadow will be cooler than objects in the sun (K.8 c). | In order to meet this standard, it is expected that students will   * make observations and conduct an investigation to determine the effect of sunlight on Earth’s surface (K.8 a) * demonstrate how shadows change as the direction of the light source changes (K.8 b) * describe how shadows occur (K.8 b) * identify sources of light that can produce shadows (K.8 b) * design and build a simple structure that will reduce the warming effect of sunlight on an area or an object (K.8 c) * compare the relative temperature of an object in sunlight vs. the same object in a shadow (K.8 c). |

**K.9 The student will investigate and understand that there are patterns in nature. Key patterns include**

* 1. **daily weather;**
  2. **seasonal changes; and**
  3. **day and night.**

**Central Idea:** Patterns exist all around us and can be observed in daily weather, seasons, and day and night.

**Vertical Alignment:** Kindergartenstudents are expected to see that there are patterns to the weather, seasonal changes, and day and night. Students will gain an understanding of why those patterns occur and the cause-and-effect aspect of the pattern in fourth grade (4.6).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Repeating patterns in nature, or events that occur together with regularity, are clues to cause-and-effect relationships.   * Weather is the combination of sunlight, wind, snow or rain, and temperature in a region at a given time. People measure these conditions to describe and record the weather and to notice patterns over time (K.9 a). * A variety of weather conditions (sunny, cloudy, rainy, snowy, windy, warm, hot, cool, and cold) can be observed and described over time (K.9 a, b). * Predictions can be made using seasonal patterns. Temperature and type of precipitation vary throughout the seasons. Seasons occur in the same order every year (K.9 b). | In order to meet this standard, it is expected that students will   * identify patterns in nature (day and night, seasons, life cycles) (K.9 a, b, c) * chart and graph daily weather conditions throughout the year to determine seasonal patterns (K.9 a) * use and share observations of daily weather conditions to describe patterns over time (K.9 a) * describe the patterns in weather conditions that may be observed during the different seasons (K.9 b). |

**K.10 The student will investigate and understand that change occurs over time. Key ideas include**

1. **natural and human-made things change over time;**
2. **living and nonliving things change over time;**
3. **changes can be observed and measured; and**

**d) changes may be fast or slow.**

**Central Idea:** Systems may exhibitstability and/or change depending on the conditions. These changes can be observed and measured. Some of the changes happen quickly, while others may happen so slowly it is hard to see the changes.

**Vertical Articulation:** In kindergarten students begin their observations about change. Students will investigate the changes in the weather in first grade (1.6).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Changes are all around us and occur over time.   * Changes are all around us. Some examples of natural things changing over time include trees changing throughout the seasons, water in a stream washing away rocks and soil, rocks breaking off a mountain, and animals and plants growing, to include changes in height and weight (K.10 a, b, c). * Some examples of human-made things changing over time include buildings, roads, and monuments changing color or breaking due to weather (K.10 a, b, c). * Slow changes should be the kinds of familiar changes that occur over weeks, months, or seasons, (e.g., leaves falling off trees). Faster changes include a weather event such as a blizzard or tornado, an earthquake, or a fire (K.10 d). | In order to meet this standard, it is expected that students will   * describe things in nature that change over time (K.10 a) * describe human-made things that change over time (K.10 a) * identify some changes that people experience over time (K.10 b) * use observations to describe the change of an object or living thing over time (K.10 c) * classify examples as fast changes or slow changes (K.10 d). |

#### Earth Resources

**K.11 The student will investigate and understand that humans use resources. Key ideas include**

* 1. **some materials and objects can be used over and over again;**
  2. **materials can be recycled; and**
  3. **choices we make impact the air, water, land and living things.**

**Central Idea:** Natural resources make up the common objects and materials that we use. These resources are limited and should be conserved. Humans can accomplish this by reusing, recycling, and conserving.

**Vertical Alignment:** This standard establishes a foundation for increasingly advanced conservation concepts developed in the primary standards.

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Natural resources are limited and should be conserved.   * Recycling, reusing, and conserving helps preserve resources for future use (K.11 a, b). * Resources last longer if we recycle, reuse, and reduce consumption (K.11 a, b). * Reusing materials means using them more than once. Reusing materials reduces the amount of trash and conserves resources. Examples include using dishes and utensils that are washed after use rather than using paper plates and plastic utensils and putting them in the trash (K.11 a). * Generally, materials such as paper, glass, aluminum cans, metals, some plastics, and cardboard can be recycled. The items that can or cannot be recycled are different based on the area recycling facility (K.11 b). * Things that people do to live comfortably can affect the world around them. People can make choices to reduce their impacts on the land, water, air, and other living things through recycling and reusing (K.11 c). | In order to meet this standard, it is expected that students will   * describe the difference between *recycle* and *reuse* (K.11 a, b) * identify materials that can be reused (K.11 a) * give examples of objects that can be recycled (K.11 b) * explain why recycling and reusing resources is good for the community (K.11 c) * communicate solutions that will reduce the impact of humans on the land, air, water, and on other living things in the local environment (K.11 c). |

## Grade One

***How I interact with my world***

In first-grade science, students become aware of factors that affect their daily lives. Students continue to learn about the basic needs of all living things and that living things respond to factors in their environment, including weather and the change of season. They continue the examination of matter by observing physical properties and how materials interact with light. Throughout the elementary years, students will develop scientific skills, supported by mathematics and computational thinking, as they learn science content. In first grade, students will develop skills in posing simple questions, conducting simple investigations, observing, classifying, and communicating information about the natural world. Students are introduced to the engineering design process.

### Scientific and Engineering Practices

Engaging in the practices of science and engineering helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the many ways to investigate, model, and explain the world. These scientific and engineering practices include the use of scientific skills and processes to explore the content of science as outlined in the *Science Standards of Learning*. The engineering design practices are the application of science content to solve a problem or design an object, tool, process, or system. These scientific and engineering practices are critical to science instruction and are to be embedded throughout the year.

* 1. **The student will demonstrate an understanding of scientific and engineering practices by**
  2. **asking questions and defining problems**
     + **ask questions and make predictions based on observations**
     + **identify a simple problem that can be solved through the development of a new tool or improved object**
  3. **planning and carrying out investigations**
* **with guidance, conduct investigations to produce data**
* **identify characteristics and properties of objects by observations**
* **use tools to measure relative length, weight, volume, and temperature of common objects**
  1. **interpreting, analyzing, and evaluating data**
* **use and share pictures, drawings, and/or writings of observations**
* **describe patterns and relationships**
* **classify and arrange objects based on a single physical characteristic or property**
* **organize and represent various forms of data using tables, picture graphs, and object graphs**
* **read and interpret data displayed in tables, picture graphs, and object graphs, using the vocabulary *more, less, fewer, greater than, less than, and equal to***
  1. **constructing and critiquing conclusions and explanations**
  + **make simple conclusions based on data or observations**
* **recognize unusual or unexpected results**
  1. **developing and using models**
* **use physical models to demonstrate simple phenomena and natural processes**
  1. **obtaining, evaluating, and communicating information**
* **communicate observations and data using simple graphs, pictures, drawings, numbers, speech and/or writing**

### Grade One Science Content

#### Force, Motion, and Energy

**1.2 The student will investigate and understand that objects can move in different ways. Key ideas include**

* 1. **objects may have straight, circular, spinning, and back-and-forth motions; and**
  2. **objects may vibrate and produce sound.**

**Central Idea**: Forces between objects can cause objects to move or have a change in their motion. In this standard, students explore the different ways that objects can move. Students also learn that it is possible to produce sound when objects vibrate.

**Vertical Alignment:** Students are introduced to the concept of forces in kindergarten as they explore the relationship between the strength of pushes and pulls and the motion of objects (K.2). In second grade, students are introduced to indirect forces (magnetism and gravity) and how these forces affect them (2.2).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Forces between objects can cause a change in motion.   * Objects may move in straight, circular, spinning (rotational), and back-and-forth motions (1.2 a). * One kind of back-and-forth motion is vibration. An object’s vibrations may create sound (1.2 b). * Sound can make matter vibrate, and vibrating matter can make sound (1.2 b). | In order to meet this standard, it is expected that students will   * make and communicate observations about the ways objects move (1.2 a) * compare the movement of two different objects (1.2 a) * design a device that uses movement to transfer an object from one location to another (1.2 a) * make and communicate observations of an object with rapid back-and-forth motion (vibration) (1.2) * describe the relationship between vibration and sound (1.2 b) * with guidance, plan and conduct an investigation that addresses the question of whether vibrating objects create sound (1.2 b). |

#### Matter

**1.3 The student will investigate and understand that objects are made from materials that can be described by their physical properties. Key ideas include**

* 1. **objects are made of one or more materials with different physical properties and can be used for a variety of purposes;**
  2. **when a material is changed in size most physical properties remain the same; and**
  3. **the type and amount of material determine how much light can pass through an object.**

**Central Idea:** Different materials may have different physical properties; these properties are used to describe and classify objects.

**Vertical Alignment:** Students are introduced to objects having physical properties, which include color, shape or form, texture, and size in kindergarten (K.3). Students relate this concept directly to water as they learn the properties of water, to include an introduction of phases (K.4). In second grade, students further explore characteristics of three phases of water and the effect heating and cooling have on each phase (2.3).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Objects can be described and compared by their properties.   * Objects are made of one or more materials. These materials can be described by their properties. These properties include light transfer, texture, weight, length, color, and odor (1.3 a). * Different properties are suited for different purposes (1.3 a). * Most properties of materials remain the same regardless of their visible size. Physical properties such as how much light passes through a material, color, texture, odor, ability to dissolve in water remain the same; however, properties such as mass, volume, and length change when the size changes (1.3 b). * Some materials allow light to pass through them, others allow only some light through, and others block all the light. For materials that allow light to pass through, adding more of that material can change the amount of light that passes through (1.3 c). *Students are not required to know the terms* translucent*,* transparent*, and* opaque*.* | In order to meet this standard, it is expected that students will   * make and communicate observations about the physical properties of materials (1.3 a) * classify objects based on physical properties and explain how the objects were classified (1.3 a) * recognize that an object may be composed of different materials and these materials have different physical properties (1.3 a) * analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose (1.3 a) * compare the physical properties of larger and smaller samples of the same material (1.3 b) * identify uses for different materials based on the amount of light that passes through each (1.3 a, c) * with guidance, conduct an investigation to determine how the type and amount of material affects how much light can pass through an object (1.3 c). |

#### Living Systems and Processes

**1.4 The student will investigate and understand that plants have basic life needs and functional parts that allow them to survive. Key ideas include**

* 1. **plants need nutrients, air, water, light, and a place to grow;**
  2. **structures of plants perform specific functions; and**
  3. **plants can be classified based on a variety of characteristics.**

**Central Idea:** Energy and matter are needed for all organisms to survive. Plants use matter and energy to grow and reproduce. Each type of plant has characteristics that allow it to function in unique and specific ways in its environment. These characteristics are used to classify plants.

**Vertical Alignment:** Students learn that all organisms need food to survive in kindergarten and first grade (K.7, 1.4, 1.5). Students in first grade are introduced to the concept that plants and animals have both physical features and behaviors that help them to survive in their environments. In second grade, students investigate and understand plant life cycles (2.4). Students learn that plants produce oxygen and food for other living things, are a source of useful products, and provide benefits in nature (2.8).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Energy and matter are required for all organisms to survive.   * Plants have basic needs, including nutrients, air, water, light, and space to grow (1.4 a). * Plants have different structures such as stems, roots, leaves, and flowers. These structures serve different functions in growth, survival, and reproduction (1.4 b). * Plants can be classified by their characteristics (1.4 c). | In order to meet this standard, it is expected that students will   * describe the basic life needs of plants (1.4 a) * with guidance, plan and conduct an investigation to determine if plants need sunlight and water to grow (1.4 a) * explain the functions of the root, stem, and leaf (1.4 b) * create and interpret a physical model/drawing of a plant, including roots, stems, leaves, and flowers to identify and explain the functions of each plant part (1.4 b) * classify plants by characteristics (1.4 c). |

**1.5 The student will investigate and understand that animals, including humans, have basic life needs that allow them to survive. Key ideas include**

* 1. **animals need air, food, water, shelter, and space (habitat);**
  2. **animals have different physical characteristics that perform specific functions; and**
  3. **animals can be classified based on a variety of characteristics.**

**Central Idea:** Energy and matter are needed for all organisms to survive. Animals use matter and energy to move, eat, breathe, and reproduce. Each type of animal has characteristics that allow it to function in unique and specific ways to obtain food, reproduce, and survive in its environment. These characteristics are used to classify animals.

**Vertical Alignment:** Students learn about classifying things as living and nonliving in kindergarten (K.6). In kindergarten, students also learn about the basic needs and life processes of animals (K.7). In second grade, students learn more about the life cycles as they learn the series of orderly changes of animal growth and development (2.4). Students learn that organisms and their living and nonliving surroundings are interdependent (2.5).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Energy and matter are required for all organisms to survive.   * Animals, including humans, have basic life needs, including air, food, water, shelter, and space (habitat) (1.5 a). * Animals, including humans, have a variety of physical characteristics that help them survive. These include   + appendages such as arms, legs, wings, fins, and tails which extend from the body and have specific functions   + body coverings which include hair, fur, feathers, scales, and shells (1.5 b). *Students will not need to classify animals by their groups (reptiles, birds, mammals, etc.).* * Physical characteristics can also determine   + whether an animal lives in water or on land (e.g., scales and fins that allow fish to live in water or fur and legs that allow dogs to live on land)   + their method of movement which may include walking, crawling, flying, and swimming (1.5 b). * Animals can be classified based on characteristics (1.5 c). | In order to meet this standard, it is expected that students will   * describe the life needs of animals, including air, food, water, shelter, and space (1.5 a) * identify physical characteristics of an animal (1.5 b) * design and construct a model of a habitat for an animal based on physical characteristics (1.5 a) * observe animals in the schoolyard and describe their physical properties (1.5 b) * predict what type of home (land or water) an animal would live in based on its physical characteristics (1.5 b) * group animals using similar characteristics and explain the grouping (1.5 c). |

#### Earth and Space Systems

**1.6 The student will investigate and understand that there is a relationship between the sun and Earth. Key ideas include**

* 1. **the sun is the source of energy and light that warms the Earth’s land, air, and water; and**

1. **the sun’s relative position changes in the Earth’s sky throughout the day.**

**Central Idea:** The sun is a source of energy that provides light and warmth for Earth and can be seen in different locations of the sky throughout the day.

**Vertical Alignment:** In kindergarten, students conduct weather investigations and understand that light influences temperature on Earth’s surfaces and can cause shadows (K.9). In second grade, students investigate and understand types of weather and weather patterns and measure and record current weather data (2.7).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| The sun is the primary source of energy for Earth and provides the Earth with light and warmth.   * Energy from the sun warms the land, air, and water by transferring energy (warmth) to the Earth (1.6 a). * Patterns of the motion of the sun in the sky can be observed, described, and predicted. The sun’s relative position in the morning is in the eastern sky and in the late afternoon is in the western sky (1.6 b). *Students are not expected to learn about the Earth’s rotation.* | In order to meet this standard, it is expected that students will   * with guidance, conduct simple investigations to show how sunlight changes the temperature of land, air, and water (1.6 a) * observe where the sun rises in the morning and sets in the evening and describe the pattern (1.6 b) * with guidance, conduct a simple investigation to show how the sunlight changes the temperature at different times during the day (1.6 b) * design a structure to reduce the change in temperature that occurs in sunlight throughout the day (1.6 a, b) * use observations of the sun to describe patterns that can be predicted (1.6 a, b). |

**1.7 The student will investigate and understand that there are weather and seasonal changes. Key ideas include**

1. **changes in temperature, light, and precipitation occur over time;**
2. **there are relationships between daily weather and the season; and**
3. **changes in temperature, light, and precipitation affect plants and animals, including humans.**

**Central Idea:** Repeating patterns are clues to cause-and-effect relationships and provide the opportunity to make predictions. In this standard, students look at how changes in temperature, light, and precipitation can help predict the weather (which affects plants and animals).

**Vertical Alignment:** In kindergarten, students investigate and understand that there are patterns in nature such as daily weather, seasonal changes, and day and night (K.9). In second grade, students investigate and understand that weather patterns and seasonal changes affect plants, animals, and their surroundings and that these changes can happen quickly or slowly (2.6, 2.7).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Repeating patterns in nature, or events that occur together with regularity, are clues to cause-and-effect relationships.   * The daily weather is composed of light, temperature, and precipitation (1.7 a). * Weather patterns and the amount of sunlight determine the seasons (1.7 b). * Seasonal changes in plants include budding, growth, and losing leaves (1.7 c). * Seasonal changes in animals include hibernation (e.g., bats and frogs) and migration (e.g., birds and butterflies), resulting in changes in habitat (1.7 c). *Students do not need to know the terms* migration*,* hibernation*, and* habitat. * The body coverings of some animals change with the seasons. This includes thickness of fur and coloration (1.7 c). * Changes made by people include their dress and recreation (1.7 c). | In order to meet this standard, it is expected that students will   * identify types of precipitation as rain, snow, and ice and describe the temperature conditions of each type of precipitation (1.7 a) * observe, record, and compare seasonal data throughout the year, including relative temperature, amount of precipitation, and relative amount of sunlight (1.7 a, b) * represent data in tables and graphic displays to describe typical weather conditions during a season (1.7 b) * observe and record seasonal changes in plants, including budding, growth, and losing leaves; recognize the seasons during which budding and losing leaves will most likely occur (1.7 c) * compare the physical characteristics of some common plants during summer and winter (1.7 c) * compare the activities of some common animals during summer and winter by describing changes in their behaviors and their body coverings (1.7 c) * infer the season based on humans’ dress and recreational activities (1.7 c). |

**Earth Resources**

**1.8 The student will investigate and understand that natural resources can be used responsibly. Key ideas include**

1. **most natural resources are limited;**
2. **human actions can affect the availability of natural resources; and**
3. **reducing, reusing, and recycling are ways to conserve natural resources.**

**Central Idea:** Our natural resources, including clean water, clean air, and undeveloped land, are limited. If we want to enjoy these resources in the future, we need to take care of them now.

**Vertical Alignment:** Students understand that materials can be reused, recycled, and conserved in kindergarten. This concept establishes the foundation for increasingly advanced conservation concepts (K.11). This standard builds on that initial introduction to reusing and recycling. In second grade, the content focuses on plants as important natural resources (2.8).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Natural resources are limited and should be conserved.   * People use natural resources in their daily lives (1.8 a). * There are a variety of natural resources, which include plants, animals, water, air, land, minerals, forests, and soil. Many of these resources are limited (1.8 a). * The decisions that people make about using natural resources makes a difference in how long natural resources last (1.8 b). * Natural resources can be conserved by reducing our use of materials, reusing items, or recycling (1.8 c). | In order to meet this standard, it is expected that students will   * identify natural resources such as plants, animals, water, air, land, forests, minerals, and soil (1.8 a) * compare ways of conserving resources (1.8 c) * determine a resource in the school or home that may be conserved, brainstorm solutions, and implement a plan to address the conservation concern (1.8 a, b, c). |

## Grade Two

***Change occurs all around us***

Science in second grade builds on previous understandings of forces, water, weather, and plants and animals, as students explore these concepts through the lens of change. They examine how water changes phase, how visible and invisible forces change motion, how plants and animals change through their life cycles, and how weather changes the Earth. Students also examine how change occurs over a short or long period of time. Throughout the elementary years, students will develop scientific skills, supported by mathematics and computational thinking, as they learn science content. In second grade, students will develop skills in posing simple questions, planning and conducting simple investigations, observing, classifying, and communicating information about the natural world. Students engage in more aspects of the engineering design process at this level.

### Scientific and Engineering Practices

Engaging in the practices of science and engineering helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the many ways to investigate, model, and explain the world. These scientific and engineering practices include the use of scientific skills and processes to explore the content of science as outlined in the *Science Standards of Learning*. The engineering design practices are the application of science content to solve a problem or design an object, tool, process, or system. These scientific and engineering practices are critical to science instruction and are to be embedded throughout the year.

**2.1 The student will demonstrate an understanding of scientific and engineering practices by**

* 1. **asking questions and defining problems**
* **ask questions that can be investigated**
* **make predictions based on observations and prior experiences**
* **identify a simple problem that can be solved through the development of a new tool or improved object**

1. **planning and carrying out investigations**

* **with guidance, plan and conduct simple investigations to produce data**
* **use appropriate tools to measure length, weight, and temperature of common objects using U.S. Customary units**
* **measure time intervals using proper tools**

1. **interpreting, analyzing, and evaluating data**

* **organize and represent data in pictographs and bar graphs**
* **read and interpret data represented in pictographs and bar graphs**

1. **constructing and critiquing conclusions and explanations**

* **make simple conclusions based on data or observations**
* **distinguish between opinion and evidence**
* **recognize unusual or unexpected results**

1. **developing and using models**
   * + **use models to demonstrate simple phenomena and natural processes**
2. **obtaining, evaluating, and communicating information**

* **communicate observations and data using simple graphs, drawings, numbers, speech, and/or writing**

### Grade Two Science Content

#### Force, Motion, and Energy

**2.2 The student will investigate and understand that different types of forces may cause an object’s motion to change. Key ideas include**

* 1. **forces from direct contact can cause an object to move;**
  2. **some forces, including gravity and magnetism, can cause objects to move from a distance; and**
  3. **forces have applications in our lives.**

**Central Idea:** Forces between objects can cause a change in motion. Objects can move because of a direct contact and from forces that are acting from a distance.

**Vertical Alignment:** Students investigate and learn that forces can be used to change the speed and the direction that an object moves in first grade (1.2). In third grade, the study of force is expanded as students investigate and understand that the direction and size of force affects the motion of an object (3.2).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Forces applied to an object can cause a change in motion. These forces may be direct forces or forces from a distance, such as magnetism and gravity.   * A force may be applied by direct contact (a push or a pull) and can cause an object to move (2.2 a). * Gravity is an attraction between any two objects. Objects do not need to touch each other for the force of gravity to affect them (2.2 b). * Magnetism is a force in which one material exerts an attractive or repulsive force on certain other materials. Magnets are not attracted to all materials. Magnets attract and repel other magnets (2.2 b). * Forces can be seen in everyday applications, such as in moving vehicles, dropping objects, and refrigerator magnets (2.2 c). | In order to meet this standard, it is expected that students will   * explain how forces can cause an object to move or cause an object to change its movement (2.2 a) * demonstrate contact and noncontact forces that cause objects to move (2.2 a) * investigate the effect of contact and noncontact magnetic forces on the movement of objects (2.2 b) * predict which materials will be attracted to magnets, test the predictions, and create a chart that shows the results, classifying materials as to whether they are attracted to magnets (2.2 b) * investigate relationships of gravitational or magnetic interactions between two objects that are not in contact with each other (2.2 b) * identify examples of the effect of gravity (2.2 b) * describe applications of forces in everyday life (2.2 c) * identify a simple problem that can be solved through the development of a new tool or an improved object that uses forces from direct contact or from a distance (2.2 c). |

#### Matter

**2.3 The student will investigate and understand that matter can exist in different phases. Key ideas include**

**a) matter has mass and takes up space;**

**b) solids, liquids, and gases have different characteristics; and**

**c) heating and cooling can change the phases of matter.**

**Central Idea:** Heating and cooling can change the phases of matter.

**Vertical Articulation:**  Students investigate the physical properties of matter, and the properties of water are observed and tested in kindergarten (K.3, K.4). In first grade, students investigate materials and their physical properties (1.3).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Matter can be described and classified by its observable properties. The phase of a substance is a physical property.   * *Matter* is anything that has mass and takes up space; all substances are made of matter. Matter most commonly occurs in three phases: solids, liquids, and gases. Different kinds of matter exist and many of them can be either solid or liquid, depending on the temperature (2.3 a). *Students are not responsible for knowing about additional phases of matter, such as plasma.* * Solids have a definite shape and volume (2.3 b). * Liquids have a definite volume and take the shape of their container (2.3 b) * Gases will completely fill any closed container (take the shape of their container) and assume the volume of their container (2.3 b). * Matter can change from one phase to another (2.3 c). * When matter changes from one phase to another, these changes are referred to as physical changes (2.3 c). *Students are not expected to identify physical or chemical properties or changes.* * Heating and cooling can change the phase of matter (2.3 c). | In order to meet this standard, it is expected that students will   * define *matter* and provide examples (2.3 a) * describe the characteristics of a solid, liquid, and gas (2.3 b) * classify and compare materials as liquids, solids, or gases (2.3 b) * identify the phases of water and the uses of water in its various phases in the home and at school (2.3 b) * communicate observations of the transformation of matter from one phase to another (e.g., ice to liquid water and liquid water to gas) (2.3 b) * plan and conduct an investigation to determine basic factors that affect the evaporation of water (2.3 b) * predict changes in phase when water is heated or cooled (2.3 c) * investigate the effect of heat on the state of matter (i.e., ice to liquid water and liquid water to water vapor) (2.3 c) * discuss the effect of cooling on the state of matter (2.3 c). |

#### Living Systems and Processes

**2.4 The student will investigate and understand that plants and animals undergo a series of orderly changes as they grow and develop. Key ideas include**

* 1. **animals have life cycles; and**
  2. **plants have life cycles.**

**Central Idea:** Plants and animals undergo change throughout their lives as they grow and develop. These changes are reflected in an organism’s life cycle.

**Vertical Alignment:** Students are introduced to living systems in kindergarten as they classify things as living and nonliving (K.6). The concept is expanded in first grade as students are introduced to the basic needs and life processes of plants and animals (K.7, 1.4, 1.5). Ecosystems and the relationships that exist among organisms to satisfy life needs is a focus in third grade (3.4, 3.5).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Patterns exist everywhere and can be seen in regularly occurring, repeating events such as life cycles.   * Throughout their lives, plants and animals undergo a series of orderly and identifiable changes. These may include changing form or growing (2.4 a). * Changes in organisms over time occur in cycles and differ among various plants and animals (2.4 a, b). * Some animals do not resemble their parents at birth and go through distinct stages as they mature to adults. Other animals resemble their parents from birth to maturity and do not have distinct stages (2.4 a). * The basic stages in the life cycle of flowering plants include: seed, germination of the seed, growth of the stem and roots, growth of leaves, growth of flowers, fertilization (pollination) of the flowers, production of fruit/new seeds, and death (2.4 b). * Flowering plants produce seeds. Seeds can be dispersed in a variety of ways such as by wind, water, and animals, including humans (2.4 b). * Although individual life cycles vary, all organisms have in common birth, growth, reproduction, and death (2.4 a, b). | In order to meet this standard, it is expected that students will   * explain how animals and plants change as they grow (2.4 a, b) * analyze a model of the life cycle of an insect and describe the changes that occur within the life cycle (2.4 a) * analyze a model of the life cycle of a mammal and describe the changes that occur with the life cycle (2.4 a) * compare life cycles of an insect and a mammal (2.4 a) * investigate the question, “What is the life cycle of a flowering plant?” and record observations using a table and/or graph; explain the results of the investigation (2.4 b) * compare life cycles of a plant and an animal (2.4 a, b) * develop models to describe the concept that organisms have unique and diverse life cycles but they all have in common birth, growth, reproduction, and death (2.4 a, b). |

**2.5 The student will investigate and understand that living things are part of a system. Key ideas include**

* 1. **plants and animals are interdependent with their living and nonliving surroundings;**
  2. **an animal’s habitat provides all of its basic needs; and**
  3. **habitats change over time due to many influences.**

**Central Idea:** Living organisms interact with other living organisms and their surroundings. These interactions allow organisms to meet basic life needs.

**Vertical Alignment:**  Students are introduced to the concept of living and nonliving as well as the basic needs of both plants and animals in kindergarten (K.6, K.7). The structures and functions of animals and plants that are necessary for satisfying these life needs are the focus of first grade (1.4, 1.5). Ecosystems and the relationships that exist among organisms to satisfy life needs is a discussed in third grade (3.4, 3.5).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| A system is comprised of components that work together to form a complex whole.  Living systems have both living and nonliving components that are affected by interactions, allowing organisms to meet basic life needs.   * The interactions among living organisms and their nonliving surroundings are referred to as a *system* (2.5). * Living things include all organisms who are alive or were once alive. Nonliving things are not alive and have never been alive (2.5 a). * Living organisms are dependent on other living organisms and their nonliving surroundings for survival (2.5 a). * An animal’s habitat provides the animal’s basic needs, including food, air, water, shelter or cover, and space. If any of the basic elements of an animal’s habitat are absent, the animal’s survival is threatened. The animal may adapt or leave the area (2.5 b). * Shelter/cover may be living, such as coral or a tree, or it may be nonliving, such as a cave or a brick house (2.5 a, b). * The habitats of living organisms may change due to natural influences. For example, plants and animals respond to seasonal changes, such as temperature and length of daylight (2.5 c). * The habitats of living organisms may change due to human influences. For example, an animal may need to change behavior or leave the area if its basics needs are not met, which may result when humans develop (build) an area (2.5 c). | In order to meet this standard, it is expected that students will   * explain how living things are part of a system composed of living and nonliving components (2.5 a) * analyze a model of a habitat and describe the living and nonliving components (2.5 b) * describe how a habitat provides for an animal’s or plant’s needs (2.5 b) * predict and describe natural changes in habitats and their effects on plants and animals (2.5 c) * describe the changes in a habitat due to various influences (2.5 c). |

#### Earth and Space Systems

**2.6 The student will investigate and understand that there are different types of weather on Earth. Key ideas include**

* 1. **different types of weather have specific characteristics;**
  2. **measuring, recording, and interpreting weather data allows for identification of weather patterns; and**
  3. **tracking weather allows us to prepare for the weather and storms.**

**Central Idea:** There are many types of weather on Earth; these types of weather have specific characteristics. Weather data can be used to identify and predict weather patterns and storms.

**Vertical Alignment:** Students collect data on weather and use this to understand seasonal changes in kindergarten and first grade (K.11, 1.6, 1.7). In third grade, students extend this knowledge as they determine impacts of natural weather events on ecosystems (3.8).

| **Enduring Understandings** | **Essential Knowledge and Practice** |
| --- | --- |
| Patterns exist everywhere and can be seen in regularly occurring, repeating events such as weather. Models based on patterns in weather data are used to predict weather.   * Common types of storms include hurricanes, tornadoes, blizzards, and thunderstorms. These storms have powerful winds, which may be accompanied by rain, snow, or other kinds of precipitation (2.6 a). * Common types of precipitation include rain, snow, and ice (sleet and hail) (2.6 a). * Extreme weather, such as too little or too much precipitation, can result in droughts or floods (2.6 a). * Scientists collect a variety of weather data such as precipitation, cloud cover, wind, and temperature (2.6 b). * Weather data is collected and recorded using instruments, such as a thermometer, rain gauge, and weather vane (2.6 b). *Students only need to measure weather data using U.S. Customary System units.* * By comparing current weather data to known patterns in weather, predictions can be made that allow us to prepare for storms and other weather conditions (2.6 c). | In order to meet this standard, it is expected that students will   * identify and describe common types of storms, including the precipitation that may be associated with each (2.6 a) * compare droughts and floods (2.6 a) * observe, describe, and record daily weather conditions using weather instruments; graph and analyze data to identify patterns; predict weather based upon identified patterns (2.6 b) * observe and describe seasonal weather patterns and local variations (2.6 c) * describe how tracking weather data helps to prepare for storms and other weather conditions (2.6 c). |

**2.7 The student will investigate and understand that weather patterns and seasonal changes affect plants, animals, and their surroundings. Key ideas include**

1. **weather and seasonal changes affect the growth and behavior of living things;**
2. **wind and weather can change the land; and**

**c) changes can happen quickly or slowly over time.**

**Central Idea:** Weather conditions and seasons affect plants, animals, and their surroundings.

**Vertical Alignment:** Students investigate and understand the relationship between seasonal change and weather in first grade. Important concepts include how plants, animals, and people respond to changes in light, temperature, and precipitation (1.7). The effects of natural events, including fire, flood, and erosion, on ecosystems is part of the third-grade standards (3.8).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Changes in weather and seasons affect both living organisms and their environment.   * Living organisms respond to weather patterns and seasonal changes that can be reflected in changes in growth and behavior (2.7 a). * Adverse conditions of weather may slow the growth and development of plants and animals, whereas optimal weather conditions may accelerate the growth and development of plants and animals (2.7 a). * Dormancy is a state of reduced metabolic activity adopted by many organisms (both plants and animals) under conditions of environmental stress or when such stressful conditions are likely to appear, such as in winter. Many trees produce new leaves in the spring and lose them in the fall due to seasonal changes in temperature and light (2.7 a). * The outward coloration and coloration patterns of many animals are similar in appearance to the plants in the places in which they live. This similarity to background is referred to as camouflage, and it enables animals to hide and avoid those that may eat or harm them (2.7 a). * Some animals (e.g., geese, monarch butterflies, tundra swans) travel from one place to another and back again (migration) in search of a new temporary habitat because of climate, availability of food, season of the year, or reproduction (2.7 a). * Some animals (e.g., groundhogs, bats) go into a resting state (hibernation) due to seasonal changes. Hibernation is a condition of biological rest or inactivity where growth, development, and metabolism slow down (2.7 a). * Some animals undergo physical changes (e.g., thickening of dog fur in the winter and shedding in the summer) from season to season (2.7 a). * Land surfaces can be changed by weathering and erosion. Land surfaces that are not covered with or protected by plants are more likely to be subject to the loss of soil by wind and water (2.7 b). * Weathering is the breaking down of rocks, which usually happens over long periods of time (2.7 b). * Erosion is the process by which the products of weathering are moved from one place to another. Erosion may happen quickly (e.g., during a flood or a hurricane) or over a long period of time (2.7 b). * Examples of weather and seasonal changes that happen quickly include mud slides and flooding. Examples of weather and seasonal changes that occur slowly include beach erosion and leaves changing color (2.7 c). | In order to meet this standard, it is expected that students will   * identify growth and behavioral responses of plants and animals to weather and seasonal changes (2.7 a) * identify animals that migrate, hibernate, or show other changes due to seasonal weather changes (2.7 a) * compare the responses of plants and animals to weather and seasonal changes (2.7 a) * explain how an animal’s behavior may change throughout the year due to food source availability (2.7 a) * model the effects of weathering and erosion on the land surface (2.7 b) * design and construct a model of a structure that can withstand changes in land due to erosion or weathering (2.7 b) * identify examples of weather and seasonal changes that happen slowly and quickly (2.7 c). |

#### Earth Resources

**2.8 The student will investigate and understand that plants are important natural resources. Key ideas include**

1. **the availability of plant products affects the development of a geographic area;**
2. **plants provide oxygen, homes, and food for many animals; and**
3. **plants can help reduce the impact of wind and water.**

**Central Idea:** Plants have many roles in a system, which include providing for the basic life needs of animals and reducing the impact of weather on land.

**Vertical Alignment:** Students investigate natural resources and conservation in kindergarten and first grade (K.11, 1.8). Third grade explores the impact of humans and natural events on ecosystems and the availability of natural resources (3.8).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Natural resources are materials with different properties and are suited for different uses. Natural resources are limited and are distributed unevenly around the planet.   * Plants provide many useful products and materials, which benefit human beings as well as other living organisms. Examples include cotton, spices, lumber, rubber, medicines, and paper (2.8 a, b). * Plants may grow well in certain geographic areas, thus enabling the production of plant products that allow humans to live in and thrive in those areas (2.8 a). * Many animals benefit from plants. Plants provide food, shelter, and oxygen. These are required to meet basic life needs (2.8 b). * Some examples of plants that grow in Virginia’s geographic regions include   + Coastal Plains (Tidewater)—peanuts, cotton, soybeans   + Piedmont—apples, tobacco, cabbage   + Blue Ridge Mountains—evergreens, apples, corn   + Valleys and Ridges—evergreens, apples, corn   + Appalachian Plateau—tobacco (2.8 a). *Students are not responsible for identifying specific regions or matching the products to the region in second grade.* * Plants are important in the prevention of soil erosion. In addition, plants help reduce the effects of flooding (2.8 c). * Plants can be used to reduce the impact of high winds and blowing snow on roadways. Trees and vegetation can be planted along roadways to reduce the impact of wind; these are called windbreaks (2.8 c). | In order to meet this standard, it is expected that students will   * describe useful plant products and the region in which they are grown in Virginia (2.8 a) * identify where crops are grown in Virginia and predict the impact they have on the area’s development (2.8 a) * explain the roles of plants in meeting the life needs of animals (2.8 b) * compare different ways animals use plants as homes and shelters (2.8 b) * construct and interpret a chart illustrating plant foods consumed by different animals (2.8 b) * construct and interpret models as to how plants help reduce the impact of wind and water (2.8 c). |

## Grade Three

***Interactions in our world***

The focus of science in third grade is interactions in our world. Students continue to study forces and matter by learning about simple machines and by examining the interactions of materials in water. They also look at how plants and animals, including humans, are constantly interacting with living and nonliving aspects of the environment. This includes examining how adaptations satisfy life needs and the importance of water, soil, and the sun in the survival of plants and animals. Throughout the elementary years, students will develop scientific skills, supported by mathematics and computational thinking, as they learn science content. In third grade, students will develop more sophisticated skills in posing questions and predicting outcomes, planning and conducting simple investigations, collecting and analyzing data, constructing explanations, and communicating information about the natural world. Students begin to use the engineering design process to apply their scientific knowledge to solve problems.

### Scientific and Engineering Practices

Engaging in the practices of science and engineering helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the many ways to investigate, model, and explain the world. These scientific and engineering practices include the use of scientific skills and processes to explore the content of science as outlined in the *Science Standards of Learning*. The engineering design practices are the application of science content to solve a problem or design an object, tool, process, or system. These scientific and engineering practices are critical to science instruction and are to be embedded throughout the year.

**3.1 The student will demonstrate an understanding of scientific and engineering practices by**

1. **asking questions and defining problems**

* **ask questions that can be investigated and predict reasonable outcomes**
* **ask questions about what would happen if a variable is changed**
* **define a simple design problem that can be solved through the development of an object, tool, process, or system**

1. **planning and carrying out investigations**

* **with guidance, plan and conduct investigations**
* **use appropriate methods and/or tools for collecting data**
* **estimate length, mass, volume, and temperature**
* **measure length, mass, volume, and temperature in metric and U.S. Customary units using proper tools**
* **measure elapsed time**
* **use tools and/or materials to design and/or build a device that solves a specific problem**

1. **interpreting, analyzing, and evaluating data**

* **organize and represent data in pictographs or bar graphs**
* **read, interpret, and analyze data represented in pictographs and bar graphs**
* **analyze data from tests of an object or tool to determine if it works as intended**

1. **constructing and critiquing conclusions and explanations**

* **use evidence (measurements, observations, patterns) to construct or support an explanation**
* **generate and/or compare multiple solutions to a problem**
* **describe how scientific ideas apply to design solutions**

1. **developing and using models**

* **use models to demonstrate simple phenomena and natural processes**
* **develop a model (e.g., diagram or simple physical prototype) to illustrate a proposed object, tool, or process**

1. **obtaining, evaluating, and communicating information**

* **read and comprehend reading-level appropriate texts and/or other reliable media**
* **communicate scientific information, design ideas, and/or solutions with others**

### Grade 3 Science Content

#### Force, Motion, and Energy

**3.2 The student will investigate and understand that the direction and size of force affects the motion of an object. Key ideas include**

1. **multiple forces may act on an object;**
2. **the net force on an object determines how an object moves;**
3. **simple machines increase or change the direction of a force; and**
4. **simple and compound machines have many applications.**

**Central Idea:** Forces between objects can cause a change in motion. A machine is any device that helps people do work by changing the direction or the size of the force.

**Vertical Alignment:** In second grade, students discover how forces affect them in daily life. They are introduced to the indirect forces, magnetism and gravity (2.2). In fifth grade, students will explore the effect of direct and indirect forces on the motion of an object. At that time, students learn about energy transformations in collisions and collect and record time and position data of a moving object (5.2, 5.3, 5.4).

| **Enduring Understanding** | **Essential Knowledge and Practices** |
| --- | --- |
| Forces between objects can cause a change in motion.   * Forces are pushes or pulls that can cause objects to move, stop moving, change speed, or change direction. Gravity is an example of a pulling force (3.2 a). * Friction is a force that opposes the motion of an object (3.2 a). * The net force is the combination of all the forces acting on an object (3.2 b). *Students are not expected to calculate net force.* * Whether an object stays still or moves often depends on the effects of multiple pushes or pulls. An object at rest typically has multiple forces acting on it, but they result in a zero net force on the object. Forces that do not sum to zero net force can cause changes in the objects speed or direction of motion (3.2 b). *Students are not expected to calculate net force.* * Simple machines are devices that change the direction or size of a force (3.2 c). * Compound machines contain more than one simple machine (3.2 d). | In order to meet this standard, it is expected that students will   * describe the relative size and direction of forces acting upon an object (3.2 a, b) * plan and conduct an investigation concerning the effect forces have on an object’s motion (3.2 b) * explain how humans use machines to make work easier (3.2 c, d) * differentiate and classify the six types of simple machines (i.e., lever, inclined plane, wedge, wheel and axle, screw, and pulley) found in school and household items (3.2 c) * collaboratively plan an investigation to demonstrate the direction of the forces acting on a lever, pulley, and inclined plane as they relate to net forces; design a model labeling identified forces (3.2 c) * plan and conduct an experiment that compares the relative force required to move an object with and without the aid of a simple machine (3.2 b, c) * identify a common task that might be easier if done with a simple machine; collaboratively design and build an apparatus that incorporates simple machines to accomplish the task, and explain how the apparatus works and the importance of using simple machines (3.2 c) * explain how simple machines work together to form a compound machine (3.2 c, d) * identify compound machines and the simple machines that comprise them within the school and household environment (3.2 c, d). |

#### Matter

**3.3 The student will investigate and understand how materials interact with water. Key ideas include**

1. **solids and liquids mix with water in different ways; and**
2. **many solids dissolve more easily in hot water than in cold water.**

**Central Idea:** Many substances interact in water; when substances dissolve in water, a solution is formed. The dissolved substance is still present even though it cannot be seen.

**Vertical Alignment:** Students explore characteristics of three phases of matter and the effect heating and cooling have on each phase in second grade (2.3). In fifth grade, students expand upon this knowledge as they learn matter has properties and interactions (5.7).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Water dissolves more substances than any other liquid. Some liquids will mix with water, while others will not.   * Dissolving is when a substance is distributed evenly throughout another substance. The substance being dissolved breaks down into smaller pieces that cannot be seen (3.3 a). * Some solids will dissolve in water while others will not (3.3 a). * Substances dissolve faster in hot water than cold water because hot water has more energy than cold water. When water is heated, the molecules gain energy and, thus, move faster. As the molecules move faster, they make contact with the sugar more often, causing it to dissolve faster (3.3 b). *Students do not need to know the terms* solute*,* solvent*,* atoms*,* molecules*, or* particles*.* | In order to meet this standard, it is expected that students will   * plan and conduct an investigation to identify liquid materials that will mix with water (3.3 a) * classify liquids by their ability to mix with water (3.3 a) * plan and conduct an investigation to determine solids that will dissolve in water (3.3 a) * classify solids based on their ability to dissolve in water (3.3 b) * plan and conduct an investigation to determine the effect of water temperature on the dissolving of a solid (3.3 b). |

#### Living Systems and Processes

**3.4 The student will investigate and understand that adaptations allow organisms to satisfy life needs and respond to the environment. Key ideas include**

1. **populations may adapt over time;**
2. **adaptations may be behavioral or physical; and**
3. **fossils provide evidence about the types of organisms that lived long ago as well as the nature of their environments.**

**Central Idea:** Lasting changes (adaptations) in populations of organisms take place gradually over long periods of time (often thousands to millions of years). These changes are due to changes in the genetic makeup of populations.

