

SUPPORT GUIDE 3.0
FOR PHYSICS

SOUTH CAROLINA ACADEMIC
STANDARDS
AND PERFORMANCE INDICATORS
FOR SCIENCE

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SOUTH CAROLINA

DEPARTMENT OF EDUCATION

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INTRODUCTION TO HIGH SCHOOL PHYSICS STANDARDS

Science is a way of understanding the physical universe using observation and experimentation to explain natural phenomena. Science also refers to an organized body of knowledge that includes core ideas to the disciplines and common themes that bridge the disciplines. This document, *South Carolina Academic Standards and Performance Indicators for Science*, contains the academic standards in science for the state's students in kindergarten through grade twelve.

As science educators we must take a 3 dimensional approach in facilitating student learning. By addressing content standards, science and engineering practices and crosscutting concepts, students are able to have relevant and evidence based instruction that can help solve current and future problems. For more information please see: <https://www.nap.edu/catalog/13165/a-framework-for-k-12-science-education-practices-crosscutting-concepts>.

ACADEMIC STANDARDS

In accordance with the South Carolina Education Accountability Act of 1998 (S.C. Code Ann. § 59-18-110), the purpose of academic standards is to provide the basis for the development of local curricula and statewide assessment. Consensually developed academic standards describe for each grade and high school core area the specific areas of student learning that are considered the most important for proficiency in the discipline at the particular level.

Operating procedures for the review and revision of all South Carolina academic standards were jointly developed by staff at the State Department of Education (SCDE) and the Education Oversight Committee (EOC). According to these procedures, a field review of the first draft of the revised South Carolina science standards was conducted from March through May 2013. Feedback from that review and input from the SCDE and EOC review panels was considered and used to develop these standards.

The academic standards in this document are not sequenced for instruction and do not prescribe classroom activities; materials; or instructional strategies, approaches, or practices. The *South Carolina Academic Standards and Performance Indicators for Science* is not a curriculum.

THE PROFILE OF THE SOUTH CAROLINA GRADUATE

The 2014 South Carolina Academic Standards and Performance Indicators for Science support the *Profile of the South Carolina Graduate*. The *Profile of the South Carolina Graduate* has been adopted and approved by the South Carolina Association of School Administrators (SCASA), the South Carolina Chamber of Commerce, the South Carolina Council on Competitiveness, the Education Oversight Committee (EOC), the State Board of Education (SBE), and the South Carolina Department of Education (SCDE) in an effort to identify the knowledge, skills, and characteristics a high school graduate should possess in order to be prepared for success as they enter college or pursue a career. The profile is intended to guide all that is done in support of college- and career-readiness.

Profile of the South Carolina Graduate



World Class Knowledge

- Rigorous standards in language arts and math for career and college readiness
- Multiple languages, science, technology, engineering, mathematics (STEM), arts and social sciences

World Class Skills

- Creativity and innovation
- Critical thinking and problem solving
- Collaboration and teamwork
- Communication, information, media and technology
- Knowing how to learn

Life and Career Characteristics

- Integrity
- Self-direction
- Global perspective
- Perseverance
- Work ethic
- Interpersonal skills

Approved by SCASA Superintendents Roundtable and SC Chamber of Commerce
 SC Education Oversight Committee, SC State Board of Education, SC Department of Education,
 SC General Assembly, SC Council on Competitiveness, TransformSC, & SC Arts in Basic Curriculum
 Steering Committee

SCIENCE AND ENGINEERING PRACTICES

In addition to the academic standards, each grade level or high school course explicitly identifies *Science and Engineering Practice* standards, with indicators that are differentiated across grade levels and core areas. The term “practice” is used instead of the term “skill,” to emphasize that scientists and engineers use skill and knowledge simultaneously, not in isolation. These eight science and engineering practices are:

1. Ask questions and define problems
2. Develop and use models
3. Plan and conduct investigations
4. Analyze and interpret data
5. Use mathematical and computational thinking
6. Construct explanations and design solutions
7. Engage in scientific argument from evidence
8. Obtain, evaluate, and communicate information

Students should engage in scientific and engineering practices as a means to learn about the specific topics identified for their grade levels and courses. It is critical that educators understand that the Science and Engineering Practices are *not* to be taught in isolation. There should *not* be a distinct “Inquiry” unit at the beginning of each school year. Rather, the practices need to be employed *within the content* for each grade level or course.

Additionally, an important component of all scientists and engineers’ work is communicating their results both by informal and formal speaking and listening, and formal reading and writing. Speaking, listening, reading and writing is important not only for the purpose of sharing results, but because during the processes of reading, speaking, listening and writing, scientists and engineers continue to construct their own knowledge and understanding of meaning and implications of their research. Knowing how one’s results connect to previous results and what those connections reveal about the underlying principles is an important part of the scientific discovery process. Therefore, students should similarly be reading, writing, speaking and listening throughout the scientific processes in which they engage.

For additional information regarding the development, use and assessment of the *2014 Academic Standards and Performance Indicators for Science* please see the official document that is posted on the SCDE science web page https://ed.sc.gov/scdoe/assets/file/agency/ccr/Standards-Learning/documents/South_Carolina_Academic_Standards_and_Performance_Indicators_for_Science_2014.pdf.

Support for the guidance, overviews of learning progressions, and explicit details of each SEP can be found in the Science and Engineering Support Document https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf.

CROSSCUTTING CONCEPTS

Seven common threads or themes are presented in *A Framework for K-12 Science Education* (2012). These concepts connect knowledge across the science disciplines (biology, chemistry, physics, earth and space science) and have value to both scientists and engineers because they identify universal properties and processes found in all disciplines. These crosscutting concepts are:

1. Patterns
2. Cause and Effect: Mechanism and Explanation
3. Scale, Proportion, and Quantity
4. Systems and System Models
5. Energy and Matter: Flows, Cycles, and Conservation
6. Structure and Function
7. Stability and Change

These concepts should not to be taught in isolation but reinforced in the context of instruction within the core science content for each grade level or course.

The link <http://www.nap.edu/read/13165/chapter/8> provides support from the framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (2012) that gives further guidance on each crosscutting concept.

1. **Patterns:** The National Research Council (2012) states that “observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them” (p. 84).
2. **Cause and Effect: Mechanism and Explanation:** The National Research Council (2012) states that “events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts” (p. 84).
3. **Scale, Proportion, and Quantity:** The National Research Council (2012) states that “in considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system’s structure or performance” (p. 84).
4. **Systems and Systems Models:** The National Research Council (2012) states that “Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering” (p. 84).
5. **Energy and Matter:** Flows, cycles, and conservation. Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems’ possibilities and limitations.
6. **Structure and Function:** The National Research Council (2012) states that “the way in which an object or living thing is shaped and its substructure determine many of its properties and functions” (p. 84).
7. **Stability and Change:** The National Research Council (2012) states that “For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study” (p. 84).

DECIPHERING THE STANDARDS

Kindergarten

Life Science: Exploring Organisms and the Environment

Standard K.L.2: The student will demonstrate an understanding of the effects of forces on the motion and stability of an object.

K.L.2A. Conceptual Understanding: The environment consists of many types of organisms including plants, animals, and fungi. Organisms depend on the land, water, and air to live and grow. Plants need water and light to make their own food. Fungi and animals cannot make their own food and get energy from other sources. Animals (including humans) use different body parts to obtain food and other resources needed to grow and survive. Organisms live in areas where their needs for air, water, nutrients, and shelter are met.

Performance Indicators: Students who demonstrate this understanding can:

K.L.2A.1 Obtain information to answer questions about different organisms found in the environment (such as plants, animals, or fungi).

Figure 1: Example from the Kindergarten Standards

The code assigned to each performance indicator within the standards is designed to provide information about the content of the indicator. For example, the **K.L.2A.1** indicator decodes as the following:

K: The first part of each indicator denotes the grade or subject. The example indicator is from Kindergarten. The key for grade levels are as follows:

K: Kindergarten	7: Seventh Grade
1: First Grade	8: Eighth Grade
2: Second Grade	H.B: High school Biology I
3: Third Grade	H.B: High School Chemistry I
4: Fourth Grade	H.P: High school Physics I
5: Fifth Grade	H.E: High School Earth Science
6: Sixth Grade	

L: After the grade or subject, the content area is denoted by an uppercase letter. The L in the example indicator means that the content covers Life Science. The key for content areas are as follows:

E: Earth Science
EC: Ecology
L: Life Science
P: Physical Science

S: Science and Engineering Practices

2: The number following the content area denotes the specific academic standard. In the example, the 2 in the indicator means that it is within the second academic standard with the Kindergarten science content.