**Vertical Alignment:** Students learn how living organisms are part of a system and interact with other living organisms and their surroundings in second grade (2.4). In fourth grade, students learn how internal and external structures enable organisms to obtain energy and reproduce (4.2).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Organisms possess physical characteristics and behaviors that enable them to survive in their environment and obtain resources to meet basic needs and carry out life processes.   * Adaptations are physical features or behaviors that aid organisms in survival (3.4 b). * A populationis a group of organisms of the same kind that live in the same place (3.4 a). * For populations to survive, their life needs must be met. This includes finding food, defending themselves, and reproducing (3.4 b). * Populations may adapt (over long periods of time) due to changes in their environment. If populations do not adapt to environmental changes or do not move to a new environment, they will not survive (3.4 a). * Physical adaptations help animals survive in their environment. An example is camouflage, a means by which animals escape the notice of predators, usually because of a resemblance to their surroundings using coloration or outer coverage patterns. Another example of a physical adaptation is the webbed feet of a swimming bird such as a duck (3.4 b). * Fossils are the remains or impressions of organisms preserved in a petrified form or as a mold or cast in rock. Paleontologists can use fossil evidence to make inferences about life and conditions of the past (3.4 c). | In order to meet this standard, it is expected that students will   * provide an example of how an environmental change may affect the ability of a population to survive (3.4 a) * explain how populations may adapt over time in response to changes in the environment (3.4 a) * differentiate between physical and behavioral adaptations (3.4 b) * explain how an animal’s behavioral adaptations help it live in its habitat (3.4 b) * compare the physical characteristics of animals and explain how they are adapted to their environment (3.4 b) * design and construct a model of a habitat for an animal with a specific adaptation (3.4 b) * explain the role of fossils in making inferences about organisms and the environment from long ago (3.4 c). |

**3.5 The student will investigate and understand that aquatic and terrestrial ecosystems support a diversity of organisms. Key ideas include**

1. **ecosystems are made of living and nonliving components of the environment; and**
2. **relationships exist among organisms in an ecosystem.**

**Central Idea:** Ecosystems are diverse in both their living and nonliving components. These complex environments lead to a diversity of organisms that engage in a variety of relationships as they strive to meet life needs.

**Vertical Articulation:** Students are introduced to the concept that living things are a part of a system that provides resources necessary for survival in second grade (2.5). In fourth grade, students examine how organisms interact with each other and with the nonliving environment (with a specific focus on ocean environments) and how food webs can illustrate the energy pathways in an ecosystem (4.3).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| All ecosystems are affected by complex biotic and abiotic interactions involving exchange in matter and energy.   * An ecosystem supports a diversity of organisms that interact with each other and their nonliving environment (3.5 a, b). * Water-related ecosystems include those with fresh water or salt water. Examples include ponds, marshes, swamps, streams, rivers, and oceans (3.5). * Dry-land ecosystems include deserts, grasslands, rain forests, and forests (3.5). * There are distinct differences in the nonliving and living components that make up pond, marshland, swamp, stream, river, ocean, desert, grassland, rainforest, and forest ecosystems (3.5 a). * Organisms depend on each other and on the nonliving components in their environment. They often compete for limited resources (3.5 b). * Nonliving components of an environment include sunlight, water, nutrients, soil, and air (3.5 b). *Students are not expected to identify additional nonliving components in third grade*. * A food chain shows a feeding relationship among organisms in a specific area or environment that illustrates the flow of energy in the ecosystem. The arrows in a food chain illustrate the flow of energy from one organism to another. The arrows always point to the organism doing the eating (receiving the energy) (3.5 b). | In order to meet this standard, it is expected that students will   * describe basic living and nonliving components in different types of terrestrial and aquatic ecosystems (3.5 a) * compare plants and animals that compose aquatic and terrestrial ecosystems (3.5 a) * differentiate among producers, consumers, and decomposers and identify examples of each within aquatic and terrestrial ecosystems (3.5 b) * construct and analyze a food chain that models the relationships and the flow of energy within an ecosystem (3.5 b) * explain how a change in one part of a food chain might affect the rest of the food chain (3.5 b) * identify the sun as the source of energy in food chains (3.5 b). |

#### Earth and Space Systems

**3.6 The student will investigate and understand that soil is important in ecosystems. Key ideas include**

1. **soil, with its different components, is important to organisms; and**
2. **soil provides support and nutrients necessary for plant growth.**

**Central Idea:** Soil is often referred to as dirt; however, it is a complex combination of organic and inorganic materials.

**Vertical Alignment:** Students learn about soil erosion and how plants help reduce erosion in second grade (2.8). In fourth grade, students expand on the importance of soil as a natural resource in Virginia (4.8).

| **Enduring Understandings** | **Essential Skills and Processes** |
| --- | --- |
| Soil is composed of different components that have properties that support organisms within an ecosystem.   * Soil is important because it provides support, nutrients, and a habitat for organisms (3.6 a, b). * Rock, clay, silt, sand, humus, air, and water are components of soil (3.6 a). * Plants and animals need nutrients to live and grow (3.6 a). * Soil is important because many plants grow in soil, and it provides support and nutrients for the plants (3.6 b). | In order to meet this standard, it is expected that students will   * explain the importance of soil to an ecosystem (3.6 a, b) * analyze and describe the different components of soil (3.6 a) * plan and conduct an investigation that determines how different types of soil affect plant growth (3.6 b). |

**3.7 The student will investigate and understand that there is a water cycle and water is important to life on Earth. Key ideas include**

1. **there are many reservoirs of water on Earth;**
2. **the energy from the sun drives the water cycle; and**
3. **the water cycle involves specific processes.**

**Central Idea:** Water is essential to Earth processes. The water cycle is a model that illustrates how water is conserved within environments.

**Vertical Alignment:** In second grade, students examine matter in different phases and discover that heating and cooling can cause a change in the phase of matter (2.3). In fourth grade, students investigate Virginia watersheds, studying the importance of rivers, bays, lakes, and the Atlantic Ocean (4.7, 4.8).

| **Enduring Understandings** | **Essential Skills and Practices** |
| --- | --- |
| The water cycle is a chain of events that repeats. The cycling of water ensures its availability for life processes.   * Water is essential for life on Earth (3.7). * The water cycle is important because its process provides Earth with the natural, continual water supply all living things need to survive (3.7 a, b, c). * The water cycle is the continuous movement of water on, in, and above Earth. As with all cycles, it does not have a specific beginning or end point. While water does circulate from one point or state to another in the water cycle, the paths it can take are variable. The energy that drives the water cycle comes from the sun (3.7 b). * During the water cycle, liquid water is heated and changed to a gas (water vapor) by a process called *evaporation*. The gas (water vapor) is cooled and changed back to a liquid by a process known as *condensation*, or it can form ice crystals (solid). Water falls to the ground as a liquid or a solid through a process called *precipitation* (3.7 c). | In order to meet this standard, it is expected that students will   * identify the ways organisms get water from the environment (3.7) * compare major waterways including rivers, lakes, ponds, oceans, groundwater, and wells (3.7 a) * identify and locate major water sources in the local community (3.7 a) * identify the origin of energy that drives the water cycle (3.7 b) * describe the processes of evaporation, condensation, and precipitation as these relate to the water cycle (3.7 c) * construct and interpret a model of the water cycle (3.7 c). |

#### Earth Resources

**3.8 The student will investigate and understand that natural events and humans influence ecosystems. Key ideas include**

**a) human activity affects the quality of air, water, and habitats;**

**b) water is limited and needs to be conserved;**

**c) fire, flood, disease, and erosion affect ecosystems; and**

**d) soil is a natural resource and should be conserved.**

**Central Idea:** Human behaviors and natural disasters can negatively affect organisms and their habitats. Conservation practices can lessen the effects of human activity and natural disasters on the environment.

**Vertical Alignment:** Students learn that organisms are interdependent with their living and nonliving surroundings in second grade. Students also learn that habitats change over time due to many influences (2.5). In fourth grade, students investigate issues that affect the local watershed (4.8).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| A variety of factors can affect an ecosystem; human actions may reduce the effects of these factors on an ecosystem.   * Human actions (e.g., polluting, clearing large plots of land to build neighborhoods or plant crops, over-fertilizing lawns, burning fossil fuels) can negatively affect the survival of organisms in an ecosystem (3.8 a). * Humans can make choices that reduce their impact on an environment (3.8 a). * The water supply on Earth is limited. Pollution reduces the amount of usable water; therefore, the supply should be conserved (3.8 b). * Natural occurrences (e.g., earthquakes, forest fires, tornadoes, hurricanes, floods, coastal erosion, disease) can harm the organisms in an environment (3.8 c). * Humans cannot eliminate natural occurrences, but they can take steps to reduce their impact. Mitigation measures such as adoption of zoning, land-use practices, and building codes can prevent or reduce damage (3.8 c). * Conservation is the careful use and preservation of natural resources. Humans need to help conserve limited resources (3.8 b, d). * Since soil takes a long time to form, it should be conserved, not wasted (3.8 d). | In order to meet this standard, it is expected that students will   * analyze the effects of human influences on the quality of air, water, and habitats (3.8 a) * describe the effects of fire, flood, disease, and erosion on organisms and habitats (3.8 c) * explain how conservation efforts can reduce the negative impacts of human activity on a habitat (3.8 a) * propose a solution or design a device that will reduce the impact of a human activity or a natural event on an ecosystem (3.8 a, c) * research, explain, and communicate methods of water conservation to be used in homes and schools (3.8 b) * observe water use in the school setting and identify possible water conservation solutions (3.8 b) * collaboratively design and implement a plan to conserve water at home or at school (3.8 b) * observe and provide evidence of soil erosion around the schoolyard or community; create and implement a plan to reduce erosion (3.8 d). |

## Grade Four

***Our place in the solar system***

Our solar system is a grand place, and in fourth grade science, students learn where we fit in this solar system. Starting with the solar system, and then moving to the planet Earth, the Commonwealth of Virginia, and finally their specific ecosystems, students examine how features of plants and animals support life. They also explore how living things interact with both living and nonliving components in their ecosystems. Throughout the elementary years, students will develop scientific skills, supported by mathematics and computational thinking, as they learn science content. In fourth grade, students will continue to develop skills in posing questions and predicting outcomes, planning and conducting simple investigations, collecting and analyzing data, constructing explanations, and communicating information about the natural world. Students continue to use the engineering design process to apply their scientific knowledge to solve problems.

### Scientific and Engineering Practices

Engaging in the practices of science and engineering helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the many ways to investigate, model, and explain the world. These scientific and engineering practices include the use of scientific skills and processes to explore the content of science as outlined in the *Science Standards of Learning*. The engineering design practices are the application of science content to solve a problem or design an object, tool, process, or system. These scientific and engineering practices are critical to science instruction and are to be embedded throughout the year.

**4.1 The student will demonstrate an understanding of scientific and engineering practices by**

1. **asking questions and defining problems**

* **identify scientific and non-scientific questions**
* **develop hypotheses as cause-and-effect relations**
* **define a simple design problem that can be solved through the development of an object, tool, process, or system**

1. **planning and carrying out investigations**

* **identify variables when planning an investigation**
* **collaboratively plan and conduct investigations**
* **use tools and/or materials to design and/or build a device that solves a specific problem**
* **take metric measurements using appropriate tools**
* **measure elapsed time**

1. **interpreting, analyzing, and evaluating data**

* **organize and represent data in bar graphs and line graphs**
* **interpret and analyze data represented in bar graphs and line graphs**
* **compare two different representations of the same data (e.g., a set of data displayed on a chart and a graph)**
* **analyze data from tests of an object or tool to determine whether it works as intended**

1. **constructing and critiquing conclusions and explanations**

* **use evidence (i.e., measurements, observations, patterns) to construct or support explanations and to make inferences**

1. **developing and using models**
   * **develop and/or use models to explain natural phenomena**

* **identify limitations of models**

1. **obtaining, evaluating, and communicating information**

* **read and comprehend reading-level-appropriate texts and/or other reliable media**
* **communicate scientific information, design ideas, and/or solutions with others**

### Grade Four Science Content

#### Living Systems and Processes

**4.2 The student will investigate and understand that plants and animals have structures that distinguish them from one another and play vital roles in their ability to survive. Key ideas include**

1. **the survival of plants and animals depends on photosynthesis;**
2. **plants and animals have different structures and processes for obtaining energy; and**
3. **plants and animals have different structures and processes for creating offspring.**

**Central Idea:** Plants and animals have different processes and structures that allow them to carry out life processes such as obtaining energy and reproducing.

**Vertical Alignment**: In third grade, students are introduced to the concept that organisms have both physical features and behaviors that help them to survive in their environment (3.4). The process of photosynthesis is expanded in Life Science to include the energy transfer between sunlight and chlorophyll and the transformation of water and carbon dioxide into sugar and oxygen (LS.4). In addition, students build on their understanding of how adaptations to the specific biotic and abiotic conditions within their environment make them better able them to survive (LS.11).

| **Enduring Understandings** | **Essential Knowledge and Processes** |
| --- | --- |
| Organisms are composed of parts that function as a system to carry out life processes such as obtaining energy and reproducing.   * Green plants produce their own food through the process of photosynthesis. They use the green pigment, chlorophyll, along with carbon dioxide, water, and sunlight to produce food (sugar). The leaf is the primary food-producing part of these plants. Oxygen is released during photosynthesis (4.2 a, b). * Photosynthesis enables plants to trap energy from the sun and convert it into sugar that can be used by organisms (4.2 a). * Because animals are not capable of producing their own food, they must consume other organisms to meet their energy needs. Animals have different methods that help them get food (4.2 b). * For many green plants, there are anatomical structures that perform basic functions. Roots anchor the plants and take water and nutrients from the soil. Stems provide support and allow movement of water and nutrients. Leaves are the primary sites for photosynthesis. Flowers are the reproductive structures (4.2 b). * For a population to thrive, its members must be able to reproduce (4.2 c). * Most plants reproduce with seeds which are formed in the reproductive process of flowering plants. Pollination is the process by which pollen is transferred from the stamen (male reproductive structure) to the pistil (female reproductive structure). This transfer can occur as a result of wind, water, or animals. Scents and colors of flowers are attractive to certain pollinators (4.2 c). *Students are not responsible for naming the male or female reproductive structures of the flower*. * Animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction (4.2 c). *Students are not responsible for knowing specific reproductive structures or the process of animal reproduction.* | In order to meet this standard, it is expected that students will   * explain the critical role of photosynthesis in the survival of plants and animals within an ecosystem (4.2 a) * create a model or diagram illustrating the parts of a plant in terms of obtaining energy; explain the role of roots, stems, and leaves (4.2 a, b) * plan and conduct an investigation to determine how the amount of sunlight a plant receives affects plant growth (4.2 b) * compare methods by which plants and animals obtain energy and describe how these processes are related (4.2 b) * compare plant characteristics used for attracting pollinators (4.2 c) * create and explain a model of a flower, illustrating the parts of the flower and its reproductive processes (4.2 c) * understand that for animal populations to survive, the animals must be able to successfully reproduce (4.2 c). |

**4.3 The student will investigate and understand that organisms, including humans, interact with one another and with the nonliving components in the ecosystem. Key ideas include**

1. **interrelationships exist in populations, communities, and ecosystems;**
2. **food webs show the flow of energy within an ecosystem;**
3. **changes in an organism’s niche and habitat may occur at various stages in its life cycle; and**
4. **classification can be used to identify organisms.**

**Central Idea:** An ecosystem is made up of interacting components that allow for the transfer of matter and energy. Each organism has a specific niche that supports life processes.

**Vertical Alignment:** Students learn about food chains and the roles that organisms occupy within their community in third grade, which is an introduction to the concept that organisms are part of a system and depend on each other and the nonliving parts of the system (3.5). The concept is expanded in Life Science to include the flow of matter and energy in food webs, the food pyramid, and the interactions that exist among organisms within a population (LS.5, LS.6).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Ecosystems and their characteristics are the result of complex interactions among Earth’s systems. An ecosystem is an area where living and nonliving things interact. Nonliving factors of an ecosystem include things such as sunlight, water, nutrients, soil, and air (a).   * All the organisms of the same species that live in the same place at the same time are a population (4.3 a). * The populations of species that live in the same place at the same time together make up a community (4.3 a).   The life processes of plants and animals are interdependent and contribute to the flow of energy and cycles of matter within an ecosystem.   * The interactions and organization within an ecosystem is based on the utilization of the energy from the sun. The greatest amount of energy in an ecosystem is in the producers (4.3 a, b). * The sun’s energy cycles through ecosystems from producers through consumers and back into the nutrient pool through decomposers (4.3 b). * Within a community, organisms are dependent on the survival of other organisms. Energy is passed from one organism to another as modeled in a food chain or food web (4.3 a, b). * A food web illustrates the interconnected and overlapping food chains in an ecosystem. The arrow in a food chain always points to the organism doing the eating. These arrows show the flow of energy within the food chain (4.3 b). *Students are not responsible for food pyramids.* * Members of a population interact with other populations in a community. They compete to obtain resources, mates, and territory, and they cooperate to meet basic needs (4.3 c). * A habitat is the place where an animal or plant naturally lives. An organism’s habitat provides food, water, shelter, and space. The size of the habitat depends on the organism’s needs (4.3 c). * A niche is the function or role that an organism performs in the food web of that community. A niche also includes everything else the organism does and needs in its environment, including what it eats and how it interacts with other organisms and the nonliving factors in its environment. Organisms that share the same need for resources must compete to meet their needs. No two types of organisms occupy the same niche in a community (4.3 c). * During its life cycle, an organism’s role in the community (niche) may change. What an animal eats, what eats it, and other relationships may change. For example, tadpoles live in water, breathe through gills, and generally are herbivores. However, adult frogs live primarily on land, breathe with lungs, and are carnivores (4.3 c).   Noticing patterns is a key step to formulating scientific questions. Classification relies on careful observation of patterns, similarities, and differences. Classification is useful in explaining relationships by organizing objects or processes into groups.   * Organisms can be organized into groups to help understand similarities and differences (4.3 d). * A dichotomous key is a tool used to classify organisms based on physical characteristics (4.3 d). | In order to meet this standard, it is expected that students will   * analyze and model how populations, communities, and ecosystems interrelate (4.3 a) * research animals and plants in a local environment and describe interrelationships among these organisms (4.3 b) * construct a food web demonstrating the flow of energy through an ecosystem (4.3 b) * illustrate the food webs in a local area (4.3 b) * explain how an organism’s niche may change at different stages in its life cycle (4.3 c) * analyze a food web and explain how changes in one part of the food web would affect other organisms (4.3 c) * compare the niches of several different organisms within the community (4.3 c) * use a simple dichotomous key to classify organisms (4.3 d). |

#### Earth and Space Systems

**4.4 The student will investigate and understand that weather conditions and phenomena affect ecosystems and can be predicted. Key ideas include**

1. **weather measurements create a record that can be used to make weather predictions;**

**b) common and extreme weather events affect ecosystems; and**

**c) long-term seasonal weather trends determine the climate of a region.**

**Central Idea:** Weather conditions and phenomena may have significant impact on ecosystems. The prediction of weather events is possible by tracking weather conditions.

**Vertical Alignment:** In second grade, students are introduced toweather events and the collection of weather data for identification of weather patterns (2.6, 2.7). The concept is expanded in sixth grade as students investigate the effects of uneven distribution of thermal energy on Earth as it relates to weather and climate (6.7).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Thermal energy transfer from the sun impacts air movement and weather conditions. Models constructed based on patterns in atmospheric conditions are used to predict weather.   * The analysis of weather data is used to predict weather events which can affect ecosystems. Such impacts include flooding, droughts, and destruction of habitats. Average weather data over at least 30 years determines a region’s climate. Some weather components that make up climate include average temperature, humidity, wind, and amount of precipitation (4.4 a, b, c). * Some components used to describe weather are temperature, atmospheric pressure, wind speed, precipitation, and cloudiness. Data describing these components, along with the knowledge of atmospheric processes, help meteorologists forecast the weather (4.4 a). * Clouds are associated with certain weather conditions (4.4 a). * Cumulus clouds are fluffy and white with flat bottoms. They usually indicate fair weather. However, when the clouds get larger and darker on the bottom, they become cumulonimbus clouds. Cumulonimbus clouds may produce thunderstorms. * Stratus clouds are smooth, gray clouds that cover the whole sky (and block out direct sunlight). Light rain and drizzle are usually associated with stratus clouds. * Cirrus clouds are feathery clouds. They are associated with fair weather. Cirrus clouds often indicate that rain or snow will fall within several hours. High pressure air masses are associated with clear skies and light winds. Low pressure air masses are associated with stormy weather and strong winds. *Students are not expected to identify or interpret fronts or pressure systems on a weather map.*   The atmosphere is a dynamic system and changes in conditions cause weather phenomena that may affect an ecosystem.   * On Earth, atmospheric conditions create weather phenomena. Common events include rain, snow, and fog. Extreme events include tornadoes, hurricanes, typhoons, and ice storms (4.4 b). * Thunderstorms—Warm, humid conditions are very favorable for thunderstorm development. A typical thunderstorm produces a brief period of heavy rain and lasts anywhere from 30 minutes to an hour. Lightning always precedes thunder. * Hurricanes—Hurricanes occur over warm, tropical water and have winds equal to or greater than 74 miles per hour. * Tornados—Most tornadoes form from thunderstorms as the wind changes direction and the air begins to rotate. * Weather is the day-to-day state of the atmosphere for a given area. Climate is the weather of a given area averaged over an extended period of time (years) (4.4 c). | In order to meet this standard, it is expected that students will   * analyze and report data on temperature and precipitation (4.4 a) * differentiate among the types of weather associated with high-pressure and low-pressure air masses (4.4 a) * differentiate among cloud types (i.e., cirrus, stratus, cumulus, and cumulonimbus clouds) and the weather associated with each (4.4 a) * use weather instruments (thermometer, barometer, rain gauge, anemometer) and observations of sky conditions to collect, record, and graph weather data over time; analyze results and determine patterns that may be used to make weather predictions (4.4 a) * discuss the importance of monitoring weather data to make weather predictions (4.4 a) * recognize a variety of storm types and the conditions and types of precipitation associated with each; explain when these storms occur (4.4 b) * research and analyze the effects of extreme weather events on the environment (4.4 b) * explain the difference between weather and climate and the effect climate has on an ecosystem (4.4 c). |

**4.5 The student will investigate and understand that the planets have characteristics and a specific place in the solar system. Key ideas include**

1. **planets rotate on their axes and revolve around the sun;**
2. **planets have characteristics and a specific order in the solar system; and**
3. **the sizes of the sun and planets can be compared to one another.**

**Central Idea:** Our solar system is composed of planets with unique characteristics, primarily due to their locations within the system. Earth is unique in that its characteristics and location allow for life to exist.

**Vertical Alignment**: Although students learn characteristics of Earth in lower grades, fourth grade is the first time students are introduced to the planets that make up the solar system. The components and interactions of celestial bodies within the solar system is the focus in sixth grade science (6.2).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
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| The solar system is a set of interrelated and interdependent elements that are connected through the flow of matter and energy. Characteristics of these elements within the solar system are determined by their composition.   * Our solar system is ancient. Early astronomers believed that Earth was the center of the universe and all other heavenly bodies orbited around Earth. We now know that our sun is the center of our solar system and the planets revolve around the sun (4.5 a). * Our solar system is made up of eight planets: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. Mercury, Venus, Earth, and Mars are considered terrestrial planets. Jupiter, Saturn, Uranus, and Neptune are called gas giants (4.5 b, c). *Student are not responsible for describing sizes of planets in relation to Earth’s size.* * Mercury is closest to the sun and is a small, heavily cratered planet. Mercury looks like our moon. Mercury is the smallest planet in our solar system and its atmosphere is very thin. * Venus is the second planet from the sun. Similar to Earth in size and mass, Venus has a permanent blanket of clouds that traps thermal energy which causes high surface temperatures. * Earth is the third planet from the sun. Earth’s atmosphere, its liquid water, and its distance from the sun (among other factors) make Earth ideal for life. * Mars is the fourth planet from the sun and is sometimes called *the red planet*. The atmosphere on Mars is thin. Mars has a vast network of canyons and riverbeds. Mars is roughly half the size of Earth. * Jupiter is the fifth planet from the sun, the largest planet in the solar system (eleven times larger than Earth), and it is considered a gas giant. Jupiter has no solid surface. Its colored cloud patterns are caused by enormous storms in its atmosphere. * Saturn is the sixth planet from the sun. Early scientists thought Saturn was the only planet with rings, but we now know that all four gas giants (Jupiter, Saturn, Uranus, and Neptune) have rings. Saturn’s atmosphere is similar to that of Jupiter. Saturn is almost ten times the size of Earth. * Uranus is the seventh planet from the sun. Uranus is a gas giant and is unique in that it spins on its side. It has a large atmosphere and is a cold planet that is four times the size of Earth. * Neptune, a very cold planet, is eighth from the sun. Neptune appears blue because of its atmosphere. It is roughly four times the size of Earth. * Pluto is no longer included in the list of planets in our solar system due to its small size and irregular orbit (4.5 b). | In order to meet this standard, it is expected that students will   * create a model that demonstrates the differences between rotation and revolution (4.5 a) * research the planets and communicate basic characteristics of each, including whether each is terrestrial or a gas giant, and its relative location in the solar system (4.5 b) * construct and interpret a simple model to show the location and order of planets in relation to the sun in our solar system (4.5 b) * compare the relative sizes of the planets to each other as well as to the sun (4.5 c). |

**4.6 The student will investigate and understand that there are relationships among Earth, the moon, and the sun. Key relationships include**

**a) the motions of Earth, the moon, and the sun;**

**b) the causes for Earth’s seasons;**

**c) the causes for the four major phases of the moon and the relationship to the tide cycles; and**

**d) the relative size, position, age and makeup of Earth, the moon, and the sun.**

**Central Idea:** The relationship of the Earth, moon, and sun in the solar system and to each other lead to seasons, tides, and the phases of the moon.

**Vertical Alignment:** Students are introduced to the effect of the sun on the temperatures of land, water, and air in first grade (1.6). In sixth grade, students further explore Earth’s unique properties and movements as well as the causes of seasons and the tides (6.3).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
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| The proximity of the Earth to the sun and moon in our solar system influences Earth systems and enable life to exist on Earth.   * The interactions and orientations of the sun, Earth, and moon lead to patterns that are evidenced in seasons, eclipses, and the phases of the moon (4.6). * Earth’s axial tilt causes the sun’s rays to hit the Earth’s surface at different angles. More direct rays are more intense, resulting in higher temperatures at those locations (4.6 b). * The phases of the moon are caused by its position relative to the Earth and the sun. The phases of the moon are caused by the reflection of sunlight off the moon’s surface and include the following phases: new, first quarter, full, and last (third) quarter (4.6 c). *Students are not responsible for the terms* waxing crescent, waxing gibbous, waning gibbous*, and* waning crescent*.* * The phases of the moon are responsible for the changes in tidal range. Highest tidal ranges are associated with full and new moons, which are when the Earth, moon and sun are aligned. The smallest tidal ranges are associated with the first and last quarter, when the earth, sun, and moon are at right angles (4.6 c) *Students are not responsible for the terms* spring *and* neap *tides.* * The sun is an average-sized yellow star, about 110 times the diameter of Earth. The sun is approximately 4.6 billion years old (4.6 d). * Our moon is a small, rocky satellite, having about one-quarter the diameter of Earth and one-eightieth its mass. It has extremes of temperature, and no atmosphere or water to support life (4.6 d). * Earth’s surface is constantly changing. Unlike the other three inner planets, it has large amounts of life-supporting water and an oxygen-rich atmosphere. Earth’s protective atmosphere blocks out most of the sun’s damaging rays (4.6 d). | In order to meet this standard, it is expected that students will   * create a model that demonstrates the motions of the moon, sun, and Earth and use it to describe how the main phases of the moon occur (i.e., new moon, first quarter, full moon, and last quarter) (4.6 a, c) * model and describe how the Earth’s rotation results in day and night (a) * model and describe how Earth’s axial tilt and its revolution around the sun causes seasons (4.6 b) * analyze data from simple tide tables to determine a pattern of high and low tides (4.6 c) * analyze simple tide tables and the phases of the moon over time to explain the relationship between the tides and the phases of the moon (4.6 c) * compare the relative size, position, age, and composition of the sun, moon, and Earth (4.6 d). |

**4.7 The student will investigate and understand that the ocean environment has characteristics. Key characteristics include**

1. **geology of the ocean floor;**
2. **physical properties and movement of ocean water; and**
3. **interaction of organisms in the ocean.**

**Central Idea:** The ocean is a dynamic system that covers most of Earth’s surface; its characteristics are unique and allow it to support a diverse number of organisms.

**Vertical Alignment**: Students are introduced to the characteristics of aquatic and terrestrial ecosystems, including living and nonliving components, in third grade (3.5). Further exploration of the geological, physical, and biological aspects of the ocean environment is conducted in Earth Science (ES.10).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
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| Ocean systems are comprised of interacting and interdependent elements that are subject to change in response to inputs and outputs of energy and matter.   * The ocean’s geological and physical properties affect the interactions among organisms (4.7 a, b, c). * Important features of the ocean floor are the continental shelf, continental slope, continental rise, abyssal plain, and ocean trenches. Most areas are covered with thick layers of sediments (e.g., sand, mud, rocks) (4.7 a). *Students are not expected to memorize these features.* * The depth of the ocean varies. Ocean trenches are very deep and the continental shelf is relatively shallow (4.7 a). *Students do not need to know the zones of the ocean*. * Ocean water is a complex mixture of gases, water, and dissolved solids. Marine organisms are dependent on dissolved gases for survival (4.7 b). * Salinity is the measure of all salts dissolved in water. The salinity of ocean water varies in some places, depending on rates of evaporation, the depth of the water, melting icebergs, and amount of runoff from nearby land (4.7 b). * Ocean currents, including the Gulf Stream, are caused by wind patterns and the differences in water due primarily to temperature differences. Ocean currents affect the mixing of ocean waters. This can affect plant and animal populations. Currents also affect navigation routes (4.7 b). *Students are not responsible for the term* density*. Students do not need to classify currents as surface and deep currents.* * In oceans, both plants and floating organisms such as algae serve as producers within a food chain (4.7 c). * Organisms in the ocean environment are grouped according to their movement: floating organisms (e.g., plankton), swimming organisms, and organisms that are non-moving and adhere to surfaces on the ocean floor. These organisms play a role in ocean food chains (4.7 c). | In order to meet this standard, it is expected that students will   * construct a model of the ocean floor and label and describe each of the major features, including the relative depths of each (4.7 a) * demonstrate and explain how wind causes the formation of currents (4.7 b) * compare the motions of water as related to currents and tides (4.7 b) * construct a model of a basic marine food web, including floating organisms (plankton), swimming organisms, and organisms living on the ocean floor (4.7 c) * interpret diagrams related to the ecological characteristics of the ocean, such as the types of organisms vs. the depth of the water (4.7 c) * research and communicate where organisms live in the ocean and infer reasons they live within those areas (4.7 c). |

#### Earth Resources

**4.8 The student will investigate and understand that Virginia has important natural resources. Key resources include**

1. **watersheds and water;**
2. **plants and animals;**
3. **minerals, rocks, and ores; and**
4. **forests, soil, and land.**

**Central Idea:** Virginia has many natural resources, including watersheds, minerals, rocks, ores, soil, land, and forests.

**Vertical Alignment**: The importance of resources is a consistent theme in all elementary years, with third grade focusing on the importance of water and soil as resources (3.8). In sixth grade, students deepen their understanding of human impact on the environment and learn how individuals can influence public policy decisions related to energy and the environment (6.9).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Natural resources are necessary or useful to humans. Many natural resources are distributed unevenly around the planet.   * Virginia has many natural resources. Some examples of Virginia’s natural resources include minerals, plants, animals, water, soil, and land (4.8 a, b, c, d). * A watershed is an area of land over which surface water flows to a single collection place. The materials from the watershed, including pollutants, add to the water flow and impact organisms that may serve as a natural resource for humans. The Chesapeake Bay watershed covers approximately half of Virginia’s land area. The other two major watershed systems in Virginia are the Gulf of Mexico and the North Carolina sounds (4.8 a). *Students do not need to identify all the major watersheds in Virginia; however, they should be able to identify the watershed in which they live.* * Virginia’s water resources include lakes, rivers, bays, and the Atlantic Ocean (4.8 a). * Virginia has a great variety of plant and animal resources. Plants hold soil in place to reduce erosion, which aids in improving water quality. Plants provide food, materials for shelter, habitats, and add oxygen to the air. Animals provide materials such as food, fiber, and leather (4.8 b). * Healthy populations of plants and animals are critical for life (4.8 b). * Minerals, ores, and rocks are considered natural resources and have specific purposes in everyday life (e.g., building materials and fuel sources) (4.8 c). *Students do not need to know specific minerals and do not need to differentiate among minerals, ores, and rocks.* * Natural and cultivated forests are widespread resources in Virginia. Uses of forests include providing building materials, fuel, and habitats (4.8 d). * Virginia’s soil and land support a great variety of life and provide space for us to live, work, and play (4.8 d). | In order to meet this standard, it is expected that students will   * describe characteristics of Virginia’s waterways (including rivers, bays, lakes, and the Atlantic Ocean), name an example of each, and discuss the importance of the waterways to Virginia (4.8 a) * create and interpret a model of a watershed (4.8 a) * use evidence to explain the statement, “We all live downstream.” (4.8 a) * explain the importance of Virginia’s animals and plants to humans (4.8 b) * research a Virginia mineral, ore, and/or rock and communicate its use in everyday applications (4.8 c) * describe a variety of important land uses in Virginia, including natural and cultivated forests (4.8 d) * investigate the school yard or local ecosystem to identify questions, problems, or issues that affect a natural resource in that area and determine a possible solution to an identified problem (4.8 a, b, c, d). |

## Grade Five

***Transforming matter and energy***

Grade five science delves more deeply into foundational concepts in physical science, and students begin to make connections between energy and matter. Students explore how energy is transformed and learn about electricity, sound, and light. They also learn about the composition of matter and explore how energy can change phases of matter. Students apply an understanding of force, matter, and energy when they explore how the Earth’s surface changes. Students continue to develop scientific skills and processes as they pose questions and predict outcomes, plan and conduct investigations, collect and analyze data, construct explanations, and communicate information about the natural world. Mathematics and computational thinking gain importance as students advance in their scientific thinking. Students continue to use the engineering design process to apply their scientific knowledge to solve problems.

### Scientific and Engineering Practices

Engaging in the practices of science and engineering helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the many ways to investigate, model, and explain the world. These scientific and engineering practices include the use of scientific skills and processes to explore the content of science as outlined in the *Science Standards of Learning*. The engineering design practices are the application of science content to solve a problem or design an object, tool, process, or system. These scientific and engineering practices are critical to science instruction and are to be embedded throughout the year.

**5.1 The student will demonstrate an understanding of scientific and engineering practices by**

1. **asking questions and defining problems**

* **ask testable questions based on observations and predict reasonable outcomes based on patterns**
* **develop hypotheses as cause-and-effect relationship**
* **define design problems that can be solved through the development of an object, tool, process, or system**

1. **planning and carrying out investigations**

* **collaboratively plan and conduct investigations to produce data**
* **identify independent variable, dependent variables, and constants**
* **determine data that should be collected to answer a testable question**
* **take­ metric measurements using appropriate tools**
* **use tools and/or materials to design and/or build a device that solves a specific problem**

1. **interpreting, analyzing, and evaluating data**

* **represent and analyze data using tables and graphs**
* **organize simple data sets to reveal patterns that suggest relationships**
* **compare and contrast data collected by different groups and discuss similarities and differences in their findings**
* **use data to evaluate and refine design solutions**

1. **constructing and critiquing conclusions and explanations**

* **construct and/or support arguments with evidence, data, and/or a model**
* **describe how scientific ideas apply to design solutions**
* **generate and compare multiple solutions to problems based on how well they meet the criteria and constraints**

1. **developing and using models**

* **develop models using an analogy, example, or abstract representation to describe a scientific principle or design solution**
* **identify limitations of models**

1. **obtaining, evaluating, and communicating information**

* **read and comprehend reading-level-appropriate texts and/or other reliable media**
* **communicate scientific information, design ideas, and/or solutions with others**

### Grade Five Science Content

#### Force, Motion, and Energy

**5.2 The student will investigate and understand that energy can take many forms. Key ideas include**

1. **energy is the ability to do work or to cause change;**
2. **there are many different forms of energy;**
3. **energy can be transformed; and**
4. **energy is conserved.**

**Central Idea:** Energy can occur in different forms, can be transformed from one form to another, but it cannot be created or destroyed.

**Vertical Alignment:** Students are introduced to the sun as the source of energy for the water cycle in third grade (3.7). The importance of the sun in the formation of most energy sources, energy transformations, and the conservation of energy is emphasized in sixth grade (6.4, 6.6, 6.9).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
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| Energy is the ability to cause change or do work. Energy can be transferred in various ways and between objects.   * Energy is the ability to cause change and that change can take multiple forms (5.2 a). *Students are not expected to give a precise or complete definition of* energy. * At the macroscopic level, energy manifests itself in multiple phenomena, such as motion, light, sound, electrical and magnetic fields, and thermal energy (5.2 a). * Energy cannot be created or destroyed; however, it can transform from one form into another. Energy can take many forms such as thermal, radiant, mechanical, and electrical (5.2 a, b, c, d). * Energy can be transformed from one form to another to do work. *Work*, in a scientific sense, is defined as a force acting upon an object, causing that object to move in the direction of the force (5.2 a). *Students are not responsible for calculating work*. * Energy can be moved from place to place by moving objects, or through sound, light, or electric currents (5.2 b). * Energy can change forms but cannot be created or destroyed. For example, electrical energy is transformed into thermal energy when a stove is turned on. The electrical energy does not just disappear and thermal energy does not just appear out of nowhere (5.2 c, d). | In order to meet this standard, it is expected that students will   * recognize examples of energy causing change or doing work (5.2 a) * compare forms of energy (5.2 b) * make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents, and through contact between objects (5.2 b) * describe everyday examples of energy changing forms (5.2 c) * identify the energy transformations that occur when energy is used to run a device in the home or school (5.2 c) * apply scientific ideas to design, test, and refine a device that converts energy from one form to another (5.2 c) * explain that energy is conserved and cannot be created or destroyed; energy can change forms (5.2 d). |

**5.3 The student will investigate and understand that there is a relationship between force and energy of moving objects. Key ideas include**

1. **moving objects have kinetic energy;**
2. **motion is described by an object’s direction and speed;**
3. **changes in motion are related to net force and mass;**
4. **when objects collide, the contact forces transfer energy and can change objects’ motion; and**
5. **friction is a force that opposes motion.**

**Central Idea:** An object’smotion is described by its direction and the speed.

**Vertical Alignment:** Students learn about net forces and apply forces to demonstrate work done by simple machines in third grade (3.2). In Physical Science, students further explore motion as they learn Newton’s laws and deepen their understanding of the relationship between machines and the force required to do work (PS.8).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Forces between objects can cause a change in motion. When two objects interact, each exerts a force on the other. These forces can transfer energy between objects which can cause changes in their motion.   * Moving objects have kinetic energy, which is the energy of motion. The motion of an object is described by its direction and speed (5.3 a). * A change in motion is related to net force and mass (5.3 c). * The net force is the combination of all the forces acting on an object (5.3 b). *Students are not expected to calculate net force.* * Whether an object stays still or moves often depends on the effects of multiple pushes or pulls. 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 net force can cause changes in the object’s speed or direction of motion (5.3 b). *Students are not expected to calculate net force.* * When objects collide, the energy from one object transfers to another object. That transfer in energy can change an object's speed and or direction (5.3 a, b, c, d, e). * Motion is described as an object’s direction and speed (5.3 b). *Students do not calculate speed until Physical Science*. * Speed describes how fast an object is moving (5.3 b). * Unless acted on by a force, objects in motion tend to stay in motion and objects at rest remain at rest (5.3 c). * A *force* is any push or pull that causes an object to move, stop, or change speed or direction (5.3 c). * With objects of the same mass, the greater the force, the greater the change in motion. The more massive an object, the less effect a given force will have on that object (5.3 c). * Friction is a force that opposes the motion of an object (5.3 e). | In order to meet this standard, it is expected that students will   * define *kinetic energy* (5.3 a) * describe the motion of an object using both direction and speed (5.3 b) * plan an experiment to collect time and position data for a moving object in a table and line graph and interpret the data to determine if the speed of the object was increasing, decreasing, or remaining the same (5.3 b) * plan and conduct an investigation related to net force and the movement of an object (5.3 c, e) * plan and conduct an investigation to test the question, “What is the relationship between motion and mass?” (5.3 c, e) * ask questions and predict outcomes about the changes in motion that occur when objects collide (5.3 d) * interpret data in graphs, charts, and/or diagrams related to force and the motion of objects (5.3 c, d) * plan and conduct an investigation to determine the effect of friction on moving objects (5.3 e). |

**5.4 The student will investigate and understand that electricity is transmitted and used in daily life. Key ideas include**

1. **electricity flows easily through conductors but not insulators;**
2. **electricity flows through closed circuits;**
3. **static electricity can be generated by rubbing certain materials together;**
4. **electrical energy can be transformed into radiant, mechanical, and thermal energy; and**
5. **a current flowing through a wire creates a magnetic field.**

**Central Idea:** Energy can move from one location to another through electrical circuits; this energy can then be transformed into different forms for multiple uses.

**Vertical Alignment:** Although students have been introduced to the concept of energy in early years, the study of electricity is new in fifth grade. In Physical Science, static and current electricity as well as electromagnets, motors, and generators will be introduced (PS.9).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| The flow of energy as a current through the circuit can be used to do work. The circuit is a system composed of various functioning components.   * Electricity is used every day. Humans transform electrical energy into different forms of energy to meet needs (5.4). * Conductors are materials which allow electricity to easily flow through them. Examples of conductors include metals. Insulators are materials that do not allow electricity to flow easily through them. Examples of insulators include rubber, wood, and plastics (5.4 a). * A closed circuit allows electricity to flow within the circuit. If there is an opening in the circuit, electricity will not flow (5.4 b). * A simple circuit consists of a bulb, battery, and wire (5.4 b). *Students are not expected to recognize or build series and parallel circuits.* * Static electricity is the transfer of negatively charged particles between materials. Common examples of static electricity include lightning, clothes sticking together when coming out of a dryer, and getting a shock when touching a door knob (5.4 c). *Students are not responsible for knowing how static electricity occurs.* * In a lamp, electrical energy is transformed into radiant energy. In a fan, electrical energy is transformed into mechanical energy. In a toaster, electrical energy is transformed into thermal energy (5.4 d). *Students do not need to account for all energy transformations within a system*. * A current flowing through a wire creates a magnetic field. Wrapping a wire around certain iron-bearing metals (e.g., an iron nail) and creating a closed circuit is an example of a simple electromagnet. The strength of an electromagnet is mainly affected by the number of coils, the amount of current, the gauge of the wire, and the iron core (5.4 e). | In order to meet this standard, it is expected that students will   * provide examples of materials that are good electrical conductors and insulators (5.4 a) * differentiate between open and closed electric circuits (5.4 b) * create a model of a simple circuit and explain how it works (5.4 b) * create a functioning simple circuit and explain how the circuit works, using appropriate scientific terms (5.4 b) * provide examples of static electricity (5.4 c) * identify ways to generate static electricity (5.4 c) * illustrate simple energy transformations (electrical to thermal, electrical to radiant, and electrical to mechanical) (5.4 d) * construct a simple electromagnet using a dry cell, wire, nail, or other object containing iron (5.4 e) * plan and conduct an investigation to determine the strength of an electromagnet (5.4 e) * define a problem and design a solution that uses an electromagnet; demonstrate and explain how the electromagnet works (5.4 e). |

**5.5 The student will investigate and understand that sound can be produced and transmitted. Key ideas include**

1. **sound is produced when an object or substance vibrates;**
2. **sound is the transfer of energy;**
3. **different media transmit sound differently; and**
4. **sound waves have many uses and applications.**

**Central Idea:** Energy can be transmitted through different media (solids, liquids, gases) in waves. The transfer of energy in waves causes vibrations that can produce sound.

**Vertical Alignment:** Students are introduced to sound as a vibrating movement of an object in first grade (1.2). In Physical Science, the understanding of sound waves is expanded to include sound wave characteristics and interactions (PS.6).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
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| Waves transmit energy from one place to another. Sound is produced as these waves cause vibrations as they travel through matter.   * Sound is a form of mechanical energy produced and transmitted by vibrating matter. Mechanical energy is the energy an object has due to its motion or position (5.5 a, b). * In sound waves, energy is transferred through the vibration of particles of the medium through which the sound travels (5.5 a). * Sound travels in compression waves and must have a medium through which to travel. Sound also travels in liquids and solids (5.5 a). * Sound travels more quickly through solids than through liquids and gases because the particles of a solid are closer together. Sound travels the slowest through gases because the particles of a gas are farthest apart (5.5 c). * Objects vibrating rapidly have a higher pitch than objects vibrating more slowly (5.5 c). * Musical instruments vibrate to produce sound. There are many different types of musical instruments and each instrument causes vibrations in different ways (5.5 d). | In order to meet this standard, it is expected that students will   * explain how sounds are formed (5.5 a, b) * collaboratively plan and conduct an investigation to demonstrate that vibrating materials can produce sound and transmit energy, determine data that should be collected and organized to identify patterns, and communicate findings (5.5 a) * compare sound traveling through a solid and sound traveling through the air (5.5 c) * analyze and explain how different musical instruments produce sound (5.5 d) * design and construct an instrument that produces at least two different pitches; record design changes made based on testing outcomes, and communicate results and challenges (5.5 d) * identify applications of sound in the home and community (5.5 d). |

**5.6 The student will investigate and understand that visible light has certain characteristics and behaves in predictable ways. Key ideas include**

1. **visible light is radiant energy that moves in transverse waves;**
2. **the visible spectrum includes light with different wavelengths;**
3. **matter influences the path of light; and**
4. **radiant energy can be transformed into thermal, mechanical, and electrical energy.**

**Central Idea:** Visible light is a form of radiant energy that can be seen and can interact in different ways when it contacts an object.

**Vertical Alignment:** Students are introduced to the sun as a source of light and warmth in first grade (1.6). In Physical Science, the concept of light is expanded to include the electromagnetic spectrum. Characteristics of light and its interactions are discussed as students build a more sophisticated understanding of technological applications of electromagnetic radiation (PS.7).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Energy may take different forms, including radiant energy. Radiant energy that can be seen by the human eye is called *visible light*.   * The sun produces radiant energy. Many types of radiant energy cannot be seen (5.6 a). *Students do not need to identify the electromagnetic spectrum.* * Light travels in transverse waves and does not need a medium through which to move (5.6 a). * Light waves are characterized by their wavelengths. A *wavelength* is the distance between any two corresponding points on successive waves (usually crest-to-crest or trough-to-trough). The wavelength can be measured from any point on a wave provided it is measured to the same point on the next wave (5.6 b). * *Frequency* is the number of waves passing a given point in a designated time. The greater the frequency, the greater the amount of energy (5.6 b). * The visible spectrum has a range of colors that are determined by wavelength. The colors of the spectrum from the longest wavelength to the shortest wavelength are red, orange, yellow, green, blue, and violet (ROYGBV). The sum of these colors is white light (5.6 b). *Students are not responsible for indicating wavelengths associated with color.* * Light travels in straight paths until it hits an object, where it is reflected, refracted, transmitted, and/or absorbed (5.6 c). Examples of refraction, or bending of waves, include * refraction causing a setting sun to look flat * a spoon appearing to bend when immersed in a cup of water * a glass prism dispersing white light into its individual colors as the colors refract at different angles (as visible light exits the prism, it is refracted and separated into the visible spectrum). * Light can be reflected when light bounces off an object. An example of this is light hitting a mirror (5.6 c). * Light passes through some materials easily (transparent materials), through some materials partially (translucent materials), and through some not at all (opaque materials). The relative terms *transparent*, *translucent*, and *opaque* indicate the amount of light that passes through objects (5.6 c). * Examples of transparent materials include clear glass, clear plastic wrap, water, and air. * Examples of translucent materials include wax paper, frosted glass, thin fabrics, and thin paper. * Examples of opaque materials include metal, wood, and bricks. * Light transfers radiant energy. For example, energy radiated from the sun is transferred to Earth by light. When this light is absorbed, it warms Earth’s land, air, and water and facilitates plant growth through the process of photosynthesis. Current technology also transforms light energy into mechanical and electrical energy; an example of this is the use of solar panels to produce electrical power (5.6 d). | In order to meet this standard, it is expected that students will   * explain the relationship between energy and visible light (5.6 a) * construct a model of a transverse wave and label a wavelength, crest, and trough (5.6 a) * describe the relationship between wavelength and color of light (5.6 b) * create models illustrating high- and low-energy light waves (5.6 b) * plan and conduct an investigation using water, mirrors, and prisms to explore the reflection and refraction of light (5.6 b, c) * plan and conduct an investigation to determine how different materials interact with light (5.6 c) * compare the reflection and refraction of light (5.6 c) * describe examples of radiant energy transfer in both nature and the manmade world (5.6 d). |

#### Matter

**5.7 The student will investigate and understand that matter has properties and interactions. Key ideas include**

1. **matter is composed of atoms;**

**b) substances can be mixed together without changes in their physical properties; and**

**c) energy has an effect on the phases of matter.**

**Central Idea:** *Matter* is defined as anything that has mass and takes up space. Properties of various types of matter determine their uses.

**Vertical Alignment:** Students are introduced to solutions in third grade as materials interact with water (3.3). In sixth grade, students further develop their understanding of atoms, as they learn about subatomic particles, compounds, and chemical change (6.5).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Matter consists of atoms that have different properties. These properties determine interactions that can occur among different atoms. Different substances with different properties are suited to different uses.   * *Matter* is anything that has mass and takes up space (has volume) (5.7 a). * *Mass* is the amount of matter in an object (5.7 a). *Students are not responsible for explaining the weight or proportion of weight on various planets and moons.* * Matter of any type can be subdivided into particles called *atoms* that are too small to see but can be detected by other means. Examples include blowing up a balloon, compressing air in a syringe, and dissolving sugar in water (5.7 a). *Students are not expected to identify the structure of the atom or subatomic particles*. * Sometimes when two or more substances are combined, they do not lose their identifying characteristics. These substances are called mixtures. Examples of mixtures include soil, concrete, and a mud puddle (5.7 b). * Solutions are a special type of mixture in which one substance is uniformly dissolved in a liquid. Examples include sugar water, salt water, and soda (5.7 b). *Students are not responsible for the terms* solubility*,* solute*, and* solvent*.* * Many kinds of matter change from a solid to a liquid to a gas when undergoing a temperature increase. As temperature decreases, that matter changes from a gas to a liquid to a solid (5.7 c). * Matter does not gain or lose mass during phase changes (5.7 c). | In order to meet this standard, it is expected that students will   * make observations and measurements to identify materials based on their properties (5.7) * define *matter* (5.7 a) * construct a simple model to show that matter is composed of atoms and identify the advantages and the limitations of the model (5.7 a) * plan and conduct an experiment to separate two or more types of matter within a mixture (5.7 b) * explain the role of energy in changing the phase of matter of a substance (5.7 c) * measure and graph quantities to demonstrate that, regardless of the type of change that occurs when heating, cooling, or mixing substances, the total mass of matter is unchanged (5.7 c). |

#### Earth and Space Systems

**5.8 The student will investigate and understand that Earth constantly changes. Key ideas include**

1. **Earth’s internal energy causes movement of material within the Earth;**
2. **plate tectonics describe movement of the crust;**
3. **the rock cycle models the transformation of rocks;**
4. **processes such as weathering, erosion, and deposition change the surface of the Earth; and**
5. **fossils and geologic patterns provide evidence of Earth’s change.**

**Central Idea:** Earth’s geosystem is constantly changing; these changes are modeled in the rock cycle and through plate tectonics.

**Vertical Alignment:** Students describe the importance of Virginia’s minerals and ores, including quartz, coal, granite, and limestone in fourth grade (4.8). In sixth grade, students investigate water’s role in weathering (6.6).

| **Enduring Understandings** | **Essential Knowledge and Skills** |
| --- | --- |
| A system is a set of interrelated parts that make up a unified whole. The Earth system is composed of interrelated parts to include the atmosphere (air), geosphere (solid Earth), biosphere (organisms), and hydrosphere (water). Systems are seamlessly connected through the flow of matter and energy.   * Earth is constantly changing; these changes occur both on and beneath Earth’s surface (5.8). * Earth is composed of four concentric layers—the crust, mantle, outer core, and inner core—each with its own distinct characteristics. The outer two layers are composed primarily of rocky material. The innermost layers are composed mostly of iron and nickel. Pressure and temperature increase with depth beneath the surface (5.8 a). * Earth’s thermal energy causes movement of material within Earth. Large continent-size plates move slowly about Earth’s surface, driven by that thermal energy (5.8 a). * Most earthquakes and volcanoes are located at the boundaries of the plates (*faults*). Plates can move toward each other (*convergent boundaries*), apart from each other (*divergent boundaries*), or slip past each other horizontally (*transform boundaries*) (5.8 b). *Students are not expected to use the terminology when demonstrating Earth’s movement.* * Geological features in the oceans (including trenches and mid-ocean ridges) and on the continents (mountain ranges, including the Appalachian Mountains) are caused by current and past plate movements (5.8 b). * Rocks move and change due to heat and pressure within Earth and due to weathering, erosion, and deposition at the surface. These and other processes constantly change rock from one type to another (5.8 c). * Depending on how rocks are formed, they are classified as *sedimentary* (layers of sediment cemented together), *igneous* (melted and cooled), and *metamorphic* (changed by heat and pressure) (5.8 c). *Students are not responsible for identifying specific examples of sedimentary, metamorphic, or igneous rocks*. * Rocks and other materials on Earth’s surface are constantly being broken down by both chemical and physical weathering. The products of weathering include clay, sand, rock fragments, and soluble substances (5.8 d). * Materials can be moved by water and wind (*erosion*) and deposited in new locations as sediment (*deposition*) (5.8 d). * Fossils provide information about life and conditions in the past. Fossils may be found in different rock layers, which allows scientists to infer changes in landscapes (5.8 e). | In order to meet this standard, it is expected that students will   * describe the structure of Earth in terms of its major layers: crust, mantle, inner core, and outer core (5.8 a) * model the movements of plates at tectonic boundaries (divergent, convergent, and transform), explain how the movement of tectonic plates relates to the changing surface of Earth, and describe the benefits and limitations of the models created (5.8 b) * compare the origins of igneous, sedimentary, and metamorphic rocks (5.8 c) * draw and label a simple diagram of the rock cycle and describe the major processes and rock types involved (5.8 c) * compare the formation of igneous, sedimentary, and metamorphic rocks (5.8 c) * use a dichotomous classification key to identify rocks (5.8 c) * make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, or wind (5.8 d) * model weathering, erosion, and deposition and explain the benefits and limitations of the model(s) created (5.8 d) * locate, chart, and report weathering, erosion, and deposition at home or on the school grounds; create and implement a plan to reduce weathering, erosion, and/or deposition problems that may be found and discuss the results of the experiment (5.8 d) * identify evidence from patterns in rock formations and fossils in rock layers to support an explanation for changes in a landscape over time (5.8 e). |

#### Earth Resources

**5.9 The student will investigate and understand that the conservation of energy resources is important. Key ideas include**

1. **some sources of energy are considered renewable and others are not;**

**b) individuals and communities have means of conserving both energy and matter; and**

**c) advances in technology improve the ability to transfer and transform energy.**

**Central Idea:** Some resources are considered renewable and others are not. It is possible to conserve energy.

**Vertical Alignment:** Students learn about the importance of Virginia’s natural resources in fourth grade (4.8). In sixth grade, students will learn how to manage the resources and the cost and benefits of that maintenance (6.9).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Energy cannot be created or destroyed; however, the availability of certain energy sources differs. Most of the energy used in the United States comes from non-renewable sources.   * Energy and fuels that humans use derive from natural sources (5.9 a). * Nonrenewable energy sources are natural resources that cannot be replaced after they are used because they take millions of years to form. Fossil fuels such as petroleum, coal, and natural gas are all nonrenewable energy sources (5.9 a). * Renewable energy sources come from resources that are replaced naturally and can be used again. Wind energy, water behind dams, and sunlight are examples of renewable energy sources (5.9 a). * Energy use affects the environment in many ways. In general, fossil fuels do more harm to the environment than the use of renewable energy sources. Some harmful consequences of energy use include air and water pollution and wildlife and habitat loss (5.9 a). * There are many ways to conserve energy. In the home, actions such as turning off the lights and electronic devices when not in use, taking shorter hot showers, and adjusting the thermostat by a few degrees (higher in summer, lower in winter) will conserve energy. Walking or biking instead of taking the car for short trips also conserves energy (5.9 b). * Advances in technology continually improve our ability to harness and use energy more efficiently (5.9 c). | In order to meet this standard, it is expected that students will   * compare energy sources, including their benefits and limitations (5.9 a) * identify the type(s) of energy used in the home or school to power devices and research the origin of the identified energy, including how long it takes to form, and classify it as either a renewable or nonrenewable source (5.9 a) * analyze and interpret data showing human consumption of energy over the last century and infer what might happen if the trend in energy consumption continues (5.9 b) * create and implement a plan to conserve energy in the home or school (5.9 b) * provide examples of current technology that use energy efficiently (5.9 c). |

## Grade Six

***Our world; our responsibility***

In sixth grade, students are transitioning from elementary to middle school. The science standards support that transition as students examine more abstract concepts, providing a foundation in the disciplines of science. They explore the characteristics of their world, from the Earth’s placement in the solar system to the interactions of water, energy, air, and ecosystems on the Earth. As students more closely examine the use of resources, they also consider how their actions and choices affect future habitability of Earth. Students continue to develop scientific skills and processes as they pose questions and predict outcomes, plan and conduct investigations, collect and analyze data, construct explanations, and communicate information about the natural world. Mathematics and computational thinking gain importance as students advance in their scientific thinking. Students continue to use the engineering design process to apply their scientific knowledge to solve problems.

### Scientific and Engineering Practices

Engaging in the practices of science and engineering helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the many ways to investigate, model, and explain the world. These scientific and engineering practices include the use of scientific skills and processes to explore the content of science as outlined in the *Science Standards of Learning*. The engineering design practices are the application of science content to solve a problem or design an object, tool, process, or system. These scientific and engineering practices are critical to science instruction and are to be embedded throughout the year.

**6.1 The student will demonstrate an understanding of scientific and engineering practices by**

1. **asking questions and defining problems**

* **ask questions to determine relationships between independent and dependent variables**
* **develop hypotheses and identify independent and dependent variables**
* **offer simple solutions to design problems**

1. **planning and carrying out investigations**

* **independently and collaboratively plan and conduct observational and experimental investigations; identify variables, constants, and controls where appropriate, including the safe use of chemicals and equipment**
* **evaluate the accuracy of various methods for collecting data**
* **take metric measurements using appropriate tools**
* **use tools and/materials to design and/or build a device to solve a specific problem**

1. **interpreting, analyzing, and evaluating data**
   * **organize data sets to reveal patterns that suggest relationships**

* **construct, analyze, and interpret graphical displays of data**
* **compare and contrast data collected by different groups and discuss similarities and differences in findings**
* **use data to evaluate and refine design solutions**

1. **constructing and critiquing conclusions and explanations**

* **construct explanations that include qualitative or quantitative relationships between variables**
* **construct scientific explanations based on valid and reliable evidence obtained from sources (including the students’ own investigations)**
* **generate and compare multiple solutions to problems based on how well they meet the criteria and constraints**

1. **developing and using models**

* **use scale models to represent and estimate distance**
* **use, develop, and revise models to predict and explain phenomena**
* **evaluate limitations of models**

1. **obtaining, evaluating, and communicating information**

* **read scientific texts, including those adapted for classroom use, to obtain scientific and/or technical information**
* **gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication**
* **construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning**

### Grade Six Science Content

**6.2 The student will investigate and understand that the solar system is organized and the various bodies in the solar system interact. Key ideas include**

1. **matter is distributed throughout the solar system;**
2. **planets have different sizes and orbit at different distances from the sun;**
3. **gravity contributes to orbital motion; and**
4. **the understanding of the solar system has developed over time.**

**Central Idea**: The solar system is a set of interrelated and interdependent elements that are seamlessly connected through the flow of matter and energy.

**Vertical Alignment**: Students are introduced to the solar system, to include characteristics and position of planets in fourth grade (4.5). Students will extend the concept of change over time of the universe, the size and spatial relationships of matter (including celestial bodies), and the nature of science and discovery through human and technological exploration in Earth Science (ES.2).

| **Enduring Understanding** | **Essential Knowledge and Practices** |
| --- | --- |
| The solar system is a set of interrelated and interdependent elements that are seamlessly connected through the flow of matter and energy. Characteristics of these elements within the solar system are determined by their composition.   * The solar system consists of the sun, moon, Earth, other planets and their moons, meteors, asteroids, and comets. Each body has its own characteristics and features (6.2 a, b). * The distance between planets and the sizes of the planets vary greatly. The outer gas planets are very large, and the four inner planets are comparatively small and rocky (6.2 b).   Gravitational interactions are attractive and depend on the masses of interacting objects. Gravity is the force that keeps the planets in motion around the sun. Gravity acts everywhere in the universe (6.2 c).  Technological advances, breakthroughs in interpretation, and new observations continuously refine our understanding of the Earth and solar system.   * The invention of the telescope provided powerful and confounding observations that rapidly challenged the Earth-centered model. The development of mathematical physics provided a scientific explanation for the motion of the nearby planets (6.2 d). * With the development of new technology over the last half-century (e.g., manned and robotic space craft, powerful Earth-based and space telescopes, and computer analyses of huge data sets), our knowledge of the solar system has increased substantially (6.2 d). *Students are not responsible for memorizing specific missions or contributions.* | In order to meet this standard, it is expected that students will   * name the components of the solar system and describe their characteristics (6.2 a, b) * describe the planets and their relative positions from the sun (6.2 b) * identify characteristics of other components of the solar system including dwarf planets, meteors, asteroids, and comets (6.2a, b) * design, construct, and interpret a scale model of the Earth-moon-sun system and the solar system to Jupiter (6.2 b) * explain the role of gravity in the formation of the solar system and in orbital motion (6.2 c) * evaluate changes in the understanding of the solar system over time as changes in technology provided more information (6.2 d) * interpret a timeline of major developments in understanding the organization and workings of the solar system and assess the role of technology and mathematics in that development (6.2 d). |

**6.3 The student will investigate and understand that there is a relationship between the sun, Earth, and the moon. Key ideas include**

1. **Earth has unique properties;**
2. **the rotation of Earth in relationship to the sun causes day and night;**
3. **the movement of Earth and the moon in relationship to the sun causes phases of the moon;**
4. **Earth’s tilt as it revolves around the sun causes the seasons; and**
5. **the relationship between Earth and the moon is the primary cause of tides.**

**Central Idea**: Earth’s position in the solar system resulted in characteristics that support life.

**Vertical Alignment:** Students learn about the relationships among the Earth, moon, and sun and how these lead to day and night, the seasons, and the phases of the moon in fourth grade (4.6). Students will extend the cause-and-effect relationship within the sun-Earth-moon system and the stability and outcomes created by the Earth-moon relationship in Earth Science (ES.2).

| **Enduring Understanding** | **Essential Knowledge and Practices** |
| --- | --- |
| The proximity of the Earth to the sun and moon in our solar system influences Earth systems and enables life to exist on Earth.   * Earth is a rocky planet, extensively covered with large oceans of liquid water, with ice caps in its polar regions. Earth has a protective atmosphere consisting predominantly of nitrogen and oxygen and has a magnetic field. The atmosphere and the magnetic field help shield Earth’s surface from harmful solar radiation (6.3 a). * Scientific evidence indicates that Earth is about 4.5 billion years old (6.3 a).   The interactions and orientations of the sun, Earth, and moon lead to patterns that are evidenced in seasons, eclipses, and the phases of the moon.   * As Earth rotates, different sides of Earth face toward or away from the sun, causing day and night, respectively (6.3 b). * The relative positions of the moon, Earth, and sun give rise to moon phases (6.3 c). * Seasons are caused by a combination of the tilt of Earth on its axis, the curvature of Earth’s surface, and the angle at which sunlight strikes the surface of Earth during its annual revolution around the sun (6.3 d). * Tides are the result of the gravitational pull of the moon and sun on the surface waters of Earth (6.3 e). | In order to meet this standard, it is expected that students will   * describe the unique properties of Earth that enable it to support life (6.3 a) * model and describe how day and night and the phases of the moon occur (6.3 b, c) * model and explain the effect of Earth’s axial tilt and its annual orbit around the sun on the seasons (6.3 d) * explain and illustrate the relationship between the gravitational pull of the moon and the cycle of tides (6.3 e). |

**6.4 The student will investigate and understand that there are basic sources of energy and that energy can be transformed. Key ideas include**

1. **the sun is important in the formation of most energy sources on Earth;**
2. **Earth’s energy budget relates to living systems and Earth’s processes;**
3. **radiation, conduction, and convection distribute energy; and**
4. **energy transformations are important in energy usage.**

**Central Idea:** The major source of energy on Earth is solar radiation.

**Vertical Alignment:** Students learn that energy can occur in different forms and can be transformed from one form to another in fifth grade (5.4). This energy cannot be created or destroyed within a closed system. The study of energy transfer and transformation continues into Life Science as students learn about photosynthesis and cellular respiration (LS.4).

| **Enduring Understanding** | **Essential Knowledge and Practices** |
| --- | --- |
| All Earth’s processes are the result of energy flowing and mass cycling within and among Earth’s systems. The energy is derived from the sun and from Earth’s hot interior.   * Solar radiation is made up of different types of radiation (including infrared, visible light, and ultraviolet) (6.4 a). * Earth receives only a very small portion of the sun’s energy, yet this energy is responsible for powering the motion of the atmosphere, the oceans, and many processes at Earth’s surface. Earth’s surface is heated unequally (6.4 b). * Earth’s energy budget refers to the tracking of how much energy is flowing into and out of the Earth’s climate, where the energy is going, and if the energy coming in balances with the energy going out (6.4 b). * The Earth’s energy budget includes the solar energy entering and exiting Earth’s atmosphere. Excess carbon dioxide and other gases affect the energy budget, creating a greenhouse effect (6.4 b). * When air or water is heated, the molecules move faster and farther apart, reducing their density and causing them to rise. Cooler air or water molecules move more slowly and are denser than warm air or water. Warm air or water rising coupled with cooler air or water descending forms a cyclic rising/falling pattern called convection (6.4 c). * Radiation and convection from Earth’s surface transfer thermal energy. This energy powers the global circulation of the atmosphere and the oceans on our planet (6.4 c).   Energy is continuously transferred from one place to another and transformed among various forms.   * Secondary sources of energy, such as electricity, are used to store, move, and deliver energy easily in usable form (6.4 d). * Thermal and radiant energy can be converted into mechanical energy, chemical energy, and electrical energy and back again (6.4 d). | In order to meet this standard, it is expected that students will   * explain the importance of the sun in the formation of most energy sources on Earth (6.4 a) * analyze and interpret a chart or diagram showing Earth’s energy budget (6.4 b) * explain and illustrate how convection currents distribute thermal energy in the atmosphere and oceans (6.4 c) * explain the role of radiation, conduction, and convection in the distribution of Earth’s energy through the atmosphere (6.4 c) * model and identify energy transformations from the sun to energy sources on Earth (6.4 d) * create and interpret a model or diagram of an energy transformation (6.4 d) * describe the transformations of energy involved with the formation and burning of coal and other fossil fuels (6.4 d) * investigate how light energy (radiant energy) can be transformed into other forms of energy (e.g., mechanical, chemical, and electrical) (6.4 d). |

**6.5 The student will investigate and understand that all matter is composed of atoms. Key ideas include**

1. **atoms consist of particles, including electrons, protons, and neutrons;**
2. **atoms of a particular element are similar but differ from atoms of other elements;**
3. **elements may be represented by chemical symbols;**
4. **two or more atoms interact to form new substances, which are held together by electrical forces (bonds);**
5. **compounds may be represented by chemical formulas;**
6. **chemical equations can be used to model chemical changes; and**
7. **a few elements comprise the largest portion of the solid Earth, living matter, the oceans, and the atmosphere.**

**Central Idea:** Atoms are the basic building blocks of all matter.

**Vertical Alignment:** Students are introduced to the atom in fifth grade (5.7). Sixth grade is the first time students are introduced to subatomic particles. Knowledge of basic chemistry concepts is fundamental to understanding the physical sciences, life processes, and earth and environmental science ideas. In Physical Science, students will learn more about the different types of bonding and how to balance simple equations. Students are introduced to the periodic table in Physical Science (PS.4).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Atoms are the basic building blocks of all matter. The properties of an atom are based on the number and arrangement of its subatomic particles.   * The basic structural components of a typical atom are electrons, protons, and neutrons. Protons and neutrons comprise the nucleus of an atom (6.5 a). * An element is a form of matter made up of one type of atom. The atoms of an element have the same number of protons and electrons, although the number of neutrons may vary (6.5 b). * The atoms of one element differ from those of another element in the number of protons (6.5 b). * Elements can be represented by chemical symbols (6.5 c).   In a chemical process, the atoms that make up the original substance (*reactants*) are regrouped into different molecules and the new substances (*products*) have different properties from the properties of the reactants.   * Two or more atoms of different elements may combine to form a compound (6.5 d). * Chemical bonds are the forces that hold atoms together to form new substances. These bonds are formed with electrons (6.5 d). * Compounds can be represented by chemical formulas. Each element in the compound is represented by its unique symbol. The number of each type of element in the compound (other than one) is represented by a small number (the subscript) to the right of the element symbol (6.5 e).   Matter is conserved because atoms are conserved in chemical and physical processes.   * Chemical equations can be used to model chemical changes, illustrating how elements become rearranged in a chemical reaction (6.5 f). *Students are not responsible for balancing equations.* * A limited number of elements form the largest portion of Earth’s crust, living matter, the oceans, and the atmosphere (6.5 g). | In order to meet this standard, it is expected that students will   * create and interpret a simplified, modern model of the structure of an atom (6.5 a) * compare the atomic structure of two elements (6.5 b) * explain that elements are represented by symbols (6.5 c) * describe the role of bonding in the formation of new substances (6.5 d) * identify the name and number of each element present in a simple molecule or compound (6.5 e) * model a simple chemical change with an equation and account for all atoms (6.5 e) * distinguish the types of elements and number of each element in the chemical equation (6.5 f) * interpret data to identify the predominant elements found in the atmosphere, the oceans, living matter, and Earth’s crust (6.5 g). |

**6.6 The student will investigate and understand that water has unique physical properties and has a role in the natural and human-made environment. Key ideas include**

1. **water is referred to as the universal solvent;**
2. **water has specific properties;**
3. **thermal energy has a role in phase changes;**
4. **water has a role in weathering;**
5. **large bodies of water moderate climate; and**
6. **water is important for agriculture, power generation, and public health.**

**Central Idea:** Due to water’s properties, it is a fundamental compound necessary for Earth’s processes.

**Vertical Alignment:** Students are introduced to the water cycle (3.7) and water conservation (4.8) in elementary science. The role of water in biological processes continue in Life Science (LS.4, LS.5).

| **Enduring Understanding** | **Essential Knowledge and Practices** |
| --- | --- |
| Water has unique properties that are essential to Earth processes.   * Due to water’s structure, many substances will dissolve in water. For this reason, water is often called the *universal solvent* (6.6 a). * Water is the only compound that commonly exists in all three states (solid, liquid, gas) on Earth (6.6 b). * The structure of water molecules allows for the attraction of these molecules to each other, leading to *cohesion*. Their structure also allows water molecules to stick to other surfaces, leading to *adhesion* (6.6 b). * Surface tension is the property of the surface of a liquid that allows it to resist an external force. This property is due to the cohesive nature of water molecules (6.6 b). * Solid water is less dense than liquid water (6.6 b).   Thermal energy added to a system increases the kinetic energy of molecules and results in temperature and phase changes.   * Water can absorb thermal energy without showing relatively large changes in temperature (6.6 c, e). * Large bodies of water act to moderate the climate of surrounding areas by absorbing thermal energy in summer and slowly releasing that energy in the winter. For this reason, the climate near large bodies of water is slightly milder than in areas without large bodies of water (6.6 c, e).   Water shapes landscapes and is a powerful agent in weathering and erosion.   * Water (rain, ice, snow) has shaped our environment by physically and chemically weathering rock and soil and transporting sediments. Freezing water can break rock without any change in the minerals that form the rock (physical weathering). This usually produces small particles and sand. Water, along with dissolved gases and other chemicals, causes the minerals in rocks to be changed, leading to the deterioration of the rock (chemical weathering). Erosion is the movement of the materials by water or wind (6.6 d).   Humans affect the quality, availability, and distribution of Earth’s water.   * Most of Earth’s water (97 percent) is salt water in the oceans. Available fresh water, used by humans and other organisms, makes up less than one percent of the water on Earth (6.6 f). * Water is essential for agriculture and in power generation (6.6 f). * Accessibility of clean, fresh water is critical in maintaining public health (6.6 f). | In order to meet this standard, it is expected that students will   * plan an investigation to demonstrate the ability of water to dissolve materials (6.6 a) * describe the properties of water and identify examples of cohesion, adhesion, and surface tension (6.6 b) * compare the effects of adding or subtracting thermal energy to the states of water (6.6 c) * relate the three states of water to the water cycle (6.6 c) * model the action of freezing water on rocks (6.6 d) * plan and conduct an investigation to determine the action of acidified water on building materials such as concrete, limestone, or marble (6.6 d) * chart, record, and describe evidence of chemical and physical weathering in the local environment (6.6 d) * analyze and explain the difference in average winter temperatures among areas in central and western Virginia and cities and counties along the Chesapeake Bay and Atlantic coast (6.6 e) * explain the role of water in power generation (6.6 f) * describe the importance of careful management of water resources (6.6 f). |

**6.7 The student will investigate and understand that air has properties and that Earth’s atmosphere has structure and is dynamic. Key ideas include**

1. **air is a mixture of gaseous elements and compounds;**
2. **the atmosphere has physical characteristics;**
3. **properties of the atmosphere change with altitude;**

**d) there is a relationship between air movement, thermal energy, and weather conditions;**

**e) atmospheric measures are used to predict weather conditions; and**

**f) weather maps give basic information about fronts, systems, and weather measurements.**

**Central Idea:** The Earth’s atmosphere is a dynamic system that changes in response to inputs and outflows of energy and matter.

**Vertical Alignment:**  Students learn about weather and climate in fourth grade (4.4). Although the students have been introduced to weather throughout their elementary years, the concept of the atmosphere and the interactions that occur to affect both the biotic and abiotic portions of Earth is new to students. Students will study the atmosphere as a complex, dynamic system in Earth Science (ES.11).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
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| Earth’s atmosphere is comprised of interacting and interdependent elements that are subject to change in response to inputs and outflows of energy and matter.   * Air is a mixture of gaseous elements and compounds. These include nitrogen, oxygen, water, argon, and carbon dioxide. Nitrogen makes up the largest proportion of air (6.7 a). * The atmosphere is made up of layers (troposphere, stratosphere, mesosphere, and thermosphere) that have distinct characteristics (6.7c). *Students are not expected to know specific altitudes or temperatures at each layer.* * Naturally occurring ozone is also found in the atmosphere and helps to shield Earth from ultraviolet radiation (6.7 c).   The atmosphere is dynamic because of the number of factors that affect it, such as pressure and temperature, which change with altitude and latitude.   * Air exerts pressure. Air pressure decreases as altitude increases (6.7 b). * Moisture in the air is called *humidity* (6.7 b). * Temperature decreases as altitude increases in the lowest layer of the atmosphere (6.7 b). * Data on characteristics such as barometric pressure, temperature, wind speed and direction, humidity, and dew point can be collected, analyzed, and used to predict weather (6.7 b, d).   Thermal energy transfer from the sun or from other geosystems influences air movement and weather conditions.   * The amounts of thermal energy and water vapor in the air and the pressure of the air largely determine weather conditions (6.7 d, e).   Models constructed based on patterns in atmospheric conditions are used to predict weather.   * Most of the air that makes up the atmosphere is found in the troposphere (the lowest layer). Virtually all weather takes place there (6.7 c, e). * Weather maps show useful information about air measurements, observations, and boundaries between air masses (fronts). The curved lines showing areas of equal air pressure and temperature are key features of weather maps. Weather maps are important for understanding and predicting the weather (6.7 f). | In order to meet this standard, it is expected that students will   * identify the composition and physical characteristics of the atmosphere (6.7 a) * analyze and interpret charts and graphs of the atmosphere in terms of temperature and pressure (6.7 b) * measure and record air temperature, air pressure, and humidity, using appropriate units of measurement and tools (6.7 b) * predict weather conditions based on air temperature, barometric pressure, and humidity (6.7 b, e) * differentiate among the layers of the atmosphere in terms of general characteristics and changes in altitude (6.7 c) * explain the impact of the addition of thermal energy on air movement (6.7 d) * compare types of precipitation (6.7 e) * compare weather-related phenomena, including thunderstorms, tornadoes, hurricanes, and drought (6.7 e) * interpret basic weather maps, including the identification of warm and cold fronts (6.7 f) * map the movement of cold and warm fronts and interpret their effects on observable weather conditions (6.7 f). |

**6.8 The student will investigate and understand that land and water have roles in watershed systems. Key ideas include**

1. **a watershed is composed of the land that drains into a body of water;**
2. **Virginia is composed of multiple watershed systems which have specific features;**
3. **the Chesapeake Bay is an estuary that has many important functions; and**
4. **natural processes, human activities, and biotic and abiotic factors influence the health of a watershed system.**

**Central Idea:** Watershed systems are dynamic and complex; interactions within these systems may influence the overall health of the watershed.

**Vertical Alignment:** Students are introduced to the interactions among the biotic and abiotic factors within ecosystems in fourth grade (4.3). Watersheds as natural resources and the conservation of watersheds is emphasized at that time (4.8). Dynamics within ecosystems are investigated in Life Science, although watersheds are not explicitly covered again until Earth Science (ES.8).

| **Enduring Understanding** | **Essential Knowledge and Practices** |
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| All ecosystems, including watershed ecosystems, are affected by complex biotic and abiotic interactions involving exchanges of matter and energy.   * An ecosystem is made up of the biotic (living) community and the abiotic (nonliving) factors that affect it. The health of an ecosystem is directly related to water quality (6.8 a). * A watershed is the land that water flows across or through on its way to a stream, lake, wetland, or other body of water (6.8 a). * Abiotic factors determine ecosystem type and its distribution of plants and animals, as well as the usage of land by people. Abiotic factors include water supply, topography, landforms, geology, soils, sunlight, and air quality/O2 availability (6.8 a). * Water-quality monitoring is the collection of water samples to analyze chemical and/or biological parameters. Simple parameters include pH, temperature, salinity, dissolved oxygen, turbidity, and the presence of macroinvertebrate organisms (6.8 a). * Areas of higher elevations, such as ridgelines and divides, separate watersheds (6.8 b). * The watershed systems in Virginia lead to three main bodies of water. These are the Chesapeake Bay, the North Carolina sounds, or the Gulf of Mexico (6.8 b). * Wetlands form the transition zone between dry land and bodies of water such as rivers, lakes, or bays. Both tidal and non-tidal wetlands perform important water-quality functions, including regulating runoff by storing flood waters; reducing erosion by slowing down run-off; maintaining water quality by filtering sediments, trapping nutrients, and breaking down pollutants; and recharging groundwater. Wetlands also provide food and shelter for wildlife and fish and nesting and resting areas for migratory birds (6.8 b). * Estuaries perform important functions, such as providing habitat for many organisms (including serving as nurseries for their young) (6.8 c). * The Chesapeake Bay is an estuary where fresh and saltwater meet and are mixed by tides. It is the largest estuary in the contiguous United States and one of the most productive (6.8 c).   Human actions and geologic processes affect the availability of freshwater resources.   * Human activities can alter abiotic components and thus accelerate or decelerate natural processes (6.8 d). | In order to meet this standard, it is expected that students will   * identify abiotic and biotic features in the students’ local watershed (6.8 a, b) * use maps to determine the location and size of Virginia’s regional watershed systems (6.8 b) * locate the local watershed and the rivers and streams associated with it (6.8 b) * explain the importance of the Virginia watersheds (6.8 c) * explain and appraise the value of wetlands to ecosystems, including humans (6.8 d) * explain the importance of estuaries, including their importance to people (6.8 d) * propose ways to maintain water quality within a watershed (6.8 d) * explain the factors that affect water quality in a watershed and how those factors can affect an ecosystem (6.8 d) * forecast potential water-related issues that may become important in the future (6.8 d) * locate and critique a media article or editorial (print or electronic) concerning water use or water quality and analyze and evaluate the science concepts involved (6.8 d) * argue for and against commercially developing a parcel of land containing a large wetland area (6.8 d) * design and defend a land-use model that minimizes negative impact (6.8 d) * measure, record, and analyze a variety of water quality indicators and describe what these mean to the health of an ecosystem (6.8 d). |

**6.9 The student will investigate and understand that humans impact the environment and individuals can influence public policy decisions related to energy and the environment. Key ideas include**

1. **natural resources are important to protect and maintain;**
2. **renewable and nonrenewable resources can be managed;**
3. **major health and safety issues are associated with air and water quality;**
4. **major health and safety issues are related to different forms of energy;**
5. **preventive measures can protect land-use and reduce environmental hazards; and**
6. **there are cost/benefit tradeoffs in conservation policies.**

**Central Idea:** Natural resource management and health and safety issues related to the use of resources should be considered in the development of public policy.

**Vertical Alignment:** Students continue building an understanding of the importance of Earth’s natural resources in fourth grade. (4.9). The complexity of resource use is further explored in Earth Science (ES.6).

| **Enduring Understanding** | **Essential Knowledge and Practices** |
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| Natural resources have different properties, making them suitable for different uses. Natural resources are limited and are distributed unevenly around the planet.   * People, as well as other living organisms, are dependent upon the availability of clean water and air and a healthy environment (6.9 a, c). * Local, state, and federal governments have significant roles in managing and protecting air, water, plant, and wildlife resources (6.9 b). * Modern industrial society is dependent upon energy. Fossil fuels are the major sources of energy in developed and industrialized nations and should be managed to minimize adverse impacts (6.9 d). * Renewable resources should be managed so that they produce continuously. Sustainable development focuses decisions about long-term use of the land and natural resources on maximum community benefit for the longest time with the least environmental damage (6.9 b). * Preventing pollutants from entering the air and water can protect the health of living things. Water pollutants such as pesticides, fertilizers, and chemicals affect the limited amount of fresh water available for living things to maintain life processes. These pollutants may also lead to an increase in bacterial, viral, and parasitic diseases (6.9 c). * Conservation of resources and environmental protection include individual acts of stewardship (6.9 f). * Human use of resources has a cause-and-effect impact on Earth systems and on the global economy (6.9 f). * There are advantages and disadvantages to using any energy source. These advantages and disadvantages may affect the environment and have economic implications (6.9 d). * Human health can be affected when pollutants, in the form of particulates and thermal energy released into the atmosphere, disrupt the natural balance in the system (6.9 c, d).   Earth scientists and engineers develop new technologies to extract resources while reducing the pollution, waste, and ecosystem degradation caused by extraction.   * Preventive measures, such as pollution prevention or thoughtfully planned and enforced land-use restrictions, can reduce future damage (6.9 e). * Regulations, incentives, and voluntary efforts help conserve resources and protect environmental quality (6.9 f). * Use of renewable (water, air, soil, plant life, animal life) and nonrenewable resources (coal, oil, natural gas, nuclear power, and mineral resources) must be considered in terms of their cost/benefit tradeoffs (6.9 f). * Pollution prevention and waste management are less costly than cleanup (6.9 f). | In order to meet this standard, it is expected that students will   * construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources affect Earth’s systems (e.g., climate, oceans, rainforest) (6.9 a) * differentiate between renewable and nonrenewable resources (6.9 b) * describe the role of local and state conservation professionals in managing natural resources, including wildlife protection; forestry and waste management; and air, water, and soil conservation (6.9 b) * analyze resource-use options in everyday activities and determine how personal choices have costs and benefits related to the generation of waste (6.9 f) * analyze how renewable and nonrenewable resources are used and managed within the home, school, and community (6.9 b) * describe ways that water and air pollution affect human health and safety (6.9 c) * compare energy sources and their effects on human health and safety (6.9 d) * investigate practices that can reduce environmental hazards or improve land use (6.9 e) * analyze reports, media articles, and other narrative materials related to waste management and resource use to determine various perspectives concerning the costs and benefits in real-life situations (6.9 f) * evaluate the effects of resource use, waste management, and pollution prevention in the school and home environment (6.9 f). |

## Life Science

The Life Science standards emphasize a more complex understanding of change, cycles, patterns, and relationships in the living world. Students build on basic principles related to these concepts by exploring the cellular organization and the classification of organisms; the dynamic relationships among organisms, populations, communities, and ecosystems; and change as a result of the transmission of genetic information from generation to generation. Students build on scientific investigation skills by independently identifying questions and planning investigations. Students evaluate the usefulness and limits of models and support their conclusions using evidence. Mathematics, computational thinking, and experience in the engineering design process gain importance as students advance in their scientific thinking.

### Scientific and Engineering Practices

Engaging in the practices of science and engineering helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the many ways to investigate, model, and explain the world. These scientific and engineering practices include the use of scientific skills and processes to explore the content of science as outlined in the *Science Standards of Learning*. The engineering design practices are the application of science content to solve a problem or design an object, tool, process, or system. These scientific and engineering practices are critical to science instruction and are to be embedded throughout the year.

**LS.1 The student will demonstrate an understanding of scientific and engineering practices by**

1. **asking questions and defining problems**

* **ask questions and develop hypotheses to determine relationships between independent and dependent variables**
* **offer simple solutions to design problems**

1. **planning and carrying out investigations**

* **independently and collaboratively plan and conduct observational and experimental investigations; identify variables, constants, and controls where appropriate and include the safe use of chemicals and equipment**
* **evaluate the accuracy of various methods for collecting data**
* **take metric measurements using appropriate tools and technologies including the use of microscopes**

1. **interpreting, analyzing, and evaluating data**

* **identify, interpret, and evaluate patterns in data**
* **construct, analyze, and interpret graphical displays of data**
* **compare and contrast data collected by different groups and discuss similarities and differences in their findings**
* **consider limitations of data analysis and/or seek to improve precision and accuracy of data**
* **use data to evaluate and refine design solutions**

1. **constructing and critiquing conclusions and explanations**

* **construct explanations that include qualitative or quantitative relationships between variables**
* **construct scientific explanations based on valid and reliable evidence obtained from sources (including the students’ own investigations)**
* **differentiate between a scientific hypothesis and theory**

1. **developing and using models**

* **construct and use models and simulations to illustrate, predict, and/or explain observable and unobservable phenomena, life processes, or mechanisms**
* **evaluate limitations of models**

1. **obtaining, evaluating, and communicating information**

* **read scientific texts, including those adapted for classroom use, to obtain scientific and/or technical information**
* **gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication**
* **construct, use, and/or present an argument supported by empirical evidence and scientific reasoning**

### Life Science Content

**LS.2 The student will investigate and understand that all living things are composed of one or more cells that support life processes, as described by the cell theory. Key ideas include**

**a) the development of the cell theory demonstrates the nature of science;**

**b) cell structure and organelles support life processes;**

**c) similarities and differences between plant and animal cells determine how they support life processes;**

**d) cell division is the mechanism for growth and reproduction; and**

**e) cellular transport (osmosis and diffusion) is important for life processes.**

**Central Idea:** All living things are composed of cells; these cells have different structures and organelles that support life processes. Cell theory describes the current understanding of cells. Theories and laws in science are used by scientists to describe natural phenomena. Theories and law are equal in terms of scientific validity.