A: After the specific content standard, the conceptual understanding is denoted by an uppercase letter. The conceptual understanding is a statement of the core idea for which students should demonstrate understanding. There may be more than one conceptual understanding per academic standard. The A in the example means that this is the first conceptual understanding for the standard. Additionally, the conceptual understandings are novel to the *2014 South Carolina Academic Standards and Performance Indicators for Science*.

1: The last part of the code denotes the number of the specific performance indicator. Performance indicators are statements of what students can do to demonstrate knowledge of the conceptual understanding. The example discussed is the first performance indicator within the conceptual understanding.

CORE AREAS OF HIGH SCHOOL PHYSICS

- Interactions and Forces
- Interactions and Energy

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CONTENT SUPPORT GUIDE
FOR HIGH SCHOOL PHYSICS
SOUTH CAROLINA ACADEMIC STANDARDS AND PERFORMANCE INDICATORS

INTRODUCTION

Local districts, schools and teachers may use this document to construct standards-based science curriculum, allowing them to add or expand topics they feel are important and to organize content to fit their students' needs and match available instructional materials. The support document includes standard, conceptual understanding, performance indicator, science and engineering practices, crosscutting concepts, essential learning experiences, extended learning experiences, assessment guidelines, learning connections, and in some cases note to teacher.

FORMAT OF THE CONTENT SUPPORT GUIDE

The format of this document is designed to be structurally uniformed for each of the academic standards and performance indicators. For each, you will find the following sections--

Standard

- This section provides the standard being explicated.

Conceptual Understanding

- This section provides the overall understanding that the student should possess as related to the standard. Additionally, the conceptual understandings are novel to the *2014 South Carolina Academic Standards and Performance Indicators for Science*.

Performance Indicator

- This section provides a specific set of content with an associated science and engineering practice for which the student must demonstrate mastery.

Science and Engineering Practices (SEPs)

- This section lists the specific science and engineering practice that are paired with the content in the performance indicator. Educators should reference the chapter on this specific science and engineering practice in the *Science and Engineering Practices Support Guide*.
- Educators have the freedom to enhance SEPs addressed during instruction.
- SEPs Support Guide

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Crosscutting Concepts (CCCs)

- Cross Cutting Concepts (<http://www.nap.edu/read/13165/chapter/8>) This link provides support from the Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (2012).
- Educators have the freedom to enhance CCCs addressed during instruction.

Essential Learning Experiences

- This section illustrates the knowledge of the content contained in the performance indicator for which it is fundamental for students to demonstrate mastery.

Note to Teacher

- If necessary or appropriate, this section provides additional instructional guidance.

Extended Learning Experiences

- This section provides educators with topics that will enrich students' knowledge related to topics learned with the explicated performance indicator.

Assessment Guidelines

- This section provides guidelines for educators and assessors to check for student mastery of content utilizing interrelated science and engineering practices.

Learning Connections

- This section provides a list of academic content along with the associated academic standard that students will have received in prior or will experience in future grade levels.

Interactions and Forces

Standard H.P.2: The student will demonstrate an understanding of how the interactions among objects and their subsequent motions can be explained and predicted using the concept of forces.	
H.P.2A. Conceptual Understanding: The linear motion of an object can be described by its displacement, velocity, and acceleration.	
Performance Indicator	H.P.2A.1: <u>Plan and conduct controlled scientific investigations</u> on the straight-line motion of an object to include an interpretation of the object's displacement, time of motion, constant velocity, average velocity, and constant acceleration.
Science and Engineering Practice	H.P.1A.3: <u>Plan and conduct controlled scientific investigations</u> to answer questions, test hypotheses, and develop explanations: (1) formulate scientific questions and testable hypotheses based on credible scientific information, (2) identify materials, procedures, and variables, (3) use appropriate laboratory equipment, technology, and techniques to collect qualitative and quantitative data, and (4) record and represent data in an appropriate form. Use appropriate safety procedures.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Cause and Effect Scale, Proportion, and Quantity

Essential Learning Experiences:

It is essential that students plan and conduct controlled scientific investigations of the motion of objects establishing the following concepts.

- The position of an object (x) is defined as the location of the object with respect to a stationary reference point.
 - Objects to the right of the reference point are often considered to be in the positive direction, and objects to the left are often considered negative.
- Distance is a measure of "how far an object has moved" and is independent of direction. For example, if a person travels 40 meters (m) due east, turns and travels 30 m due west, the distance traveled is 70 m.
- Displacement has both magnitude and direction. It is a change of position in a particular direction. For example: 40 m east is a displacement.
- Velocity
 - Velocity is defined as the rate of change in position.
 - The average velocity of an object is discussed in terms of total displacement divided by total time as outlined above.
 - An object has a constant velocity if the velocity is unchanging throughout the motion of the object.

- An object can have a constant speed while its velocity changes, such as when going around a curved path at a constant speed.
- Acceleration
 - Acceleration is defined as a rate of change in velocity: speeding up, slowing down or changing direction.
 - The rate of acceleration is determined by both the degree of change in the velocity and the time it takes for that change to occur.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Students could predict the motion of an object by analyzing data from a video, stop motion video, motion detector, or tape timer pattern.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 8.P.2A.7: Use mathematical and computational thinking to describe the relationship between the speed and velocity (including positive and negative expression of direction) of an object in determining average speed ($v=d/t$).</p> <p>Chemistry Learning Connections: H.C.4A.1: Develop and use models to explain the arrangement and movement of the particles in solids, liquids, gases, and plasma as well as the relative strengths of their intermolecular forces.</p>
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Interactions and Forces

Standard H.P.2: The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.	
H.P.2A. Conceptual Understanding: The linear motion of an object can be described by its displacement, velocity, and acceleration.	
Performance Indicator	H.P.2A.2: <u>Construct explanations</u> for an object's change in motion using one-dimensional vector addition.
Science and Engineering Practice	H.P.1A.6: <u>Construct explanations</u> of phenomena using (1) primary or secondary scientific evidence and models, (2) conclusions from scientific investigations, (3) predictions based on observations and measurements, or (4) data communicated in graphs, tables or diagrams.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Scale, Proportion, and Quantity Systems and System Models

Essential Learning Experiences:

It is essential that students construct explanations for motion of various objects, which demonstrate an understanding of the vector nature of motion. The following points are essential to such understanding.

- Displacement is defined as having both magnitude and direction.
- Velocity is described as having both magnitude and direction and students explore the concept that the velocity of an object can change if either the speed or the direction of the object is changed.
- Acceleration is defined as a change in velocity, speeding up, slowing down or changing direction. The rate of acceleration is determined by both the degree of change in the velocity and the time it takes for that change to occur.
- A scalar quantity is a value that includes a magnitude with no direction while vector quantities include a magnitude and a direction.
- Differentiate between scalar (distance, speed, and mass) and vector (displacement, velocity, acceleration, and force) quantities.
- The resultant is the sum of two or more vectors that have been combined.
- Vectors in the same directions are added together. For example, 40 m/s, west and 30 m/s, west yields 70 m/s, west.
- Vectors in the opposite directions are subtracted. For examples 50 m, north and 30 m, south yields 20 m, north.
- Use a vector diagram to represent the magnitude and direction of vector quantities (displacement, velocity, and acceleration).
- Solve problems using graphical method of vector addition.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Solve vector problems using analytical method of vector addition for two dimensional motion.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

[https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete 2014SEPsGuide_SupportDoc2_0.pdf](https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete%202014SEPsGuide_SupportDoc2_0.pdf)

Learning Connections	<p>Previous Learning Connections (6-8): 8.P.2: The student will demonstrate an understanding of the effects of forces on the motion and stability of an object.</p> <p>Chemistry Learning Connections: H.C.4A.1: Develop and use models to explain the arrangement and movement of the particles in solids, liquids, gases, and plasma as well as the relative strengths of their intermolecular forces. H.C.7A.4: Develop and use models to explain the relationships between collision frequency, the energy of collisions, the orientation of molecules, activation energy , and the rates of chemical reactions.</p> <p>Earth Science Learning Connections: H.E.2A.1: Construct explanations for how gravity and motion affect the formation and shapes of galaxies (including the Milky Way Galaxy).</p>
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Interactions and Forces

Standard H.P.2: The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.	
H.P.2A. Conceptual Understanding: The linear motion of an object can be described by its displacement, velocity, and acceleration.	
Performance Indicator	H.P.2A.3: Use <u>mathematical and computational thinking</u> to apply formulas related to an object's displacement, constant velocity, average velocity and constant acceleration. Interpret the meaning of the sign of displacement, velocity, and acceleration.
Science and Engineering Practice	H.P.1A.5 Use <u>mathematical and computational thinking</u> to (1) use and manipulate appropriate metric units, (2) express relationships between variables for models and investigations, and (3) use grade-level appropriate statistics to analyze data.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Scale, Proportion, and Quantity Systems and System Models