**Vertical Alignment:** In fourth grade, students learn that plants and animals have structures that distinguish them from one another and play a vital role in their ability to survive (4.2). In Biology, students build on the concept of cell theory and focus on the relationships and interactions of organelles in biochemical processes (BIO.2, BIO.3).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
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| The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world. The nature of science continually tests and refines our understanding of the natural world. The nature of science includes the concept that   * the natural world is understandable * science is based on evidence—both observational and experimental * science is a blend of logic and innovation * scientific ideas are durable yet subject to change as new data are collected * science is a complex social endeavor * scientists try to remain objective and engage in peer review to help avoid bias.   Theories and laws are two different types of knowledge used by scientists to describe natural phenomena. They are equal in terms of scientific validity. Theories are generally used to explain complex natural processes not easily quantifiable (e.g., cells, evolution). Laws often use mathematical formulas to show relationships and make predictions about the natural world (e.g., heredity).   * The cell theory is a shared understanding that encapsulates our current understanding of the cell. The development of this theory illustrates the nature of science (LS.2 a). *Students are not responsible for identifying the contributions of specific scientists.*   Scientists and engineers use two-dimensional (2-D), three-dimensional (3-D), mathematical, and virtual models to represent, predict, and elaborate upon objects and systems and their interactions. Scientists use models when the object of investigation is too large, too small, or too complex to be studied directly.   * Science and technology are tightly linked. Science seeks to understand the natural world through observation and experimentation. Technologies are developed to aid in gathering data. New data bring fresh insights, raise new questions, and prompt further investigation. In this way, scientific knowledge evolves slowly over time (LS.2 a). * A good example of the link between science and technology is how advances in microscopes have helped us investigate cells—the smallest part of living things—and how they work to sustain life processes (LS.2 a).   Sustaining life requires substantial energy and matter inputs. The complex structural organization of organisms accommodates the capture, transformation, and elimination of the matter and energy needed to sustain them.   * Living cells are full of highly organized organelles that function as a system to carry out life processes within the cell. Life processes include growth and repair, reproduction, gas exchange, metabolism, and response (LS.2 b). * Metabolism refers to all interactions among molecules within the well-ordered environment of the cell. Photosynthesis and cellular respiration are two important metabolic activities within living cells (LS.2 b). *Students are not responsible for explaining specific endothermic and exothermic metabolic pathways.*   The structure of an object or living thing determines many of its properties and functions.   * Animal and plant cells may differ in shape, size, and the organelles they contain. Most often these differences in structure are related to the function of the cell (LS.2 c). * Similarities and differences between plants and animals are evident at the cellular level (LS.2 c). * Plant cells differ from animal cells in that plant cells contain cell walls, chloroplasts, and large, central vacuoles to aid in photosynthesis that help them convert matter and energy to usable forms (LS.2 c).   Reproduction is a life process (system) by which living things transfer genetic information to their offspring.   * All living things grow and reproduce. As an organism grows and repairs itself, the number of its cells increase. For this to happen, existing cells divide through the process of mitosis so that new cells can be made. The cells which divide go through the cell cycle. The cell cycle has two main components—interphase and mitosis (LS.2 d). * During mitosis, a body cell first duplicates its chromosomes and then divides into two identical daughter cells, each one with a complete set of chromosomes identical to the original parent cell (LS.2 d). * The purpose of mitosis is to produce new cells for growth and repair that are identical to the parent cell. The purpose of meiosis is to produce reproductive (sex) cells that carry half the genetic material of the parent (LS.2 d).   Living things must move materials into, out of, and within the cell.   * Two passive processes that allow for this exchange of materials are diffusion and osmosis. These processes require no energy on the part of the cell. Substances merely move toward equilibrium (from an area of high concentration to an area of low concentration) (LS.2 e). * *Osmosis* is the movement of water molecules across a cell membrane. *Diffusion* is the movement of substances other than water across a cell membrane. Cell membranes are selectively permeable to various substances (LS.2 e). *Students are not responsible for describing facilitated diffusion, tonicity, and active transport.* | In order to meet this standard, it is expected that students will   * make connections among the components of the nature of science, their investigations, and the greater body of scientific knowledge and research (LS.2 a) * differentiate among a scientific hypothesis, theory, and law (LS.2 a) * identify the three components of the original cell theory (LS.2 a) * provide examples to illustrate how the development of cell theory illustrates the nature of science (LS.2 a) * explain how advances in microscope technology have improved our understanding of cells and their parts (LS.2 a) * conduct an investigation to provide evidence that living things are made of cells, either one cell or many different numbers and types of cells (LS.2 a) * identify and relate cellular organelles (cell membrane, cytoplasm, nucleus, cell wall, vacuole, mitochondrion, endoplasmic reticulum and chloroplast) with the life processes they perform within a living cell (LS.2 b) * develop and use a model to demonstrate how organelles function as a system to carry out life processes within the cell (LS.2 b) * evaluate limitations of models to accurately represent the cell and its organelles (LS.2 b) * compare plant and animal cells and their parts, using microscopes and microscopic images (LS.2 c) * explore differences in the structure and function of animal and plant cells (LS.2 c) * relate the parts of a cell to the life functions they perform within the cell (LS.2 c) * explain how the parts of a cell work as a system to carry out life processes in the cell and the organism (LS.2 c) * sequence the steps and recognize images of each stage in the cell cycle, including mitosis (LS.2 d) * identify and explain the role of each stage of mitosis to ultimately support successful cell division (LS.2 d) * explain why cell division is essential to the growth and reproduction of all living things (LS.2 d) * differentiate between the purpose of mitosis and meiosis (LS.2 d) * model how materials move into and out of cells in the processes of osmosis, diffusion, and selective permeability (LS.2 e) * predict and provide an explanation to account for the net movement of materials across a selectively-permeable membrane during osmosis and diffusion (LS.2 e). |

**LS.3 The student will investigate and understand that there are levels of structural organization in living things. Key ideas include**

**a) patterns of cellular organization support life processes;**

**b) unicellular and multicellular organisms have comparative structures; and**

**c) similar characteristics determine the classification of organisms.**

**Central Idea:** Among organisms, there is a universality of the functions that maintain life.

**Vertical Alignment:** Students use classification to identify organisms in fourth grade (4.3). In Biology, students investigate how cell specialization leads to differentiation, comparative structures, and how the modern classification system can be used as an organizational tool in the study of organisms in their respective domains, kingdoms, and phyla (BIO.3, BIO.4, BIO.6**).**

| **Enduring Understandings** | **Essential Knowledge and Practices** |
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| Organisms are complex, organized, and built on a hierarchical structure, with each level providing the foundation for the next, from the chemical foundation of elements and atoms, to the cells and systems of individual organisms, to species and populations living and interacting in complex ecosystems.   * Organisms range in composition from unicellular microorganisms to multicellular organisms (LS.3 a). * In multicellular organisms, large groups of cells work together to form systems of tissues and organs that are specialized and aid the organism in carrying out its life processes of growth, reproduction, gas exchange, metabolism, and response (LS.3 a). * Multicellular organisms exhibit a hierarchy of cellular organization allowing for a division of labor when carrying out life processes (LS.3 b). * A key concept in science is that *form fits function*. In multicellular organisms, cells have specialized shapes that enable them to perform specific roles within the organism (LS.3 b).   Classification is useful in explaining relationships and organizing objects or processes into groups. Classification relies on careful observation of patterns of similarities and differences.   * Biological classification (taxonomy) uses a systematic method to name, organize, and show relationships among species (LS.3 c). * Any grouping of organisms into domains or kingdoms is based on several factors, including the presence or absence of cellular structures, such as the nucleus, mitochondria, or a cell wall; whether the organisms exist as single cells or are multicellular; and how the organisms get their food (LS.3 c). * As living things are investigated, new attributes (physical and chemical) are revealed that affect the relationships and taxonomic group into which an organism is placed (LS.3 c). * Information about the physical features and activities of living things are organized into a hierarchy of increasing specificity. The levels in this hierarchy include *domain*, *kingdom*, *phylum*, *class*, *order*, *family*, *genus*, and *species* (LS.3 c). * Classifications at one scale may not be valid at a different scale. For example, classification of organisms based on physical traits may not be the same as those based on DNA sequences (LS.3 c). * The current biological classification system groups organisms into three domains: Archaea, Bacteria, and Eukarya (LS.3 c). * A group of similar-looking organisms that can interbreed under natural conditions and produce offspring that are capable of reproduction defines a species which are differentiated using binomial nomenclature (LS.3 c). | In order to meet this standard, it is expected that students will   * explain the relationship among cells, tissue, organs, and organ systems (LS.3 a) * differentiate among common examples of unicellular and multicellular organisms (LS.3 b) * compare how unicellular and multicellular organisms perform various life functions, including the application of knowledge about systems in organisms and division of labor (LS.3 b) * provide evidence to support the idea that a cell’s form fits its function within a multicellular organism (LS.3 b) * classify organisms based on a comparison of key physical features and activities (LS.3 c) * arrange organisms in a hierarchy according to similarities and differences in features (LS.3 c) * apply classification criteria to categorize examples of organisms as representatives of the three domains: Archaea, Bacteria, and Eukarya (LS.3 c) * apply classification criteria to categorize examples of four kingdoms of Eukarya: protists, fungi, plants, and animals (LS.3 c) * apply classification criteria to categorize examples of organisms as representative of major animal phyla and plant divisions (LS.3 c) * recognize scientific names as part of a binomial nomenclature (LS.3 c). |

**LS.4 The student will investigate and understand that there are chemical processes of energy transfer which are important for life. Key ideas include**

1. **photosynthesis is the foundation of virtually all food webs; and**

**b) photosynthesis and cellular respiration support life processes.**

**Central Idea:** Energy from the sun enters the food web through photosynthesis which produces sugar (glucose) and then is transferred through the food web. Animal and plant cells use glucose for energy through the process of cellular respiration.

**Vertical Alignment:** Students learn that plants have structures that enable them to use photosynthesis to obtain energy and survive in fourth grade (4.2). In Biology, the processes of photosynthesis and cellular respiration are investigated as essential processes for the flow of energy (BIO.2).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
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| Energy is continually transferred from one object to another and transformed between various forms. As matter and energy flow through different organizational levels of living systems, chemical elements are recombined to form different products. The result of these chemical reactions is that energy is transferred from one system of interacting molecules to another.   * Some organisms obtain energy for life processes by storing energy from the sun in chemical bonds. This process is called *photosynthesis* (LS.4 a, b). *Students are not responsible for explaining the biochemical mechanisms of photosynthesis.* * Photosynthesizing organisms, including green plants, algae, and phytoplankton, produce their own food (sugar), and are called *producers* (LS.4 a). * No process is more important for life on Earth than photosynthesis. Producers are the foundation of virtually all food webs (LS.4 a).   Sustaining life processes requires substantial energy and matter inputs. The complex structural organization of organisms accommodates the capture, transformation, and elimination of the matter and energy needed to sustain them.   * Two organelles—chloroplasts and mitochondria—act as change agents within the cells of living things to make energy available for life processes (LS.4 b). * The organelles, cells, tissues, organs, and organ systems of plants work as a system to obtain the raw materials (sunlight, water, and carbon dioxide) and produce the products (sugars and oxygen) in photosynthesis (LS.4 b). * Chloroplasts, organelles found in some plant cells, convert radiant energy from sunlight into chemical energy. Chloroplasts do this with the help of the pigment chlorophyll. Chlorophyll aids in the energy transformation of sunlight (radiant energy) to chemical energy in sugar (LS.4 b). * The sugar molecules produced from photosynthesis can be used immediately by plants and animals for energy, stored for later use, or rearranged into other compounds to carry out life processes (LS.4 b). *Students are not responsible for identifying the details of the complex chemical reactions for photosynthesis.* * Cellular respiration occurs in the mitochondria of all cells (including plant cells). In this process, sugar molecules combine with oxygen to release energy in a form that cells can more easily use (LS.4 b). *Students are not responsible for identifying the details of the complex chemical reactions for respiration.* * Although they occur in different organelles, photosynthesis and cellular respiration are interdependent processes. The products of one process are the reactants for the other process and vice versa (LS.4 b). * Matter and energy are conserved in chemical processes. This is true of all biological systems, from individual cells to ecosystems (LS.4 b).   Living things are composed of systems which are dynamic and change in response to inputs and outflows of energy and matter.   * The availability of raw materials and other factors can affect the life processes of living things, including the rate of photosynthesis and cellular respiration (LS.4 b). * Factors affecting the rate of photosynthesis are light intensity, carbon dioxide concentration, and temperature (LS.4 b). * Cellular respiration also releases the energy needed to maintain body temperature, despite ongoing energy loss to the surrounding environment (LS.4 b). | In order to meet this standard, it is expected that students will   * 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 (LS.4 a) * relate the importance of photosynthesis to the role of producers as the foundation of food webs (LS.4 a) * plan and conduct an investigation related to photosynthesis (LS.4 a) * explain how organisms use energy stored from the products of photosynthesis (LS.4 b) * demonstrate an understanding of the interaction of reactants, products, plant parts, and cellular organelles in the process of photosynthesis (LS.4 a, b) * explain how the processes of photosynthesis and cellular respiration serve to make energy available for life processes within living systems (LS.4 b) * provide evidence to demonstrate the interdependence of photosynthesis and cellular respiration (LS.4 b) * develop a model of cellular respiration 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(LS.4 b) * discuss how matter and energy are conserved in chemical changes within biological systems (individual cells to ecosystems) (LS.4 b) * create plausible hypotheses about the effects of changes in available materials on the rate of photosynthesis or cellular respiration; evaluate whether the hypotheses are testable in your laboratory, and test the hypotheses if possible (LS.4 a, b). |

**LS.5 The student will investigate and understand that biotic and abiotic factors affect an ecosystem. Key ideas include**

1. **matter moves through ecosystems via the carbon, water, and nitrogen cycles;**
2. **energy flow is represented by food webs and energy pyramids; and**
3. **relationships exist among producers, consumers, and decomposers.**

**Central Idea:** Both biotic and abiotic factors affect the movement of matter and energy within an ecosystem.

**Vertical Alignment:** Students investigate the flow of energy in food webs and within an ecosystem in fourth grade (4.3). In Biology, students expand their understanding of the nutrient cycle and energy flow and apply it to interactions of populations (BIO.8).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
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| As matter and energy flow through different organizational levels of living systems, many important elements and compounds cycle through the living (biotic) and nonliving (abiotic) components of the environment. This chain of events continuously repeats. The cycling of matter ensures its availability for life processes.   * Biotic factors are all the living, or once living, things that directly or indirectly affect an organism and its environment. Biotic factors also include the presence of organisms, their parts, and wastes. In addition, parasites and diseases are classified as biotic factors (LS.5). * Abiotic factors are nonliving components that determine the types and numbers of organisms that exist in an environment. Some examples include annual rainfall, the pH level in lakes and ponds, levels of minerals in the soil, and the amount of light at different depths of the ocean (LS.5). * The carbon, nitrogen, and water cycles serve to transfer matter through all levels of the ecosystem to support life processes (LS.5 a). * The processes of the nitrogen cycle include nitrogen fixation, nitrification, assimilation, ammonification, and de-nitrification (LS.5 a). *Students are not responsible for identifying the names of these processes.* * The main processes of the carbon cycle include photosynthesis, respiration, combustion, and decomposition (LS.5 a). * The main processes of the water cycle include precipitation, evaporation, condensation, and transpiration (LS.5 a).   Within natural and designed systems, it is possible to track the flow, cycles, and conservation of matter and energy.   * Food chains and webs illustrate how energy is transferred from producers to different levels of consumers in an ecosystem (LS.5 b). * The amount of energy available decreases from producer to first-order, second-order, and third-order consumers. This concept can be modeled through an energy pyramid (LS.5 b). * No energy conversion is perfectly efficient. Each level of the energy pyramid has less energy to pass on to the next with roughly one-tenth of the energy in one level available for the next. Energy is given off to the environment as thermal energy through metabolism (LS.5 b).   The life processes of plants and animals are interdependent and contribute to the flow of energy and cycles of matter within an ecosystem.The need to obtain matter and resources drives the behavior and interactions among living things within an ecosystem.   * Producers are consumed (eaten) by consumers. When either producers or consumers die, they are broken down and consumed by decomposers. Decomposers return nutrients to the environment where they can be used by producers (LS.5 c). * Human actions can positively and negatively affect the populations of producers, consumers, and decomposers in an ecosystem (LS.5 c). | In order to meet this standard, it is expected that students will   * differentiate among key processes in the water, carbon, and nitrogen cycles and provide examples to illustrate how they support life (LS.5 a) * develop and/or use a model to illustrate the cycling of matter and flow of energy among living and nonliving parts of an ecosystem (LS.5 a) * analyze local aquatic and terrestrial ecosystems, identify biotic and abiotic components, and describe their roles in the cycling of matter and flow of energy (LS.5 a) * explain and provide examples to illustrate the cause-and-effect relationship of human activity on the cycling of matter and flow of energy in an ecosystem (LS.5 a) * explain matter and energy transfer as modeled through food webs and energy pyramids (LS.5 b) * determine the relationship between a population’s position in a food web and its size (LS.5 b) * interpret energy pyramids to determine the relative amount of energy available at each trophic level (LS.5 b) * develop and/or interpret a model of a food web using organisms found in a local ecosystem and classify organisms as producers or first-, second-, or third-order consumers (LS.5 b, c) * recognize examples of common producers, consumers, and decomposers and explain the role of each in the flow of energy and cycling of matter through an ecosystem (LS.5 c) * provide examples to illustrate the effects of human activity on the activity of producers, consumers, and decomposers in an ecosystem (LS.5 c). |

**LS.6 The student will investigate and understand that populations in a biological community interact and are interdependent. Key ideas include**

1. **relationships exist between predators and prey and these relationships are modeled in food webs;**
2. **the availability and use of resources may lead to competition and cooperation;**
3. **symbiotic relationships support the survival of different species; and**
4. **the niche of each organism supports survival.**

**Central Idea:** Each organism exists as a member of a population and interacts with other members in a population in a variety of ways. Members of different populations interact in a variety of ways within communities.

**Vertical Alignment:** Students investigate the relationships among organisms in an ecosystem in third grade (3.5). In fourth grade, students study the interrelationships in populations, communities, and ecosystems, as well an organism’s niche (4.3). These concepts are expanded in Biology to include limiting factors and carrying capacities (BIO.8).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
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| The life processes of plants and animals are interdependent and contribute to the flow of energy and cycles of matter within an ecosystem.   * The interaction between a consumer that captures and consumes another consumer is the predator-prey relationship (LS.6 a). * Many animals exhibit social behaviors that help them obtain resources. Herbivores often exhibit herding behaviors, which can protect the group from predators. Predators often work together to hunt, capture, and share their preyas well as to raise offspring (LS.6 a). * Organisms may exist as members of a population; populations interact and are interdependent with other populations in a community (LS.6 a).   Members of a population interact with other populations in a community. They compete to obtain the matter and energy they need for basic resources, mates, and territory, and cooperate to meet basic needs and carry out life processes.   * Organisms or populations that rely on each other for basic needs form interdependent communities, where a change in the population of one organism will affect the survival of others (LS.6 b). * Environmental factors (biotic and abiotic), which determine the types and number of organisms of a species in an ecosystem, are called *limiting factors*. Many limiting factors affect the growth of populations in nature (LS.6 b). * Symbiosis is a close relationship between individuals of two different species living together. Symbiotic relationships include *mutualism* (whereby both organisms benefit), *commensalism* (whereby one organism benefits and the other is unaffected), and *parasitism* (whereby one organism benefits and the other is harmed) (LS.6 c). * The physical location where organisms live is called their *habitat*. Each living thing fills a specific role, or *niche*, in its habitat. A niche helps an organism meet basic needs for life processes (LS.6 d). | In order to meet this standard, it is expected that students will   * explain how the interactions of populations form communities within an ecosystem (LS.6 a) * formulate inferences based on graphs and other data about predator-prey populations (LS.6 a) * argue based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors help them to obtain resources (LS.6 a) * analyze and interpret data to predict and explain the effects of resource availability on organisms and populations in an ecosystem (LS.6 b) * predict the effect of limiting factors on organisms, populations, and/or communities in a food web/ecosystem (LS.6 b) * provide examples to illustrate how organisms cooperate and/or compete with one another for resources (LS.6 b) * analyze and interpret data about the effects of resource availability on organisms and populations of organisms in an ecosystem (LS.6 a) * differentiate among the types of symbiosis and recognize and/or provide examples of each (LS.6 c) * infer the niche of organisms from their physical characteristics (LS.6 d). |

**LS.7 The student will investigate and understand that adaptations support an organism’s survival in an ecosystem. Key ideas include**

1. **biotic and abiotic factors define land, marine, and freshwater ecosystems; and**
2. **physical and behavioral characteristics enable organisms to survive within a specific ecosystem.**

**Central Idea:** Populations adapt to survive within an ecosystem.

**Vertical Alignment:** Students begin to explore physical and behavioral adaptations as well as the living and nonliving components of the environment in third grade (3.5). In fourth grade, students are introduced to the ocean environment and the interactions of organisms in the oceans. These concepts are extended in Biology, to include changes in populations through time. Evidence of these changes, to include fossil records and DNA analysis, is provided as support to the theory of evolution (BIO.7).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
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| Ecosystems and their characteristics are the result of complex interactions among Earth’s systems (biosphere, geosphere, atmosphere, and hydrosphere).   * Earth’s tilt on its axis, combined with its revolution around the sun, plays a major role in determining the climate of a given location. Other factors, such as latitude, temperature, precipitation, topography, elevation, and human actions can also influence climate (LS.7 a). * Ecosystems can be large or small, terrestrial or aquatic (LS.7 a). * Ecosystems are dynamic, experiencing shifts in population composition and abundance and changes in the physical environment over time, which ultimately affects the stability and resilience of the entire system (LS.7 a).   Organisms possess physical characteristics and behaviors that enable them to survive in their environment and obtain resources to meet basic needs and carry out life processes, increasing their chances of survival (LS.7 b). | In order to meet this standard, it is expected that students will   * compare the biotic and abiotic factors that distinguish land, marine, and freshwater ecosystems (LS.7 a) * analyze and describe how physical characteristics and behaviors enable organisms to survive in an ecosystem (LS.7 a, b) * investigate how structural adaptations among populations allow organisms to survive with ecosystems (LS.7 b). |

**LS.8 The student will investigate and understand that ecosystems, communities, populations, and organisms are dynamic and change over time. Key ideas include**

1. **organisms respond to daily, seasonal, and long-term changes;**
2. **changes in the environment may increase or decrease population size; and**
3. **large-scale changes such as eutrophication, climate changes, and catastrophic disturbances affect ecosystems.**

**Central Idea:** As conditions change, organisms, populations, communities, and ecosystems respond to those changes to survive.

**Vertical Alignment:** Students learn how organisms respond to changes in temperature, light, and precipitation in first and second grade (1.7, 2.7). Students investigate the effect of large-scale changes on plants and animals in sixth grade and at a more complex level in Biology (6.9, BIO.8).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
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| Living things have a range of conditions that are optimal for survival. Living things respond to daily, seasonal, and long-term changes in their environment to survive.   * To survive, plants require light and water for photosynthesis. Plants have developed responses, called *tropisms,* to help ensure they grow toward adequate sources of light and water (i.e., *phototropism* and *geotropism*) (LS.8 a). * Some plants and animals can better survive adverse environmental conditions through periods of dormancy. Dormancy occurs when normal physical functions are slowed down or suspended (LS.8 a). *Students are not responsible for defining the terms* torpor*, and* estivation*.* * A *circadian rhythm* is a roughly 24-hour cycle in the physiological processes of living things, including plants, animals, fungi, and cyanobacteria. This cycle aids life processes (LS.8 a).   Systems are dynamic and change in response to inputs and outflows of energy and matter.   * Factors can positively and negatively affect the cycles of matter and the life processes of living things within an ecosystem. Disruptions to any component of an ecosystem can lead to shifts in the size and/or distribution of its populations (LS.8 b). * Changes in the living and nonliving components of an ecosystem can accelerate or decelerate natural processes (LS.8 b). * Many factors such as pollution, habitat destruction, disease, and over-harvesting can increase or decrease population size (LS.8 b).   Systems are comprised of a group of interacting and interdependent elements forming a complex whole. Systems change in response to inputs and outflows of energy and matter. A change in one part of the system affects other parts of the system.   * Long-term changes may affect entire communities and ecosystems (LS.8 c). * When excess nutrients flow into an aquatic ecosystem, a chain of events may take place which leads to a low dissolved-oxygen level in the water. This is called *eutrophication* (LS.8 c). * Natural disasters, such as forest fires, floods, and tornados are disruptive factors that shift the balance with in an ecosystem and initiate a process of gradual change from one community of organisms to another (LS.8 c). | In order to meet this standard, it is expected that students will   * categorize responses as daily, seasonal, or long-term (LS.8 a) * construct a scientific explanation based on evidence to explain the benefit(s) of daily, seasonal, and/or long-term responses of organisms to their enhanced survival (LS.8 a) * classify as long-term, short-term, or seasonal the various types of changes that occur over time in ecosystems, communities, populations, and organisms (LS.8 b) * predict the effect of changes to living and/or nonliving factors on the size and distribution of populations in an ecosystem (LS.8 b) * compare the factors that increase or decrease population size (LS.8 b) * argue, citing evidence, that changes to physical or biological components of an ecosystem affect populations (LS.8 b) * predict the effect of large-scale changes on ecosystems and communities (LS.8 c) * analyze data to determine the effect of a catastrophic event on a community (LS.8 c) * predict the environmental effects of large-scale changes, such as climate change, ocean acidification, and sea-level rise (LS.8 c). |

**LS.9 The student will investigate and understand that relationships exist between ecosystem dynamics and human activity. Key ideas include**

1. **changes in habitat can disturb populations;**
2. **disruptions in ecosystems can change species competition; and**
3. **variations in biotic and abiotic factors can change ecosystems.**

**Central Idea:** Human interactions affect ecosystem dynamics.

**Vertical Alignment:** Students study the impact of human activity on air, water, and habitats in both third and sixth grades (3.8, 6.8, 6.9). In Biology, students investigate competition among species and the natural events and human activities that impact ecosystems and their flora and fauna, specifically in Virginia (BIO.8).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
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| An ecosystem can be viewed as many components that interact together to form a complex whole. A change in one part of the system affects other parts of the system.   * Changes in the interactions among the living and nonliving components of an ecosystem cause change in the system (LS.9 a). * Factors (natural and human-caused) can positively and negatively affect the cycles of matter and the life processes of living things within an ecosystem (LS.9 a, b). * Humans are a natural part of the ecosystem. Humans use the ecosystem to meet their basic needs, such as to obtain food (LS.9 a). * Human input can disturb the balance of populations in a habitat. These disturbances may lead to a decrease or increase in a population’s size. Since populations in an ecosystem are interdependent, these disturbances can have a ripple effect throughout the larger ecosystem (LS.9 a, b). * The interaction of humans with the dynamic ecosystem may lead to changes in climate, water supply, air quality, energy production, ocean acidification, and waste management (LS.9 c). | In order to meet this standard, it is expected that students will   * describe ways that human interaction has altered habitats positively and negatively (LS.9 a) * describe the relationship between human food harvest and habitat stability (LS.9 a) * debate the pros and cons of human land use vs. ecosystem stability (LS.9 a) * compare population disturbances that affect competition among species and species survival (LS.9 b) * use evidence to describe the impact of human activity on the biotic and abiotic factors within an ecosystem (LS.9 c) * interpret data obtained through observations and electronic and print resources to determine the effects of human interaction on local ecosystems (LS.9 a, b, c) * plan an investigation examining relationships between ecosystem dynamics and human activity (it may be a complete experimental design or may focus on systematic observation, description, measurement, and/or data collection and analysis) (LS.9 a, b, c) * analyze and critique the experimental design of basic investigations related to the relationships between ecosystem dynamics and human activity (LS.9 a, b, c). |

**LS.10 The student will investigate and understand that organisms reproduce and transmit genetic information to new generations. Key ideas include**

1. **DNA has a role in making proteins that determine organism traits;**
2. **the role of meiosis is to transfer traits to the next generation; and**
3. **Punnett squares are mathematical models used to predict the probability of traits in offspring.**

**Central Idea:** DNA is key in the production and transfer of traits from one generation to another.

**Vertical Alignment:** Students learn that plants and animals have different structures and processes for creating offspring in fourth grade (4.7). In Biology, inheritance, DNA as the structure and foundation for protein synthesis, the stages of meiosis, and synthetic biology are investigated (BIO.5).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
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| The structure and function of DNA are intimately linked. DNA is a double helix molecule containing a specific sequence of nitrogenous bases which create a code for making proteins. Proteins are used to build cells, tissues, organs, and to perform life processes.   * Chromosomes are strands of tightly wound DNA. Genes are sections of a chromosome that carry the code for a particular protein (LS.10 a). * Each gene controls the production of specific proteins, which in turn affects the traits of the organism. Proteins carry out most of the work of cells to perform life functions (LS.10 a). * DNA provides the code that tells the cell exactly which proteins to make. The sequence of the bases A, T, C, and G along a section of DNA forms a code to make each protein (LS.10 a). * The sugar and phosphate molecules on the sides of the DNA molecule are always the same for all living things, so when scientists write out the DNA code, they write only the sequence of the pairs of nitrogenous bases in the center (i.e., on the rungs) of the ladder-like DNA molecule (LS.10 a). * A series of contributions and discoveries has led to our current understanding of DNA, genes, chromosomes, and traits. This process illustrates the nature of science (LS.10 a). *Students are not responsible for identifying the contributions of specific scientists.*   A complex system functions to pass characteristics (traits) from one generation to the next. The interaction of heredity mechanisms and the environment creates both stability from one generation to the next and drives the changes that produce the diversity of life on our planet.   * Living organisms must reproduce to continue the existence of their species. Through reproduction, new individuals that resemble their parents are formed. All the organisms alive today arose from preexisting organisms (LS.10 b). * Reproduction is a life process (system) by which living things transfer genetic information to their offspring (LS.10 b). * Sexual reproduction involves the production of sex cells through meiosis. Sex cells each carry half the parent’s genetic material, resulting in variation between parent and offspring (LS.10 b). * During meiosis, chromosome pairs independently become distributed so that each sex cell contains one-half of the chromosomes of the original cell. The probability of a sex cell containing either allele from the pair is 50 percent (LS.10 b). *Students are not responsible for describing the stages of meiosis.*   The Punnett square is one mathematical model that predicts the probability of the genotype (genetic makeup) and phenotype of the offspring of a cross between parents.   * A Punnett square predicts the probability of the ratios of genotypes and phenotypes among offspring (LS.10 c). *Students are not responsible for identifying multi-trait crosses, multiple alleles, incomplete dominance, and sex-linked crosses.* * Traits that are expressed through genes can be inherited. Characteristics that are acquired through environmental influences, such as injuries or practiced skills, cannot be inherited (LS.10 c). * The basic laws of Mendelian genetics explain the transmission of most traits that can be inherited (LS.10 c). * Genotype refers to the specific combination of genes. Phenotype refers to the physical expression of traits. Dominant traits mask the expression (phenotype) of recessive traits (LS.10 c). | In order to meet this standard, it is expected that students will   * use a variety of models to investigate the structure of DNA (LS.10 a) * describe the structure and function of DNA (LS.10 a) * discuss how the contributions and discoveries leading to our current understanding of DNA, genes, chromosomes, and traits illustrate the nature of science (LS.10 a) * explain the relationship among genes, chromosomes, and alleles (LS.10 a) * explain that DNA contains coded instructions that store and pass on genetic information from one generation to the next (LS.10 a) * 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 (LS.10 b) * compare genetic variation of offspring produced from sexual and asexual reproduction (LS.10 b) * explain the significance of gametes contributing half of their genetic material through sexual reproduction (LS.10 b) * differentiate between characteristics that can be inherited and those that cannot be inherited (LS.10 c) * distinguish between dominant and recessive traits (LS.10 c) * use Punnett squares to predict the possible genetic combinations and phenotype expressions from single trait crosses using dominant and recessive traits (LS.10 c). |

**LS.11 The student will investigate and understand that populations of organisms can change over time. Key ideas include**

1. **mutation, adaptation, natural selection, and extinction change populations;**
2. **the fossil record, genetic information, and anatomical comparisons provide evidence for evolution; and**
3. **environmental factors and genetic variation, influence survivability and diversity of organisms.**

**Central Idea:** Species respond to changes in their environment through adaptation, which is a gradual process that occurs over a long period of time. The progression of these long-term changes is well documented in the fossil record.

**Vertical Alignment:** Students investigate and understand how adaptations enable organisms to satisfy life needs and respond to the environment, which includes behavioral and physical adaptations and the use of fossils as evidence about life in the past, in third grade (3.4). Students investigate fossil records, genetic variation, natural selection, and evolution in Biology (BIO.7).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
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| The genetic variation in a population will remain stable from one generation to the next in the absence of disturbing factors (changes) such as mutations and natural selection.   * As habitats change, some organisms survive and reproduce, some move out of or into the transformed habitat, and some die (LS.11 a). * A change in the sequence of DNA (and thus the protein produced) can have a positive, negative, or no effect on an organism (LS.11 a). *Students are not responsible for identifying types of genetic mutations.* * Mutations can be caused by random errors during DNA replication, exposure to radiation, or chemicals (LS.11 a). * Whereas mutations in the body cells of an organism won’t be passed on to its offspring, mutations in the sex cells of an organism will be passed on to its offspring (LS.11 a). * The interaction of heredity mechanisms and the environment creates both stability from one generation to the next and drives change that produces the diversity of life on our planet (LS.11 b). * *Natural selection* describes the survival and reproduction of individuals within a population exhibiting variations for traits that best enable them to survive in their environment (LS.11 a). * The frequency of certain traits in a species can shift over time in response to natural and artificial selection. This process acts over generations, producing traits that support successful survival and reproduction in the new environment (LS.11 a). * Adaptation is any alteration to the structure, function, or behavior of an organism resulting from natural selection. Adaptation makes the organism better suited to survive and reproduce in its environment (LS.11 a). * If a species does not possess traits that enable survival in its environment or adaptation to changes in the environment, then the species may become extinct (LS.11 a).   The fossil record documents the existence, diversity, extinction, and change of many life forms and their environments through Earth’s history. The fossil record and comparisons of anatomical similarities among organisms enables the inference of lines of evolutionary descent.   * The theory of evolution is a shared understanding that encapsulates our current understanding of how biological systems change over time (LS.11 b). * Mechanisms which drive evolution include mutation, adaptation, natural selection, and extinction (LS.11 b). * Evidence for evolution is drawn from a variety of data sources, including the fossil record, genetic information, and anatomical similarities across species (LS.11 b).   Organisms can be described by their physical features, such as color, shape, body covering, and height. Although individuals within a population have the same basic physical characteristics, close examination will reveal slight variations for a given trait.   * Genetic variations occur randomly among individuals of any population and may or may not help the individual organism survive and reproduce in its environment (LS.11 c). * The expression of many traits involves both inheritance and the environment (LS.11 c). * Individuals of a population each exhibit a range of variations in a trait as a result of the variations in their genetic codes. Genetic variations create diversity within a species (LS.11 c). * Changes in environmental factors such as habitat loss, increased pollution, climate change, and invasive species can challenge the survival of members of a population. Organisms that survive pass their traits on to offspring (LS.11 c). | In order to meet this standard, it is expected that students will   * interpret data from simulations that demonstrate natural selection (LS.11 a) * explain the relationship among mutations, variations in traits in a population, and natural selection (LS.11 a) * compare natural selection and extinction (LS.11 a) * explain how mutations differ from adaptations (LS.11 a) * construct an evidence-based explanation about how genetic variations in traits in a population increase some individuals’ probability of surviving and reproducing in a specific environment (LS.11 a) * describe the role of fossils in determining events in Earth’s history (LS.11 b) * explain the evidence for evolution from a variety of sources of scientific data (LS.11 b) * 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 (LS.11 b) * explain how genetic variations in offspring, which leads to variations in successive generations, can result from the same two parents (LS.11 c) * construct an evidence-based explanation about how environmental factors and genetic variation can influence a species’ survival, reproduction, and diversity (LS.11 c) * explain what is meant by the phrase, “survival of the fittest” (LS.11 a, c). |

## Physical Science

Physical Science standards stress an in-depth understanding of the nature and structure of matter and the characteristics of energy. Major areas covered by the standards include the particle nature of matter; the organization and use of the periodic table; physical and chemical changes; energy transfer and transformations; properties of longitudinal and transverse waves; electricity and magnetism; and work, force, and motion. The standards build on skills of systematic investigation with a clear focus on variables and repeated trials. Validating conclusions with evidence and data becomes increasingly important at this level. Mathematics, computational thinking, and experiences in the engineering design process gain importance as students advance in their scientific thinking.

### Scientific and Engineering Practices

Engaging in the practices of science and engineering helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the many ways to investigate, model, and explain the world. These scientific and engineering practices include the use of scientific skills and processes to explore the content of science as outlined in the *Science Standards of Learning*. The engineering design practices are the application of science content to solve a problem or design an object, tool, process, or system. These scientific and engineering practices are critical to science instruction and are to be embedded throughout the year.

**PS.1 The student will demonstrate an understanding of scientific and engineering practices by**

1. **asking questions and defining problems**

* **ask questions that require empirical evidence to answer**
* **develop hypotheses indicating relationships between independent and dependent variables**
* **offer simple solutions to design problems**

1. **planning and carrying out investigations**

* **independently and collaboratively plan and conduct observational and experimental investigations; identify variables, constants, and controls where appropriate and include the safe use of chemicals and equipment**
* **evaluate the accuracy of various methods for collecting data**
* **take metric measurements using appropriate tools and technologies**
* **apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process, or system**

1. **interpreting, analyzing, and evaluating data**

* **construct and interpret data tables showing independent and dependent variables, repeated trials, and means**
* **construct, analyze, and interpret graphical displays of data and consider limitations of data analysis**
* **apply mathematical concepts and processes to scientific questions**
* **use data to evaluate and refine design solutions to best meet criteria**

1. **constructing and critiquing conclusions and explanations**

* **construct scientific explanations based on valid and reliable evidence obtained from sources (including the students’ own investigations)**
* **construct arguments supported by empirical evidence and scientific reasoning**
* **generate and compare multiple solutions to problems based on how well they meet the criteria and constraints**
* **differentiate between a scientific hypothesis, theory, and law**

1. **developing and using models**

* **construct, develop, and use models and simulations to illustrate and/or explain observable and unobservable phenomena**
* **evaluate limitations of models**

1. **obtaining, evaluating, and communicating information**

* **read scientific texts, including those adapted for classroom use, to determine the central idea and/or obtain scientific and/or technical information**
* **gather, read, and synthesize information from multiple** **appropriate sources and assess the credibility, accuracy, and possible bias of each publication**
* **construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning**

### Physical Science Content

**PS.2 The student will investigate and understand that matter is composed of atoms. Key ideas include**

**a) our understanding of atoms has developed over time;**

**b) the periodic table can be used to predict the chemical and physical properties of matter; and**

**c) the kinetic molecular theory is used to predict and explain matter interactions.**

**Central Idea:** Atoms are composed of subatomic particles, each with its own location and characteristics. Atomic structure and properties are reflected in the periodic table.

**Vertical Alignment:** Students are introduced to the atom and elements in sixth grade (6.5). In Physical Science, the subatomic particles are introduced, along with general information that can be found in the periodic table. More detailed information about atomic structure and periodic trends are investigated in Chemistry (CH.2, CH.6).

| **Enduring Understanding** | **Essential Knowledge and Practices** |
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| The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world (refer to LS.2).   * A series of contributions and discoveries has led to the development of the atomic theory. The atomic theory encapsulates our current understanding of the atom and its structure. The development of this theory illustrates the nature of science (PS.2 a). *Students are not responsible for describing the contributions of specific scientists.* * The electron cloud model best represents our current understanding of the atomic structure. The electron cloud model describes the atom as containing a dense nucleus of protons and neutrons surrounded by regions of space (clouds) where electrons are most likely to be found (PS.2 a). (Note: the Bohr model is an inaccurate model and does not depict the 3-D nature of the atom; it implies that electrons are in static orbits.) *Students do not need to know electron configurations and the quantum mechanical model.*   Matter consists of atoms held together by electromagnetic forces; matter exists as different substances which can be utilized based on their properties. Different substances with different properties are suited to different uses.   * Atoms are the basic building blocks of all matter. The properties of an atom are based on the number and arrangement of its parts (PS.2 a). * The atom consists of subatomic particles (protons, neutrons, and electrons) that differ in location, charge, and relative mass (PS.2 a). * The organization of the periodic table can be used to predict the metallic character and tendency of main group elements to form ionic or covalent bonds (PS.2 b). *Students do not need to know the properties of transition elements.* * Elements in the same vertical column or group of the periodic table contain the same number of electrons in their outer energy levels. These electrons are called *valence electrons* and give rise to similar chemical properties (PS.2 b). *Students do not need to determine the number of valence electrons*. * Elements in the same row of the periodic table contain the same number of energy levels (PS.2 b). *Students do not need to determine principle energy levels or electron configurations*.   The kinetic molecular theory states that atoms and molecules are perpetually in motion and have kinetic energy.   * The relative amount of kinetic energy in a group of atoms or molecules is an important factor in determining its physical state (PS.2 c). * The changes of state that occur with variations in temperature or pressure can be described and predicted using the kinetic molecular theory (PS.2 c). | In order to meet this standard, it is expected that students will   * provide examples to demonstrate how the development of atomic theory illustrates the nature of science (PS.2 a) * construct and use models and simulations to represent the structure of atoms; evaluate the limitations of models used (PS.2 a) * differentiate among scientific hypotheses, theories, and laws (PS.2 a) * interpret data in the periodic table to predict the chemical and physical properties of main group elements (PS.2 b) * construct and use models and simulations to represent and/or explain the atom and phases of matter; evaluate the limitations of models used, when appropriate (PS.2 c) * 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 (PS.2 c) * interpret diagrams representing different phases of matter (PS.2 c) * compose evidence-based conclusions, explanations, and arguments to identify changes in matter when thermal energy is added or taken away (PS.2 c). |

**PS.3 The student will investigate and understand that matter has properties and is conserved in chemical and physical processes. Key ideas include**

1. **pure substances can be identified based on their chemical and physical properties;**
2. **pure substances can undergo physical and chemical changes that may result in a change of properties;**
3. **compounds form through ionic and covalent bonding; and**
4. **balanced chemical equations model the conservation of matter.**

**Central Idea:** During a chemical reaction, atoms stay the same, but rearrange to form new molecules or compounds. The new substances that results from the reaction have different physical properties from the original substances.

**Vertical Alignment:** In sixth grade, students learn that all matter is composed of atoms and these atoms may interact to form new substances. These substances are held together by electrostatic forces called *bonds* (6.5). Although students learn in sixth grade that chemical equations model chemical changes, they do not write or balance chemical reactions until grade eight. The chemistry standards reflect a greater depth of understanding as students study the electron’s role in bonding and create models to show electrons within the bonds. Students also will classify balanced reactions based on reactants and products (CH.3).

| **Enduring Understanding** | **Essential Knowledge and Practices** |
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| Matter consists of atoms held together by electromagnetic forces. Matter exists as different substances which can be utilized based on their properties. Different substances with different properties are suited to different uses.   * Matter exists in different physical states (phases) as a solid, liquid, gas, or plasma (PS.3 a). * Measurements of a variety of properties can be used to identify matter (PS.3 a). * Physical properties of matter include temperature, state, color, hardness, texture, odor, mass, volume, density, conductivity, luster, malleability, boiling point, melting point, and solubility (PS.3 a). *Students are not expected to know or apply the terms* buoyancy *or* viscosity. * Density represents the relationship between the mass of the substance and its volume (PS.3 a). * Some physical properties, such as density, melting point, and boiling point are characteristic of a pure substance and do not depend on the size of the sample. These physical properties can be used to identify unknown pure substances (i.e., matter that consists only of one type of atom, molecule, or compound) (PS.3 a). * Chemical properties of matter include reactivity, combustibility, flammability, and acidity/basicity (PS.3 a). *Students are not expected to identify heat of combustion, chemical stability, preferred oxidation state, toxicity, or half-life*. * Matter can undergo physical and chemical changes (PS.3 b). * No new substances are created during a physical change, although matter may take a different form. The size, shape, state, and color of matter may be modified. Examples of physical changes include (but are not limited to) ice cream melting, a diamond forming from carbon, and salt dissolving in water (PS.3 b). * Mixtures consist of two or more substances; however, the substances are not chemically combined. They can be separated by physical means (PS.3 b). * Attraction and repulsion among electric charges at the atomic level explains the structure, properties, and transformations of matter (PS.3 b). * Elements combine in many ways to produce compounds that make up all other substances on Earth (PS.3 b). * Chemical changes include a rearrangement of the atoms of one or more substances, leading to the formation of at least one new substance with different chemical properties. Examples of chemical changes include (but are not limited to) rust forming on an iron nail, burning wood, cooking an egg (PS.3 b). * Chemical changes involve the breaking and making of chemical bonds. If the total energy required to break bonds in the reactants is more than the total energy released when new bonds are formed in the products, the reaction is endothermic. If the total energy required to break bonds in the reactants is less than the total energy released when new bonds are formed in the products, the reaction is exothermic (PS.3 b). *Students are not expected to indicate the type of reaction (synthesis, decomposition, and replacement reactions).* * To become chemically stable, the atoms of elements gain, lose, or share electrons (PS.3 c). * Compounds consist of two or more elements that are chemically combined in a fixed ratio (PS.3 c). * A chemical formula is a mathematical model that displays the number of atoms of each element that form a chemical compound (e.g., H2O2, C6H12O6) (PS.3 c). * Compounds can be classified as ionic or covalent based on the type of chemical bonds they contain (PS.3 c). * When a metallic element reacts with a non-metallic element, their atoms gain and lose electrons respectively, forming ionic bonds. Generally, when two nonmetals react, atoms share electrons, forming covalent (molecular) bonds (PS.3 c). * A chemical equation represents the changes that take place in a chemical reaction. The chemical formulas of the reactants are written on the left, an arrow indicates a change to new substances, and the chemical formulas of the products are written on the right (PS.3 d). * The law of conservation of matter (mass) states that regardless of how substances within a closed system are changed, the total mass remains the same (PS.3 d). | In order to meet this standard, it is expected that students will   * distinguish between physical properties and chemical properties of matter (PS.3 a) * generate, analyze, and interpret data in tables, graphs, charts, diagrams, and/or other displays related to physical and chemical properties of matter (PS.3 a) * apply mathematical and computational thinking to calculate and compare the densities of substances (PS.3 a) * identify and describe a pure substance based on its physical and/or chemical properties (PS.3 a) * provide examples of the specific uses of matter that are suited to their physical or chemical properties (PS.3 a) * plan and conduct investigations to explore the relationship among mass, volume, and density, collecting and analyzing data in metric units and the International System of Units (SI units) (PS.3 a) * generate, analyze, and interpret data in tables, graphs, charts, and/or other displays related to mass, volume, and density (PS.3 a) * distinguish between physical and chemical changes (PS.3 b) * compose evidence-based conclusions, explanations, and arguments from data obtained in an investigation related to chemical changes in matter (PS.3 b) * analyze and interpret diagrams and/or other displays to determine if a chemical or physical change has occurred (PS.3 b) * analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical change has occurred (PS.3 b) * use evidence and scientific reasoning to differentiate between a chemical reaction that requires an input of energy (endothermic) and one that releases energy (exothermic) (PS.3 b) * apply scientific principles and the engineering process to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes (PS.3 b) * differentiate among elements, compounds, and mixtures (PS.3 b) * apply scientific principles to develop a plan to separate a mixture (PS.3 b) * compare ionic and covalent bonding (PS.3 c) * apply scientific principles to predict if an ionic or covalent bond will form when main group metals and non-metals are chemically combined (PS.3 c) * identify the reactants and products in a given chemical equation (PS.3 d) * apply the law of conservation of matter to balance simple chemical equations (PS.3 d). |

**PS.4 The student will investigate and understand that the periodic table is a model used to organize elements based on their atomic structure. Key uses include**

1. **symbols, atomic numbers, atomic mass, chemical groups (families), and periods are identified on the periodic table; and**
2. **elements are classified as metals, metalloids, and nonmetals.**

**Central Idea:** The periodic table is a foundational organizational tool that outlines knowledge about matter in the discipline of chemistry. Memorizing information is not nearly as important as being able to use the tool to understand the interactions and nature of the elements that make up the natural world.