Essential Learning Experiences:

It is essential that students use mathematical and computational thinking to:

- Analyze the relationships among speed, velocity, and constant acceleration.
- Understand the interrelationship between the concept of speed, velocity and constant acceleration, and the mathematical formulas used to describe it.
- Solve problems involving displacement, velocity, and constant acceleration.
 - Use mathematical equations for displacement. $\Delta x = x_2 - x_1$
 - Use mathematical equations for constant or average velocity. $v = \Delta x/t$
 - Use mathematical equations for constant acceleration. $a = (\Delta v)/t$
- Explain that if the velocity and acceleration have the same direction, the object will speed up; while if the velocity and acceleration have opposite directions, the object will slow down.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Solve word problems involving velocity, and constant acceleration using the following equations:
 - $\Delta x = v_1 t + \frac{1}{2} a t^2$
 - $\Delta x = \frac{1}{2} (v_2 + v_1) t$
 - $v_2^2 = v_1^2 + 2a\Delta x$

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 8.P.2: The student will demonstrate an understanding of the effects of forces on the motion and stability of an object.</p> <p>Chemistry Learning Connections: H.C.4A.1: Develop and use models to explain the arrangement and movement of the particles in solids, liquids, gases, and plasma as well as the relative strengths of their intermolecular forces.</p>
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Interactions and Forces

Standard H.P.2: The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.	
H.P.2A. Conceptual Understanding: The linear motion of an object can be described by its displacement, velocity, and acceleration.	
Performance Indicator	H.P.2A.4: <u>Develop and use models</u> to represent an object's displacement, velocity, and acceleration (including vector diagrams, data tables, motion graphs, dot motion diagrams, and mathematical formulas).
Science and Engineering Practice	H.P.1A.2: <u>Develop, use, and refine models</u> to (1) understand or represent phenomena, processes, and relationships, (2) test devices or solutions, or (3) communicate ideas to others.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Scale, Proportion, and Quantity Systems and System Models

Essential Learning Experiences:

It is essential that students develop, use, and refine models as noted below to analyze the motion of objects.

- A scalar quantity is a value that includes a magnitude with no direction while vector quantities include a magnitude and a direction.
- Vector diagrams are graphical representations of the magnitude and direction of vector quantities.
- Vectors can be added graphically to solve linear mechanical problems (head to tail vector addition) to find either the resultant of two vectors, or the components of one vector. Use a ruler and protractor to measure the magnitude and direction of the resultant vector. Vectors can be added graphically using the following steps:
 - Establish a scale for the vectors being added together.
 - Establish a coordinate system.
 - Draw the first vector to scale in the origin of the coordinate system.
 - Draw subsequent vectors, where each tail is added to the head of the previous vector.
 - Draw the resultant vector from the tail of the first to the head of the last.

- A dot diagram is a way of analyzing the motion of objects. The distance between dots represents the change in distance during that time period. If the distance between the dots does not change, the velocity is constant.

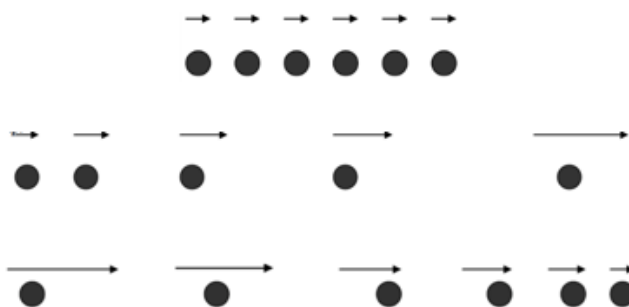


Figure 2. Dot diagram (SCDE 2018).

- Motion can be represented on displacement-time and velocity-time graphs.
 - Types of graphs should include: position-time graphs, velocity-time graphs.
 - Examples of motion should include: rest, constant velocity, (positive and negative direction), positive and negative acceleration.

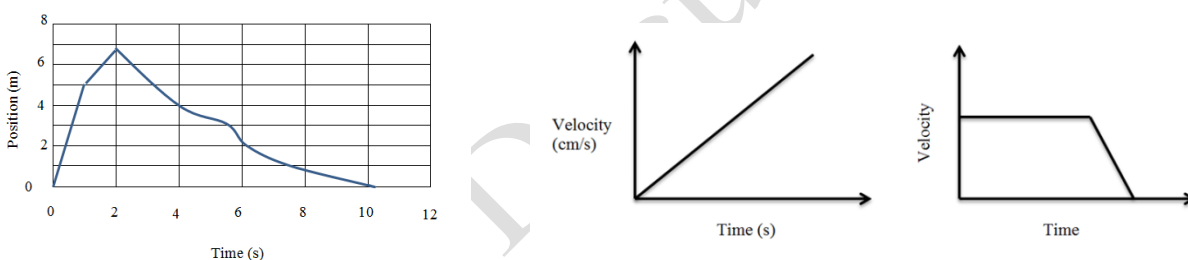


Figure 3. Distance, time, velocity (SCDE, 2018).

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Solve vector problems analytically (using trigonometry) to find either the resultant of two or more vectors, or the components of a vector.
- Create a graphical representation of three or more vectors and find the resultant.
- Create, analyze, and interpret acceleration-time graphs.
- Determine the slope and the area under the curve of a graph and understand the meaning of these in terms of magnitude and direction of the motion.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 8.P.2: The student will demonstrate an understanding of the effects of forces on the motion and stability of an object.</p> <p>Chemistry Learning Connections: H.C.4A.1: Develop and use models to explain the arrangement and movement of the particles in solids, liquids, gases, and plasma as well as the relative strengths of their intermolecular forces.</p>
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Interactions and Forces

Standard H.P.2: The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.	
H.P.2A. Conceptual Understanding: The linear motion of an object can be described by its displacement, velocity, and acceleration.	
Performance Indicator	H.P.2A.5: <u>Construct explanations</u> for what is meant by “constant” velocity and “constant” acceleration (including writing descriptions of the object’s motion and calculating the sign and magnitude of the slope of the line on a position-time and velocity-time graph).
Science and Engineering Practice	H.P.1A.6: <u>Construct explanations</u> of phenomena using (1) primary or secondary scientific evidence and models, (2) conclusions from scientific investigations, (3) predictions based on observations and measurements, or (4) data communicated in graphs, tables, or diagrams.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Patterns Scale, Proportion, and Quantity

Essential Learning Experiences:

It is essential that students construct graphical explanations for constant velocity and acceleration.

- Understand that a linear relationship on a position versus time graph shows an object with constant velocity.
- Determine the slope of a linear position versus time graph and use it to define the object’s constant velocity.
- Explain that in a position versus time graph, a positive slope indicates a positive velocity, and negative slope indicates negative velocity.

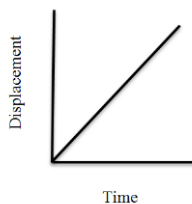


Figure 4. Velocity positive and negative (SCDE, 2018).

- Understand that a linear relationship on a velocity versus time graph shows an object with constant acceleration.

- Determine the slope of a linear velocity versus time graph and use it to define the object's constant acceleration.
- Explain that in a velocity versus time graph, a positive slope indicates a positive acceleration and a negative slope indicates a negative acceleration.

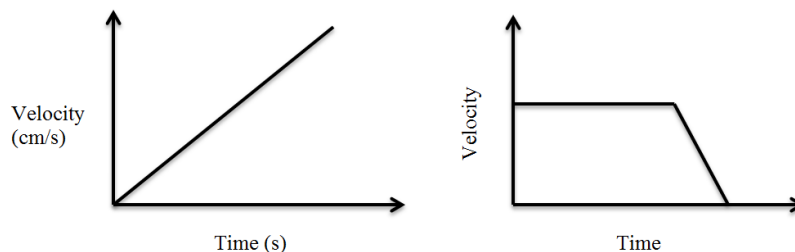


Figure 5. Velocity 2 (SCDE, 2018).

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Use the area under a velocity versus time graph to determine the displacement of an object over a certain time period using an object with constant velocity.
- Compare and contrast acceleration-time graphs for objects with constant velocity and acceleration.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 8.P.2: The student will demonstrate an understanding of the effects of forces on the motion and stability of an object.</p> <p>Chemistry Learning Connections: H.C.4A.1: Develop and use models to explain the arrangement and movement of the particles in solids, liquids, gases, and plasma as well as the relative strengths of their intermolecular forces.</p>
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Interactions and Forces

Standard H.P.2: The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.	
H.P.2A. Conceptual Understanding: The linear motion of an object can be described by its displacement, velocity, and acceleration.	
Performance Indicator	H.P.2A.6: <u>Obtain information</u> to communicate the similarities and differences between distance and displacement; speed and velocity; constant velocity and instantaneous velocity; constant velocity and average velocity; and velocity and acceleration.
Science and Engineering Practice	H.P.1A.8: <u>Obtain and evaluate scientific information</u> to (1) answer questions, (2) explain or describe phenomena, (3) develop models, (4) evaluate hypotheses, explanations, claims, or designs or (5) identify and/or fill gaps in knowledge. Communicate using the conventions and expectations of scientific writing or oral presentations by (1) evaluating grade-appropriate primary or secondary scientific literature, or (2) reporting the results of student experimental investigations.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Patterns Scale, Proportion, and Quantity Systems and System Models

Essential Learning Experiences:

It is essential that students communicate the following information in their comparisons.