**Vertical Alignment:** Students begin their study of the atom in sixth grade. Included in the introduction to the atom are subatomic particles, elements, the fundamentals of bonding, and the chemical equations to model a chemical reaction (6.5). In Chemistry, students use the periodic table to predict trends within groups and periods and to predict bonding (CH.2).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
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| Predictable properties emerge when elements are arranged according to the number of protons. The periodic table models these patterns and can be used to predict properties of elements.   * All atoms of an element contain the same number of protons and cannot be broken down into simpler substances using chemical reactions (PS.4 a). * Each element is distinguished by the number of protons in the nuclei of its atoms (atomic number). The number of protons never changes in an atom during chemical or physical changes (PS.4 a). * There are more than 118 known elements. Elements with an atomic number greater than 92 are not found naturally in measurable quantities on Earth. These elements are artificially produced in a laboratory setting (PS.4 a). * The periodic table is a tool used to organize information about the elements. The boxes in the periodic table are arranged in increasing order of atomic number (PS.4 a). * Although an element’s atoms all have the same number of protons, they can have different numbers of neutrons (PS.4 a). * Atomic mass is equivalent to the number of protons and neutrons in the atom of an element (PS.4 a). * Atoms of an element with differing numbers of neutrons are known as *isotopes,* which leads to a different atomic mass; however, the chemical properties of the isotopes are the same. The atomic mass presented in the periodic table represents a population-weighted average of naturally occurring isotopes (PS.4 a). * Gaining or losing electrons makes an atom an ion. An ion has different chemical properties than the original atom (PS.4 a). * Elements in the same column (group or family) of the periodic table have similar properties because they contain the same number of electrons in their outer energy level (valence) (PS.4 a). *Students are not expected to indicate the number of valence of electrons of any atom*. * The horizontal rows of the periodic table are called *periods* (PS.4 a). *Students are not expected to indicate the number of principal energy levels.* * The vertical columns in the table are called *groups*. They are also commonly referred to as *families*. Elements in the same group share many physical and chemical properties because they contain the same number of electrons in their outer energy level (valence) (PS.4 a). * Elements on the left side of the periodic table are metals (PS.4 b). * Elements have fewer metallic properties as one reads from left to right across the periodic table (PS.4 b). * The nonmetals are located to the right of the stair-step line on the periodic table (PS.4 b). * Metalloids, which occur along the stair-step line, have both metallic and non-metallic properties (PS.4 b). | In order to meet this standard, it is expected that students will   * compare the location, charge, and relative mass of protons, neutrons, and electrons in a single atom (PS.4 a) * differentiate between atoms of an element and its isotopes (PS.4 a) * recognize that an atom’s identity is related to the number of protons in its nucleus (PS.4 a) * use the periodic table to obtain the following information about the atom of an element: symbol, atomic number, and atomic mass (PS.4 a) * describe the organization of the periodic table in terms of atomic number, metals vs. nonmetals, and groups vs. periods (PS.4 a) * use basic information provided for an element (atomic mass, atomic number, symbol, and name) to determine its place on the periodic table (PS.4 a) * recognize that the number of electrons in the outermost energy level determines an element’s chemical properties or chemical reactivity (PS.4 a) * classify a given element as metal, nonmetal, or metalloid based on its position in the periodic table (PS.4 b) * given a chemical formula of a compound, identify the elements and the number of atoms of each that comprise the compound (PS.4 b). |

**PS.5 The student will investigate and understand that energy is conserved. Key ideas include**

1. **energy can be stored in different ways;**
2. **energy is transferred and transformed; and**
3. **energy can be transformed to meet societal needs.**

**Central Idea:** Energy is a quantifiable 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 between various forms.

**Vertical Alignment:** Students investigate energy and energy transformations in fifth grade (5.2). The study of these transformation is continued in sixth grade as students focus on sun as the primary source of energy (6.4). Mathematical processes will be applied to matter and energy interactions in Physics (PH.4).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
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| Energy is the ability to cause change. Energy can be transferred between components in a system and transformed from one form to another.   * Energy exists in two states: potential and kinetic (PS.5 a). * Potential energy is energy based on position or chemical composition. Potential energy can be in the form of chemical energy (energy in bonds), nuclear energy (the energy that holds the nucleus of an atom together), elastic energy (energy in objects that have a restorative force, such as springs or rubber bands) and gravitational potential energy (energy of place or position) (PS.5 a). * Kinetic energy is energy of motion. Kinetic is the motion of waves, electrons, molecules, or an object (PS.5 a). * [When the motion energy of an object changes, there is inevitably some other change in energy at the same time (PS.5 a)](http://www.nap.edu/openbook.php?record_id=13165&page=124). * Important forms of energy include radiant, thermal, chemical, electrical, mechanical, and nuclear (PS.5 a). * Visible light is a form of radiant energy and sound is a form of mechanical energy (PS.5 a). * The law of conservation of energy states that energy cannot be created or destroyed but only changed from one form to another (PS.5 b). * In any energy transfer and transformation, some of the energy goes into the environment as thermal energy (PS.5 b). * Thermal energy is transferred by conduction, by convection, and by radiation (PS.5 b). * The amount of kinetic energy in a substance is directly proportional to its Kelvin temperature (PS.5 b). * Heat is the transfer of thermal energy between substances due to a difference in temperature. As thermal energy is added, the temperature of a substance increases. The exception is when a phase change occurs (PS.5 b). * A change in state (phase change) occurs when thermal energy is added or taken away from a system. There is no change in temperature during a phase change (freezing, melting, condensing, evaporating, boiling, and vaporizing) as this energy is being used to make or break bonds between molecules (PS.5 b). * Energy is spontaneously transferred out of hotter regions or objects and into colder ones (PS.5 b). * Temperature is the average kinetic energy of molecules of a substance. Increased temperature means greater kinetic energy of the molecules in the substance being measured, and most substances expand when heated. The temperature of absolute zero (-273oC/0 K) is the theoretical temperature at which molecular motion stops (PS.5 b). * 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 (PS.5 b).   Energy and fuels that humans use derive from natural sources, and their use affects the environment in multiple ways. Some resources are renewable over time and others are not.   * 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 geological processes. Renewable energy resources, and the technologies to exploit them, are being rapidly developed (PS.5 c). * Electrical energy is produced through a series of energy transformations from a variety of original forms which include coal, oil, solar, nuclear, wind, biomass, and natural gas (PS.5 c). * Nuclear energy is the energy stored in the nucleus of an atom. This energy can be released by joining nuclei together (fusion) or by splitting nuclei (fission), resulting in the conversion of minute amounts of matter into energy. In nuclear reactions, a small amount of matter produces a large amount of energy. However, there are potential negative effects of using nuclear energy, including the dangers of radioactive nuclear waste storage and disposal (PS.5 c). | In order to meet this standard, it is expected that students will   * identify and give examples of common forms of energy (PS.5 a) * recognize examples of energy causing change (PS.5 a) * differentiate between kinetic and potential energy (PS.5 a) * plan and conduct observational and/or experimental investigations related to transformations of kinetic and potential energy (PS.5 a) * generate, analyze, and interpret data in tables, graphs, charts, diagrams, and/or other displays to compare relative amounts of potential and kinetic energy (PS.5 a) * construct and use models to show that different amounts of potential energy are stored in the system when the arrangement of objects interacting at a distance changes (PS.5 a) * plan and conduct experimental and/or observational investigations to provide evidence that energy can be transferred and transformed between its different forms (PS.5 b) * identify the energy transformations that occur when energy is used to run a device in the home or school (PS.5 b) * identify the energy transformations that occur between radiant energy in sunlight and the food we eat (PS.5 b) * plan and conduct an investigation related to energy transfer through conduction, convection, and radiation (PS.5 b) * generate, analyze, and interpret data in graphs, charts, diagrams, and/or other displays related to thermal energy transfer through conduction, convection, and radiation (PS.5 b) * apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer (PS.5 b) * compare Celsius and Kelvin temperature scales and use them to describe absolute zero (PS.5 b) * explain absolute zero in terms of molecular movement (kinetic energy) (PS.5 b) * use scientific principles to explain the function of a thermometer (PS.5 b) * analyze a time/temperature graph of a phase change to determine the temperature at which the phase change occurs (freezing point, melting point, or boiling point) (PS.5 b) * ask questions and define problems related to electrical energy production in Virginia (PS.5 c) * describe energy systems, to include transformations in nature and those that are used to meet societal needs (PS.5 c) * evaluate and use credible, accurate, and unbiased sources of print and electronic media to gather and summarize scientific and technical information to describe how energy and fuels (fossil, renewable, and nuclear) are derived from natural resources and how their uses affect the environment (PS.5 c). |

**PS.6 The student will investigate and understand that waves are important in the movement of energy. Key ideas include**

1. **energy may be transferred in the form of longitudinal and transverse waves;**
2. **mechanical waves need a medium to transfer energy;**
3. **waves can interact; and**
4. **energy associated with waves has many applications.**

**Central Idea:** Waves transfer energy and can exist in the form of longitudinal and transverse waves. Wave interactions include reflection, refraction, diffraction, and interference.

**Vertical Alignment:** Students are introduced to the concept of waves in fifth grade through the study of sound and visible light (5.5). In Physics, the concept of waves is extended to include all waves and their role in transferring energy (PH.5).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
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| Waves transmit energy from one place to another without a permanent transfer of mass.   * One wavelength is measured from any point on a wave to the corresponding point on the next wave (PS.6 a). * The amplitude of a wave depends on the type of wave and will be described for two types below. As the energy carried by a wave increases, the amplitude of the wave increases (PS.6 a). * Wave frequency is the number of waves produced over a given period. There is an inverse relationship between frequency and wavelength. As the frequency of a wave increases, wavelength decreases. A wave with a higher frequency (shorter wavelength) carries more energy than a wave with a lower frequency (longer wavelength) (PS.6 a). * The speed of a wave is defined as the distance a point on a wave travels over time. It is expressed in units of meters/second (m/s). Waves can reflect, refract, and diffract (PS.6 a). * Refraction occurs when a wave passes through different materials, resulting in a change in the speed of the wave (PS.6 a). * Reflection occurs when a wave bounces from a surface back toward its source (PS.6 a). * Diffraction is a characteristic of all wave types and occurs when a wave encounters irregular surfaces. This causes the waves to change direction and be scattered. Diffraction is the bending of longitudinal waves around small obstacles or the spreading out of waves beyond openings (PS.6 a). * Longitudinal waves are caused by vibrations carried through a substance, sometimes referred to as a *medium* (solid, liquid. or gas) (PS.6 a). * When energy is being transferred through a medium by a longitudinal wave, the particles of the medium vibrate back and forth along the same path that the wave travels. The particles in a longitudinal wave do not move along the wave—only energy travels from one place to another (PS.6 a). * A compression (longitudinal) wave consists of a repeating pattern of compressions and rarefactions. Wavelength is measured as the distance from one compression to the next compression (PS.6 a). * The amplitudeof a longitudinal wave is the largest distance the particles vibrate from their rest (starting) positions. A wave with greater amplitude carries more energy. For example, a longitudinal sound wave with greater amplitude will be louder than one with less amplitude (PS.6 a). * When energy passes through a medium (matter) in a transverse wave, particles vibrate in an up-and-down motion. The particles move across, or at right angles to, the direction the wave is going. A wave moving on a rope is an example of a transverse wave. Radiant energy travels in transverse waves (PS.6 a). * A wavelength on a transverse wave is the distance from one point to the next corresponding point (e.g., from the tip of one crest to the tip of the next crest) (PS.6 a). * The amplitude of a transverse wave is the distance from the rest position to the crest of a wave or to the trough of a wave. It is the maximum distance the particles of a medium vibrate from their rest position. A wave with a high amplitude carries more energy than a wave with a small amplitude carries (PS.6 a). * Mechanical waves (also called compression or longitudinal waves) are caused by vibrations carried through a substance, sometimes referred to as a medium (solid, liquid. or gas). When energy is being transferred through a medium by a longitudinal wave, the particles of the medium vibrate back and forth along the same path that the wave travels (e.g., vocal chords of a person, the vibrating string and sound board of a guitar or violin, the vibrating prongs of a tuning fork, or the vibrating diaphragm of a radio speaker) (PS.6 b). * The speed of a longitudinal wave depends on several factors, including the medium through which it travels. For example, the speed of sound is slowest in a gas, faster in liquids, and fastest in solids. Sound does not go through empty space (a vacuum). Temperature also affects the speed of a longitudinal wave. For example, the warmer the medium, the faster sound travels (PS.6 b). * Sound, a form of mechanical energy, is propagated through longitudinal waves and needs a medium through which it is transmitted (PS.6 b). * Sound is caused when something vibrates, making particles vibrate back and forth in the direction of the wave. Loudness (of sounds) is related to the amplitude of the mechanical wave. Greater amplitudes equate with louder sounds. Pitch (of sounds) is related to the frequency of the mechanical wave. Higher frequencies equate with higher pitches (PS.6 b). * Interference is the addition of two or more waves, resulting in a new wave pattern. Interference can be constructive or destructive. Waves of the same type that encounter each other pass through each other and exhibit interference (PS.6 c). * Resonance is the tendency of a system to vibrate at maximum amplitude at certain frequencies. For instance, when several musical instruments of the same kind play the same notes, the waves may combine to produce a louder sound (PS.6 c). * Wave-based technology has many applications. Examples include (but are not limited to) sonar, ultrasonography, vehicle parking sensors, and wave power generators (PS.6 d). | In order to meet this standard, it is expected that students will   * describe the role of waves in transferring energy (PS.6 a) * explain the relationship between frequency and wavelength (PS.6 a) * construct and use models and simulations to represent waves, including how the amplitude of a wave is related to its energy (PS.6 a) * model a longitudinal (compression) wave and diagram, label, and describe the components (wavelength, compression, and frequency) (PS.6 a) * model a transverse wave and diagram, label and describe the components (wavelength, amplitude, frequency, crest, and trough) (PS.6 a) * compare longitudinal and transverse waves and their characteristics (PS.6 a) * plan and conduct investigations related to the refraction, reflection, and diffraction of longitudinal and transverse waves (PS.6 a) * develop and use a model to describe mechanical waves being reflected, absorbed, or transmitted through various materials (PS.6 b) * plan and conduct an investigation related to sound (the investigation may be a complete experimental design or may focus on systematic observation, description, measurement, and/or data collection and analysis) (PS.6 b) * interpret graphs and charts to determine factors that determine the speed of sound through various materials (PS.6 b) * identify the property of a sound wave that corresponds to its loudness (PS.6 b) * apply scientific principles to compose an argument as to which of several wires of different lengths would produce the highest-pitch sound (PS.6 b) * identify examples illustrating interference and/or resonance of transverse or longitudinal waves (PS.6 c) * evaluate and use credible, accurate, unbiased sources of print and electronic media to gather and summarize scientific and technical information about technological applications of sound and water waves and how each application functions (PS.6 d). |

**PS.7 The student will investigate and understand that electromagnetic radiation has characteristics. Key ideas include**

1. **electromagnetic radiation, including visible light, has wave characteristics and behavior; and**
2. **regions of the electromagnetic spectrum have specific characteristics and uses.**

**Central Idea:** All electromagnetic waves travel at the speed of light and exhibit the behavior and properties of waves. Due to the amazing range of frequencies and wavelengths, diffraction and reflection vary greatly.

**Vertical Alignment:** Students are introduced to the concept of waves in fifth grade through the study of sound and visible light (5.5, 5.6). In Physics, the concept of visible light is expanded to include all forms of electromagnetic radiation (PH.5).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
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| Radiant energy travels through space in transverse waves of varying lengths and frequencies. The different wavelengths and frequencies of radiant energy are referred to as *electromagnetic radiation*.   * Electromagnetic radiation consists of changing electric and magnetic fields (PS.7 a). * All types of electromagnetic radiation travel at the speed of light but differ in frequency (PS.7 a). * The sun gives off radiant energy of all frequencies in the electromagnetic spectrum. The energy transmitted by various wavelengths of radiant energy (electromagnetic radiation) may be converted to other forms of energy only after it is absorbed by matter (PS.7 a). * Scientists have divided the wavelengths of electromagnetic radiation (radiant energy) into a spectrum. Electromagnetic waves are arranged on the electromagnetic spectrum according to wavelength and frequency (PS.7 a). * The electromagnetic spectrum includes gamma rays, X-rays, ultraviolet, visible light, infrared, microwaves, and radio waves (PS.7 a). * Radio waves are the lowest-energy waves and have the longest wavelength and the lowest frequency. Gamma rays are the highest energy waves and have the shortest wavelength and the highest frequency. Visible light lies in between and makes up only a small portion of the electromagnetic spectrum (PS.7 a). * Radiant energy travels in straight lines until it strikes an object where it can be reflected, absorbed, or transmitted (PS.7 a). * When a wave encounters a new material, the new material may absorb the energy of the wave by transforming it to another form of energy, usually thermal energy. The material may reflect the wave or the material may transmit the wave, allowing it to pass through (PS.7 a). * When visible 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 (PS.7 a). * The color of an object is due to the wavelengths of reflected visible light coming from the object to the viewer’s eye. For example, when a ball looks blue, it is because it reflects blue light wavelengths; other wavelengths of visible light are absorbed by the ball. A black object absorbs all wavelengths of visible light (PS.7 a). * Mirrors reflect light. The direction of the reflected light rays is predicted by the law of reflection (PS.7 a). * The law of reflection states that the incident light ray, the reflected light ray, and the normal surface of the mirror all lie on the same plane. Furthermore, the angle of reflection is equal to the angle of incidence (PS.7 a). * A concave mirror focuses light rays to a point and produces an upright, magnified image if the mirror is close to the object (e.g., make-up mirrors). If the concave mirror is far from the object, the image is inverted and smaller than the object (PS.7 a). * Aconvex mirror spreads light rays and produces only upright, smaller images (PS.7 a). * 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 (PS.7 a). * As visible light travels through different media, it undergoes a change in speed that may result in refraction (PS.7 a). * Refraction occurs when a wave passes through different materials which results in a change in the speed of the wave (PS.7 a). * Lenses refract visible light rays. When visible light enters a lens, it bends toward the thickest part of the lens (PS.7 a). * Optical instruments such as cameras, telescopes, binoculars, and microscopes use lenses and combinations of lenses to change the path of light rays and produce a specific type of image (PS.7 a). * A concave lens spreads light rays, forming a smaller, upright image (PS.7 a). * A convex lens focuses light rays to a point. When the object is far from the lens, the image formed is smaller and inverted. When the object is close to the convex lens, the image is larger than the object and is upright (PS.7 a). * Electromagnetic radiation has many practical uses in everyday life, such as in medicine, security, and telecommunications (PS.7 b). * Electromagnetic radiation is used for communications and transmission of information. The waves that are used in this way are radio waves, microwaves, infrared radiation, and visible light. Digitized signals encode and transmit information more reliably than analog signals (PS.7 b). | In order to meet this standard, it is expected that students will   * describe the wave behavior of visible light (PS.7 a) * compare the various types of electromagnetic waves in terms of wavelength, frequency, and energy (PS.7 a) * construct and use models and simulations to represent how waves are reflected, absorbed, or transmitted through various materials (PS.7 a) * apply an understanding of the law of reflection to explain why objects appear as specific colors (PS.7 a) * identify the images formed by concave, convex, and plane mirrors (PS.7 a) * plan and conduct investigations related to the reflection of visible light (PS.7 a) * identify the images formed by concave and convex lenses (PS.7 a) * plan and conduct investigations related to the refraction of visible light (PS.7 a) * identify and explain in general terms the uses of mirrors and lenses in everyday life (PS.7 b) * compare the various types of electromagnetic waves in terms of wavelength, frequency, and energy (PS.7 b) * describe an everyday application of each of the major forms of electromagnetic energy (PS.7 b). |

**PS.8 The student will investigate and understand that work, force, and motion are related. Key ideas include**

1. **motion can be described using position and time; and**
2. **motion is described by Newton’s laws.**

**Central Idea:** Newton’s laws of motion describe the relationship between a body and the forces acting upon it, and its motion in response to those forces.

**Vertical Alignment**: The concept of force is interwoven throughout elementary science instruction. Fifth grade science lays a foundation for motion depending on position and time and how forces, both of contact and at a distance, can affect motion (5.3). In Physics, Newton’s laws continue to be a focus as students study velocity, acceleration, and linear, circular, and projectile motion (PH.2).

| **Enduring Understanding** | **Essential Knowledge and Practices** |
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| Object positions, force directions, and motions are compared using a chosen reference frame and chosen units of size.   * Speed is the change in position of an object per unit of time. Speed always has a positive value and is non-directional (PS.8 a). * Velocity is the speed an object moves. Velocity may have a positive or a negative value depending on the direction of the change in position (PS.8 a). * Acceleration is the change in velocity per unit of time. An object moving with constant velocity has no acceleration. A decrease or increase in velocity are considered acceleration. A distance-time graph for an accelerating object is always a curve. Objects moving with circular motion are constantly accelerating because direction (and hence velocity) is constantly changing (PS.8 a). * Formulas (mathematical models) are used to calculate speed, velocity, and acceleration (PS.8 a). *Students are not expected to memorize formulas.* * Graphs (2-D models) are constructed to better understand relationships and patterns of motion (PS.8 a). *Students are not responsible for describing more complex curves, only simple linear relationships.*   Forces cause motion. Forces can cause objects to move, stop moving, change speed, or change direction. Newton’s laws describe the motion of all common objects. Force is measured in Newtons (PS.8 b).   * The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion (PS.8 b). * Mass and weight are not equivalent. Mass is the amount of matter in a given substance. Weight is a measure of the force due to gravity acting on a mass. Weight is measured in Newtons and mass in kilograms (PS.8 b). * A variety of models can be used to illustrate Newton’s laws of motion (PS.8 b). * Newton’s first law states that an object at rest will remain at rest and an object in motion will remain in constant straight motion unless acted on by an external force (PS.8 b). * Newton’s second law states that force equals mass times acceleration. Net force and acceleration are directly proportional. As the net force increases, the acceleration increases by the same proportion. Acceleration and mass are inversely proportional (PS.8 b). * Newton’s third law states that for every force there is an equal and opposite force. Forces always occur in pairs (PS.8 b). * For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton’s third law) (PS.8 b). * Work is done when an object is moved through a distance in the direction of the applied force (PS.8 b). * Friction impedes motion when two surfaces are in contact (PS.8 b). * Power is the rate at which work is done (PS.8 b). * A simple machine is a device that makes work easier. Simple machines have different purposes: to change the effort needed, to change the direction or distance through which the force is applied, to change the speed at which the resistance moves, or a combination of these. Due to friction, the work put into a machine is always greater than the work output (PS.8 b). | In order to meet this standard, it is expected that students will   * apply the concept of frame of reference to motion scenarios (PS.8 a) * apply the concepts of speed, velocity, and acceleration when describing motion (PS.8 a) * compare the speed of two or more objects (PS.8 a) * develop hypotheses, identify constants, variables, and apply repeated trials when conducting experimental investigations related to motion (PS.8 a) * make measurements and apply mathematical and computational thinking to calculate and analyze speed, velocity, and acceleration (PS.8 a) * generate, analyze, and interpret data in tables, graphs, charts, diagrams, models, equations, and/or other displays related to motion (PS.8 a) * construct and use models and simulations to represent and/or explain motion (PS.8 a) * critique and improve an investigation about forces (PS.8 b) * plan and conduct 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 (PS.8 b) * differentiate between mass and weight (PS.8 b) * plan and conduct investigations related to mass and weight, collecting and analyzing data in metric and SI units where appropriate (PS.8 b) * identify situations that illustrate each of Newton’s laws of motion (PS.8 b) * apply an understanding of scientific principles and laws to describe and predict motion (PS.8 b) * construct and use models and simulations to represent and/or explain Newton’s laws of motion (PS.8 b) * plan and conduct an investigate regarding Newton’s second law of motion to show the relationship among force, mass, and acceleration (PS.8 b) * explain how force, mass, and acceleration are related (PS.8 b) * apply Newton’s third law of motion to design a solution to a problem involving the motion of two colliding objects (PS.8 b) * state the direction of motion after the interaction of two objects (PS.8 b) * explain how the concept of work, force, and motion apply to everyday uses and current technologies (PS.8 b) * recognize the direction of the force of friction (PS.8 b) * explain why force must be exerted continually to keep an object sliding across a carpeted surface (PS.8 b) * recognize examples of mechanical work (PS.8 b) * apply mathematical and computational thinking to solve basic problems related to work (PS.8 b) * make measurements and apply mathematical and computational thinking to calculate the power of an object (PS.8 b) * use models to illustrate and explain concepts related to work and power (PS.8 b). |

**PS.9 The student will investigate and understand that there are basic principles of electricity and magnetism. Key ideas include**

1. **an imbalance of charge generates static electricity;**
2. **materials have different conductive properties;**
3. **electric circuits transfer energy;**
4. **magnetic fields cause the magnetic effects of certain materials;**
5. **electric current and magnetic fields are related; and**
6. **many technologies use electricity and magnetism.**

**Central Idea:** Electricity is a form of energy resulting from the existence of charged particles (such as electrons or protons), either statically as an accumulation of charge or dynamically as a current. In the majority of applications, it is the electron that is in motion to transfer charge and thus create a flow of electrical current. Changing electric fields are the cause of magnetic fields and changing magnetic fields can cause electrical charge to move.

**Vertical Alignment:** Students are introduced to the concept of electricity as a means of transmitting energy in fifth grade. This energy is then transformed by devices into other forms of energy. Terminology concerning circuits are used as students build simple circuits. Electromagnets are also introduced and constructed in fifth grade (5.4). In Physics, students will build on Physical Science standards to include calculations using Ohm’s law as applied to series and parallel circuits (PH.8).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Electric charge is a property of an object or system that affects its interactions with other objects or systems containing charge.   * Friction can cause electrons to be transferred from one object to another. The resulting imbalance in static electrical charges can build up on an object and be discharged slowly or rapidly. This is often called *static electricity* (PS.9 a). * A conductor is a material that transfers an electric current. An insulator is material that does not transfer an electric current. A semiconductor is a material that is in between a conductor and an insulator in terms of transferring electric current (PS.9 b). * Several factors affect how much electricity can flow through a system. Resistance is a property of matter that affects the flow of electricity. Some substances have more resistance than others (PS.9 b). * Voltage is the potential difference in charge between two points (PS.9 c). * Current is the uniform flow of electrons through a circuit (PS.9 c). * Resistance is a measure of the degree to which an object opposes the passage of an electric current (PS.9 c). * Basic principles applicable to circuits include   + electrons need a complete, conducting pathway (circuit)   + electrons must receive energy (voltage) from a source   + electrons move around the circuit, traveling from high to low potential through a device (current) * electrons transfer energy to perform some useful function (work) * thermal energy is transferred to the surroundings (PS.9 c). * An electronic circuit is composed of individual electronic components, such as transistors and diodes, connected by conductive wires through which electric current can flow. Many common devices utilize electronic circuits (PS.9 c). *Students are not responsible for describing other* *components of electronic circuits such as capacitors, inductors, and resistors.* * Electronic circuits have advantages over electric circuits, providing transfer of data and miniaturization (PS.9 c). * Transistors are semiconductor devices made from silicon, and other semiconductor materials. These are used to amplify electrical signals (in stereos or radios) or to act like a light switch, turning the flow of electricity on and off (PS.9 c). * Forces that act at a distance can be explained by fields that extend through space and can be mapped by their effect on a test object (PS.9 d).   Electric and magnetic (electromagnetic) forces can be attractive or repulsive. The sizes of these forces depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. Many technologies use principles of electromagnetism to operate.   * Moving electricity can produce a magnetic field and cause iron and steel objects to act like magnets (PS.9 e). * Electromagnets are temporary magnets that lose their magnetism when the electric current is removed. Both a motor and a generator have magnets (or electromagnets) and a coil of wire that creates another magnetic field (PS.9 e). * Changing magnetic fields can produce electrical current in conductors. This phenomenon is called *electromagnetic induction* (PS.9 e). * A generator is a device that converts mechanical energy into electrical energy. Most of the electrical energy we use comes from generators (PS.9 f). * Electric motors convert electrical energy into mechanical energy that is used to do work. Examples of motors include those in many household appliances, such as blenders and washing machines (PS.9 f). | In order to meet this standard, it is expected that students will   * model the transfer of electrons that results in a static charge (PS.9 a) * provide examples of materials that are good electrical conductors, semiconductors, and insulators (PS.9 b) * apply scientific principles and the engineering process to use a battery, several wires, and a bulb to determine if an object is an electrical conductor or insulator and create a model to help explain your solution (PS.9 b) * define and recognize examples of voltage, current, and resistance in electric circuits (PS.9 c) * construct simple series and parallel circuits to determine the relationship among voltage, resistance, and current (PS.9 c) * describe the energy flow and transformation in a circuit containing a power source and no more than three loads (PS.9 c) * discuss the advantages of electronic over electrical circuits (PS.9 c) * evaluate and use credible, accurate, and unbiased sources of print and electronic media to gather and summarize scientific and technical information about current applications of semiconductors (e.g., diodes and transistors) (PS.9 c) * 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 (PS.9 d) * identify technologies that utilize electromagnetism (PS.9 e) * apply an understanding of electromagnetic induction to explain the current produced when a coil of wire is moved through a magnetic field (PS.9 e) * plan and conduct an investigation to determine the factors that affect the strength of electric and magnetic forces (PS.9 e) * compare generators and motors and how they function (PS.9 f) * identify everyday appliances and technologies that utilize motors and generators (PS.9 f). |

## Biology

The Biology standards are designed to provide students with a detailed understanding of living systems. Students investigate biochemical life processes, cellular organization, mechanisms of inheritance, dynamic relationships among organisms, and the changes in organisms through time. Skills necessary to examine scientific explanations, conduct experiments, analyze and communicate information, and gather and use information in scientific literature continues to be important. The importance of scientific research that validates or challenges ideas is emphasized at this level. Tools and technology, including calculators, computers, probes and sensors, and microscopes are used when feasible. Students will use chemicals and equipment safely. Mathematics, computational thinking, and experiences in the engineering design process are important as students advance in their scientific thinking.

### Scientific and Engineering Practices

Engaging in the practices of science and engineering helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the many ways to investigate, model, and explain the world. These scientific and engineering practices include the use of scientific skills and processes to explore the content of science as outlined in the *Science Standards of Learning*. The engineering design practices are the application of science content to solve a problem or design an object, tool, process, or system. These scientific and engineering practices are critical to science instruction and are to be embedded throughout the year.

**BIO.1 The student will demonstrate an understanding of scientific and engineering practices by**

1. **asking questions and defining problems**
   * **ask questions that arise from careful observation of phenomena and/or organisms, from examining models and theories, and/or to seek additional information**
   * **determine which questions can be investigated within the scope of the school laboratory or field to determine relationships between independent and dependent variables**
   * **generate hypotheses based on research and scientific principles**
   * **make hypotheses that specify what happens to a dependent variable when an independent variable is manipulated**
2. **planning and carrying out investigations**
   * **individually and collaboratively plan and conduct observational and experimental investigations**

* **plan and conduct investigations or test design solutions in a safe and ethical manner including considerations of environmental, social, and personal effects**
* **determine appropriate sample size and techniques**
* **select and use appropriate tools and technology to collect, record, analyze, and evaluate data**

1. **interpreting, analyzing, and evaluating data**

* **construct and interpret data tables showing independent and dependent variables, repeated trials, and means**
* **construct, analyze, and interpret graphical displays of data**
* **use data in building and revising models, supporting an explanation for phenomena, or testing solutions to problems**
* **analyze data using tools, technologies, and/or models to make valid and reliable scientific claims or determine an optimal design solution**

1. **constructing and critiquing conclusions and explanations**
   * **make quantitative and/or qualitative claims regarding the relationship between dependent and independent variables**
   * **construct and revise explanations based on valid and reliable evidence obtained from a variety of sources including students’ own investigations, models, theories, simulations, and peer review**
   * **apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and design solutions**
   * **compare and evaluate competing arguments or design solutions in light of currently accepted explanations and new scientific evidence**
   * **construct arguments or counterarguments based on data and evidence**
   * **differentiate between a scientific hypothesis and theory**
2. **developing and using models**
   * + **evaluate the merits and limitations of models**
     + **develop, revise, and/or use models based on evidence to illustrate or predict relationships**
     + **develop and/or use models to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems**
3. **obtaining, evaluating, and communicating information**

* **compare, integrate, and evaluate sources of information presented in different media or formats to address a scientific question or solve a problem**
* **gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and credibility of each source**
* **communicate scientific and/or technical information about phenomena in multiple formats**

### Biology Content

**BIO.2 The student will investigate and understand that chemical and biochemical processes are essential for life. Key ideas include**

* 1. **water chemistry has an influence on life processes;**
  2. **macromolecules have roles in maintaining life processes;**
  3. **enzymes have a role in biochemical processes;**
  4. **protein synthesis is the process of forming proteins which influences inheritance and evolution; and**
  5. **the processes of photosynthesis and respiration include the capture, storage, transformation, and flow of energy.**

**Central Idea:** Organisms are complex systems that require energy and materials to support biochemical processes that maintain metabolism.

**Vertical Alignment:** Students are introduced to the fundamental life processes in Life Science to include the transfer of energy through photosynthesis and cellular respiration, the flow of matter via the carbon, water, and nitrogen cycles, and the role of DNA in making proteins (LS.4, LS.5, LS.10). In Biology, these life processes are explored at greater depth as students explore the mechanics of each of these processes and the effects of the processes at the system level (cellular, organism, population, and ecosystem).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| The structure of an object or living thing determines many of its properties and functions.   * Water has chemical and physical properties that facilitate metabolic activities in living cells. Water is a solvent and dissolves chemicals, minerals, and nutrients that are used to support life processes. The polarity of water molecules causes them to be strongly attracted to one another and gives rise to surface tension and cohesion. Water is also a thermal regulator in living systems (BIO.2 a). * Carbon and other elements play a key role in determining the structure and function of macromolecules needed to sustain life processes. Life processes include growth and repair, reproduction, gas exchange, metabolism, and response (BIO.2 b). * Cells make a variety of macromolecules needed for life processes from a relatively small set of monomers. These macromolecules include carbohydrates, proteins, nucleic acids, and lipids (BIO.2 b). * Carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules (BIO.2 b).   The structure of enzymes moderates their function in chemical reactions in living things.   * Enzymes are a group of proteins that function to moderate the rate of metabolic reaction by acting as catalysts (BIO.2 c).   The structure of DNA serves as a code for the production of proteins through the process of protein synthesis.   * Proteins carry out the essential functions of life processes through systems of specialized cells (BIO.2 d). * Protein synthesis is a biochemical process that uses information coded in DNA to construct proteins (BIO.2 d).   Sustaining life processes requires substantial energy and matter inputs. The complex structural organization of organisms accommodates the capture, transformation, and elimination of the matter and energy needed to sustain life.   * As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. As a result of these complex chemical processes, energy is transferred from one system of interacting molecules to another (BIO.2 e). * The breakdown of nutrient molecules provides energy to the cell. This energy is stored in specific chemicals that are used to carry out the life functions of the cell (BIO.2 e). * Metabolism refers to all interactions among molecules within the well-ordered environment of the cell. Photosynthesis and cellular respiration are two important metabolic activities within living cells important in the transfer and transformation of energy for life processes. Energy transfer and transformation are subject to conservation laws (BIO.2 e). * Chloroplasts and mitochondria act as change agents within the cells of plants to make energy available for life processes (BIO.2 e). * Plant cells and many microorganisms use solar energy to combine molecules of carbon dioxide and water into complex, energy-rich organic compounds and release oxygen into the environment (BIO.2 e). * Chloroplasts convert radiant energy from sunlight into chemical energy with the help of the pigment chlorophyll. Chlorophyll aids in the energy transformation of sunlight (radiant energy) to chemical energy in sugar (BIO.2 e). * The sugar molecules produced from photosynthesis can be used immediately by plants and animals for energy, stored for later use, or rearranged into other compounds to carry out life processes (BIO.2 e). * Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy. In most animals and plants, oxygen reacts with carbon-containing molecules (sugars) to provide energy (in the form of ATP) and produce carbon dioxide and water (BIO.2 e). * Cellular respiration is a chemical reaction in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that store energy in a useful form for use by living cells (BIO.2 e). *Students are not expected to know the complex multistep processes of photosynthesis and respiration.* * The energy released during cellular respiration comes from chemical bonds. When these bonds are broken, energy is released. Most of this energy is lost as thermal energy but some is captured in the bonds of small molecules of ATP. ATP bonds are broken each time energy is needed by the cell for life processes (BIO.2 e). | In order to meet this standard, it is expected that students will   * relate the chemical and physical properties of water that contribute to metabolism (BIO.2 a) * recognize that living cells are composed of relatively few elements (BIO.2 b) * differentiate the four major categories of macromolecules (lipids, carbohydrates, proteins, and nucleic acids) through their primary roles and functions (BIO.2 b) * describe the structure of enzymes and explain their role in acting as catalysts to control the rate of metabolic reactions (BIO.2 c) * plan and conduct an investigation to determine the effect of an enzyme on a biochemical reaction and apply biological principles and evidence to explain the results (BIO.2 c) * explain the process of protein synthesis, including transcription and translation (BIO.2 d) * use a DNA or RNA codon chart to determine protein strands based on a segment of nucleic acid (BIO.2 d) * explain how biological systems use energy and matter to maintain organization, to grow, and to reproduce (BIO.2 e) * illustrate and explain the process in which photosynthesis transforms light energy into stored chemical energy (BIO.2 e) * explain the interrelatedness of photosynthesis and cell respiration, including energy transfer (BIO.2 e) * describe how the presence of oxygen affects the amount of energy available to an organism (BIO.2 e). |

**BIO.3 The student will investigate and understand that cells have structure and function. Key ideas include**

1. **the cell theory is supported by evidence;**
2. **structures in unicellular and multicellular organisms work interdependently to carry out life processes;**
3. **cell structures and processes are involved in cell growth and division;**
4. **the structure and function of the cell membrane support cell transport; and**
5. **specialization leads to the development of different types of cells.**

**Central Idea:** All living things are composed of cells. Although there are many different types of cells in terms of size, structure, and function, all cells have certain characteristics in common. The cell theory encapsulates the current understanding of the cell. Both theories and laws describe natural phenomena and are equal in terms of scientific validity.

**Vertical Alignment:** Students are introduced to cell structure as a critical part of the system that allows for processes such as photosynthesis, cellular respiration, and asexual reproduction (mitosis) in Life Science (LS.2). In Biology, students learn of the role of cells in performing and maintaining life processes in both unicellular and multicellular organisms. The processes include, but are not limited to, mitosis and meiosis, protein synthesis, aerobic and anaerobic respiration, photosynthesis and cellular respiration, and cell transfer.

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| The cell theory is a shared understanding that encapsulates our current understanding of the cell. The development of this theory illustrates the nature of science.  Advances in science and technology have added to our understanding of the cell. In addition to the original three tenets of the cell theory (which students learned about in Life Science), the current cell theory contains the following: metabolism occurs within cells, hereditary information (DNA) is passed from one cell to another, and all cells have the same basic composition (BIO.3 a). *Students are not responsible for describing the contributions of specific scientists.*  Organisms are complex, organized systems built on a hierarchical structure, with each level providing the matter and energy foundations for the next. This occurs from the chemical foundation of elements and atoms, to the cells and systems of individual organisms, to species and populations living and interacting in complex ecosystems.   * 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 (BIO.3 b). * Cells and organisms have structures that perform specific functions that allow for the movement of matter and energy to maintain life processes (BIO.3 b). * Some organisms exist as a single cell, while others are composed of many cells, each specialized to perform distinct metabolic functions. A single-celled organism has to conduct all life processes by itself. A multicellular organism has groups of cells that specialize to perform specific functions (BIO.3 b). * Cellular activities necessary for life include chemical reactions that facilitate energy acquisition, reproduction, and the maintenance of life processes (BIO.3 b).   Reproduction is a life process by which living things transfer genetic information to their offspring. Reproduction (of cells and organisms) is essential to the existence of all living things. In multicellular organisms, cell division creates new cells for growth, development, and repair.   * A typical cell goes through a process of growth, development, and reproduction called the *cell cycle* (BIO.3 c). * *Mitosis* refers to division of the nuclear material and produces two genetically identical cells. *Cytokinesis* is the division of the cytoplasm and organelles (BIO.3 c). * During DNA replication, enzymes unwind and unzip the double helix and each strand serves as a template for building a new DNA molecule. Free nucleotides bond to the template (A-T and C-G), forming a complementary strand. The final products of replication are two identical DNA molecules (BIO.3 c).   Living things must move materials into, out of, and within the cell.   * The life processes of a cell are maintained by the plasma membrane, which is comprised of a variety of organic molecules. The membrane controls the movement of material in and out of the cell, communication between cells, and the recognition of cells to facilitate multiple metabolic functions (BIO.3 d). * Substances can move across the cell membrane passively (i.e., osmosis and diffusion) or actively (i.e., active transport) (BIO.3 d). * Two passive processes that allow for this exchange of materials are diffusion and osmosis. These processes require no energy on the part of the cell. Substances merely move toward equilibrium (from an area of high concentration to an area of low concentration) (BIO.3 d). * The processes of diffusion, osmosis, and facilitated diffusion require no energy (BIO.3 d). * Active transport requires energy. Endocytosis and exocytosis are examples of active transport (BIO.3 d).   A key concept in science is that *form fits function*. In multicellular organisms, cells have specialized shapes that enable them to perform specific roles within the organism.   * Organisms differ from one another in cell structure and chemistry. The diversity that exists ranges from simple prokaryotic cells to complex multicellular organisms (BIO.3 e). * Multicellular organisms possess different types of cells to carry out life processes. Each specialized cell type has a specific structure that helps it perform a specific function (BIO.3 e). * Organelles perform specific functions in the cell. Different types of cells have different numbers and types of organelles (BIO.3 e). | In order to meet this standard, it is expected that students will   * provide examples to illustrate how additions to the original cell theory illustrate the nature of science (BIO.3 a) * differentiate among a scientific hypothesis, theory, and law (BIO.3 a) * compare how life processes are maintained within cells and within organisms (BIO.3 b) * explain how the organelles function individually and in a system to support life processes (BIO.3 b) * explain how the levels of cellular organization contribute to division of labor in multicellular organisms (BIO.3 b) * use an argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells (BIO.3 b) * plan and conduct an investigation to provide evidence that mechanisms maintain homeostasis within living things, such as heart rate response to exercise, stomate response to moisture and temperature, and root development in response to water levels (BIO.3 b) * model and describe the parts of cell cycle to include the processes involved in each stage of mitosis (BIO.3 c) * explain the importance of DNA replication in cell division (BIO.3 c) * describe how the composition of the cell membrane contributes to cell function (BIO.3 d) * construct and use models and simulations to represent and explain how substances move across the cell membrane by osmosis, diffusion, facilitated diffusion, and active transport; evaluate the limitations of models used when appropriate (BIO.3 d) * describe how the cell’s surroundings influence the direction and type of cell transport (BIO.3 d) * plan and conduct investigations related to how concentration affects the rate of diffusion across a semipermeable membrane, using proper sampling techniques, data collection, and analysis procedures (BIO.3 d) * compare the energy needed to move substances across the cell membrane by osmosis, diffusion, facilitated diffusion, and active transport (BIO.3 d) * describe the role of cell specialization (or lack thereof) in the life processes of unicellular and multicellular organisms (BIO.3 e) * provide evidence to support the idea that a cell’s *form fits its function* within a multicellular organism (BIO.3 e). |

**BIO.4 The student will investigate and understand that bacteria and viruses have an effect on living systems. Key ideas include**

1. **viruses depend on a host for metabolic processes;**
2. **the modes of reproduction/replication can be compared;**
3. **the structures and functions can be compared;**
4. **bacteria and viruses have a role in other organisms and the environment; and**
5. **the germ theory of infectious disease is supported by evidence.**

**Central Idea:** Bacteria have diverse structures and metabolic functions and affect other organisms and the environment. Viruses have similarities to living organisms but are not living, even though they affect host organisms.