- Distance is a scalar quantity and does not have a direction like displacement.
- Speed is a scalar quantity and does not have a direction like velocity.
- Constant velocity occurs when an object has the same displacement for each period of time while instantaneous velocity is the speed and direction of an object at any given instant in time.
- Average velocity is the total displacement of an object divided by the total time.
- Acceleration is the rate of change of velocity.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Use a tangent line to find instantaneous velocity of distance time graphs for accelerating objects

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

[https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete 2014SEPsGuide_SupportDoc2_0.pdf](https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete%202014SEPsGuide_SupportDoc2_0.pdf)

Learning Connections	<p>Previous Learning Connections (6-8): 8.P.2: The student will demonstrate an understanding of the effects of forces on the motion and stability of an object.</p> <p>Chemistry Learning Connections: H.C.4A.1: Develop and use models to explain the arrangement and movement of the particles in solids, liquids, gases, and plasma as well as the relative strengths of their intermolecular forces. H.C.7A.4: Develop and use models to explain the relationships between collision frequency, the energy of collisions, the orientation of molecules , activation energy , and the rates of chemical reactions.</p>
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Interactions and Forces

Standard H.P.2: The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.	
H.P.2B. Conceptual Understanding: The interactions among objects and their subsequent motion can be explained and predicted by analyzing the forces acting on the objects and applying Newton’s laws of motion.	
Performance Indicator	H.P.2B.1: <u>Plan and conduct controlled scientific investigations</u> involving the motion of an object to determine the relationships among the net force on the object, its mass, and its acceleration (Newton’s second law of motion, $F_{\text{net}} = ma$) and analyze collected data to construct an explanation of the object’s motion using Newton’s second law of motion
Science and Engineering Practice	H.P.1A.3: <u>Plan and conduct controlled scientific investigations</u> to answer questions test hypotheses, and develop explanations: (1) formulate scientific questions and testable hypotheses based on credible scientific information, (2) identify materials, procedures and variables, (3) use appropriate laboratory equipment, technology, and techniques to collect qualitative and quantitative data, (4) record and represent data in an appropriate form. Use appropriate safety procedures
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Cause and Effect: Mechanism and Explanation Systems and System Models

Essential Learning Experiences:

It is essential that students understand the following in order to plan and conduct controlled investigations of Newton’s Second Law.

- Newton’s Second Law of Motion
 - Newton’s Second Law of Motion is also called the Law of Acceleration. It states that the acceleration of an object is directly proportional to the force applied to the object and inversely proportional to the object’s mass.
 - As force increases, the acceleration of the object should increase (given constant mass).
 - As the mass increases, the acceleration of the object should decrease (given constant net force).
 - The equation for Newton’s Second Law of Motion is $F_{\text{net}} = ma$.
- Newton’s First Law is a special case of the Second Law where the net force is zero.
 - Object’s exposed to a net force of zero have zero acceleration.

- Inertia is the resistance of an object to change in motion as determined by the mass of the object.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Plot the force on the object versus acceleration and determine that the slope of the line should equal the mass of the object.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 8.P.2: The student will demonstrate an understanding of the effects of forces on the motion and stability of an object.</p> <p>Earth Science Learning Connections: H.E.2A.1: Construct explanations for how gravity and motion affect the formation and shapes of galaxies (including the Milky Way Galaxy). H.E.2 B.3: Use mathematical and computational thinking to explain the motion of an orbiting object in the solar system.</p>
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Interactions and Forces

Standard H.P.2: The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.	
H.P.2B. Conceptual Understanding: The interactions among objects and their subsequent motion can be explained and predicted by analyzing the forces acting on the objects and applying Newton’s laws of motion.	
Performance Indicator	H.P.2B.2: Use a free-body diagram to represent the forces on an object.
Science and Engineering Practice	H.P.1A.2: <u>Develop, use, and refine models</u> to (1) understand or represent phenomena, processes, and relationships, (2) test devices or solutions, or (3) communicate ideas to others.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Systems and System Models

Essential Learning Experiences:

It is essential that students understand the following in order to construct a proper free body diagram.

- Force is a push or pull on an object and is a vector quantity because it has a magnitude and a direction. Free body diagrams show all the forces that are acting on an object. Forces are drawn as vectors with all forces originating from the center of the object.
- Illustrate the forces acting on an object using a vector diagram when given a verbal description or data.
- Examples of free body diagrams include:
 - An object being pulled horizontally with friction opposing the motion.
 - An object (like a lawn mower) being pushed at a particular angle with the ground, with friction opposing the motion.
 - An object (like a sled) being pulled at a particular angle with the ground, with friction opposing the motion.
 - An object projected upward with a constant force (such as a rocket engine) with the gravitational force opposing the motion.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Consider objects sliding down a ramp with friction opposing the motion of objects being pulled up a ramp with friction opposing the motion.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 8.P.2: The student will demonstrate an understanding of the effects of forces on the motion and stability of an object.</p> <p>Earth Science Learning Connections: H.E.2A.1: Construct explanations for how gravity and motion affect the formation and shapes of galaxies (including the Milky Way Galaxy). H.E.2 B.3: Use mathematical and computational thinking to explain the motion of an orbiting object in the solar system.</p>
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Interactions and Forces

Standard H.P.2: The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.	
H.P.2B. Conceptual Understanding: The interactions among objects and their subsequent motion can be explained and predicted by analyzing the forces acting on the objects and applying Newton’s laws of motion.	
Performance Indicator	H.P.2B.3: Use Newton’s Third Law of Motion to <u>construct explanations</u> of everyday phenomena (such as a hammer hitting a nail, the thrust of a rocket engine, the lift of an airplane wing, or a book at rest on a table) and identify the force pairs in each given situation involving two objects and compare the size and direction of each force.
Science and Engineering Practice	H.P.1A.6: <u>Construct explanations</u> of phenomena using (1) primary or secondary scientific evidence and models, (2) conclusions from scientific investigations, (3) predictions based on observations and measurements, or (4) data communicated in graphs, tables, or diagrams.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Patterns Cause and Effect: Mechanism and Explanation Scale, Proportion, and Quantity

Essential Learning Experiences:

It is essential that students understand the following:

- Newton’s Third Law of Motion
 - Forces always exist in pairs between two interacting objects.
 - When object A exerts a force on object B, object B will always exert a force equal in magnitude and opposite in direction on object A.
 - Newton’s Third Law applies to contact forces as well as field forces.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Students must calculate the acceleration of one of the objects within the pair, based on given masses and acceleration of the other object.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 8.P.2: The student will demonstrate an understanding of the effects of forces on the motion and stability of an object.</p> <p>Chemistry Learning Connections: H.C.7A.4: Develop and use models to explain the relationships between collision frequency, the energy of collisions, the orientation of molecules, activation energy, and the rates of chemical reactions.</p> <p>Earth Science Learning Connections: H.E.3A.3: Construct explanations of how forces cause crustal changes as evidenced in sea floor spreading, earthquake activity, volcanic eruptions, and mountain building using evidence of tectonic environments (such as mid-ocean ridges and subduction zones).</p>
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Interactions and Forces

Standard H.P.2: The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.	
H.P.2B. Conceptual Understanding: The interactions among objects and their subsequent motion can be explained and predicted by analyzing the forces acting on the objects and applying Newton’s laws of motion.	
Performance Indicator	H.P.2B.4: <u>Use mathematical and computational thinking</u> to derive the relationship between impulse and Newton’s Second Law of Motion.
Science and Engineering Practice	H.P.1A.5: <u>Use mathematical and computational thinking</u> to (1) use and manipulate appropriate English and metric units, (2) express relationships between variables for models and investigation, or (3) use grade-level appropriate statistics to analyze data.
Crosscutting Concepts	<p>The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6.</p> <p>Cause and Effect Systems and System Models</p>

Essential Learning Experiences:

It is essential that students understand the following in order to use mathematical and computational thinking to derive the relationship.

- Momentum is the product of the mass of the moving body and its velocity.
 - the symbol for momentum is “p”
 - $p = mv$
- Momentum of an object can be changed by a force applied over time. The longer that a force is applied to an object, the more the momentum of an object will change.
- The product of force and the time interval during which it acts ($F\Delta t$) is called impulse (J).
 - Impulse = change in momentum
 - $J = F\Delta t = m\Delta v$
 - $F = ma$

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Use the Impulse-Momentum Theorem to support Newton’s Third Law within a collision mathematically.
- Take the area under a force versus time graph to determine the impulse and change in momentum of an object.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 8.P.2: The student will demonstrate an understanding of the effects of forces on the motion and stability of an object.</p> <p>Chemistry Learning Connections: H.C.7A.4: Develop and use models to explain the relationships between collision frequency, the energy of collisions, the orientation of molecules, activation energy, and the rates of chemical reactions.</p> <p>Earth Science Learning Connections: H.E.3A.3: Construct explanations of how forces cause crustal changes as evidenced in sea floor spreading, earthquake activity, volcanic eruptions, and mountain building using evidence of tectonic environments (such as mid-ocean ridges and subduction zones).</p>
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Interactions and Forces

Standard H.P.2: The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.	
H.P.2B. Conceptual Understanding: The interactions among objects and their subsequent motion can be explained and predicted by analyzing the forces acting on the objects and applying Newton’s laws of motion.	
Performance Indicator	H.P.2B.5: <u>Plan and conduct controlled scientific investigations</u> to support the Law of Conservation of Momentum in the context of two objects moving linearly ($p=mv$).
Science and Engineering Practice	H.P.1A.3: <u>Plan and conduct controlled scientific investigations</u> to answer questions test hypotheses, and develop explanations: (1) formulate scientific questions and testable hypotheses based on credible scientific information, (2) identify materials, procedures and variables, (3) use appropriate laboratory equipment, technology, and techniques to collect qualitative and quantitative data, (4) record and represent data in an appropriate form. Use appropriate safety procedures.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Cause and Effect Systems and System Models Energy and Matter

Essential Learning Experiences:

It is essential that students understand the following in order to plan and conduct and investigation of linear momentum.

- The total momentum of a system of objects remains constant before and after a collision.
 - The Law of Conservation of Momentum applies to closed, isolated systems.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Use the impulse momentum theorem to mathematically support Newton’s Third Law within a collision.
- Take the area under a force versus time graph to determine the impulse and change in momentum of an object.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 8.P.2: The student will demonstrate an understanding of the effects of forces on the motion and stability of an object.</p> <p>Chemistry Learning Connections: H.C.7A.4: Develop and use models to explain the relationships between collision frequency, the energy of collisions, the orientation of molecules, activation energy, and the rates of chemical reactions.</p> <p>Earth Science Learning Connections: H.E.3A.3: Construct explanations of how forces cause crustal changes as evidenced in sea floor spreading, earthquake activity, volcanic eruptions, and mountain building using evidence of tectonic environments (such as mid-ocean ridges and subduction zones).</p>
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Interactions and Forces

Standard H.P.2: The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.	
H.P.2B. Conceptual Understanding: The interactions among objects and their subsequent motion can be explained and predicted by analyzing the forces acting on the objects and applying Newton’s laws of motion.	
Performance Indicator	H.P.2B.6: <u>Construct scientific arguments</u> to defend the use of the conservation of linear momentum in the investigation of traffic accidents in which the initial motions of the objects are used to determine the final motions of the objects..
Science and Engineering Practice	H.P.1A.7: <u>Construct and analyze scientific arguments</u> to support claims, explanations, or designs using evidence and valid reasoning from observations, data, or informational texts.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Cause and Effect Systems and System Models Energy and Matter

Essential Learning Experiences:

It is essential that students understand the following:

- The Law of Conservation of Momentum describes (both qualitatively and quantitatively) the motion of objects that collide in one dimension. The Law of Conservation of Momentum states that the momentum of a system prior to a collision is equal to the momentum contained in the system after the collision.
- These collisions could be elastic or inelastic. Elastic collisions are those that involve the objects bouncing back, thereby conserving the momentum and kinetic energy. Inelastic collisions involve objects that are stuck together after the collision, conserving momentum but transferring the kinetic energy into unusable forms.
- The final velocities in elastic and inelastic collisions can be calculated using $p_f = p_i$.
- Compute the final velocities of objects in elastic and inelastic collisions using the law of conservation of momentum.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Compute energy converted to other forms in inelastic collisions.

- Model collisions by drawing (i.e. a comic strip), using props to take still pictures in sequence, or making a video (using such techniques as claymation, or animation).

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 8.P.2: The student will demonstrate an understanding of the effects of forces on the motion and stability of an object.</p> <p>Chemistry Learning Connections: H.C.7A.4: Develop and use models to explain the relationships between collision frequency, the energy of collisions, the orientation of molecules , activation energy , and the rates of chemical reactions.</p> <p>Earth Science Learning Connections: H.E.3A.3: Construct explanations of how forces cause crustal changes as evidenced in sea floor spreading, earthquake activity, volcanic eruptions, and mountain building using evidence of tectonic environments (such as mid-ocean ridges and subduction zones).</p>
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Interactions and Forces

Standard H.P.2: The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.	
H.P.2B. Conceptual Understanding: The interactions among objects and their subsequent motion can be explained and predicted by analyzing the forces acting on the objects and applying Newton’s laws of motion.	
Performance Indicator	H.P.2B.7: Apply physics principles to <u>design a device</u> that minimizes the force on an object during a collision and construct an explanation for the design.
Science and Engineering Practice	H.P.1B.1: <u>Construct devices or design solutions</u> using scientific knowledge to solve specific problems or needs: (1) ask questions to identify problems or needs, (2) ask questions about the criteria and constraints of the device or solutions, (3) generate and communicate ideas for possible devices or solutions, (4) build and test devices or solutions, (5) determine if the devices or solutions solved the problem and refine the design if needed, and (6) communicate results.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Systems and System Models Energy and Matter

Essential Learning Experiences:

It is essential that students understand the following in order to design a device.

- The momentum of an object can be changed by a force applied over time. The longer that a force is applied to an object, the more the momentum of an object will change.
 - For the same change in momentum to occur, as the impact time increases the impact force decreases. Examples: airbags, bumpers

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Mathematically compute the force of impact of devices.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 8.P.2: The student will demonstrate an understanding of the effects of forces on the motion and stability of an object.</p> <p>Chemistry Learning Connections: H.C.7A.4: Develop and use models to explain the relationships between collision frequency, the energy of collisions, the orientation of molecules, activation energy, and the rates of chemical reactions.</p> <p>Earth Science Learning Connections: H.E.3A.3: Construct explanations of how forces cause crustal changes as evidenced in sea floor spreading, earthquake activity, volcanic eruptions, and mountain building using evidence of tectonic environments (such as mid - ocean ridges and subduction zones).</p>
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Interactions and Forces

Standard H.P.2: The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.	
H.P.2B. Conceptual Understanding: The interactions among objects and their subsequent motion can be explained and predicted by analyzing the forces acting on the objects and applying Newton’s laws of motion.	
Performance Indicator	H.P.2B.8: <u>Develop and use models</u> (such as a computer simulation, drawing, or demonstration) and Newton’s Second Law of Motion to construct explanations for why an object moving at a constant speed in a circle is accelerating.
Science and Engineering Practice	H.P.1A2: <u>Develop, use, and refine models</u> to (1) understand or represent phenomena, processes, and relationships, (2) test devices or solutions, or (3) communicate ideas to others.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Systems and System Models Energy and Matter

Essential Learning Experiences:

It is essential that students understand the following in order to develop and use models to explain the acceleration of objects travelling in a circular path.

- Use Newton’s Second Law to assess, measure, and calculate the relationship among the force acting on a body, the mass of the body, and the nature of the acceleration produced.
- Understand that rotating objects or objects in circular motion with constant speed are accelerating because they are changing direction. This acceleration is known as centripetal acceleration and is caused by a centripetal force.
- Create a diagram of an object moving in a circle. Include vectors for tangential velocity, centripetal force, and centripetal acceleration.
 - For rotating objects centripetal acceleration and centripetal force are vectors with the direction toward the center of the circular path.
 - Velocity vectors are drawn as vectors tangent to the circular path. See drawing below.