**Vertical Alignment:** Students have studied the classification of organisms and general characteristics of each of the domains and kingdoms in Life Science (LS.3); however, Biology is the first time students will take an in-depth look at both bacteria and viruses**.**

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| Viruses can dramatically affect living things. The influenza, West Nile, and Ebola viruses have killed millions of people. Plants, too, can be infected by viruses. By studying viruses, scientists can develop vaccines and antiviral medicines to reduce their lethality.   * Viruses are small, infectious agents that replicate only inside the living cells of organisms. Because viruses transmit DNA or RNA into the host cell, they can introduce genetic variation into the hosts. Viruses that infect bacteria may give an organism a selective advantage and enable it to fight off an infection (BIO.4 a). * Viruses do not share many of the characteristics of living organisms. Viruses are not cells. Basic viral structure consists of a nucleic acid core surrounded by a protein coat. Viruses can reproduce only inside a living cell, the host cell (BIO.4 a). * Viruses reproduce through the lytic cycle. The lysogenic cycle results in delayed viral reproduction but eventually concludes with the lytic cycle (BIO.4 b). * Virus structure consists of a nucleic acid (single or double-stranded RNA or DNA) and a protein coat (capsid) which serves as a protective covering (BIO.4 c). * Viruses are important microbial predators that influence global biochemical cycles and drive microbial evolution (BIO.4 d).   Bacteria play important roles in the global ecosystem, including a lead role in the cycling of nutrients (BIO.4 d).   * Bacteria reproduce sexually (conjugation) and asexually (budding and binary fission). Sexual reproduction in bacteria is rare (BIO.4 b). *Students are not expected to know other types of sexual reproduction in bacteria or the mechanisms of either sexual or asexual reproduction in bacteria.* * Bacteria can also be classified according to how they obtain energy for cellular respiration or fermentation. Bacteria may be heterotrophs, photoautotrophs, or chemoautotrophs (BIO.4 c).   The germ theory is a shared understanding that encapsulates our current understanding of disease transmission. The development of this theory illustrates the nature of science.   * Throughout history, people have created explanations for disease. The introduction of the germ theory led to the understanding that many diseases are caused by microorganisms. Changes in health practices have resulted from the acceptance of the germ theory of disease (BIO.4 e). * Modern health practices emphasize sanitation, the safe handling of food and water, aseptic techniques to keep germs out of the body, and the development of vaccinations and other chemicals and processes to destroy microorganisms (BIO.4 e). * Vaccines and antibiotics are used to prevent or cure diseases. Vaccines are used to prevent diseases by exposing hosts to a dead or weakened forms of a virus. The body’s immune system builds an immune response that will be employed with future exposure to the same virus. Antibiotics are used to cure a bacterial disease by killing the bacterium (BIO.4 e). | In order to meet this standard, it is expected that students will   * explain in simple terms how viruses infect host organisms (BIO.4 a) * use evidence to support the description of bacteria as living and viruses as nonliving (BIO.4 a) * compare a virus and a bacterium in relation to genetic material and reproduction (BIO.4 b, c) * examine effects of bacteria and viruses on human health (BIO.4 d) * provide an evidence-based explanation that connects the germ theory to the nature of science, such as describing the effects of Pasteur’s and Koch’s experiments on the understanding of disease transmission (BIO.4 e) * describe how germ theory exemplifies the nature of science as supported by evidence (BIO.4 e) * use evidence from scientific literature and research to support a claim on the use or misuse of vaccines or antibiotics (BIO.4 e). |

**BIO.5 The student will investigate and understand that there are common mechanisms for inheritance. Key ideas include**

1. **DNA has structure and is the foundation for protein synthesis;**

**b) the structural model of DNA has developed over time;**

**c) the variety of traits in an organism are the result of the expression of various combinations of alleles;**

**d) meiosis has a role in genetic variation between generations; and**

**e) synthetic biology has biological and ethical implications.**

**Central Idea:** Traits of living things are influenced by genetic makeup and can be predicted using genetic information. Genetic information can be determined and altered through synthetic means.

**Vertical Alignment:** Students begin their study on the mechanisms for heredity in Life Science through an introduction to the process of meiosis (LS.10). Although this process is introduced, the steps involved in meiosis are outside the scope of Life Science. Students predict the probability of a trait being expressed with monohybrid crosses. Terminology is introduced in Life Science to include: *homozygous*, *heterozygous*, *dominant*, *recessive*, *gametes*, *genotype*, and *phenotype* (LS.10).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
| --- | --- |
| The structure and function of DNA are intimately linked.   * Scientists use 2-D, 3-D, and virtual models to represent the structure of DNA. Models are used when the object is too small or too complex to be studied directly (BIO.5 a). * DNA is a helical macromolecule consisting of nucleotides. Each nucleotide is identified by the base it contains: adenine (A), guanine (G), cytosine (C) or thymine (T) (BIO.5 a). * Nucleotides are connected by covalently bonded sugar and phosphate molecules (BIO.5 a). * The information encoded in DNA molecules provides instructions for assembling amino acids, which ultimately form protein molecules. The code for specific amino acids is virtually the same for all life forms (BIO.5 a). * Modern advances (since 1990) in science and technology have added to our understanding of the structure of DNA and its function (e.g., Sanger technique, Human Genome Project, sequencing chromosomes) (BIO.5 b). *Students are not responsible for describing the contributions of specific scientists.*   A complex system functions to pass characteristics (traits) from one generation to the next. The interaction of heredity mechanisms and the environment creates both stability from one generation to the next and drives change that produces the diversity of life on our planet.   * 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 (BIO.5 a). * Organisms transfer their genetic information to their offspring when they reproduce (BIO.5 c). * Sexual reproduction involves the production of sex cells (gametes). Sex cells each carry half the parent’s genetic material (on chromosomes) (BIO.5 c). * In sexual reproduction, each parent contributes half of the genetic information acquired by the offspring, resulting in variation between parent and offspring (BIO.5 c). * Genes and chromosomes are present in pairs (e.g., allele B or b) in individuals (for diploid organisms). All genes assort independent of other genes during sex cell production in meiosis. The probability of a sex cell containing either allele from the pair is 50 percent (BIO.5 c). * Asexual reproduction produces offspring which are genetically identical to the parent (mitosis) (BIO.5 c). * Genetically diverse populations are more likely to survive changing environments. Recombination and mutation provide for genetic diversity. Some new gene combinations have little effect, some can produce organisms that are better suited to their environments, and others can be deleterious (BIO.5 c). * Each chromosome consists of a single, very long DNA molecule, and each gene on the chromosome is a particular 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 (BIO.5 c). * Mendel’s laws of heredity are based on his mathematical analysis of observations of patterns of inheritance of dominant-recessive traits (BIO.5 c). * Geneticists apply mathematical principles of probability to Mendel’s laws of heredity to predict the results of simple genetic crosses. The laws of probability govern simple genetic recombinations (BIO.5 c). * A Punnett square is a mathematical model that shows the probability of certain genetic combinations in offspring (BIO.5 c). * Genotype describes the genetic make-up of an organism and phenotype describes the organism’s appearance based on its genes. Phenotype describes the observable physical or biochemical characteristics of the organism (BIO.5 c). * Variations of dominant-recessive expression of alleles include incomplete dominance and co-dominance (BIO.5 c). *Students are not responsible for describing sex-linked and polygenic inheritance.*   In eukaryotes, heritable information is passed to the next generation via processes that include the cell cycle and mitosis or meiosis plus fertilization.   * Meiosis refers to division of the nuclear material. Cytokinesis is the division of the cytoplasm and organelles (BIO.5 d). *Students are not responsible for identifying the stages of meiosis.* * Many organisms combine genetic information from two parents to produce offspring. Sex cells (gametes) are produced through meiosis. This allows sexually reproducing organisms to produce genetically differing offspring and maintain their number of chromosomes (BIO.5 c).   Science and technology are tightly linked. Technologies have improved our understanding of DNA, its function, and how its code can be manipulated for a variety of purposes.   * Genetic engineering techniques are used in a variety of industries, in agriculture, in basic research, and in medicine. There is great benefit in terms of useful products derived through genetic engineering (e.g., human growth hormone, insulin, and pest- and disease-resistant fruits and vegetables) (BIO.5 e). * Synthetic biology combines many different science disciplines to design and build new biological parts, devices, and systems. Synthetic biology has many different applications (BIO.5 e). * Tools and techniques are used in genetic engineering, such as polymerase chain reaction, restriction enzymes, gel electrophoresis, DNA ligase, bacterial plasmids, and CRISPR have improved our ability to genetically alter the DNA or organisms for a specific purpose. Synthetic biology employs different tools, depending on the desired product (BIO.5 e). | In order to meet this standard, it is expected that students will   * compare a variety of DNA models and evaluate them for their effectiveness in explaining its structure and function (BIO.5 a) * provide examples to illustrate how modern advances related to DNA structure and function illustrate the nature of science (BIO.5 b) * relate the expression of a phenotype to a given genotype (BIO.5 c) * use a Punnett square to predict all possible combinations of gametes and the likelihood that a given combination will occur in monohybrid and dihybrid crosses (BIO.5 c) * predict possible genotypes and phenotypes of non-Mendelian traits (BIO.5 c) * identify sources of genetic diversity and explain how it can be an advantage for populations (BIO.5 c) * apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population (BIO.5 c) * describe in general terms the stages of meiosis and explain the processes occurring at each stage; differentiate these from the end products of mitosis (BIO.5 d) * explain why meiosis is important for sexual reproduction (BIO.5 d) * compare the process of mitosis and meiosis and determine which conditions are necessary for each process to occur (BIO.5 d) * make and defend a claim based on evidence from scientific literature that inheritable genetic variations may result from * new genetic combinations through meiosis * viable errors occurring during replication * environmental factors (BIO.5 c, d) * evaluate and use credible, accurate, and unbiased resources to gather and summarize scientific and technical information about how genetic engineering tools and technologies can be used to alter the genome of an organism (BIO.5 e) * debate the pros and cons of synthetic biology (BIO.5 e) * evaluate data from databases or experimentation to support an argument for the transmission of traits across generations (BIO.5 e). |

**BIO.6 The student will investigate and understand that modern classification systems can be used as organizational tools for scientists in the study of organisms. Key ideas include**

1. **organisms have structural and biochemical similarities and differences;**
2. **fossil record interpretation can be used to classify organisms;**
3. **developmental stages in different organisms can be used to classify organisms;**
4. **Archaea, Bacteria, and Eukarya are domains based on characteristics of organisms;**
5. **the functions and processes of protists, fungi, plants, and animals allow for comparisons and differentiation within the Eukarya kingdoms; and**
6. **systems of classification are adaptable to new scientific discoveries.**

**Central Idea:** Taxonomic classification is a hierarchal system for classifying organisms. Organisms are classified based on physiological structures, embryology and ontogeny, and phylogenetic relationships. Evidence shows how species can change over time. Species are related to varying degrees, which can be determined through evolutionary relationships.

**Vertical Alignment:** Students are introduced to the concept of classification in elementary science and the concept is expanded in Life Science. Students learn characteristics of the domains and kingdoms and use this knowledge to classify organisms. Students are also introduced to the major phyla of the plant and animalkingdoms (LS.3). InBiology, students will build on their classification and taxonomy knowledge as they compare organisms using biochemical, cellular, and embryologic properties and fossil evidence.

| **Enduring Understandings** | **Essential Knowledge and Processes** |
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| Classification relies on careful observation of patterns of similarities and differences. Classification is useful in explaining relationships and organizing objects or processes into groups.   * Organisms that live on Earth today, or once lived on Earth, are classified into a hierarchy of groups and subgroups based on similarities of physiological structures, embryology and ontogeny (development), and phylogenetic (evolutionary) relationships (BIO.6 f). * The organisms that live on Earth today share many physiologic structures and metabolic processes, including cellular organization; common molecular mechanisms for energy transformation, utilization, and maintenance of life processes; common genetic code; and mechanisms for the transmission of traits from one generation to the next (BIO.6 a, b, c). * Evolutionary relationships can be represented using a branching diagram called a *cladogram* or *phylogenetic tree,* on which they are organized by shared, derived characteristics (BIO.6 a, b, c, f). * Biological classification (*taxonomy*) uses a systematic method to name, organize, and show how organisms are related (BIO.6 d, e, f). * Binomial nomenclature is a standard way of identifying a species with a scientific two-word name. The first word is the genus name and the second is the species name. Species is the basic unit of classification (BIO.6 f). * Similarities among organisms on the structural and metabolic levels are reflected in the large degree of similarity in proteins and nucleic acids of different organisms. Diversity is the product of variations in these molecules (BIO.6 a). * Information about relationships among living organisms and those that inhabited Earth in the past is gained by examining and interpreting the fossil record. Fossilsprovide a time-ordered record of the unique characteristics of organisms over millions of years. Data from fossilscan be used to infer phylogenetic relationships among existing and extinct organisms (BIO.6 b).   A cladogram is a model (diagram) used to show relationships among organisms. A cladogram uses lines that branch off in different directions, ending at a group of organisms with a common ancestor (*clade*) (BIO.6 b).   * Embryology is the study of an organism’s embryological development and may reveal that there arefeatures present in early stages that that are absent in the adult form of the organism (BIO.6 c). * Information about the physical features and activities of living things are organized into a hierarchy of increasing specificity (BIO.6). * Characteristics used to classify organisms into domains include, but are not limited to, whether the organism is prokaryotic vs. eukaryotic, differences in sequences of nucleic acids (RNA), and the cell membrane and/or cell wall structure (BIO.6 d).   Characteristics used to group organisms into kingdoms include, but are not limited to, prokaryote vs. eukaryote, unicellular vs. multicellular, cell wall vs. no cell wall, level of organization of cells into tissues, autotroph vs. heterotroph, and within heterotrophs, decomposer vs. ingestion (BIO.6 e).   * Protists are simple, predominately unicellular, eukaryotic organisms (BIO.6 e). * Fungi are unicellular or multicellular, eukaryotic organisms. The cells of fungi have cell walls but are not organized into tissues. They are heterotrophs and obtain nutrients through absorption (BIO.6 e). * Plants are multicellular, eukaryotic organisms. The cells of plants have cell walls and are organized into tissues. Plants are autotrophs and obtain nutrients through photosynthesis and absorption. Plant divisions include mosses, ferns, conifers, and flowering plants (BIO.6 e). * Animals are multicellular, eukaryotic organisms. The cells of animals do not have a cell wall. Animals are heterotrophs and are mobile for at least a part of their life cycles (BIO.6 e). | In order to meet this standard, it is expected that students will   * arrange organisms in a hierarchy according to similarities and differences in structural and biochemical characteristics (BIO.6 a) * recognize scientific names as part of a binomial nomenclature (BIO.6 a) * compare structural characteristics of an extinct organism, as evidenced by its fossil record, with present, familiar organisms (BIO.6 b) * 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) (BIO.6 b) * interpret a cladogram or phylogenetic tree to make inferences about the evolutionary relationships among organisms (BIO.6 b) * recognize similarities in embryonic stages in diverse organisms in the animal kingdom, from zygote through embryo, and infer relationships (BIO.6 c) * apply classification criteria to categorize examples of organisms as representatives of the three domains: Archaea, Bacteria, and Eukarya (BIO.6 d) * apply classification criteria to categorize examples of organisms as representatives of the six kingdoms: archaebacteria, eubacteria, protista, fungi, plantae, and animalia (BIO.6 e) * recognize new attributes (physical and chemical) that affect the taxonomic group into which an organism is (or was) placed (BIO.6 f). |

**BIO.7 The student will investigate and understand that populations change through time. Key ideas include**

1. **evidence is found in fossil records and through DNA analysis;**
2. **genetic variation, reproductive strategies, and environmental pressures affect the survival of populations;**
3. **natural selection is a mechanism that leads to adaptations and may lead to the emergence of new species; and**
4. **biological evolution has scientific evidence and explanations.**

**Central Idea:** Similarities and differences in inherited characteristics of organisms alive today or in the past can be used to infer the relatedness of any two species, changes in species over time, and lines of evolutionary descent. Speciation, extinction, and changes in population genetics result from evolution.

**Vertical Alignment:** Students learn about change over time as it relates to mutations that may lead to adaptations within a population in Life Science. Natural selection, leading to the evolution of a population, is evidenced through fossil records, genetic information, and anatomical comparisons (LS.11).

| **Enduring Understandings** | **Essential Knowledge and Skills** |
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| Genetic variation, reproductive strategies, and environmental pressures affect the survival of populations   * A fossil is any evidence of an organism that lived long ago. Scientists have used the fossil record to construct a history of life on Earth. Although there is not a complete record of ancient life for the past 3.5 billion years, a great deal of modern knowledge about the history of life comes from the fossil record (BIO.7 a). * Having similar DNA is a strong indicator that organisms share a common ancestor. Identifying DNA sequences through comparative genomics has helped to identify and better understand similarities in DNA sequences across species (BIO.7 a). * Variations within a population for a given trait can arise through mutations, gene flow, and sexual reproduction. Mutations are changes in the sequence of DNA nitrogenous bases. The accumulation of mutations within a population over time can result in changes to the gene pool. The movement of genes from one population to another also provides greater genetic variation. The genetic shuffling that takes place during meiosis and sexual reproduction introduces new gene combinations within a population (BIO.7 b). * Organisms possess reproductive strategies and rates that maximize the probability that their offspring, and thus the population, can survive (BIO.7 b). * Populations produce more offspring than the environment can support. Organisms with certain genetic variations will be favored to survive and pass their variations on to the next generation (BIO.7 b). * Variations within populations sometimes arise abruptly in response to strong environmental selective pressures (BIO.7 b).   Natural selection is a mechanism that leads to adaptations and may lead to the emergence of new species.   * Natural selection occurs only if there is both variation in the genetic information among organisms in a population and variation in the expression of that genetic information that leads to differences in performance among individuals (BIO.7 c). * The unequal ability of individuals to survive and reproduce leads to the gradual change in a population, generation after generation, over many generations (BIO.7 b). * Traits that positively affect survival are more likely to be reproduced and are more common in the population (BIO.7 c). * Natural selection leads a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment (BIO.7 c). * Depending on the selective pressure, these changes can be rapid over few generations (i.e., antibiotic resistance) or may take millions of years to develop (BIO.7 d). * Speciation, the emergence of new species, occurs when a lineage has split into groups that can no longer naturally interbreed and produce fertile offspring and/or are no longer genetically aligned (BIO.7 d). * If a population is not able to respond to environmental pressures, it may become extinct (BIO.7 c).   Biological evolution is supported by scientific evidence from many disciplines.   * Natural selection may lead to the permanent change in the frequency of a gene in a given population. This is called *biological evolution* (BIO.7 c). * Biological evolution is supported by scientific evidence from many disciplines such as, but not limited to, paleontology, geology, embryology, anatomy, biology, genetics, and biochemistry (BIO.7 d). | In order to meet this standard, it is expected that students will   * determine the relative age of a fossil, given information about its position in the rock and absolute dating by radioactive decay (BIO.7 a) * differentiate between relative and absolute dating based on fossils in biological evolution (BIO.7 a) * explain how advancements in our understanding of DNA and its function contribute to the understanding that species change over time (BIO.7 a) * provide evidence to support the argument that variations for a given trait within a population may be helpful or harmful to the survival of a population when environmental pressures arise (BIO.7 b) * discuss sources of genetic variation within a population (BIO.7 b) * describe the effect of reproductive strategies and rates on a population’s survival (BIO.7 b) * predict the effects of environmental pressures on populations (BIO.7 b) * explain how natural selection leads to changes in gene frequency in a population over time (BIO.7 c) * compare punctuated equilibrium with gradual change over time (BIO.7 d) * construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships (BIO.7 d) * explain how advancements in genetic technology contribute to the understanding that species change over time (BIO.7 a) * construct an explanation based on evidence that the process of evolution primarily results from   + the potential for a species to increase in number   + the heritable genetic variation of individuals in a species due to mutation and sexual reproduction   + competition for limited resources   + the proliferation of those organisms that are better able to survive and reproduce in the environment (BIO.7 a, b, c, d) * evaluate evidence supporting the claim that changes in environmental conditions may result in an increased number of some species, the emergence of new species over time, and/or the extinction of other species (BIO.7 b, c, d). |

**BIO.8 The student will investigate and understand that there are dynamic equilibria within populations, communities, and ecosystems. Key ideas include**

1. **interactions within and among populations include carrying capacities, limiting factors, and growth curves;**
2. **nutrients cycle with energy flow through ecosystems;**
3. **ecosystems have succession patterns; and**
4. **natural events and human activities influence local and global ecosystems and may affect the flora and fauna of Virginia.**

**Central Idea:** Organisms are part of living systems and demonstrate interdependence with other organisms and the environment.

**Vertical Alignment:** Students study both the biotic and abiotic factors that affect an ecosystem, to include the movement of matter and energy through the ecosystem (including both biochemical cycles and organism interactions) in Life Science. Interactions of organisms, populations, communities, and ecosystems are emphasized, including human interactions and the impact of these interactions on ecosystem dynamics (LS.8, LS.9).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
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| All biological systems from cells and organisms to populations, communities, and ecosystems are affected by complex biotic and abiotic interactions involving exchange in matter and energy.   * *Carrying capacity* is the number of organisms that can be supported by the resources in an ecosystem (BIO.8 a). * Ecosystems have carrying capacities, which refer to the limits to the numbers of organisms and populations ecosystems 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 (BIO.8 a). * Populations are groups of interbreeding individuals that live in the same place at the same time and compete for food, water, shelter, and mates (BIO.8 a). * Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives (BIO.8 a). * As any population of organisms grows, it is held in check by interactions among a variety of biotic and abiotic factors (BIO.8 a). * Abiotic factors are the nonliving elements in an ecosystem, such as temperature, moisture, air, salinity, and pH. Biotic factors are all the living organisms that inhabit the environment, including predators, food sources, and competitors (BIO.8 a). * Communities are composed of populations of organisms that interact in complex ways. Members of a population interact with other populations in a community. These organisms compete to obtain the matter and energy they need for basic resources, mates, and territory. They also cooperate to meet basic needs and carry out life processes (BIO.8 a). * Population growth curves exhibit many characteristics, such as initial growth stage, exponential growth, steady state, decline, and extinction. Limiting factors are the components of the environment that restrict the growth of populations (BIO.8 a).   Systems are dynamic and change in response to inputs and outflows of energy and matter. A healthy ecosystem has a state of dynamic equilibrium, when the inflow and outflow of energy and matter is steady. When one of the variables is out of balance, the health of the ecosystem changes.   * Ecosystems demonstrate an exchange of energy and nutrients among inhabiting organisms (BIO.8 b). * An ecosystem consists of all the interacting species and the abiotic environment in a given geographic area. All matter, including essential nutrients, cycle through an ecosystem. The most common examples of such matter and nutrients include carbon, nitrogen, and water (BIO.8 b). * Photosynthesis and cellular respiration are important components for the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes (BIO.8 b). * The main components of the nitrogen cycle include nitrogen fixation, nitrification, assimilation, ammonification, and de-nitrification (BIO.8 b). * The main components of the carbon cycle include photosynthesis, respiration, combustion, and decomposition (BIO.8 b).   Ecological succession is the process by which the structure of a biological community evolves over time.   * Ecological succession is a predictable change in the sequence of species that establish in an area over time (BIO.8 c). * A *climax community* occurs when succession slows and a stable community is established. The climax community in most of Virginia is a deciduous oak-hickory (hardwood) forest (BIO.8 c).   Human and natural activities affect ecosystems on local, regional, and global scales.   * As the human population increases, so does the human impact on the environment. Human activities, such as reducing the amount of forest cover, increasing the amount and variety of chemicals released into the environment, and intensive farming, have changed Earth’s land, oceans, and atmosphere. Some of these changes have decreased the capacity of the environment to support some life forms (BIO.8 d). * Large-scale changes that influence ecosystems include the addition of excess nutrients to the system (eutrophication), which alters environmental balance; dramatic changes in climate; and catastrophic events, such as fire, drought, flood, and earthquakes (BIO.8 d). | In order to meet this standard, it is expected that students will   * use mathematical representations such as charts, graphs, histograms, and population change data, to support explanations of factors that affect carrying capacity of ecosystems (BIO.8 a) * make predictions about changes that could occur in population numbers as the result of population interactions (BIO.8 a) * graph and interpret a population growth curve and identify the carrying capacity of the populations (BIO.8 a) * interpret how the flow of energy occurs between trophic levels in all ecosystems in a   + food chain   + food web   + pyramid of energy   + pyramid of biomass (BIO.8 b) * develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere (BIO.8 b) * evaluate 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 BIO.8 c) * recognize and understand the cause-and-effect relationship between changes in the abiotic and biotic conditions in an ecosystem and succession (BIO.8 c) * describe the patterns of succession found in aquatic and terrestrial ecosystems of Virginia (BIO.8 c) * identify factors leading to primary and secondary succession (BIO.8 c) * describe the characteristics of a climax community (BIO.8 c) * provide examples to illustrate and explain how habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change can disrupt an ecosystem and threaten the survival of species (BIO.8 d) * design, evaluate, and refine a solution for reducing the negative effects of human activity on a Virginia watershed or ecosystem (BIO.8 d). |

## Chemistry

The Chemistry standards are designed to provide students with a detailed understanding of the interaction between matter and energy. This interaction is investigated using experimentation, mathematical reasoning, and problem solving. Areas of study include atomic theory, chemical bonding, chemical reactions, molar relationships, kinetic molecular theory, and thermodynamics. Concepts are illustrated with current practical applications that should include examples from environmental, nuclear, organic, and biochemistry content areas. Technology, including graphing calculators, computers, simulations, and probeware are used when feasible. Students will use chemicals and equipment safely. Mathematics, computational thinking, and experience with the engineering design process are essential as students advance in their scientific thinking.

### Scientific and Engineering Practices

Engaging in the practices of science and engineering helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the many ways to investigate, model, and explain the world. These scientific and engineering practices include the use of scientific skills and processes to explore the content of science as outlined in the *Science Standards of Learning*. The engineering design practices are the application of science content to solve a problem or design an object, tool, process, or system. These scientific and engineering practices are critical to science instruction and are to be embedded throughout the year.

**CH.1 The student will demonstrate an understanding of scientific and engineering practices by**

1. **asking questions and defining problems**

* **ask questions that arise from careful observation of phenomena, examination of a model or theory, unexpected results, and/or to seek additional information**
* **determine which questions can be investigated within the scope of the school laboratory**
* **make hypotheses that specify what happens to a dependent variable when an independent variable is manipulated**
* **generate hypotheses based on research and scientific principles**
* **define design problems that involve the development of a process or system with interacting components, criteria and constraints**

1. **planning and carrying out investigations**
   * **individually and collaboratively plan and conduct observational and experimental investigations**

* **plan and conduct investigations or test design solutions in a safe manner, including planning for response to emergency situations**
* **select and use appropriate tools and technology to collect, record, analyze, and evaluate data**

1. **interpreting, analyzing and evaluating data**

* **record and present data in an organized format that communicates relationships and quantities in appropriate mathematical or algebraic forms**
* **use data in building and revising models, supporting explanations for phenomena, or testing solutions to problems**
* **solve problems using mathematical manipulations including the International System of Units (SI), scientific notation, derived units, significant digits, and dimensional analysis**
* **analyze data using tools, technologies, and/or models (e.g., computational, mathematical) to make valid and reliable scientific claims or determine an optimal design solution**
* **analyze data graphically and use graphs to make predictions**
* **differentiate between accuracy and precision of measurements**
* **consider limitations of data analysis when analyzing and interpreting data**
* **analyze data to optimize a design**

1. **constructing and critiquing conclusions and explanations**

* **construct and revise explanations based on valid and reliable evidence obtained from a variety of sources**
* **apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena or design solutions**
* **compare and evaluate competing arguments in light of currently accepted explanations and new scientific evidence**
* **construct arguments or counterarguments based on data and evidence**
* **differentiate between scientific hypothesis, theory, and law**

1. **developing and using models**

* **evaluate the merits and limitations of models**
* **develop, revise, and/or use models based on evidence to illustrate or predict relationships**
* **use models and simulations to visualize and explain the movement of particles, to represent chemical reactions, to formulate mathematical equations, and to interpret data sets**

1. **obtaining, evaluating, and communicating information**

* **compare, integrate, and evaluate sources of information presented in different media or formats to address a scientific question or solve a problem**
* **gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and credibility of each source**
* **communicate scientific and/or technical information about phenomena and/or a design process in multiple formats**

### Chemistry Content

**CH.2 The student will investigate and understand that elements have properties based on their atomic structure. The periodic table is an organizational tool for elements based on these properties. Key information pertaining to the periodic table includes**

1. **average atomic mass, isotopes, mass number, and atomic number;**
2. **nuclear decay;**
3. **trends within groups and periods including atomic radii, electronegativity, shielding effect, and ionization energy;**
4. **electron configurations, valence electrons, excited electrons, and ions; and**
5. **historical and quantum models.**

**Central Idea:** The properties of elements, to include the periodic trends, are based on their atomic structure. The periodic table is an organizational tool that allows for the prediction of chemical and physical properties.

**Vertical Alignment:** Students are introduced to the periodic table as a tool that can be used to predict chemical and physical properties in Physical Science (PS.2, PS.4). Students used the periodic tool to identify groups, periods, atomic numbers, atomic masses, and valence electrons.

| **Enduring Understandings** | **Essential Knowledge and Practices** |
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| Atoms are the basic building blocks of all matter. The properties of an atom are based on the number and arrangement of its parts.   * The subatomic particles have specific characteristics of mass, charge, and location (CH.2). * An isotope is an atom that has the same number of protons as another atom of the same element but has a different number of neutrons. Some isotopes are radioactive. The average atomic mass for each element is the weighted average of that element’s naturally occurring isotopes (CH.2 a). * Nuclear changes involve a change in the composition of the nucleus of an atom and may result in a new element (CH.2 b). * Half–life is the amount of time it takes for half of the substance to undergo nuclear change and is important in the use and storage of radioactive materials (CH.2 b). * Electron configuration is a numeric representation of the arrangement of electrons around the nucleus of an atom based on their energy levels. The number of paired and unpaired electrons determine chemical properties, particularly bonding (CH.2 d). * Ions form when atoms gain or lose an electron (CH.2 d). * A valence electron can absorb energy and become excited, thus moving to a higher principal energy level. The subsequent return of the valence electron to the ground state emits energy that is used in many applications (CH.2 d). * Electrons occupy equal-energy orbitals, resulting in a maximum number of unpaired electrons (CH.2 d).   Predictable patterns of properties emerge when elements are arranged according to the number of valence electrons. The periodic table models these patterns and can be used to predict properties of elements.   * The periodic table is a tool that shows an organization of elements and allows predictions about physical and chemical properties. The periodic table is arranged in order of increasing atomic numbers (CH.2 a). * Groups (families) have similar properties because of their similar valence electron configurations (CH.2 a, d). * Periods have predictable properties due to an increasing number of electrons in the outer energy levels (CH.2 c). * The periodic trends (i.e., electronegativity, ionization energy, shielding, and atomic radius) are determined by both the number of principal energy levels of the element and the number of protons of an element (CH.2 c). * Atomic radius, electronegativity, ionization energy, and shielding are periodic trends that explain the chemical properties of elements (CH.2 c). * The periodic table changes as new elements are made in laboratory settings (CH.2).   The Quantum-mechanical model of the atom encapsulates our current understanding of the atom. The development of these models illustrates the nature of science (LS.2).   * Discoveries and insights related to the atom’s structure have changed the model of the atom (CH.2 e). *Students are not responsible for describing the contributions of specific scientists.* | In order to meet this standard, it is expected that students will   * differentiate among a proton, neutron, and electron in terms of relative size, composition, charge, and location in the atom (CH.2) * calculate the number of electrons in an ion given its charge (CH.2 a) * calculate the *weighted* average atomic mass (CH.2 a) * calculate the number of neutrons in an isotope, given its mass number (CH.2 a) * use equations to predict products of nuclear decay, to include those that emit alpha, beta, and gamma radiation (CH.2 b) * use half-life calculations to determine the amount of a radioactive substance that remains after a designated period (CH.2 b) * use the periodic table as a model to predict relative properties of elements based on the patterns of valence electrons; relate the position of an element on the periodic table to its electron configuration (CH.2 c) * compare elements on the periodic table within a single group or single period in terms of electronegativity, shielding effect, and ionization energy (CH.2 c) * relate the roles of principal energy levels and number of protons to the periodic trends (CH.2 c) * use electron configurations to predict bonding (CH.2 d) * identify the number of valence electrons using an element’s electron configuration (CH.2 d) * determine the ions formed when selected atoms gain or lose electrons (CH.2 d) * explain how excited electrons result in the release of electromagnetic radiation (CH.2 d) * explain how the development of the modern atomic theory reflects the nature of science (CH.2 e). |

**CH.3 The student will investigate and understand that atoms are conserved in chemical reactions. Knowledge of chemical properties of the elements can be used to describe and predict chemical interactions. Key ideas include**

1. **chemical formulas are models used to represent the number of each type of atom in a substance;**
2. **substances are named based on the number of atoms and the type of interactions between atoms;**
3. **balanced chemical equations model rearrangement of atoms in chemical reactions;**
4. **atoms bond based on electron interactions;**
5. **molecular geometry is predictive of physical and chemical properties; and**
6. **reaction types can be predicted and classified.**

**Central Idea**: The law of conservation of mass governs all interactions among atoms. These interactions occur as valence electrons are shared and transferred between atoms in the process of bonding. Chemical equations model the interactions of atoms in a chemical reaction and these interactions can be predicted and classified.

**Vertical Alignment:** Students are introduced to bonding and use simple balanced equations to model chemical reactions in Physical Science. The practice of balancing equations is used to support the law of conservation of mass (PS.3).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
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| Matter is conserved because atoms are conserved in chemical and physical processes. The law of conservation of matter (mass) states that, regardless of how substances within a closed system are changed, the total mass remains the same.   * Conservation of matter is represented in balanced chemical equations. A coefficient indicates the relative number of particles involved in the reaction (CH.3). * The products formed in a chemical reaction have different properties than the original reactants (CH.3 c). * Chemical formulas are used to represent compounds. Subscripts represent the relative number of each type of atom in a molecule or formula unit (CH.3 a).   Matter consists of atoms held together by electromagnetic forces and exists as different substances which can be utilized based on their properties.   * The strong electrostatic forces of attraction between atoms in a compound are called *chemical bonds* (CH.3 d). * Intramolecular bonds form between atoms to achieve stability. Covalent bonds involve the sharing of electrons between nonmetal atoms. Ionic bonds involve the transfer of electrons between metal and nonmetal ions.Elements with low ionization energy form positive ions (cations) easily. Elements with high ionization energy form negative ions (anions) easily (CH.3 d). * Polar bonds form between covalently bonded elements with very different electronegativities. Non-polar bonds form between covalently bonded elements with similar electronegativities (CH.3 d). * Some elements, such as hydrogen, oxygen, nitrogen, fluorine, chlorine, bromine, and iodine naturally occur as diatomic molecules (CH.3 b).   Bonded and non-bonded pairs of electrons can be used to predict molecular geometry.   * Lewis dot diagrams are used to represent valence electrons in an element. Lewis structures can be used to determine the shape of molecules using the valence shell electron pair repulsion (VSEPR) model (bent, linear, trigonal planar, tetrahedral, and trigonal pyramidal) (CH.3 e).   Carbon is an important element in biological systems and combines with oxygen and hydrogen, as well as other elements, to form compounds that are essential for living processes. This class of bonds are called *organic compounds*.   * Carbon atoms can form single, double, and triple bonds with other carbon atoms (CH.3 e). * Carbon-based compounds have different shapes based on their bonding (CH.3 e). * The flexibility of carbon to bond in various shapes allows for a wide range of technological application (CH.3 e).   Classification of chemical equations relies on careful observation of patterns.   * In a chemical process, the atoms that make up the original substance are regrouped into different molecules (CH.3 c, f). * Many of the products of chemical reactions can be predicted by recognizing patterns (CH.3 f). | In order to meet this standard, it is expected that students will   * use particulate models and mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction (CH.3) * name and write the chemical formulas for binary covalent (molecular) and ionic compounds (CH.3 b) * name and write the chemical formula for ionic compounds containing polyatomic ions (CH.3 b) * explain how chemical equations support the law of conservation of mass (CH.3 c) * transform word equations into balanced chemical equations (CH.3 b, c) * construct and revise an explanation for the outcome of a simple chemical reaction, based on the outermost electron states of the atom, trends in the periodic table, and knowledge of the periodic properties (CH.2, CH.3 c) * identify the intramolecular bonds in compounds and predict their physical properties based on the type of bond (CH.3 d) * conduct an investigation to determine the trends and properties of compounds with ionic and covalent bonds (investigation may include melting point, solubility, and conductivity) (CH.3 d) * draw Lewis dot diagrams to represent valence electrons in elements and show covalent bonding (CH.3 d) * compare covalently bonded molecules to determine if the intramolecular bonds are polar or non-polar (CH.3 d) * explain the molecular shape of a covalently bonded molecule using the VSEPR model (CH.3 e) * describe how the valence electrons of carbon impact its bonding and molecular geometry, allowing it to be important in both biological and technological applications (CH.3 e) * classify chemical reactions as one of six major types: synthesis, decomposition, single replacement, double replacement, combustion, or neutralization (CH.3 f) * predict products of single and double replacement reactions, given the reactants (CH.3 f). |

**CH.4 The student will investigate and understand that molar relationships compare and predict chemical quantities. Key ideas include**

1. **Avogadro’s principle is the basis for molar relationships; and**
2. **stoichiometry mathematically describes quantities in chemical composition and in chemical reactions.**

**Central Idea**: For chemical equations to be useful, quantities of reactants and products must be able to be measured. Stoichiometry allows for the quantification of chemical relationships.

**Vertical Alignment:** Students are introduced to the law of conservation of mass and balanced equations in Physical Science (PS.3). These topics are covered conceptually; students have no experience with molar relationships prior to Chemistry.

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| Matter can be tracked in terms of the weight of the substances before and after a process occurs. The total weight of the substances does not change.   * Atoms and molecules are too small to count by usual means. A *mole* is a fundamental unit for counting particles (atoms, molecules, and formula units) (CH.4 a). * Stoichiometry involves quantitative relationships in a balanced equation, which are based on mole ratios (CH.4 b). * When two elements combine to form two or more compounds, the ratios of the masses of one element that combines with the fixed mass of the other are simple whole numbers (law of multiple proportions) (CH.4 b). * Empirical and molecular formulas are used to show the chemical composition of a compound. These are useful in determining the formula of a substance based on the mass of the elements of an unknown substance (CH.4 b). * The limiting reactant (reagent) is the reactant that determines the moles of product(s) that can be produced in a reaction. The limiting reactant can be identified by comparing calculated ratios of moles and coefficients of reactants available at the beginning of the reaction (CH.4 b). * Although matter is conserved, chemical reactions rarely convert all the reactions to products. Percent yield can be used to determine the efficiency of a reaction as well as the percent error (CH.4 b). | In order to meet this standard, it is expected that students will   * use particulate models and mathematical representations to model the number of moles in a substance (CH.4 a) * understand the significance of Avogadro’s number and relate Avogadro’s number to the mole (CH.4 a) * convert among mass, volume, and moles of a substance (CH.4 a) * determine the empirical and molecular formulas of a compound, given masses of elements that compose it (CH.4 b) * conduct an investigation to determine the percent composition and/or the empirical formula of a substance (CH.4 b) * perform stoichiometric calculations to quantify reactants and/or products in balanced chemical reactions (CH.4 b) * use particulate models and mathematical representations to identify the limiting reactant in a reaction (CH.4 b) * conduct an investigation to determine the percent yield of a reaction (CH.4 b) * plan and conduct an investigation to show how mass or moles are conserved in a chemical reaction (CH.4 b) * explain how and why limiting reagents affect the production of industrial products (CH.4 b). |

**CH.5 The student will investigate and understand that solutions behave in predictable and quantifiable ways. Key ideas include**

1. **molar relationships determine solution concentration;**
2. **changes in temperature can affect solubility;**
3. **extent of dissociation defines types of electrolytes;**
4. **pH and pOH quantify acid and base dissociation; and**
5. **colligative properties depend on the extent of dissociation.**

**Central Idea:** Solutions are homogeneous mixtures in which the physical properties are dependent on concentration of the solute and the strength of the interactions among the particles of solute and solvent. Molarity is used to quantify the amount of solute in the liters of solution.

**Vertical Alignment:** Students are introduced to solutions in elementary school and have exposure to acids and bases in Physical Science (PS.3). The concepts in this standard are novel to most students in Chemistry.

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| Solutions are homogeneous mixtures in which the physical properties are dependent on the concentration of the solute and the strengths of all interactions among the particles of solutes and solvents. These forces of attraction are important in determining properties of a substance.   * Temperature influences the solubility of a solute. A solubility chart indicates the effect of temperature on the solubility of a substance (CH.5 c). * Colligative properties are properties dependent on the amount of solute dissolved in a solution (CH.5 e). * As solute particle numbers increase, the boiling point of a solution increases and the freezing point decreases(CH.5 e). *Students are not responsible for calculating boiling point elevation and freezing point depression.* * Many substances with ionic bonds dissociate when added to a polar solvent. This dissociation is caused as the different ions of the solute are attracted to the polar solvent (CH.5 c). * Polar substances dissolve ionic or polar substances; nonpolar substances dissolve nonpolar substances (CH.5 c).   Acids and bases are a subset of solutions and react chemically in characteristic ways.   * Acids and bases form when ionic compounds dissociate, producing hydrogen ion (H+) or hydroxide ion (OH-) (CH.5 d). * The pH scale allows for a comparison of the dissociation of an acid or base (CH.5 d). * Acids and bases are described through several theories (Arrhenius and Bronsted-Lowry theories). The construction and revising of these theories demonstrate the nature of science (CH.5 d). * Titrations are conducted in the laboratory in conjunction with calculations to determine the concentration of an acid or base (CH.5 d). * Indicators can be used to determine the pH of a solution (CH.5 d). | In order to meet this standard, it is expected that students will   * calculate the molarity of a solution (CH.5 a) * interpret solubility curves to determine the effect of temperature on solution concentration (CH.5 b) * apply the terms *dilute*, *saturated,* and *supersaturated* to solutions (CH.5 c) * explain the phrase *like dissolves like* and use it to predict solubility (CH.5 c) * apply the terms *strong electrolyte*, *weak electrolyte*, and *non-electrolyte* to different solutions (CH.5 c) * write balanced chemical equations of neutralization reactions between strong acids and strong bases (CH.5 d) * explain the difference between strength and concentration of acids and bases (CH.5 d) * relate the hydronium ion concentration to the pH scale (CH.5 d) * differentiate between the pH and pOH scales and determine acid and base concentrations using each scale (CH.5 d) * perform strong acid-strong base titrations, using indicators, and calculate the concentration of the unknown molarity solution (CH.5 d) * explain the role of indicators in titrations (CH.5 d) * explain how the development of the acid-base theories reflects the nature of science (CH.5 d) * explain the role of dissociation of solutes in the boiling point and freezing point of a solution (CH.5 e) * describe how colligative properties are used in everyday applications (CH.5 e). |

**CH.6 The student will investigate and understand that the phases of matter are explained by the kinetic molecular theory. Key ideas include**

1. **pressure and temperature define the phase of a substance;**
2. **properties of ideal gases are described by gas laws; and**
3. **intermolecular forces affect physical properties.**

**Central Idea:** The movement of atoms and the relationship of energy and the phases is outlined in the kinetic molecular theory. The gas laws describe the relationships among pressure, volume, temperature, and number of particles of a gas.