NOTE TO TEACHER: Centrifugal force cannot be identified in an inertial frame of reference. Centrifugal force can only be identified in a rotating frame of reference.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Understand that rotational motion is the motion of an object about an internal axis
 - Angular displacement (θ) can be measured in units of revolutions
 - Angular velocity (ω) can be measured in units of revolutions per second.
 - Angular acceleration (α) can be measured in units of revolutions per second-square.
- Compare and contrast centripetal and centrifugal force.
- Calculate centripetal force on an object using $F_c = mv^2 / r$.
- Calculate tangential acceleration for rotating objects changing speed.
- Use vector analysis to calculate total acceleration of rotating objects.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 8.P.2: The student will demonstrate an understanding of the effects of forces on the motion and stability of an object.</p> <p>Earth Science Learning Connections: H.E.2B.3: Use mathematical and computational thinking to explain the motion of an orbiting object in the solar system.</p>
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Interactions and Forces

<p>Standard H.P.2: The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.</p>	
<p>H.P.2B. Conceptual Understanding: The interactions among objects and their subsequent motion can be explained and predicted by analyzing the forces acting on the objects and applying Newton’s laws of motion.</p>	
<p>Performance Indicator</p>	<p>H.P.2B.9: <u>Construct explanations</u> for the practical applications of torque (such as a see-saw, bolt, wrench, and hinged door).</p>
<p>Science and Engineering Practice</p>	<p>H.P.1A.6 <u>Construct explanations</u> of phenomena using (1) primary or secondary scientific evidence and models, (2) conclusions from scientific investigations, (3) predictions based on observations and measurements, or (4) data communicated in graphs, tables, or diagrams.</p>
<p>Crosscutting Concepts</p>	<p>The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6.</p> <p>Systems and System Models Structure and Function</p>

Essential Learning Experiences:

It is essential that students understand the following in order to construct explanations involving torque.

- Torque is a product of force and distance from the center of rotation, when force is applied at a 90° angle.
- Objects experiencing torque rotate about a pivot point. For example, children will balance of a see-saw when torque is balanced. A wrench and bolt system turns when a force is applied.
- Torque causes rotational (angular) acceleration.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Students must be able to calculate the torque exerted by multiplying the force times the distance from the center of rotation (r).
- Calculate torque for angles other than 90°.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 8.P.2: The student will demonstrate an understanding of the effects of forces on the motion and stability of an object.</p> <p>Earth Science Learning Connections: H.E.2B.3: Use mathematical and computational thinking to explain the motion of an orbiting object in the solar system.</p>
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Interactions and Forces

Standard H.P.2: The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.	
H.P.2B. Conceptual Understanding: The interactions among objects and their subsequent motion can be explained and predicted by analyzing the forces acting on the objects and applying Newton’s laws of motion.	
Performance Indicator	H.P.2B.10: <u>Obtain information to communicate</u> physical situations in which Newton’s Second Law of Motion does not apply
Science and Engineering Practice	H.P.1A.8 <u>Obtain and evaluate scientific information</u> to (1) answer questions, (2) explain or describe phenomena, (3) develop models, (4) evaluate hypotheses, explanations, claims, or designs or (5) identify and/or fill gaps in knowledge. <u>Communicate</u> using the conventions and expectations of scientific writing or oral presentations by (1) evaluating grade-appropriate primary or secondary scientific literature, or (2) reporting the results of student experimental investigations.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Systems and System Models

Essential Learning Experiences:

It is essential that students understand the following:

- Newton’s Second Law applies on a macroscopic scale for objects within an inertial reference frame.
- Newton’s Second Law does not apply to objects which are approaching the speed of light or to objects on the molecular or subatomic level.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Students will explain Einstein’s Theory of Relativity and Special Theory of Relativity.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

**Learning
Connections****Previous Learning Connections (6-8):**

8.P.2: The student will demonstrate an understanding of the effects of forces on the motion and stability of an object.

Chemistry Learning Connections:

H.C.2B.4: Use mathematical and computational thinking to explain the relationship between mass and energy in nuclear reactions ($E=mc^2$).

Interactions and Forces

Standard H.P.2: The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.	
H.P.2C. Conceptual Understanding: The contact interactions among objects and their subsequent motion can be explained and predicted by analyzing the normal, tension, applied, and frictional forces acting on the objects and by applying Newton's Laws of Motion.	
Performance Indicator	H.P.2C.1: Use a free-body diagram to represent the normal, tension (or elastic), applied, and frictional forces on an object.
Science and Engineering Practice	H.P.1A.2 <u>Construct explanations of phenomena</u> using (1) primary or secondary scientific evidence and models, (2) conclusions from scientific investigations, (3) predictions based on observations and measurements, or (4) data communicated in graphs, tables or diagrams.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Systems and System Models

Essential Learning Experiences:

It is essential that students understand the following in order to construct proper free body diagrams.

- Free body diagrams show all forces acting on a single object.
- normal forces - perpendicular to the surface
- tension forces – forces exerted on an object by a string, rope or chain
- applied forces – forces that are applied to objects
- frictional forces – forces that oppose the motion

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Combine the free body diagrams and Newton's Second Law to solve for unknowns using the given quantities.
 - Atwood machine problems
 - Interactions of several forces at one time (3 boxes acting on each other)
 - Rope/pulley problems

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 8.P.2: The student will demonstrate an understanding of the effects of forces on the motion and stability of an object.</p> <p>Earth Science Learning Connections: H.E.3A.3: Construct explanations of how forces cause crustal changes as evidenced in sea floor spreading, earthquake activity, volcanic eruptions, and mountain building using evidence of tectonic environments (such as mid - ocean ridges and subduction zones).</p>
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Interactions and Forces

Standard H.P.2: The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.	
H.P.2C. Conceptual Understanding: The contact interactions among objects and their subsequent motion can be explained and predicted by analyzing the normal, tension, applied, and frictional forces acting on the objects and by applying Newton’s Laws of Motion.	
Performance Indicator	H.P.2C.2: <u>Plan and conduct controlled scientific investigations</u> to determine the variables that could affect the kinetic frictional force on an object.
Science and Engineering Practice	H.P.1A.3: <u>Plan and conduct controlled scientific investigations</u> to answer questions test hypotheses, and develop explanations: (1) formulate scientific questions and testable hypotheses based on credible scientific information, (2) identify materials, procedures and variables, (3) use appropriate laboratory equipment, technology, and techniques to collect qualitative and quantitative data, (4) record and represent data in an appropriate form. Use appropriate safety procedures.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Cause and Effect Systems and System Models

Essential Learning Experiences:

It is essential that students understand the following in order to plan and conduct investigations of kinetic friction.

- Friction is caused by the intermolecular force between the two surfaces.
- Kinetic (dynamic) friction is the value of the frictional force when one surface is sliding over another.
- The factors that affect friction include:
 - Normal force (f_n) (the force perpendicular to the surface)
 - The physical properties of the two substances
 - The chemical properties of the two substances
- The ratio between the frictional forces between two surfaces to the force that is pushing them together (the normal force) is called the coefficient of friction.
- The coefficient of friction may be calculated using $\mu = f_f/f_n$.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Use a graph to show the relationship between normal force and friction force.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 8.P.2: The student will demonstrate an understanding of the effects of forces on the motion and stability of an object.</p> <p>Earth Science Learning Connections: H.E.3A.3: Construct explanations of how forces cause crustal changes as evidenced in sea floor spreading, earthquake activity, volcanic eruptions, and mountain building using evidence of tectonic environments (such as mid - ocean ridges and subduction zones).</p>
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Interactions and Forces

Standard H.P.2: The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.	
H.P.2C. Conceptual Understanding: The contact interactions among objects and their subsequent motion can be explained and predicted by analyzing the normal, tension, applied, and frictional forces acting on the objects and by applying Newton's Laws of Motion.	
Performance Indicator	H.P.2C.3: <u>Obtain and evaluate information</u> to compare kinetic and static friction.
Science and Engineering Practice	H.P.1A.8: <u>Obtain and evaluate scientific information</u> to (1) answer questions, (2) explain or describe phenomena, (3) develop models, (4) evaluate hypotheses, explanations, claims, or designs or (5) identify and/or fill gaps in knowledge. Communicate using the conventions and expectations of scientific writing or oral presentations by (1) evaluating grade-appropriate primary or secondary scientific literature, or (2) reporting the results of student experimental investigations.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Systems and System Models

Essential Learning Experiences:

It is essential that students understand the following:

- Kinetic friction is friction between two surfaces which are in motion.
- Static friction is friction between two non-moving surfaces.
- Typically, for a pair of surfaces, the coefficient of static friction is greater than the coefficient of kinetic friction.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Students can determine the coefficient of friction graphically using data analysis software.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 8.P.2: The student will demonstrate an understanding of the effects of forces on the motion and stability of an object.</p> <p>Earth Science Learning Connections: H.E.3A.3: Construct explanations of how forces cause crustal changes as evidenced in sea floor spreading, earthquake activity, volcanic eruptions, and mountain building using evidence of tectonic environments (such as mid - ocean ridges and subduction zones).</p>
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Interactions and Forces

Standard H.P.2: The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.	
H.P.2C. Conceptual Understanding: The contact interactions among objects and their subsequent motion can be explained and predicted by analyzing the normal, tension, applied, and frictional forces acting on the objects and by applying Newton's Laws of Motion.	
Performance Indicator	H.P.2C.4: <u>Analyze and interpret data</u> on force and displacement to determine the spring (or elastic) constant of an elastic material (Hooke's Law, $F=-kx$), including constructing an appropriate graph in order to draw a line-of-best-fit whose calculated slope will yield the spring constant, k .
Science and Engineering Practice	H.P.1A.4: <u>Analyze and interpret data</u> from information texts and data collected from investigations using a range of methods (such as tabulation, graphing, or statistical analysis) to (1) reveal patterns and construct meaning, (2) support or refute hypotheses, explanations, claims, or designs, or (3) evaluate the strength of conclusions.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Patterns Cause and Effect Energy and Matter

Essential Learning Experiences:

It is essential that students understand the following in order to analyze and interpret data to determine a spring constant.