**Vertical Alignment:** In Physical Science, students are introduced to the constant movement of atoms and the relationship of the kinetic energy in a substance and Kelvin temperature, through the study of the kinetic molecular theory. The role of energy in phase changes is discussed (PS.2).

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| The kinetic molecular theory (KMT) of gases is a model that helps understand the physical properties of gases at the molecular level (CH.6).   * Gases have mass and occupy space. Gas particles are in constant, rapid, random motion and exert pressure as they collide with the walls of their containers. Gas molecules with the lightest mass travel fastest. Relatively large distances separate gas particles from each other (CH.6). * Equal volumes of gases at the same temperature and pressure contain an equal number of particles (CH.6 a). * Solid, liquid, and gas phases of a substance have different energy content. Pressure, temperature, and volume changes can cause a change in physical state. Specific amounts of energy are absorbed or released during phase changes (CH.6 a).   The gaseous state can be modeled through mathematical equations, relating macroscopic properties.   * An ideal gas does not exist, but this concept is used to model gas behavior. A real gas exists, has intermolecular forces and particle volume, and can change states. The ideal gas law states that PV = nRT and includes the relationship among pressure, volume, temperature, and the number of moles (CH.6 b). * The pressure and volume of a sample of a gas at constant temperature are inversely proportional (Boyle’s law: P1V1 = P2V2) (CH.6 b). * At constant pressure, the volume of a fixed amount of gas is directly proportional to its absolute temperature (Charles’ law: V1/T1 = V2/T2) (CH.6 b). * The combined gas law (P1V1/T1 = P2V2/T2) relates pressure, volume, and temperature of a gas (CH.6 b). * The sum of the partial pressures of all the components in a gas mixture is equal to the total pressure of a gas mixture (Dalton’s law of partial pressures) (CH.6 b).   Intermolecular forces play a key role in determining the properties of a substance.   * Forces of attraction (intermolecular forces) among molecules determine their state of matter at a given temperature. Forces of attraction include hydrogen bonding, dipole-dipole attraction, and London dispersion (van der Waals) forces (CH.6 c). * Intermolecular forces are significantly weaker than intramolecular forces (CH.6 c). * Vapor pressure is the pressure of the vapor found directly above a liquid in a closed container. When the vapor pressure equals the atmospheric pressure, the liquid boils. Volatile liquids have high vapor pressures, weak intermolecular forces, and low boiling points. Nonvolatile liquids have low vapor pressures, strong intermolecular forces, and high boiling points (CH.6 c). * Energy is required to break intermolecular forces to allow a phase change to occur from solid to liquid and from liquid to gas (CH.6 c). | In order to meet this standard, it is expected that students will   * explain the behavior of gases, using the kinetic molecular theory (CH.6) * explain deviations in the behavior of real gases from the ideal gas law, using the kinetic molecular theory(CH.6 b) * use the kinetic molecular theory to describe the relationships among volume, temperature, pressure, and the number of moles in a sample of gas (CH.6 b) * solve problems and interpret graphs, including pressure, temperature, volume, and moles of a gas (CH.6 b) * plan and conduct an experiment that confirms the effect of a change in pressure, temperature, and/or volume of a gas (CH.6 a, b) * create a particulate model that shows the relationship among temperature, pressure, volume, and/or the number of moles of a gas (CH.6 a, b) * explain how intermolecular forces account for the physical properties of matter (CH.6 c) * explain how intermolecular forces differ from intramolecular bonds (CH.6 c). |

**CH.7 The student will investigate and understand that thermodynamics explains the relationship between matter and energy. Key ideas include**

1. **heat energy affects matter and interactions of matter;**
2. **heating curves provide information about a substance;**
3. **reactions are endothermic or exothermic;**
4. **energy changes in reactions occur as bonds are broken and formed;**
5. **collision theory predicts the rate of reactions;**
6. **rates of reactions depend on catalysts and activation energy; and**
7. **enthalpy and entropy determine the extent of a reaction.**

**Central Idea:** Thermodynamics is the branch of science that deals with the relationship between heat and other forms of energy. Chemical systems undergo three main processes that use thermal energy: phase changes, heating/cooling, and chemical reactions.

**Vertical Alignment:** In Physical Science, students were introduced to energy transfer and transformation to include chemical energy. The dissolution and formation of bonds during chemical reactions involves chemical energy. Terms such as *exothermic* and *endothermic* are used to explain whether energy is absorbed or released in a chemical reaction (PS.5).

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| Chemical systems undergo three main processes that change their energy: heating/cooling, phase transitions, and chemical reactions.   * Temperature is a measurement of the average kinetic energy in a sample. There is a direct relationship between temperature and average kinetic energy (CH.7 a). * A heating curve graphically describes the relationship between temperature and energy (heat). It can be used to identify a substance’s phase of matter at a given temperature as well as the temperature(s) at which it changes phase. It also shows the strength of the intermolecular forces present in a substance (CH.7 b). * The energy changes in chemical reactions occurs when atoms rearrange to form new substances. Breaking bonds requires energy and making bonds releases energy (CH.7 d).   Chemical and physical transformations typically involve a change in energy. The relationship between the temperature and the total energy of a system depends on the types, states, and amount of matter.   * All reactions involve the transfer of energy. *Enthalpy* is a measure of the energy of a chemical or physical system. Since enthalpy cannot be directly measured, the change in enthalpy is used to determine the heat given off or absorbed in a given reaction (CH.7 a, g) * Endothermic reactions require an input of energy to proceed and are signified by a positive enthalpy (CH.7 c, g). * Exothermic reactions release energy upon completion and are signified by a negative enthalpy (CH.7 c, g). * The enthalpy (ΔH) of a reaction can be determined through a variety of ways, to include calorimetry and calculating bond energies (CH.7 c, d, g). *Students are not responsible for calculations of bond energy and the use of Hess’s law.* * Calorimetry is an experimental technique that is used to determine the thermal energy exchanged/transferred in a chemical system (CH.7 a). * Bond energy is the energy required to break a chemical bond. One way the enthalpy of a reaction can be determined is by comparing the bond energies associated with the breaking (endothermic) and forming of bonds (exothermic) in a reaction (CH.7 d). *Students are not responsible for calculations of bond energy and the use of Hess’s law.* * Molar heat of fusion is a property that describes the amount of energy needed to convert one mole of a substance between its solid and liquid states. Molar heat of vaporization is a property that describes the amount of energy needed to convert one mole of a substance between its liquid and gas states (CH.7 a). * Specific heat capacity is a property of a substance that tells the amount of energy needed to raise one gram of a substance by one degree Celsius. The values of these properties are related to the strength of their intermolecular forces (CH.7 a).   The rates of reactions are influenced by the concentration or pressure of the reactants, the phase of the reactants or products, and the environmental factors such as temperature.   * The collision theory is used to predict the rate of chemical reactions. It assumes that for a reaction to occur, it is necessary for the reacting species (atoms or molecules) to come together with the right amount of energy and the geometric orientation needed to break existing bonds and to reform new bonds (CH.7 e). * *Activation energy* is the amount of energy needed to start a chemical reaction (CH.7 f). * A *catalyst* is a chemical agent that can lower the activation needed to start a chemical reaction. The catalyst is not consumed or altered in a chemical reaction (CH.7 f). * *Entropy* (S) is a thermodynamic quantity representing the degree of disorderliness or randomness in a chemical system (CH.7 g). * Enthalpy (H) is related to the internal energy. When a process occurs at constant pressure, the heat evolved (either released or absorbed) is equal to the change in enthalpy. Exothermic reactions are favored (CH.7 g). Students are not responsible for determining enthalpy that occurs with changes in pressure. | In order to meet this standard, it is expected that students will   * contrast temperature and heat (CH.7 a) * explain how energy transfer plays a role in the heating and cooling of a system, in phase transitions, and in chemical reactions (CH.7 a, c) * interpret heating curves and reaction diagrams to draw conclusions about energy transfers with a system (CH.7 b) * predict the phase of water if pressure or temperature of a substance changes by interpreting a phase diagram of water (CH.7 b) * create a particulate model of a phase change (CH.7 a) * calculate energy changes, using specific heat capacity (CH.7 a) * use calorimetry to measure the amount of thermal energy released or absorbed during a chemical reaction (CH.7 a, c) * explain the role of energy in bond formation and the breaking of bonds (CH.7 d) * create a particulate model that describes necessary particle interactions needed for a chemical reaction to occur (collision theory) (CH.7 e) * describe the factors that affect the rate of a chemical reaction (CH.7 e) * apply scientific principles and evidence to provide an explanation for the effects of changing temperature or concentration of the reacting particles on the rate of a reaction (CH.7 e) * explain the role of catalysts in a reaction and describe the effect on a system if a catalyst is not present (CH.7 f) * distinguish between enthalpy and entropy (CH.7 g) * recognize that there is a natural tendency for systems to increase entropy (CH.7 g). |

## Earth Science

The Earth Science standards focus on the complex nature of the Earth system, including Earth’s composition, structure, processes, and history; its atmosphere, fresh water, and oceans; and its environment in space as a set of complex, interacting, and overlapping systems. The standards emphasize the nature of science as students learn about the development of scientific thought about Earth and space. The standards stress the interpretation of maps, charts, tables, and profiles; the use of technology to collect, analyze, and report data; and the utilization of science skills in systematic investigation. Problem solving and decision making are integral parts of the standards, especially as related to the costs and benefits of utilizing Earth’s resources. Mathematics and computational thinking are important as students advance in their scientific thinking.

### Scientific and Engineering Practices

Engaging in the practices of science and engineering helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the many ways to investigate, model, and explain the world. These scientific and engineering practices include the use of scientific skills and processes to explore the content of science as outlined in the *Science Standards of Learning*. The engineering design practices are the application of science content to solve a problem or design an object, tool, process, or system. These scientific and engineering practices are critical to science instruction and are to be embedded throughout the year.

**ES.1 The student will demonstrate an understanding of scientific and engineering practices by**

1. **asking questions and defining problems**

* **ask questions that arise from careful observation of phenomena, examination of a model or theory, or unexpected results, and/or to seek additional information**
* **determine which questions can be investigated within the scope of the school laboratory or field experience**
* **generate hypotheses based on research and scientific principles**
* **make hypotheses that specify what happens to a dependent variable when an independent variable is manipulated**
* **define design problems that involve the development of a process or system with multiple components and criteria**

1. **planning and carrying out investigations**
   * **individually and collaboratively plan and conduct observational and experimental investigations**
   * **plan and conduct investigations to test design solutions in a safe and ethical manner including considerations of environmental, social and personal impacts**
   * **select and use appropriate tools and technology to collect, record, analyze, and evaluate data**
2. **interpreting, analyzing, and evaluating data**

* **construct and interpret data tables showing independent and dependent variables, repeated trials, and means**
* **construct, analyze, and interpret graphical displays of data, including scatterplots and line plots and consider limitations of data analysis**
* **apply mathematical concepts and processes to scientific questions**
* **use data in building and revising models, supporting explanations of phenomena, or testing solutions to problems**
* **analyze data using tools, technologies, and/or models in order to make valid and reliable scientific claims or determine an optimal design solution**

1. **constructing and critiquing conclusions and explanations**

* **make quantitative and/or qualitative claims based on data**
* **construct and revise explanations based on valid and reliable evidence obtained from a variety of sources, including students’ own investigations, models, theories, simulations, peer review**
* **apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena or design solutions**
* **construct arguments or counter arguments based on data and evidence**
* **differentiate between a scientific hypothesis, theory, and law**

1. **developing and using models**

* **evaluate the merits and limitations of models**
* **develop, revise, and/or use models based on evidence to illustrate or predict relationships**
* **construct and interpret scales; diagrams; classification charts; graphs; tables; imagery; models; including geologic cross sections and topographic profiles**
* **read and interpret topographic and basic geologic maps and globes, including location by latitude and longitude**

1. **obtaining, evaluating, and communicating information**

* **compare, integrate, and evaluate sources of information presented in different media or formats to address a scientific question or solve a problem**
* **gather, read, and evaluate scientific and/or technical information from multiple sources, assessing the evidence and credibility of each source**
* **communicate scientific and/or technical information about phenomena and/or a design process in multiple formats**

### Earth Science Content

**ES.2 The student will demonstrate an understanding that there are scientific concepts related to the origin and evolution of the universe. Key ideas include:**

1. **the big bang theory is the current scientific explanation of the origin of universe;**
2. **stars, star systems, and galaxies change over long periods of time;**
3. **characteristics of the sun, planets, and their moons, comets, meteors, asteroids, and dwarf planets are determined by materials found in each body; and**
4. **evidence attained through space exploration has increased our understanding of the structure and nature of our universe**.

**Central Idea:** By examining the characteristics and motion of objects within our universe, we can use scientific evidence to theorize how it was created and how it has evolved over time.

**Vertical Alignment:** Students study the distribution of matter throughout the solar system and as well as the organization of various celestial bodies in sixth grade (6.2). The spatial relationships, characteristics, and interactions among the various celestial bodies, and the role of gravity, are emphasized in Earth Science.

| **Enduring Understandings** | **Essential Knowledge and Practices** |
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| The big bang and solar nebular theories encapsulate our current understanding of the origin of the universe and the origin of stars and planetary systems. The development of these theories illustrates the nature of science.   * The universe is a dynamic system of interacting components that is vast in size, still expanding, and about 13.8 billion years old (ES.2 a). * The big bang theory is our best current model for the development of the universe. The big bang theory states that the universe began in a very hot, dense state that expanded and eventually condensed into galaxies (ES.2 a). * The big bang theory is based on scientific evidence obtained through astronomical research, including evidence about the nature of light and the red shift, Hubble’s law and the movement of distant objects, cosmic microwave background radiation, and the composition and abundance of elements from star and nebular spectra (ES.2 a). * Shortly after the big bang, the very lightest elements (lowest atomic number), predominantly hydrogen and helium, were formed. Stars of all sizes initially fuse this hydrogen to helium; however, the mass of a star determines what other fusion products it will create during the remainder of its lifetime. Stars that are several times more massive than the sun produce heavier elements, up to iron. The largest stars at the end of their lives become supernovae. In those highly energetic explosions in the presence of abundant neutrons, the heaviest natural elements are created (ES.2 a). * The solar nebular theory is science’s best current idea for the formation of stars and planetary systems. The nebular theory explains that stars form through the condensation of the nebula. Photographic images show likely examples of stellar nurseries and star formation within the galaxy (i.e., Crab Nebula) (ES.2 b). * Stars have finite lifetimes and go through changes over time. The mass of a star controls its evolution, lifespan, and fate. Stars form by condensation and gravitational compression of interstellar gas and dust (ES.2 b). * The Hertzsprung-Russell diagram illustrates the relationship between the absolute magnitude or luminosity of a star and the surface temperature of stars. As stars age, their position on the Hertzsprung-Russell diagram changes (ES.2 b).   The solar system is a set of interrelated and interdependent components that are seamlessly connected through the flow of matter and energy. Characteristics of these components within the solar system are determined by their composition.   * Galaxies are collections of billions of stars (ES.2 b). * The solar system is in the Milky Way galaxy (ES.2 b). * There are essentially two types of planets in our solar system. The four inner (terrestrial) planets consist mostly of rocky outer layers and have cores of metallic elements. The four outer planets are gas giants, consisting mostly of hydrogen and helium. The nature of the gas planets’ interiors is subject to ongoing research (ES.2 c). * The dwarf planet, Pluto, is about two-thirds the diameter of Earth's moon and probably has a rocky core surrounded by a mantle of water ice. It is part of the Kuiper Belt (ES.2 c). * Moons are natural satellites of planets that vary widely in composition and in method of formation (ES.2 c). * Comets orbit the sun and consist mostly of frozen gases (ES.2 c). * There are countless fragments comprised of rock and dust floating throughout the solar system. Those that enter Earth’s atmosphere are known as meteors. Meteors that are large enough to pass through the atmosphere contain information regarding the age, composition, and evolution of our solar system, as well as potential signs of life having developed extra-terrestrially (ES.2 c). * Asteroids are usually leftover debris from the formation of the solar system, or creations from the collisions of other asteroids (ES.2 c). * Technological advances, breakthroughs in interpretation, and new observations continuously refine our understanding of Earth and the solar system. *Students are not responsible for describing the contributions of specific scientists or space missions.* * Much of our knowledge about the solar system is a result of space exploration efforts. These efforts continue to improve our understanding of the solar system. For example, ongoing research including information about magnetic and gravitational fields, surface features, volcanism, tectonics, atmospheric composition, and overall density reveals much about planets’ internal structures, formation, and evolution (ES.2 d). *Students are not responsible for describing the contributions of specific scientists or space missions.* * A light-year is the distance light travels in one year and is the most commonly used measurement for distance in astronomy (ES.2 d). * Much of the information about our galaxy and the universe comes from ground-and space-based observations across the electromagnetic spectrum. Information about other planets comes from observations and measurements from Earth’s surface; space telescopes; and interplanetary missions including landers, flybys, and orbiting spacecraft (ES.2 d). *Students are not responsible for describing the contributions of specific scientists or space missions.* | In order to meet this standard, it is expected that students will   * describe the big bang theory and provide evidence used to support the theory (ES.2 a) * compare the characteristics and evolution of more massive stars to that of the sun (ES.2 b) * relate Earth’s ability to sustain life to the sun’s current stage in its stellar evolution and proximity to the Earth (ES.2 b) * use the Hertzsprung-Russel diagram to classify stars and use this classification to determine the projected stellar life cycle (ES.2 b) * analyze the variations in chemical compositions of stars of different masses and relate to the process of fusion and the star’s stage in its stellar evolution (ES.2 b) * understand the connection between fusion of elements in stars and the presence and abundance of elements that make up our solar system and its contents, including living organisms (ES.2 b) * analyze recent research findings (i.e., from NASA) about the terrestrial and gaseous planets; compare their atmospheres, internal composition, surface conditions, size, and rotation; and interpret why each planet has such characteristics as related to nebular theory(ES.2 b, c) * compare the classification of the dwarf planet Pluto to the planets in relation to its orbit, and its similarity to other objects in the Kuiper Belt (ES.2 c) * compare the defining characteristics among moons, comets, meteoroids, and asteroids (ES.2 c) * describe how technology (e.g., Galileo’s telescope, Hubble telescope, planetary orbiters, landers/rovers) has contributed to our scientific understanding of the cosmos (ES.2 d). |

**ES.3 The student will investigate and understand that Earth is unique in our solar system. Key ideas include**

1. **Earth supports life because of its relative proximity to the sun and other factors; and**
2. **the dynamics of the sun-Earth-moon system cause seasons, tides, and eclipses.**

**Central Idea:** The accretion of nebular materials to form our solar system in its precise location and with its specific characteristics gives it the unique ability to foster past and current lifeforms on Earth. The location and characteristics also are responsible for observable, systemic interactions.

**Vertical Alignment:** Students are introduced to the cause-and-effect relationships of the motion and position of the sun, Earth, and moon as it pertains to the moon phases, seasons, and tides in sixth grade science (6.3). These concepts and interactions are investigated further in Earth Science.

| **Enduring Understandings** | **Essential Knowledge and Practices** |
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| The proximity of the Earth to the sun and moon in our solar system affects Earth systems and enables life to exist on Earth.   * The solar system consists of many types of celestial bodies. Earth is the third planet from the sun and is located between the sun and the asteroid belt. It has one natural satellite, the moon. Water occurs on Earth as a solid (ice), a liquid, and a gas (water vapor), due to Earth’s position in the solar system (ES.3 a). * The sun consists largely of hydrogen gas. Its energy comes from nuclear fusion of hydrogen to helium (ES.3 a).   The interactions and orientations of the sun, Earth, and moon lead to patterns that are evidenced in seasons, eclipses, and the phases of the moon.   * Earth revolves around the sun while tilted on its axis. The axial tilt is responsible for the incidence and duration of sunlight striking a given hemisphere that varies during the Earth’s revolution around the sun, thus causing seasons. Equinoxes and solstices represent distinct, quarterly points signaling the cyclic change of seasons (ES.3 b). * The moon revolves around Earth, creating moon phases and eclipses. Solar eclipses occur when the moon blocks sunlight from Earth’s surface, while lunar eclipses occur when Earth blocks sunlight from reaching the moon’s surface (ES.3 b). * The tides are the periodic rise and fall of water level caused by the gravitational pull of the sun and moon (ES.3 b). * Grid systems of latitude and longitude are used to define locations and directions on maps, globes, and charts (ES.3). * Lines of latitude (parallels) run east-west and increase from 0° at the Equator to 90°at the poles. The Equator represents the center of the Earth, where the sun appears to pass directly overhead on the spring and fall equinoxes. The Earth bulges slightly at the equator. Lines of latitude are spaced equally apart and never intersect (ES.3). *Students are not responsible for memorizing the names or values of specific latitude lines.* * Lines of longitude run north to south and are not parallel, intersecting at the poles. As opposed to latitude lines, which are determined by natural phenomena, longitude lines were determined arbitrarily, with the Prime Meridian (0°) running through Greenwich, England and 180° representing the International Date Line (ES.3). | In order to meet this standard, it is expected that students will   * explain the role of the position of Earth in the solar system, the size of Earth and sun, Earth’s axial tilt, and the presence of a large moon, in affecting the planet’s evolution and life forms (ES.3 a) * predict what conditions would need to be in place for another celestial object to support life (ES.3 a) * create a 3-D scale model of Earth and the orbiting moon and explain the progression of moon phases (ES.3 b) * relate the moon’s orbit and tilt to type and frequency of eclipses (ES.3 b) * create a model showing the positions of the Earth, moon, and sun during a solar and lunar eclipse (ES.3 b) * explain why solar and lunar eclipses do not occur each month (ES.3 b) * read and interpret maps, using latitude and longitude coordinates, to * locate landmarks and geographic features * examine the significance of certain lines of latitude (Tropics of Cancer & Capricorn, Arctic & Antarctic Circles, Equator, and poles) in representing the sun-Earth relationship(ES.3 b). |

**ES.4 The student will investigate and understand that there are major rock-forming and ore minerals. Key ideas include**

1. **analysis of physical and chemical properties supports mineral identification;**
2. **characteristics of minerals determine the uses of minerals; and**
3. **rock-forming minerals originate and are formed in specific ways.**

**Central Idea:** Minerals can be identified by multiple characteristics, including atomic structure. These characteristics determine the use of the minerals.

**Vertical Alignment:** Students learn that there are a limited number of elements that comprise the solid portion of planet Earth in sixth grade (6.5). The concept that these elements and compounds have unique physical and chemical properties, based on atomic composition and bonding, is introduced in eighth grade; however, this is not explicitly applied to Earth processes (PS.2, PS.3).

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| The structure of a mineral determines many of its properties and functions. The chemical and physical properties of minerals are used to classify minerals. *Students are not expected to recognize or identify specific minerals and their uses without a classification key.*   * Earth materials take many different forms as they cycle through the geosphere (ES.4 a). * A mineral is a naturally occurring, inorganic, solid substance (at room temperature), with a definite chemical composition and a defined geometric arrangement of atoms (a crystalline structure). A mineral can be identified by its specific chemical and physical properties. The appearance and properties of the mineral can vary due to inclusion of other elements, rate of cooling/crystallization, and space (ES.4 a). * Different minerals have different internal arrangements of atoms, with certain minerals having planes of weaker bonds in one or more directions. When hit, some minerals may tend to break regularly along planes of weakness (ES.4 a). * The major elements found in Earth’s crust are oxygen, silicon, aluminum, and iron (ES.4 a). * Silicate minerals are composed of silica tetrahedra (SiO4-2) that are organized in various patterns and frequently bonded with metal cations. Silicate minerals are the largest rock-forming group and comprise over 90 percent of crustal materials (ES.4 a). * The carbonate group of minerals is composed of the carbonate ion (CO3-2)and metal cations (ES.4 a). * The oxide group of minerals is composed of oxygen and a metal (ES.4 a).   Minerals are suited for different uses.   * Soil, rocks, and minerals provide essential materials for agriculture, manufacturing, and building (ES.4 b). * In Virginia, major rock and mineral resources include coal and natural gas, gravel and crushed stone, silica, titanium, and limestone (ES.4 b).   Within natural systems, the transfer of energy drives the cycling of matter. Both the transfer of energy and chemical composition play a role in the formation of different types of minerals.   * Minerals can form under a variety of conditions (ES.4 c). These conditions include   + cooling of molten magma or lava   + evaporation of liquids   + cooling of saturated solutions (liquids)   + high pressure and temperature. * Minerals that form from lava tend to be very small because of the lava cooling quickly. Minerals that form from the cooling of magma are larger due to the relatively long cooling period (ES.4 c). | In order to meet this standard, it is expected that students will   * relate the abundance of mineral-forming elements with the processes and conditions required to form them (ES.4 a) * identify minerals at or near Earth’s surface and relate these to the Earth’s general structure, plate tectonics, and chemical and physical weathering (ES.4 a) * relate how the structure and composition determine the properties of silicates, carbonates, and oxide minerals (ES.4 a) * relate cleavage patterns of minerals to atomic structure and bonding arrangement (ES.4 a) * plan and conduct an investigation to identify minerals based on their physical and chemical properties, such as hardness, color, luster, density (specific gravity), cleavage, fracture, streak, and effervescence (ES.4 a) * identify formation processes by attributes observed in rock-forming and ore mineral samples (ES.4 a) * utilize a table of mineral properties to identify and/or classify an unknown mineral (ES.4 a) * explain the uses and importance of ore minerals (ES.4 b) * describe the conditions needed to create large and small crystals (ES.4 c). |

**ES.5 The student will investigate and understand that igneous, metamorphic, and sedimentary rocks can transform. Key ideas include**

1. **Earth materials are finite and transformed over time;**
2. **the rock cycle models the transformation of rocks;**
3. **layers of Earth have rocks with specific chemical and physical properties; and**
4. **plate tectonic and surface processes transform Earth materials.**

**Central Idea:** Rocks transform through different processes that can be described by the rock cycle. The rock cycle is a model of the transformation of rocks and the actual process is affected by the Earth’s conditions and may not be cyclical. Plate tectonics and surface processes transform Earth’s materials.

**Vertical Alignment:** Students are introduced to the role of Earth’s internal energy in moving the crust and transforming rocks through the theory of plate tectonics and the rock cycle in fifth grade (5.8). The concept is expanded in Earth Science, to include specifics on the processes as well as the physical and chemical properties of different types of rocks.

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| Within natural and designed systems, it is possible to track the flow, cycles, and conservation of matter and energy. Earth materials take many different forms as they cycle through the geosphere.   * The processes by which rocks are formed define the three major groups of rocks (ES.5 a). * The traditional rock cycle is a model that shows the processes by which all rocks are formed and shows how basic Earth materials are recycled through time. The rock cycle does not show the evolutionary nature of processes that yield the increased volume of less-dense, silica-rich rocks and continental crust over time (ES.5 b). * Rock material in the lithosphere (crust and upper mantle) is generally solid and relatively rigid. The rock of the deeper mantle may exhibit plastic flow but is not uniformly molten (ES.5 b). * Molten rock develops in the crust and mantle when   + temperature is high enough to bring about partial melting   + sudden reduction in pressure (as with faulting) allows melting   + the presence of water (or other volatiles) reduces the melting point of the parent material (ES.5 b). * Magmas are highly associated with mid-ocean ridges and rift zones, subduction zones, and hot spots (b).   Similarities and differences in chemical and physical properties can be used to sort and classify rocks. *Students are not expected to recognize or identify specific rocks and their uses without a classification key.*   * Rocks can be identified by mineral content and texture (ES.5 c). * Igneous rock forms from molten rock that cools and hardens either below or on Earth’s surface. Extrusive igneous rocks most often have small or no crystals, resulting in fine-grained or glassy textures. Intrusive igneous rocks generally have larger crystals and a coarser texture. The composition and textures of igneous rocks provide detailed clues about their formation (ES.5 c). * Generally, clastic, sedimentary rocks are made up of fragments of other rocks (ES.5 c). * Sedimentary rocks may be formed by many different processes; thus, some rock types don’t fit neatly into a standard classification, such as *clastic* or *chemical* (ES.5 c). * Chemical sedimentary rocks are formed through predominantly inorganic, chemical means (e.g., precipitation) (ES.5 c). * Biochemical or biological sedimentary rocks are formed from the stratified remains of plant material or carbonate-shelled organisms (ES.5 c). * Metamorphic rocks form when any rock is changed by the effects of heat, pressure, or chemical action. Foliation in metamorphic rocks includes slaty cleavage, schistosity, and mineral banding. Non-foliated metamorphic rocks have little or no mineral banding and are relatively homogenous (ES.5 c).   Systems are comprised of interacting and interdependent elements that are subject to change in response to inputs and outflows of energy and matter. All Earth processes are the result of energy flowing and mass cycling within and among Earth’s systems.   * Weathered and unstable rock materials erode from some parts of Earth’s surface and are deposited in others (ES.5 d). * Weathering, erosion, and deposition are interrelated processes that work with Earth’s internal processes to alter the composition of rock material. Uplift and increased elevation caused by tectonic processes lead to increased erosion. Weathering is the process by which rocks are broken down chemically and physically by the action of water, air, and organisms. Erosion is the process by which Earth materials are physically incorporated into moving water, ice, or wind and transported. Deposition is the process by which Earth materials carried by wind, water, or ice settle out and are left in a location when energy levels decrease. The size of the material deposited is proportional to the available energy in the medium of transport (ES.5 d). * The large-scale plate tectonic processes (e.g., subduction, island arc formation, continental collisions, and orogeny) occurring at and near plate boundaries are responsible for significant transformations of Earth materials (ES.5 d). | In order to meet this standard, it is expected that students will   * explain how the model of the rock cycle demonstrates conservation of matter and energy (ES.5 a) * relate the size of igneous crystals (texture) with rate and location of cooling (ES.5 b) * model and interpret a vertical sequence of rocks and label the rock types and the related features in the sequence (ES.5 b) * describe characteristics of metamorphic and sedimentary rocks (ES.5 c) * classify rock types as igneous, metamorphic, or sedimentary (ES.5 c) * plan and conduct an investigation to identify an unknown rock sample based on chemical and physical characteristics (ES.5 c) * differentiate between clastic and non-clastic (chemical, and biological/organic) sedimentary rocks (ES.5 c) * compare distinguishing characteristics of the crystal structure and textures of extrusive and intrusive igneous rocks (ES.5 c) * differentiate between the structure of foliated and non-foliated metamorphic rocks (ES.5 c) * explain how surface processes and Earth’s movement relate to rock formations and the availability of rock (ES.5 d). |

**ES.6 The student will investigate and understand that resource use is complex. Key ideas include**

1. **global resource use has environmental liabilities and benefits;**
2. **availability, renewal rates, and economic impact are considerations when using resources;**
3. **use of Virginia resources has an impact on the environment and the economy; and**
4. **the selection of various energy sources has environmental and economic impacts.**

**Central Idea:** Earth is our home; its resources mold civilizations, drive human exploration, and drive human endeavors that include art, literature, and science. Many factors affect the use and the conservation of natural resources to include availability, renewal rates, and economics. The use and allocation of these resources globally have economic, political, and environmental impacts.

**Vertical Alignment:** Students study the importance of managing and conserving natural resources as well as reducing environmental hazards in sixth grade science (6.9). In sixth grade, students also focus on the policy involved with the use and conservation of natural resources. In Earth Science, the focus shifts to the environmental and economic impacts of natural resource use.

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| Natural resources are materials with different properties and suited for different uses. Many natural resources are limited and are distributed unevenly around the planet.   * Virginia has many natural resources, including those that are renewable and nonrenewable (ES.6 c). * Renewable resources can be replaced by nature at a rate close to the rate at which they are used. Renewable resources include vegetation, sunlight, and surface water (ES.6 a). * Nonrenewable resources are replenished very slowly by natural processes or not at all. Nonrenewable resources include coal, oil, and minerals (ES.6 a).   Humans resource use has a cause-and-effect impact on Earth systems and on the global economy.   * Living standards include the use of both renewable and nonrenewable resources (ES.6 b). * Extraction and use of any resource carries an environmental cost that must be weighed against economic benefit (ES.6 b). * Earth scientists and engineers develop new technologies to extract resources while reducing the pollution, waste, and ecosystem degradation caused by extraction (ES.6 b). * Technologies that harness renewable energy still require an initial energy and materials investment, thus long-term cost-and-benefit analyses need to be considered (ES.6 b). * Clean water resources, while renewable, are directly affected by human activity through extraction and pollution (ES.6 b). * In Virginia, major rock and mineral resources include coal and natural gas for energy, gravel and crushed stone for road and building construction, silica for electronics, zirconium and titanium for advanced metallurgy, and limestone for making concrete (ES.6 c).   There are advantages and disadvantages to using any energy source. These advantages and disadvantages may affect the environment and have economic implications.   * Fossil fuels are nonrenewable in human timescale, create carbon dioxide when burned, and may cause pollution, but are relatively cheap and easy to use once they are extracted.New sources of energy and methods of resource extraction, such as hydraulic fracturing, create new economic and environmental tradeoffs (ES.6 d). * Renewable energy resources include biomass, geothermal, hydropower, and solar and wind power. Although these are renewable resources, there are still costs and benefits associated with each type of energy (ES.6 d). | In order to meet this standard, it is expected that students will   * construct an explanation based on evidence for how the availability of natural resources have influenced human activity (ES.6 a) * relate the formation of fossil fuels (coal and natural gas) in terms of the rock cycle to ancient biologic and atmospheric/climatic conditions and changes within Virginia (ES.6 b) * determine the sources of clean water in their community, analyze consumption and supply data, and forecast potential issues related to sustainability (ES.6 b) * analyze how Virginia’s production and use of various natural resources has changed over the last 150 years (ES.6 c) * research and analyze various types of recent data (e.g., climate, agriculture, and biomass production) and evaluate Virginia’s potential as a producer of renewable energy sources (ES.6 d) * assess the role of fossil fuels and renewable energy sources in the future and compare the environmental benefits and costs among the various options (ES.6 d) * analyze data concerning a range of emerging energy and mineral resources in Virginia in terms of costs and benefits and create an evidence-based forecast of trends and effects on the environment and economy (ES.6 d) |

**ES.7 The student will investigate and understand that plate tectonic theory explains Earth’s internal and external geologic processes. Key ideas include**

1. **convection currents in Earth’s interior lead to the movement of plates, creation of the magnetic field, and the distribution of materials in Earth’s layers;**
2. **features and processes occur within plates and at plate boundaries;**
3. **interaction between tectonic plates causes the development of mountain ranges and ocean basins; and**
4. **evidence of geologic processes is found in Virginia’s geologic landscape.**

**Central Idea:** The theory of plate tectonics is central to many Earth Science concepts as it explains how the structure of the Earth’s crust and many associated phenomena result from the interaction of rigid lithospheric plates that move slowly over the underlying mantle.

**Vertical Alignment:** Students are introduced to the theory of plate tectonics in fifth grade as they describe the role of energy in the movement of plates and the resulting changes in the Earth’s surface (5.8). The role of convection currents in the creation of Earth’s magnetic field, the interactions resulting from plate movement, and the impact of these interactions on the crust is the focus of Earth Science.

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| Plate tectonic theory is a shared understanding that encapsulates our current understanding of geologic processes.   * Plate tectonic processes serve as the major driver of the transformations of rock materials represented in the traditional rock cycle. Plate tectonics drive the evolution of Earth’s surface features and materials by fractionating material by chemical, mineralogical, and physical properties (ES.7 a). * Earth’s interior is in constant motion through the process of convection (ES.7 a). * Earth consists of a solid, mostly iron inner core; a liquid, mostly iron outer core; a crystalline but largely plastic mantle; and a rocky, brittle crust (ES.7 a). * Earth's geomagnetic field is thought to be created as a result of electric currents generated by convection of molten iron and nickel in the outer core. Heat flow, Earth’s rotation, and the existence of a solid inner core influence the convection-driven dynamo (ES.7 a). * The geomagnetic field imprints a magnetic signature in crystallizing igneous rock, thus leaving information that can be used to determine the motion and latitude of the Earth’s crust over time. Scientific evidence shows that Earth's geomagnetic field reverses itself periodically (a).   The cycling of energy and matter in Earth’s interior occurs through the process of convection and has important consequences for Earth’s surface.   * Plate motion occurs due to convection in Earth’s mantle, including upwelling of material from the deep mantle in rift zones, the lateral movement of tectonic plates, and the pull of sinking dense, old plates at subduction zones (ES.7 b). * Earth’s tectonic plates consist of the rocky crust and uppermost mantle and move slowly in respect to one another (ES.7 b). * Earth’s lithosphere is divided into plates that are in motion with respect to one another. The lithosphere is composed of the crust and upper portion of the mantle. There are two different types of lithospheres—oceanic and continental—that have very different physical and mineralogical characteristics. The ocean lithosphere is relatively thin, young, and dense. The continental lithosphere is relatively thick, old, and less dense (ES.7 b). * Most large scale, high-energy events of geologic activity (e.g., earthquakes, volcanoes, and mountain building) occur as a result of relative motion along plate boundaries (ES.7 c). * Relative plate motions and plate boundaries are convergent (subduction and continental collision), divergent (seafloor spreading), or transform. Major features of convergent boundaries include collision zones (folded and thrust-faulted mountains) and subduction zones (volcanoes and trenches). Major features of divergent boundaries include mid-ocean ridges, rift valleys, fissure volcanoes, and flood lavas. Major features of transform boundaries include strike-slip faults (ES.7 c). * All plate boundaries show earthquake activity of varying energy levels and depths (ES.7 c). * A volcano is an opening where magma erupts onto Earth’s surface as lava and/or other extrusive material. Most volcanic activity is associated with plate boundaries: subduction, rifting, or seafloor spreading. Hot spot volcanic activity, such as the volcanic islands of Hawaii, is exceptional in that it is not related to plate boundaries. A hot spot is thought to be derived from a deep, localized heat source known as a mantle plume, though there is some scientific debate on this (ES.7 c). * A fault is a break or crack in Earth’s crust along which movement has occurred (ES.7 c). * Topographic maps and satellite imagery are 2-D models that provide information defining 3-D landforms. They contain extensive information related to geographic as well as human structures and changes to the land surface and are useful in understanding geologic processes (ES.7 c).   Earth’s rock and other materials provide a record of Earth’s geologic movement over time. This history is evidenced in the features of the different provinces in Virginia; geologic processes produce characteristic structures and features.   * Virginia has over a billion-year-long tectonic and geologic history (ES.7 d). * Virginia has five physiographic/geologic provinces produced by past episodes of tectonic activity and continuous geologic activity. The five physiographic provinces (landforms) correspond very closely, but not completely, to the geologic provinces (underlying rocks and structures) of the state (ES.7 d).   + - * The Coastal Plain is a flat area composed of young, unconsolidated sediments underlain by older crystalline basement rocks. These layers of sediment were produced by erosion of the Appalachian Mountains and Piedmont and then deposited on the Coastal Plain when sea levels were higher in the past. * The Piedmont is an area of rolling hills underlain by mostly ancient igneous and metamorphic rocks. The igneous rocks are the roots of volcanoes formed during ancient episodes of subduction that occurred before and during the formation of the Appalachian Mountains. * The Blue Ridge is a high ridge separating the Piedmont from the Valley and Ridge Province. The billion-year-old igneous and metamorphic rocks of the Blue Ridge are the oldest in the state. * The Valley and Ridge province is an area with long parallel ridges and valleys underlain by ancient folded and faulted sedimentary rocks. The folding and faulting of the sedimentary rocks occurred during a collision between Africa and North America. The collision, which occurred in the late Paleozoic era, produced the Appalachian Mountains. * The Appalachian Plateau has rugged, irregular topography and is underlain by ancient, flat-lying sedimentary rocks. The area is actually a series of plateaus separated by faults and erosional down-cut valleys. Most of Virginia’s coal resources are found in the plateau province. | In order to meet this standard, it is expected that students will   * use available data (seafloor age, magnetic information, seismic profiles, laser-measured motion studies, fossil evidence, rock types, tectonic history) to support plate tectonics theory (ES.7 a) * analyze the scientific evidence for plate motion, multiple continental collisions, and rifting events over the last billion years (ES.7 a) * comprehend and apply the details of plate tectonics theory to the formation of continents, mountain chains, island arcs, deep open trenches, earthquake zones, and continental and mid-ocean volcanism (ES.7 b) * model the composition and structure of the continental and oceanic lithosphere in terms of, topographic features, density, thickness, and rates of motion (ES.7 b) * compare different types plate boundaries and resulting features. Cite current examples of convergent, divergent, and transform boundaries (ES.7 b) * analyze data on the speed, behavior, and paths of different types of seismic waves and determine Earth layer composition, density, and viscosity (ES.7 b) * analyze field and laboratory evidence and construct an explanation for the various structures produced in convergent continental and oceanic plate boundaries (ES.7 c) * interpret the tectonic history of an area based on the sequences, structures, and type of rocks found in that area (ES.7 c) * compare the tectonic activity of the east coast and the west coast of North America (ES.7 b, c) * integrate the rock cycle with plate tectonics theory and determine how this is reflected in the geology of Virginia’s five physiographic/geologic provinces (ES.7 a, c, d) * interpret landforms, water features, elevation and elevation changes, and other pertinent features on topographic maps (ES 7 c, d) * construct profiles from topographic contours (ES 7 c, d) * label on a map the physiographic provinces of Virginia (ES 7 d) * comprehend the topographic, rock-type and geologic-structural characteristics of each physiographic province of Virginia (ES.7 d) * analyze the geology of Virginia in terms of the rock structures, types, ages, and topography represented in the five physiographic provinces and reconstruct a geologic history (ES.7 d) * integrate and interpret the rock cycle, plate tectonics, and Virginia’s geology (ES.7 d). |

**ES.8 The student will investigate and understand that freshwater resources influence and are influenced by geologic processes and activities of humans. Key ideas include**

1. **water impacts geologic processes including soil development and karst topography;**
2. **the nature of materials in the subsurface affect the water table and future availability of fresh water;**
3. **weather and human usage impact freshwater resources, including water locations, quality, and supply; and**
4. **stream processes and dynamics impact the major watershed systems in Virginia, including the Chesapeake Bay and its tributaries**.

**Central Idea:** Earth is a water planet; it is found everywhere on Earth from the heights of the atmosphere to the depths of the mantle. Although 70 percent of the planet’s surface is covered in water, only 2.5 percent is in the form of freshwater. Water not only impacts geologic processes, but the limited amount of freshwater indicates it is a resource that must be conserved.

**Vertical Alignment:** The importance of water and its properties is studied throughout K-12 science. Students study the properties of water and water’s role in weathering, moderating climate, agriculture, power generation, and public health in sixth grade (6.6, 6.8). In Earth Science, the focus is on freshwater resources and their impact on geologic processes.

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| Systems are comprised of interacting and interdependent elements that are subject to change in response to inputs and outflows of energy and matter. Freshwater is a component of the Earth system and is critical to geologic and life processes.   * Freshwater is less than 3 percent of the Earth’s surface (ES.8 a). * Earth’s fresh water supply is finite. Geological processes, such as erosion, and human activities, such as waste disposal, can pollute water supplies (ES.8 a). * Earth’s water cycles among the reservoirs of the atmosphere, streams, lakes, ocean, glaciers, groundwater, and deep interior of the planet (ES.8 a). * Water is continuously being passed through the hydrologic cycle. Fresh water is necessary for survival and most human activities (ES.8 a). * Permeability is a measure of the ability of a rock or sediment to transmit water or other liquids. Water does not pass through impermeable materials. A substantial amount of water is stored in permeable soil and rock underground (ES.8 b). * Soil is formed from the weathering of rocks and organic activity and is composed of loose rock fragments and clay derived from weathered rock mixed with organic material (ES.8 a). * Karst topography is developed in areas underlain by carbonate rocks, including limestone and dolomite. Karst topography includes features like caves and sinkholes and forms when limestone is slowly dissolved away by slightly acidic groundwater. Where limestone is abundant in the Valley and Ridge province of Virginia, karst topography is common (ES.8 a).   Human actions and geologic processes affect the availability of freshwater resources.   * Humans affect the quality, availability, and distribution of Earth’s water through modifications of streams, lakes, and groundwater (ES.8 c). * The flow of surface water shapes landscapes and causes changes in topography over time (ES.8 d). * Rivers (streams) continuously alter the landscape, eroding their channels downward toward base level and cutting back and forth into their sides, which slowly widens the valleys through which they flow. Broad, relatively flat areas adjacent to the river, floodplains, are produced over time. The confluence of smaller tributaries continually adds water, dissolved substances, and sediment to the river (ES.8 d). * Rivers carry a range of sediments (including organic debris) that settles out depending on the particle size and density of the material. During times of high flow, streams often spill out onto their floodplains, depositing sediments, and in the process, building up natural levees along their banks (ES.8 d). * Rivers with broad floodplains often move in a meandering fashion characterized by broad wave-like curves and arched, cut-off channels (oxbows). The lower energy of slowly-moving rivers allows small-grained sediments such as fine silt and clays to be carried in suspension with some bed load of coarser material (ES.8 d). * The three major regional watershed systems in Virginia lead to the Chesapeake Bay, the North Carolina sounds, and the Gulf of Mexico (ES.8 d). * As rivers near their mouths, such as those flowing into the Chesapeake Bay or the Gulf of Mexico, much of that sediment is deposited. Excessive sediment and dissolved nutrients may damage ecosystems (ES.8 d). * Stream processes that impact watershed systems include stream velocity and discharge. Stream dynamics include the process of receiving or losing water from the groundwater, flood erosion, and deposition (ES.8 d). | In order to meet this standard, it is expected that students will   * interpret a hydrologic cycle diagram, including evaporation, condensation, precipitation, transpiration, infiltration, underground storage, and runoff (ES.8 a) * examine the formation of karst in terms of rock type, solubility and permeability, uplift, the water table, and chemical and physical weathering (ES.8 a) * interpret a simple groundwater diagram showing the zone of aeration, the zone of saturation, the water table, and an aquifer (ES.8 b) * examine the presence of groundwater in various types of rock terrains, including areas found in each of the physiographic/geologic provinces of Virginia (ES.8 b) * gather and synthesize information about groundwater issues (groundwater withdrawal, recharge rates, salt water intrusion, septic migration, chemical waste leakage, land subsidence), and describe potential consequences, including short- and long-term availability of the resource (ES.8 b) * plan and conduct an investigation to determine the effects of human activities on local freshwater sources (ES.8 c) * use data to identify a freshwater problem in the community and propose a solution(s) (ES.8 c) * locate the major Virginia watershed systems (i.e., Chesapeake Bay, Gulf of Mexico, and North Carolina sounds) on a map (ES.8 d) * utilize topographic maps, to trace and delineate a Virginia watershed utilizing geologic and topographic evidence (ES.8 d). |

**ES.9 The student will investigate and understand that many aspects of the history and evolution of Earth and life can be inferred by studying rocks and fossils. Key ideas include**

1. **traces and remains of ancient, often extinct, life are preserved by various means in sedimentary rocks;**
2. **superposition, cross-cutting relationships, index fossils, and radioactive decay are methods of dating rocks and Earth events and processes;**
3. **absolute (radiometric) and relative dating have different applications but can be used together to determine the age of rocks and structures; and**
4. **rocks and fossils from many different geologic periods and epochs are found in Virginia.**

**Central Idea:** Life evolves on a dynamic Earth and continuously modifies Earth.

**Vertical Alignment:** In fifth grade, students are introduced to the use of fossils and geologic patterns to provide evidence of Earth’s change (Standard 5.9). Evidence to support the history of Earth and its changes, including fossil evidence, is the focus of Earth Science.

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| Earth’s rocks and fossils document the existence, diversity, extinction, and change of many life forms and their environmental though Earth’s history.   * The history of Earth and the ages of rocks can be investigated and understood by studying rocks and fossils (ES.9 a). * Evidence of ancient, often extinct life is preserved in many sedimentary rocks. A fossil is the remains, impression, or other evidence preserved in rock of the former existence of life. Fossil evidence indicates that life forms have changed and become more complex over geologic time. Some ways in which fossils can be preserved are molds, casts, and original bone or shell (ES.9 a).   Technological advances, breakthroughs in interpretation, and new observations continuously refine our understanding of Earth.   * Relative time places events in a sequence without assigning any numerical ages. Fossils, superposition, and cross-cutting relations are used to determine the relative ages of rocks (ES.9 b). * Absolute time places a numerical age on an event. Radiometric dating is used to determine the absolute age of rocks by measuring the products of radioactive decay of certain elements (ES.9 c).   Explanations of stability and change in natural systems can be constructed by examining changes over time. Evidence, in the form of rocks and fossils from different geologic periods and epochs, has been found in Virginia.   * In Virginia, fossils are found mainly in the Coastal Plain, Valley and Ridge, and Appalachian Plateau provinces. Most Virginia fossils are of marine organisms. This indicates that large areas of the state have been periodically covered by seawater (ES.9 d). * Paleozoic, Mesozoic, and Cenozoic fossils are found in Virginia (ES.9 d). | In order to meet this standard, it is expected that students will   * describe how life has changed and become more complex over geologic time (ES.9 a) * explain short- and long-term global occurrences and assess proposed explanations as related to mass extinctions (short-term occurrences include asteroid/comet impacts, volcanism, earthquakes; long-term occurrences include continental collisions, climate collapse, global glaciation) (ES.9 a) * using a geologic history diagram (cross section) sequence the order of events from oldest to youngest and identify cross-cutting relationships (ES.9 b) * analyze data and graphs concerning the ratio of parent isotopes to daughter decay products present in a rock to calculate the age of the material based on absolute dating, and assess how radioactive decay provides a reliable method to determine the age of many types of organic and inorganic materials (ES.9 c) * analyze and interpret complex cross sections using both relative and absolute dating to sequence and define the geologic history of the section (ES.9 b, c) * analyze a sequence of rocks in terms of types, textures, composition, fossils, structural and weathering features to infer the history of the sequence over time(ES.9 a, b) * use index fossils to infer the geologic history of a complex cross section (ES.9 b) * analyzing rock and fossil evidence and other scientific data to depict an evolution of Earth’s geologic, oceanic, and atmospheric conditions over time (ES.9 d). |

**ES.10 The student will investigate and understand that oceans are complex, dynamic systems and are subject to long- and short-term variations. Key ideas include**

1. **chemical, biological, and physical changes impact the oceans;**
2. **environmental and geologic occurrences affect ocean dynamics;**
3. **unevenly distributed heat in the oceans drives much of Earth’s weather;**
4. **features of the sea floor reflect tectonic and other geological processes; and**
5. **human actions, including economic and public policy issues, impact oceans and the coastal zone including the Chesapeake Bay.**

**Central Idea:** Oceans are dynamic systems that support life, affect weather, and help moderate temperatures on the planet. Both natural occurrences and human activities can disrupt the equilibrium of the system.

**Vertical Alignment:** Students study water as applied to watershed systems in sixth grade. The effects of both biotic and abiotic factors on watershed health is introduced (6.8). In Earth Science, the focus is on oceans as systems.

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| Ocean systems are comprised of interacting and interdependent elements that are subject to change in response to inputs and outflows of energy and matter.   * The ocean is a dynamic system in which many chemical, biological, and physical changes are taking place (ES.10 a). * Upwellings brings cold, nutrient-rich water from the deep ocean to the surface and are areas of rich biological activity (ES.10 a). * The tides are the periodic rise and fall of water level caused by the gravitational pull of the sun and moon (ES.10 a).   Environmental and geologic occurrences may lead to changes in ocean dynamics.   * A significant amount of atmospheric CO2 is naturally absorbed by the oceans. However, scientific evidence indicates that this amount is slowly increasing as the CO2 levels in the atmosphere rise. Scientific observations have indicated potential negative impact on marine organisms with calcium carbonate skeletons and shells (ES.10 b). * Sea level falls when glacial ice caps grow and rises when the ice caps melt (ES.10 b).   Systems are dynamic and change in response to inputs and outflows of energy and matter. Temperature differentials and the resulting transfer of energy within the oceans drive Earth’s weather.   * The ocean is the single largest reservoir of heat at Earth’s surface. The stored heat in the ocean drives much of Earth’s weather and causes climate near the ocean to be milder than climate in the interior of continents (ES.10 c). * Most waves on the ocean surface are generated by wind, the movement of air from high to low pressure, is caused by the uneven heating of Earth’s surface by the sun (ES.10 c). * Convection is the major mechanism of energy transfer in the oceans, atmosphere, and Earth’s interior (ES.10 c). * There are large current systems in the oceans that carry warm water toward the poles and cold water toward the equator (ES.10 c).   The cycling of energy and matter in Earth’s interior occurs through the process of convection and has important consequences for ocean topography.   * The topography of the seafloor is at least as variable as that on the continents. Features of the seafloor that are related to plate tectonic processes include mid-ocean ridges and trenches (ES.10 d).   The oceans’ resources are finite and should be utilized with care. Human activities significantly change the rates of many of Earth’s surface processes and alter the biosphere.   * The oceans are an important source of food and mineral resources as well as a venue for recreation and transportation (ES.10 e). * Algae in the oceans are an important source of atmospheric oxygen (ES.10 a). * The oceans are environmentally and economically important. Human activities and public policy have important consequences for the oceans. The impact of human activities, such as waste disposal, construction, and agriculture, affect the water quality within watershed systems and ultimately the ocean. Pollution and overfishing can harm or deplete valuable resources (ES.10 e). * Estuaries, like the Chesapeake Bay, are areas where fresh and salt water mix, producing variations in salinity and high biological activity. Chemical pollution and sedimentation are great threats to the well-being of estuaries and oceans (ES.10 e). | In order to meet this standard, it is expected that students will   * explain the role of oceans in the extraction of atmospheric carbon dioxide and the relation to the formation of carbonates (ES.10 a) * investigate trends of ocean temperature and pH over time as it relates to the extraction of CO2 and the formation of carbonates (ES.10 a) * analyze the effects of changing ocean pH on marine organisms, carbon sequestration, and the production of atmospheric oxygen (ES.10 a) * analyze the environmental effects of oceanic disasters on the base of the food web; economics; and future productivity of the ocean environment (ES.10 b) * describe the relationship among moving continents, the presence of ice caps, and ocean circulation over long periods of time (ES.10 c) * relate important ocean conditions, including El Niño, and La Nina to weather on the continents (ES.10 c) * analyze the role of ocean currents in the distribution of heat from the equatorial regions to the poles, and predict what changes may occur as continents move and atmospheric conditions and climate vary (ES.10 c) * analyze water temperatures during the yearly cycle, and relate this to the formation of storms (ES.10 c) * model the relationship between tectonic processes and the features of the sea floor (ES.10 d) * describe different types of pollution (e.g., sediment, toxins, fertilizer, salt water intrusion) that can pollute the Chesapeake Bay throughout its entire six-state watershed (ES.10 e) * identify the effects of human activities on the oceans (ES.10 e) * analyze reports, media articles, and other narrative materials related to the health of oceans or a local watershed system; propose a solution and analyze cost benefits to the implementation of the solution (ES.10 e). |

**ES.11 The student will investigate and understand that the atmosphere is a complex, dynamic system and is subject to long-and short-term variations. Key ideas include**

1. **the composition of the atmosphere is critical to most forms of life;**
2. **biologic and geologic interactions over long and short time spans change atmospheric composition;**
3. **natural events and human actions may stress atmospheric regulation mechanisms; and**
4. **human actions, including economic and policy decisions, impact the atmosphere.**

**Central Idea:** The atmosphere is a dynamic system that support life through retaining heat, blocking damaging rays, and provides gases needed for homeostasis. Both natural occurrences and human activities can disrupt the equilibrium of the system.

**Vertical Alignment:** Students investigate the atmosphere’s composition and characteristics in sixth grade and study the effects of changes in altitude, thermal energy, and motion (6.7). In Earth Science, students study atmospheric interactions and examine the atmosphere as a complex system.

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| Earth’s atmosphere is comprised of interacting and interdependent elements that are subject to change in response to inputs and outflows of energy and matter.   * Earth’s atmosphere is 21 percent oxygen, 78 percent nitrogen, and one percent trace gases. The composition of the atmosphere can change due to human, biologic, and geologic activity (ES.11 a). * The ability of Earth’s atmosphere to absorb and retain heat is affected by the presence of gases like water vapor and carbon dioxide (ES.11 a).   The cycling of energy and matter through various natural and manmade processes have led to changes in the composition of Earth’s atmosphere.   * Evolution, including the origination and extinction of species, has altered the composition of gases in the atmosphere (ES.11 b). * The composition of Earth’s atmosphere has changed over geologic time. Earth’s atmosphere is unique in the solar system in that it contains substantial oxygen (ES.11 b). * Earth’s most primitive atmosphere may have beencomprised of mainly helium and hydrogen~~.~~; however, it is unclear whether Earth had an atmosphere at its formation due to radiation from the young sun Scientific evidence suggests that Earth’s early atmosphere contained mostly CO2, CO, nitrogen, SO2, and water vapor, resulting from volcanic outgassing. This atmosphere was then modified by early photosynthetic life (ES.11 b). * The atmospheres of Earth, Mars, and Venus apparently had very different paths toward the evolution of their current conditions. Many factors may have influenced this, including distance from the sun, planetary mass, the nature of the planets’ interiors, the presence of a large moon, and the origin and nature of each planet’s early atmosphere (ES.11 b). * Early photosynthetic life such as cyanobacteria (blue-green algae) consumed carbon dioxide and generated oxygen. It was only after early photosynthetic life generated oxygen that animal life became possible (ES.11 b).   Human activities and natural occurrences may significantly change the rates of many of Earth’s atmospheric processes.   * Interaction among Earth’s spheres leads proportions of gases staying within ranges that support life. The biosphere interacts with other spheres in many ways including the carbon cycle, water cycle, and nitrogen cycle (ES.11 c). * Volcanic activity and meteorite impacts can inject large quantities of dust and gases into the atmosphere (ES.11 c). * Human activities have increased the carbon dioxide content of the atmosphere. Man-made chemicals have decreased the ozone concentration in the atmosphere (ES.11 c). * Climate change maintained deviation in at least two climatic variables. This natural process has been accelerated by human activities. Evidence for climate change includes: global temperature rise, warming oceans, shrinking ice sheets, glacial retreat, decreased snow cover, sea level rise, declining Arctic sea ice, extreme weather events, and ocean acidification (ES.11 c). * Legislation can promote change in human actions and reverse or stall the negative effects of their actions on the atmosphere. An example is evidenced through the policy that banned the use of chlorofluorocarbons (CFC) resulting in the reduction of ozone-layer depletion (ES.11 d). | In order to meet this standard, it is expected that students will   * describe the role of different atmospheric components in supporting life (ES.11 a) * analyze atmospheric change over geologic time and assess the role and evidence of photosynthetic organisms in this transformation (e.g., ice cores, stromatolites, red beds) (ES.11 b) * explain how volcanic activity or meteor impacts could affect the atmosphere, and life on Earth (ES.11 c) * explain how biologic activity, including human activities, may influence global temperature and climate (ES.11 c) * research historical information and scientific data on the impact of major volcanic eruptions and other natural events on the atmosphere (ES.11 c) * research data on the effect of human activities and public policy on Earth’s ozone layer since chlorofluorocarbons (CFC) were banned (ES.11 d) * research and analyze the effects of the development of fossil fuels and other human activity on atmospheric composition; develop a suggestive set of steps or sample policies to monitor and mitigate potential issues and concerns (ES.11 d). |

**ES.12 The student will investigate and understand that Earth’s weather and climate are the result of the interaction of the sun’s energy with the atmosphere, oceans, and the land. Key ideas include**

1. **weather involves the reflection, absorption, storage, and redistribution of energy over short to medium time spans;**
2. **weather patterns can be predicted based on changes in current conditions;**
3. **extreme imbalances in energy distribution in the oceans, atmosphere, and the land may lead to severe weather conditions;**
4. **models based on current conditions are used to predict weather phenomena; and**
5. **changes in the atmosphere and the oceans due to human activity affect global climate.**

**Central Idea:** Weather and climate are driven by the energy from the sun and the interaction of this energy with the atmosphere, oceans, and the land.

**Vertical Alignment:** The concept of weather, tools to measure weather conditions, and the ability to predict weather is focused on throughout elementary science. Students expand on the concept of weather to look at the causes of weather in sixth grade. These include the transfer of radiant energy, the impact of atmospheric conditions on weather, and that role of large bodies of water on weather and climate (6.4, 6.6, 6.7). In Earth Science, students study the interactions of the various systems as they influence weather.

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| All Earth’s processes are the result of energy flowing and mass cycling within and among Earth’s systems. Energy transfer between Earth’s surface and the atmosphere creates the weather.   * Earth’s surface is much more efficiently heated by the sun than is the atmosphere. The amount of energy reaching any given point on Earth’s surface is controlled by the angle of sunlight striking the surface and varies with the seasons (ES.12 a). * Winds are created by uneven heat distribution at Earth’s surface and modified by the rotation of Earth. The Coriolis effect causes deflections of the atmosphere due to the rotation of Earth. Global wind patterns result from the uneven heating of Earth by the sun and are influenced by the Coriolis effect (ES.12 b). * Convection in the atmosphere is a major cause of weather. Convection is the major mechanism of energy transfer in the oceans, atmosphere, and Earth’s interior (ES.12 b). * The conditions necessary for cloud formation are air at or below dew point and presence of condensation nuclei. Cloud droplets can join together to form precipitation (ES.12 b). * A tornado is a narrow, violent funnel-shaped column of spiral winds that extends downward from the cloud base toward Earth. A hurricane is a tropical cyclone (counterclockwise movement of air) characterized by sustained winds of 120 kilometers per hour (75 miles per hour) or greater (ES.12 c).   Models constructed based on patterns in atmospheric conditions are to predict weather.   * Weather forecasting is the application of science and technology to predict the conditions of the atmosphere for a given location and time (ES.12 d). * Weather models take observational data (such as wind speed, wind direction, air temperature, pressure, and humidity) collected from many locations and sources across a region, and use mathematical equations that represent the physics of the atmosphere to fill in the gaps between measured points. Models then use these equations to predict what will happen in the future, including the development of storms and other weather events (ES.12 d). * Earth’s climate is an example of how complex interactions among systems can result in relatively sudden and significant changes (ES.12 d). * Weather and climate are different. Both weather and climate are measurable and, to a certain extent, predictable. Weather describes day-to-day changes in atmospheric conditions. Climate describes the typical weather patterns for a given location over a period of many years. Instrumentation is used to collect weather and climate data (ES.12 e). * The four major factors affecting climate are latitude, elevation, proximity to bodies of water, and position relative to mountains. Earth’s major climatic zones are the polar, temperate, and tropical zones. Areas near the equator receive more of the sun’s energy per unit area than areas nearer the poles (ES.12 e). | In order to meet this standard, it is expected that students will   * research and construct a diagram that demonstrates the interaction of solar radiation, Earth’s atmosphere, and energy transfer (conduction, convection, and radiation) (ES.12 a) * predict the direction of local winds and relate these to the presence of fronts and high- and/or low-pressure systems or other atmospheric phenomena (ES.12 b) * over a multi-day period, read and interpret data from a thermometer, a barometer, and a psychrometer; determine if there is a correlation between the data and observed weather phenomena (ES.12 b) * identify types and origins of air masses, fronts and the accompanying weather conditions (ES.12 b) * collect evidence for how the motions and complex interactions of air masses results in changes in weather conditions (ES.12 b) * plan and conduct an investigation to predict weather based on cloud type, temperature, jet stream location, relative humidity, and barometric pressure (ES.12 b) * read and interpret a weather map containing fronts, isobars, and isotherms and relate these factors to potential weather conditions occurring at specific locations (ES.12 b) * analyze the conditions that lead to severe weather events such as tornadoes and hurricanes. (ES.12 c) * describe the effect of satellite technology on weather prediction and storm tracking, including hurricanes, and evaluate the costs and benefits in terms of lives and property saved; predict the impact on storm preparedness if there were no weather satellites (ES.12 d) * describe human and natural factors that have led to the rise in global temperature over the past century (ES.12 e) * analyze geoscience data and the results of global climate models to make an evidence-based forecast of the current rate of global and regional climate change and associated future effects on Earth systems (ES.12 e). |

## Physics

The Physics standards emphasize a more complex understanding of experimentation, the analysis of data, and the use of reasoning and logic to evaluate evidence. The use of mathematics, including algebra and trigonometry is important, but conceptual understanding of physical systems remains a primary concern. Students build on basic physical science principles by exploring in-depth the nature and characteristics of energy and its dynamic interaction with matter. Key areas covered by the standards include force and motion, energy transformations, wave phenomena and the electromagnetic spectrum, electricity, fields, and non-Newtonian physics. Technology, including graphing calculators, computers, and probeware are used when feasible. Students will use equipment safely. Mathematics, computational thinking, and experience in the engineering design process are essential as students advance in their scientific thinking.

### Scientific and Engineering Practices

Engaging in the practices of science and engineering helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the many ways to investigate, model, and explain the world. These scientific and engineering practices include the use of scientific skills and processes to explore the content of science as outlined in the *Science Standards of Learning*. The engineering design practices are the application of science content to solve a problem or design an object, tool, process, or system. These scientific and engineering practices are critical to science instruction and are to be embedded throughout the year.

**PH.1 The student will demonstrate an understanding of scientific and engineering practices by.**

1. **asking questions and defining problems**

* **ask questions that arise from careful observation of phenomena, examination of a model or theory, or unexpected results, and/or to seek additional information**
* **determine which questions can be investigated within the scope of the school laboratory**
* **make hypotheses that specify what happens to a dependent variable when an independent variable is manipulated**
* **generate hypotheses based on research and scientific principles**
* **define design problems that involves the development of a process or system with interacting components and criteria and constraints**

1. **planning and carrying out investigations**

* **individually and collaboratively plan and conduct observational and experimental investigations**
* **plan and conduct investigations or test design solutions in a safe manner**
  + **select and use appropriate tools and technology to collect, record, analyze, and evaluate data**

1. **interpreting, analyzing, and evaluating data**

* **record and present data in an organized format that communicates relationships and quantities in appropriate mathematical or algebraic forms**
* **use data in building and revising models, supporting explanation for phenomena, or testing solutions to problems**
* **analyze data using tools, technologies, and/or models (e.g., computational, mathematical, statistical) in order to make valid and reliable scientific claims or determine an optimal design solution**
* **analyze data graphically and use graphs to make predictions;**
* **consider limitations of data analysis when analyzing and interpreting data**
* **evaluate the impact of new data on a working explanation and/or model of a proposed process or system**
* **analyze data to optimize a design**

1. **constructing and critiquing conclusions and explanations**

* **make quantitative and/or qualitative claims based on data**
* **construct and revise explanations based on valid and reliable evidence obtained from a variety of sources**
* **apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena or design solutions**
* **compare and evaluate competing arguments in light of currently accepted explanations and new scientific evidence**
* **construct arguments or counterarguments based on data and evidence**
* **differentiate between scientific hypothesis, theory, and law**

1. **developing and using models**
   * **evaluate the merits and limitations of models**
   * **identify and communicate components of a system orally, graphically, textually, and mathematically**
   * **develop and/or use models (including mathematical and computational) and simulations to visualize, explain, and predict phenomena and to interpret data sets**
2. **obtaining, evaluating, and communicating information**

* **compare, integrate, and evaluate sources of information presented in different media or formats to address a scientific question or solve a problem.**
* **gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and credibility of each source**
* **communicate scientific and/or technical information about phenomena and/or a design process in multiple formats**

### Physics Content

**PH.2 The student will investigate and understand, through mathematical and experimental processes, that there are relationships between position and time. Key topics include**

1. **displacement, velocity, and uniform acceleration;**
2. **linear motion;**
3. **uniform circular motion; and**
4. **projectile motion.**

**Central Idea:** The movement of objects can be described using position, velocity, and acceleration. These quantities are related to each other with respect to time.

**Vertical Alignment:** Students begin their study of motion in early elementary and build on this understanding throughout their elementary years. In eighth grade, student instigate the relationships among work, force, and motion and are introduced to Newton’s laws (PS.8).

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| Because all motion is relative, all positions of objects and the directions of forces and motions must be described in a chosen frame of reference.   * Kinematics is the branch of mechanics concerned with the motion of objects without reference to forces (PH.2 b). * Position, displacement, velocity, and acceleration are vector quantities (PH.2 a). * Motion is described in terms of position, displacement, time, velocity, and acceleration (PH.2 b). * Velocity is the change in position (i.e., displacement) divided by the change in time. A straight-line, position-time graph indicates constant velocity. The slope of a position time graph is the velocity and the sign of the slope describes the direction of the velocity (PH.2 a). * Acceleration is the change in velocity divided by the change in time. A straight-line, velocity-time graph indicates constant acceleration. A horizontal-line, velocity-time graph indicates zero acceleration. The slope of a velocity-time graph is the acceleration and the sign of the slope describes the direction of the acceleration (PH.2 a). * Uniform circular motion is when an object travels in a circle with a constant speed. The constant change in direction of the object is caused by an acceleration that is directed toward the center of the circle and is always perpendicular to the velocity of the object (PH.2 c). * In a uniform vertical gravitational field with negligible air resistance, horizontal and vertical components of the motion of a projectile are independent of one another with constant horizontal velocity and constant vertical acceleration (PH.2 d). | In order to meet this standard, it is expected that students will   * construct and analyze graphs showing position vs. time, velocity vs. time, and acceleration vs. time (PH.2 a) * design a model, illustration, and/or graph to explain how distance and velocity change for a free-falling object (PH.2 a) * solve problems involving displacement, velocity, acceleration, and time in one and two dimensions (only constant acceleration) (PH.2 a, b, d) * resolve vector diagrams involving displacement and velocity into their components along perpendicular axes (PH.2 b) * draw vector diagrams of a projectile’s motion. Find range, trajectory, height of the projectile, and time of flight (uniform gravitational field, no air resistance) (PH.2 d) * solve problems related to free-falling objects, including 2-D motion (PH.2 b, d) * solve problems using uniform circular motion (PH.2 c) * plan, conduct, and communicate the results of experiments using kinematics (PH.2 b). |

**PH.3 The student will investigate and understand, through mathematical and experimental processes, that there are relationships among force, mass, and acceleration. Key laws include**

1. **Newton’s laws of motion; and**
2. **Newton’s law of universal gravitation.**

**Central Idea:** Newton's laws of motion are three physical laws that, together, laid the foundation for classical mechanics. These laws describe the relationship between a body and the forces acting upon it, and its motion in response to those forces.

**Vertical Alignment:** Students begin their study of motion in early elementary and build on this understanding throughout their elementary years. In eighth grade, student instigate the relationships among work, force, and motion and are introduced to Newton’s laws (PS.8)

| **Enduring Understandings** | **Essential Knowledge and Practices** |
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| The interactions of an object with other objects can be described by forces. These forces can transfer energy between objects which can cause a change in their motion.   * Dynamics is the branch of mechanics concerned with the effect of forces on motion of a body or a system of bodies (PH.3 a). * Newton’s three laws of motion are the basis of understanding the mechanical universe (PH.3 a). * Net force is the vector sum of all forces acting on an object (PH.3 a). * An object with no net force acting on it is stationary or moves with constant velocity (PH.3 a). * Forces are interactions that can cause objects to accelerate. When one object exerts a force on a second object, the second exerts a force on the first that is equal in magnitude but opposite in direction (PH.3 a). * The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass (PH.3 a). * Position, displacement, velocity, and acceleration are vector quantities (PH.3 a). * Motion is described in terms of position, displacement, time, velocity, and acceleration (PH.3 a). * Free body diagrams are used to show the relative magnitude and direction of all forces acting upon a system in a given situation (PH.3 a). * An object moving along a circular path with a constant speed experiences an acceleration directed toward the center of the circle (PH.3 a). * Friction is the force resisting the relative motion between surfaces in contact with each other (PH.3 a). * Weight is the gravitational force acting on a body (PH.3 b). * Newton’s law of universal gravitation states that any two bodies in the universe attract each other with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them (PH.3 b). | In order to meet this standard, it is expected that students will   * qualitatively explain motion in terms of Newton’s laws (PH.3 a) * solve problems involving force, mass, and acceleration (PH.3 a) * construct and analyze position vs. time, velocity vs. time, and acceleration vs. time, and force vs acceleration graphs (PH.3 a) * solve problems involving force(s), displacement, velocity, acceleration, and time in one and two dimensions (PH.3 a) * resolve vector diagrams involving force, displacement and velocity into their components along perpendicular axes (PH.3 a) * draw vector diagrams of a projectile’s motion. Find range, trajectory, height of the projectile, and time of flight (uniform gravitational field, no air resistance) (PH.3 a) * solve problems involving multiple forces, using free-body diagrams (PH.3 a) * describe the forces involved in circular motion (PH.3 a) * plan and conduct experiments involving dynamics, including one dealing with Newton’s second law (PH.3 a) * communicate results of experiments involving dynamics (PH.3 a) * design a model, illustration, and/or graph to explain how distance and velocity change for a free-falling object (PH.3 a) * use Newton’s laws of motion to predict the effect of motion on objects (PH.3 a) * explain with words, charts, diagrams, and models the effects of distance and the amount of mass on the gravitational force between objects (PH.3 a) * solve problems using Newton’s law of universal gravitation (PH.3 b). |

**PH.4 The student will investigate and understand, through mathematical and experimental processes, that conservation laws govern all interactions. Key ideas include**

1. **momentum is conserved unless an impulse acts on the system; and**
2. **mechanical energy is conserved unless work is done on, by, or within the system.**

**Central Idea**: Conservation and momentum are two of the most fundamental concepts in physics and apply to all interactions.

**Vertical Alignment:** In Physical Science, students are introduced to the concepts of energy, energy conservation, and energy transfer and transformations (PS.5).

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| Changes that occur as a result of interactions are constrained by conservation laws.   * Kinetic energy is the energy of motion. Potential energy is the energy due to an object’s position or state (PH.4 b). * Forces within a system transform energy from one form to another with no change in the system’s total energy (PH.4 b). * Work is the mechanical transfer of energy to or from a system and is the product of a force at the point of application and the parallel component of the object’s displacement (PH.4 b). * Power is the rate of change of the energy of the system (PH.4 b). * For a constant force acting on an object, the impulse by that force is the product of the force and the time the object experiences the force. The impulse also equals the change in the momentum of the object (PH.4 b). * Total energy and momentum are conserved PH.4 a, b). * For elastic collisions, total momentum and total kinetic energy are conserved. For inelastic collisions, total momentum is conserved and some kinetic energy is transformed to other forms of energy (PH.4 a). * In all systems, the principal of mass/energy applies, but only in a small number of systems is it significant enough to be considered (PH.4 b). | In order to meet this standard, it is expected that students will   * illustrate that energy can be transformed from one form to another, using examples from everyday life (PH.4 b) * qualitatively identify the various energy transformations in a simple scenario (PH.4 b) * investigate conservation of energy in a mechanical system in which energy is transformed from one form into another (b) * solve problems with conservation of energy and work and power (b) * investigate conservation of momentum in a mechanical system in which momentum is transferred between objects (PH.4 a) * 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 (PH.4 a) * solve problems with conservation of momentum (PH.4 a) * apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision (PH.4 a) * plan and conduct an experiment to investigate the conservation of electric charge (PH.4 b). |

**PH.5 The student will investigate and understand, through mathematical and experimental processes, that waves transmit energy and move in predictable patterns. Key ideas include**

1. **waves have specific characteristics;**
2. **wave interactions are part of everyday experiences; and**
3. **light and sound transmit energy as waves.**

**Central Idea:** Waves can transfer energy and momentum from one location to another time with little or no permanent displacement of the particles of the medium.

**Vertical Alignment:** In Physical Science, students focus on waves as the movement of energy. Students explore characteristics of waves and their interactions by studying sound waves and electromagnetic radiation (PS.6, PS.7).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
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| Waves can transfer energy and momentum from one location to another without the permanent transfer of mass.   * Mechanical waves transport energy as a traveling disturbance in a medium (PH.5 a). * In a transverse wave, particles of the medium oscillate in a direction perpendicular to the direction the wave travels (PH.5 a). * In a longitudinal wave, particles of the medium oscillate in a direction parallel to the direction the wave travels (PH.5 a). * Wave velocity equals the product of the frequency and the wavelength (PH.5 a). * Frequency and period are reciprocals of each other (PH.5 a). * Waves are reflected and transmitted when they encounter a change in medium or a boundary (PH.5 a). * The overlapping of two or more waves results in constructive or destructive interference (PH.5 a). * When source and observer are in relative motion, a shift in frequency occurs (Doppler effect) (PH.5 a). * Sound is a longitudinal mechanical wave that travels through matter (PH.5 c). * Light is a transverse electromagnetic wave that can travel through matter as well as a vacuum (PH.5 c). * Reflection is the change of direction of the wave in the original medium (PH.5 c). * Refraction is the change of direction of the wave at the boundary between two media (PH.5 c). * Diffraction is the spreading of a wave around a barrier or an aperture (PH.5 c). * The pitch of a note is determined by the frequency of the sound wave (PH.5 c).   Electromagnetic radiation travels in waves and occurs over a wide range of frequencies. The dual nature of light is addressed in PH.9.   * The color of light is determined by the frequency of the light wave (PH.5 c). * As the amplitude of a sound wave increases, the loudness of the sound increases (PH.5 c). * As the amplitude of a light wave increases, the intensity of the light increases (PH.5 c). * Frequency, wavelength, and energy vary across the entire electromagnetic spectrum (PH.5 b). * The long wavelength, low frequency portion of the electromagnetic spectrum is used for communication (e.g., radio, TV, cellular phone) (PH.5 b). * Medium wavelengths (infrared) are used for heating and remote-control devices (PH.5 b). * Visible light comprises a relatively narrow portion of the electromagnetic spectrum (PH.5 b). * Ultraviolet (UV) wavelengths (shorter than the visible spectrum) are ionizing radiation and can cause damage to humans. UV is responsible for sunburn and can be used for sterilization and fluorescence (PH.5 b). * X-rays and gamma rays are the highest frequency (shortest wavelength) and are used primarily for medical purposes. These wavelengths are also ionizing radiation and can cause damage to humans (PH.5 b). | In order to meet this standard, it is expected that students will   * use simulations and models to differentiate between examples of transverse and longitudinal waves (PH.5 a) * use a model representation of a wave to identify the period, wavelength, and amplitude (PH.5 a) * solve problems involving frequency, period, wavelength, and velocity (PH.5 a) * model or simulate reflection, refraction and diffraction of a wave when it encounters a change in medium or a boundary (PH.5 c) * explain the phenomena of constructive and destructive interference (PH.5 b) * plan and conduct an experiment investigating standing waves (PH.5 a) * describe the change in observed frequency of waves due to the motion of a source or a receiver (Doppler effect) (PH.5 c) * identify technological applications throughout the electromagnetic spectrum (PH.5 b) * identify common uses for radio waves, microwaves, X-rays and gamma rays (PH.5 b) * use mathematical representations to support a claim regarding the relationships among the frequency, wavelength, and speed of waves traveling through various media (PH.5 a) * compare electromagnetic waves to mechanical waves (PH.5 b). |

**PH.6 The student will investigate and understand, through mathematical and experimental processes, that optical systems form a variety of images. Key ideas include**

1. **the laws of reflection and refraction describe light behavior; and**
2. **ray diagrams model light as it travels through different media.**

**Central Idea**: Light is an electromagnetic wave that does not need a medium to travel through space. Since light bends it is possible to alter what is seen using optical devices called lenses and mirrors. The path that light travels will bend in such a way that various images are formed that are used in projectors, cameras, and eyeglasses.

**Vertical Alignment:** In Physical Science, students are introduced to characteristics of electromagnetic radiation through an exploration of the electromagnetic spectrum and through observing the results of interactions of light (PS.7).

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| Electromagnetic radiation travels in waves and occurs over a wide range of frequencies. Cause-and-effect relationships may be used to predict the path of light caused by interactions with other materials.   * The ray model of light can be used to understand the behavior of optical systems (PH.6 b). * Light incident on a smooth plane surface is reflected such that the angle of incidence equals the angle of reflection (PH.6 a). * The index of refraction is the ratio of the speed of light in a vacuum to the speed of light in the medium (PH.6 a). * This relationship between the angles of incidence and refraction and the indices of refraction of the two media is known as Snell's law. Snell's law applies to the refraction of light in any situation, regardless of what the two media are (PH.6 a). * For a converging lens, the focal point is the point at which a beam of light parallel to the principal axis converges (PH.6 b). * For a diverging lens, the focal point is the point from which a beam of light parallel to the principal axis appears to originate (PH.6 b). * A virtual image can be seen by an observer but cannot be projected on a screen because the light does not actually emanate from the image (PH.6 b). * The focal point is the point at which rays converge or from which they appear to diverge in a lens or mirror (PH.6 b). | In order to meet this standard, it is expected that students will   * conduct an experiment utilizing Snell’s law to determine the index of refraction for a given material (PH.6 a) * investigate propagation, refraction, and reflection, using the ray model of light (PH.6 a) * construct ray diagrams to determine the location and type of image of an object using the laws of reflection and refraction (PH.6 b) * conduct an experiment to find the location of an image using an optical system (PH.6 b). |

**PH.7 The student will investigate and understand, through mathematical and experimental processes, that fields provide a unifying description of force at a distance. Key ideas include**

1. **gravitational, electric, and magnetic forces can be described using the field concept; and**
2. **field strength diminishes with increased distance from the source.**

**Central Idea**: Field theories describe how forces interact with matter. A gravitational field is one that is created due to the mass of the object. Electric fields are created by the electric charge, positive or negative, that an object possesses. Finally, magnetic fields are created by the movement of an electric charge. All fields are considered vectors and are often represented by field lines to give a visual picture of the field location and strength.

**Vertical Alignment:** Students are exposed to the basic principles of electricity and magnetism in eighth grade to include electrical circuits, and the relationship between electric and magnetic fields (PS.9).

| **Enduring Understandings** | **Essential Knowledge and Practices** |
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| Fields existing in space can be used to explain interactions.   * A field is a region in which each point is affected by a force. Objects fall to the ground because they are affected by the force of the Earth’s gravitational field. A paper clip, placed in a magnetic field, is pulled toward the magnet, and the two like magnetic poles repel each other when one is placed in the other’s magnetic field (PH.7 a). * An electric field surrounds an electric charge; when another charged particle is placed in that region, it experiences an electric force that either attracts or repels it (PH.7 a). * The strength of a field, or the forces in a particular region, could be represented by field lines; the closer the lines, the stronger the forces in that part of the field (PH.7 a). * The force found from Newton’s law of gravitation and in Coulomb’s law is dependent on the inverse square of the distance between two objects (PH.7 b). * The interaction of two particles at a distance can be described as a two-step process that occurs simultaneously: the creation of a field by one of the particles and the interaction of the field with the second particle (PH.7 a, b). * The force a magnetic field exerts on a moving electrical charge has a direction perpendicular to both the velocity and field directions. Its magnitude is dependent on the velocity of the charge, the magnitude of the charge, and the strength of the magnetic field (PH.7 a). | In order to meet this standard, it is expected that students will   * describe thevector nature of the forces on an object in the presence of a field (PH.7 a) * compare Newton’s law of universal gravitation and Coulomb’s law of electrostatics (PH.7 a) * describe the effect of a uniform magnetic field on a moving electrical charge (PH.7 a) * plan and conduct an experiment utilizing sensors to explore and explain the nature of fields (PH.7 a, b) * develop and use of model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction (PH.7 a) * 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 (PH.7 a) * describe the relationship between electric charges and magnetic fields (PH.7 a). |

**PH.8 The student will investigate and understand, through mathematical and experimental processes, that electrical circuits are a system used to transfer energy. Key ideas include**

1. **circuit components have different functions within the system;**
2. **Ohm’s law relates voltage, current, and resistance;**
3. **different types of circuits have different characteristics and are used for different purposes;**
4. **electrical power is related to the elements in a circuit; and**
5. **electrical circuits have everyday applications.**

**Central Idea:**  An electrical circuit is a closed loop that begins and ends at a power source. Within that circuit voltages and currents are determined by the choice of power source and resistance of electrical components. The electrical power of a circuit or component in a circuit is the product of the current and the voltage.

**Vertical Alignment:** Students are exposed to the basic principles of electricity and magnetism in eighth grade to include electrical circuits, and the relationship between electric and magnetic fields (PS.9).

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| Electric charge is a property of an object or system that affects its interactions with other objects or systems containing charge.   * Current is the rate at which charge moves through a circuit element (PH.8 b). * Electric potential difference (voltage) in a circuit provides the energy that drives the current (PH.8 b). * Elements in a circuit are positioned relative to other elements either in series or parallel (PH.8 a, c). * According to Ohm’s law, the resistance of an element equals the voltage across the element divided by the current through the element (PH.8 b). * Potential difference (voltage) is the change in electrical potential energy per unit charge across that element (PH.8 b). * The dissipated power of a circuit element equals the product of the voltage across that element and the current through that element (PH.8 d). * In a DC (direct current) circuit, the current flows in one direction, whereas in an AC (alternating current) circuit, the current switches direction several times per second (PH.8 e). | In order to meet this standard, it is expected that students will   * describe the function of components in an electrical system (PH.8 a) * recognize a series and a parallel circuit (PH.8 b) * apply Ohm’s law to a series and a parallel circuit (PH.8 b) * assemble and analyze simple circuits composed ofvoltage sources and loads in series and in parallel (PH.8 c) * solve simple circuits using Ohm’s law (PH.8 b, c) * calculate the dissipated power of a circuit element (PH.8 d) * recognize that DC power is supplied by batteries and that AC power is supplied by electrical wall sockets (PH.8 e). |

**PH.9 The student will investigate and understand that extremely large and extremely small quantities are not necessarily described by the same laws as those studied in Newtonian physics. Topics, such as these listed, may be included.**

1. **wave/particle duality;**
2. **quantum mechanics and uncertainty;**
3. **relativity;**
4. **nuclear physics;**
5. **solid state physics;**
6. **nanotechnology;**
7. **superconductivity;**
8. **the standard model; and**
9. **dark matter and dark energy.**

**Central Idea:** Newtonian physics doesn’t adequately describe phenomena at the extremes of small size or high speed. As modern physics has explored areas of extreme speeds and subatomic particles, new paradigms have been created.

**Vertical Alignment:** Prior to this standard, students may have little or no classroom experience with these topics.

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| The study of modern and non-Newtonian physics can be applied in varied technological applications. The intent of this standard is not that each area be taught; instead, the teacher should select areas based on student interest and their own understandings of physics concepts.   * For processes that are important on the atomic scale, objects exhibit both wave characteristics (e.g., interference) as well as particle characteristics (e.g., discrete amounts and a fixed definite number of electrons per atom) (PH.9 a, b). * Quantum mechanics requires an inverse relationship between the measurable location and the measurable momentum of a particle. The more accurately one determines the position of a particle, the less accurately the momentum can be known, and vice versa. This is known as the Heisenberg uncertainty principle (PH.9 a, b). * The special theory of relativity states that the laws of physics are the same for all inertial reference frames and the speed of light in a vacuum is constant and independent of the motion of all observers (PH.9 c). * The general theory of relativity is a theory of space and time. The central idea is that space and time are two aspects of spacetime. Spacetime is curved in the presence of mass (PH.9 c). * The strong nuclear force binds protons and neutrons in the nucleus. Fission is the breakup of heavier nuclei into lighter nuclei. Fusion is the combination of lighter nuclei into heavier nuclei. The study of these topics is called *nuclear physics* (PH.9 d). * Natural radioactivity is the spontaneous disintegration of unstable nuclei. Alpha, beta, and gamma rays are different emissions associated with radioactive decay (PH.9 d). * Solid state physics is the study of rigid matter or solids through methods such as quantum mechanics, crystallography, electromagnetism, and metallurgy. It is the largest branch of condensed matter physics (PH.9 e). * Matter behaves differently at nanometer scale (size and distance) than at macroscopic scale (PH.9 f). * Certain materials at very low temperatures exhibit the property of zero resistance called *superconductivity* (PH.9 g). * Nuclear physics is the study of the nature of atomic nuclei, including the interactions among protons, neutrons, and the quarks that comprise them (PH.9 d). * The Standard Model of particle physics is a theory concerning the electromagnetic, weak, and strong nuclear interactions, as well as classifying all the known subatomic particles (PH.9 h). * The fundamental particles (quarks, protons, and neutrons) that emerged in the early universe soon after the big bang are the same types of particles that are studied today in particle physics experiments at laboratories such as the Large Hadron Collider (LHC) in Switzerland and the Thomas Jefferson National Accelerator Facility (JLab) in Newport News, Virginia (PH.9 h). | In order to meet this standard, it is expected that students will   * evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described by either a wave model or a particle model, and that for some situations one model is more useful than another (PH.9 a, b) * communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy (PH.9 a, b) * provide examples of technologies used to explore topics in modern physics (PH.9, b, c, d, e, f, g, h, i) * compare classical physics and modern physics at the extremes of speed and size (PH.9 a, b, c, d, e, f, g, h, i) * explore the connections between and the benefits of the pursuit of pure science and subsequent applications (PH.9 a, b, c, d, e, f, g, h, i). |