- Hooke's Law explains that the force exerted by a spring is proportional to its change in length.
- The spring constant (k) represents this relationship and is measured in N/m.
- Spring constant is an intrinsic characteristic describing the elasticity of a material.
- k value is represented by the slope of a graph of stretch of string vs. force.

NOTE TO TEACHER: It is generally accepted that rubber bands do not obey Hooke's Law. This may be established by examining a graph of stretch of string vs. force with a wide range of data points, and noting that it is not linear. If too narrow a range of points is plotted, the graph may indeed appear linear, and the band thus appears to follow Hooke's Law.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Explain how positioning springs in series and parallel affect the k value.

- Experimentally determine if rubber bands obey Hooke's Law.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 8.P.2: The student will demonstrate an understanding of the effects of forces on the motion and stability of an object.</p> <p>Chemistry Learning Connections: H.C.7A.1: Analyze and interpret data from energy diagrams and investigations to support claims that the amount of energy released or absorbed during a chemical reaction depends on changes in total bond energy.</p>
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Interactions and Forces

Standard H.P.2: The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.	
H.P.2C. Conceptual Understanding: The contact interactions among objects and their subsequent motion can be explained and predicted by analyzing the normal, tension, applied, and frictional forces acting on the objects and by applying Newton’s Laws of Motion.	
Performance Indicator	H.P.2C.5: Use mathematical and computational thinking to apply $F_{\text{net}} = ma$ to analyze problems involving contact interactions and gravity.
Science and Engineering Practice	H.P.1A.5: Use mathematical and computational thinking to (1) use and manipulate appropriate English and metric units, (2) express relationships between variables for models and investigation, or (3) use grade-level appropriate statistics to analyze data.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Cause and Effect

Essential Learning Experiences:

It is **essential** that students understand the following in order to analyze and interpret data to determine a spring constant.

- The basic mathematical relationship that supports Newton’s Second Law is defined in H.P.2B.1 with the equation $F_{\text{net}} = ma$.
- Mass is the amount of matter contained in an object.
- Weight is the force with which gravity pulls on an object.
- The relationship between mass and weight is defined as $W = mg$.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Use a free body diagram to explain why a falling object reaches terminal velocity.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

[https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete 2014SEPsGuide_SupportDoc2_0.pdf](https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete%202014SEPsGuide_SupportDoc2_0.pdf)

**Learning
Connections****Previous Learning Connections (6-8):**

8.P.2: The student will demonstrate an understanding of the effects of forces on the motion and stability of an object.

Earth Science Learning Connections:

H.E.2B.3: Use mathematical and computational thinking to explain the motion of an orbiting object in the solar system.

Interactions and Forces

Standard H.P.2: The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.	
H.P.2D. Conceptual Understanding: The non-contact (at a distance) interactions among objects and their subsequent motion can be explained and predicted by analyzing the gravitational, electric, and magnetic forces acting on the objects and applying Newton's laws of motion. These non-contact forces can be represented as fields.	
Performance Indicator	H.P.2D.1: Develop and use models (such as computer simulations, demonstrations, diagrams, and drawings) to explain how neutral objects can become charged and how objects mutually repel or attract each other and include the concept of conservation of charge in the explanation.
Science and Engineering Practice	H.P.1A.2 Construct explanations of phenomena using (1) primary or secondary scientific evidence and models, (2) conclusions from scientific investigations, (3) predictions based on observations and measurements, or (4) data communicated in graphs, tables or diagrams.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Cause and Effect Systems and System Models

Essential Learning Experiences:

It is essential that students understand the following in order to

- A charged object is an object with an unequal number of charged particles.
- The basic law of electrostatics states objects that are similarly charged repel each other; objects that are oppositely charged attract each other.
- A negatively charged object has a net excess of electrons and a positively charged object has a net deficit of electrons.
- Originally neutral objects can gain a charge through friction between the objects creating a transfer of electrons resulting in a difference in charge.
- Charging by conduction occurs when a charged object comes into contact with a neutral object and electrons are transferred to give the neutral object the same charge.
- Charging by induction occurs when a charged object comes near a neutral object and electrons are relocated within the neutral object to give the neutral object the opposite charge which accomplishes polarization. To complete induction, the object has to be grounded or broken in half.
- An electroscope is a device used to determine if an object has a charge.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Electric fields become concentrated at points on a conductor.
- Plasma is produced when electrons are stripped from a gas. This happens in high energy environments such as found in the sun.
- Construct explanations for the formation of corona discharge (St. Elmo's Fire), and the functioning of lightning rods.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 7.P.2: The student will demonstrate an understanding of the structure and properties of matter and that matter is conserved as it undergoes changes.</p> <p>Chemistry Learning Connections: H.C.2: The student will demonstrate an understanding of atomic structure and nuclear processes.</p>
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Interactions and Forces

Standard H.P.2: The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.	
H.P.2D. Conceptual Understanding: The non-contact (at a distance) interactions among objects and their subsequent motion can be explained and predicted by analyzing the gravitational, electric, and magnetic forces acting on the objects and applying Newton’s laws of motion. These non-contact forces can be represented as fields.	
Performance Indicator	H.P.2D.2: <u>Use mathematical and computational thinking</u> to predict the relationships among the masses of two objects, the attractive gravitational force between them, and the distance between them (Newton’s Law of Universal Gravitation, $F=Gm_1m_2/r^2$).
Science and Engineering Practice	H.P.1A.5: <u>Use mathematical and computational thinking</u> to (1) use and manipulate appropriate English and metric units, (2) express relationships between variables for models and investigation, or (3) use grade-level appropriate statistics to analyze data.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Cause and Effect

Essential Learning Experiences:

It is essential that students understand the following in order to predict gravitational relationships among two objects.

- Newton’s Law of Universal Gravitation states that there is a force of attraction between all objects in the universe.
- The Law of Universal Gravitation can be used to explain:
 - how the force is affected by the mass of each particle or object
 - how the force is affected by the distance between the particles or objects
- G is a constant and equals $6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$
- Law of Universal Gravitation is an inverse square law.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Explain why “ g ” has a constant value at or near the Earth’s surface.
- Calculate the weight of an object on other planets given the value of “ g ” at those locations.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 8.P.2: The student will demonstrate an understanding of the effects of forces on the motion and stability of an object.</p> <p>Earth Science Learning Connections: H.E.2A.1: Construct explanations for how gravity and motion affect the formation and shapes of galaxies (including the Milky Way Galaxy). H.E.2 B.3: Use mathematical and computational thinking to explain the motion of an orbiting object in the solar system.</p>
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Interactions and Forces

Standard H.P.2: The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.	
H.P.2D. Conceptual Understanding: The non-contact (at a distance) interactions among objects and their subsequent motion can be explained and predicted by analyzing the gravitational, electric, and magnetic forces acting on the objects and applying Newton’s laws of motion. These non-contact forces can be represented as fields.	
Performance Indicator	H.P.2D.3: <u>Obtain information to communicate</u> how long-term gravitational interactions govern the evolution and maintenance of large-scale structures in the universe (such as the solar system and galaxies) and the patterns of motion within them.
Science and Engineering Practice	H.P.1A.8: <u>Obtain and evaluate scientific information</u> to (1) answer questions, (2) explain or describe phenomena, (3) develop models, (4) evaluate hypotheses, explanations, claims, or designs or (5) identify and/or fill gaps in knowledge. <u>Communicate</u> using the conventions and expectations of scientific writing or oral presentations by (1) evaluating grade-appropriate primary or secondary scientific literature, or (2) reporting the results of student experimental investigations.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Patterns Cause and Effect Scale, Proportion, and Quantity Systems and System Models

Essential Learning Experiences:

It is essential that students understand the following:

- Kepler’s three Laws of Planetary Motion
 - Planets follow an elliptical orbit with the Sun at one focus.
 - Planets “sweep out” equal areas in equal time periods.
 - The cube of the radius of the orbit is proportional to the square of the period of orbit.
- Generally, smaller objects will fall into orbit around larger objects that are in close proximity.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Derive Kepler’s Third Law mathematically.

- Students may research how stars formed from large groups of particles.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 8.P.2: The student will demonstrate an understanding of the effects of forces on the motion and stability of an object.</p> <p>Earth Science Learning Connections: H.E.2A.1: Construct explanations for how gravity and motion affect the formation and shapes of galaxies (including the Milky Way Galaxy). H.E.2 B.3: Use mathematical and computational thinking to explain the motion of an orbiting object in the solar system.</p>
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Interactions and Forces

Standard H.P.2: The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.	
H.P.2D. Conceptual Understanding: The non-contact (at a distance) interactions among objects and their subsequent motion can be explained and predicted by analyzing the gravitational, electric, and magnetic forces acting on the objects and applying Newton’s laws of motion. These non-contact forces can be represented as fields.	
Performance Indicator	H.P.2D.4: <u>Use mathematical and computational thinking</u> to predict the relationships among the charges of two particles, the attractive or repulsive electrical force between them, and the distance between them (Coulomb’s Law. $F=kq_1q_2/r^2$).
Science and Engineering Practice	H.P.1A.5: <u>Use mathematical and computational thinking</u> to (1) use and manipulate appropriate English and metric units, (2) express relationships between variables for models and investigation, or (3) use grade-level appropriate statistics to analyze data.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Cause and Effect Systems and System Models

Essential Learning Experiences:

It is essential that students understand the following in order to use mathematical and computational thinking to predict relationships among charged particles.

- Coulomb’s law states that any two charges exert a force on each other. The force is inversely related to the distance between the two charges.
- The electric force between two charged objects can be attractive or repulsive.
- Coulomb’s law is an inverse square law.
- k is a constant and equals $8.99 \times 10^9 \text{ Nm}^2/\text{C}^2$
- The quantity of charge on a body, represented by the letter Q , is determined by the number of electrons in excess of (or less than) the number of protons
- The quantity of charge is measured in coulombs (C)
 - 1 coulomb = the charge on 6.25×10^{18} electrons

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Use superposition principle or vector analysis to find the net electric force on three or more charges in a straight line and perpendicular.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 7.P.2: The student will demonstrate an understanding of the structure and properties of matter and that matter is conserved as it undergoes changes.</p> <p>Chemistry Learning Connections: H.C.2: The student will demonstrate an understanding of atomic structure and nuclear processes.</p>
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Interactions and Forces

Standard H.P.2: The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.	
H.P.2D. Conceptual Understanding: The non-contact (at a distance) interactions among objects and their subsequent motion can be explained and predicted by analyzing the gravitational, electric, and magnetic forces acting on the objects and applying Newton's laws of motion. These non-contact forces can be represented as fields.	
Performance Indicator	H.P.2D.5: <u>Construct explanations</u> for how the non-contact forces of gravity, electricity, and magnetism can be modeled as fields by sketching field diagrams for two given charges, two massive objects, or a bar magnet and use these diagrams to qualitatively interpret the direction and magnitude of the force at a particular location in the field.
Science and Engineering Practice	H.P.1A.6: <u>Construct explanations</u> of phenomena using (1) primary or secondary scientific evidence and models, (2) conclusions from scientific investigations, (3) predictions based on observations and measurements, or (4) data communicated in graphs, tables, or diagrams.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Scale, Proportion, and Quantity Systems and System Models

Essential Learning Experiences:

It is essential that students understand the following in order to construct explanations for how non-contact forces can be modeled as fields.

- Long range (non-contact) forces are exerted over empty space.
- Long range forces can be described using field lines that represent the gravitational, electric or magnetic forces at any point in space.
- Field lines never cross and are closer together where the field is stronger.
- Field lines for gravitational forces are directed towards the center of mass of a body.
- Field lines for electric forces originate in a positively charged object and terminate in a negatively charged object.
- Field lines for magnetic forces originate in a north pole and terminate in a south pole
- The density of the field lines represents the magnitude of the field force at any given point in space.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Students must be able to draw field lines for any specific given situation.

- Electric Field lines are concentrated at points on a conductor.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 8.P.2: The student will demonstrate an understanding of the effects of forces on the motion and stability of an object.</p> <p>Earth Science Learning Connections: H.E.2A.1: Construct explanations for how gravity and motion affect the formation and shapes of galaxies (including the Milky Way Galaxy). H.E.2B.3: Use mathematical and computational thinking to explain the motion of an orbiting object in the solar system.</p>
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Interactions and Forces

Standard H.P.2: The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.	
H.P.2D. Conceptual Understanding: The non-contact (at a distance) interactions among objects and their subsequent motion can be explained and predicted by analyzing the gravitational, electric, and magnetic forces acting on the objects and applying Newton’s laws of motion. These non-contact forces can be represented as fields.	
Performance Indicator	H.P.2D.6: Use a free-body diagram to represent the gravitational force on an object.
Science and Engineering Practice	H.P.1A.2: <u>Construct explanations of phenomena</u> using (1) primary or secondary scientific evidence and models, (2) conclusions from scientific investigations, (3) predictions based on observations and measurements, or (4) data communicated in graphs, tables or diagrams.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Systems and System Models

Essential Learning Experiences:

It is essential that students understand the following in order to construct proper free body diagrams depicting gravitational forces.

- Free body diagrams show all the forces acting on an object.
- Gravitational force is a vector represented by a downward pointing arrow in a free body diagram.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Use vector analysis to determine the magnitude of the effective gravitational force (either analytically or by graphical analysis)

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

[https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete 2014SEPsGuide_SupportDoc2_0.pdf](https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete%202014SEPsGuide_SupportDoc2_0.pdf)

**Learning
Connections****Previous Learning Connections (6-8):**

8.P.2: The student will demonstrate an understanding of the effects of forces on the motion and stability of an object.

Earth Science Learning Connections:

H.E.2A.1: Construct explanations for how gravity and motion affect the formation and shapes of galaxies (including the Milky Way Galaxy).

H.E.2 B.3: Use mathematical and computational thinking to explain the motion of an orbiting object in the solar system.

Interactions and Forces

Standard H.P.2: The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.	
H.P.2D. Conceptual Understanding: The non-contact (at a distance) interactions among objects and their subsequent motion can be explained and predicted by analyzing the gravitational, electric, and magnetic forces acting on the objects and applying Newton's laws of motion. These non-contact forces can be represented as fields.	
Performance Indicator	H.P.2D.7: Use a free-body diagram to represent the electrical force on a charge.
Science and Engineering Practice	HP.1A.2: <u>Construct explanations of phenomena</u> using (1) primary or secondary scientific evidence and models, (2) conclusions from scientific investigations, (3) predictions based on observations and measurements, or (4) data communicated in graphs, tables or diagrams.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Systems and System Models

Essential Learning Experiences:

It is essential that students understand the following in order to construct proper free body diagrams depicting electrical forces.

- The magnitude of the electrical force acting on an object in an electric field is based on the magnitude of the electric field.
- The direction of the electric force is determined by the charge on the object and the direction of the electric field.
- Electric force is a vector quantity that is represented by an arrow in a free body diagram.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Calculate the net force on and acceleration of an electric charge in the presence of multiple charges.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

[https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete 2014SEPsGuide SupportDoc2 0.pdf](https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete%202014SEPsGuide%20SupportDoc2%200.pdf)

Learning Connections	<p>Previous Learning Connections (6-8): 7.P.2: The student will demonstrate an understanding of the structure and properties of matter and that matter is conserved as it undergoes changes.</p> <p>Chemistry Learning Connections: H.C.2: The student will demonstrate an understanding of atomic structure and nuclear processes.</p>
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Interactions and Forces

Standard H.P.2: The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.	
H.P.2D. Conceptual Understanding: The non-contact (at a distance) interactions among objects and their subsequent motion can be explained and predicted by analyzing the gravitational, electric, and magnetic forces acting on the objects and applying Newton’s laws of motion. These non-contact forces can be represented as fields.	
Performance Indicator	H.P.2D.8: <u>Develop and use models</u> (such as computer simulations, drawings, or demonstrations) to explain the relationship between moving charged particles (current) and magnetic forces and fields.
Science and Engineering Practice	H.P.1A.2: <u>Develop, use, and refine models</u> to (1) understand or represent phenomena, processes, and relationships, (2) test devices or solutions, or (3) communicate ideas to others.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Cause and Effect Systems and System Models

Essential Learning Experiences:

It is essential that students understand the following in order to develop and use models of charged particles in magnetic fields.

- The concept of electrical current (symbol I) as the rate of flow of electric charge (Q)
 - $I = \Delta Q / \Delta t$
- Electric current is measured in units of coulombs per second, $I = C/s$.
- One ampere (symbol A) is defined as a flow of one coulomb of charge per second
- Electromagnetic induction is a change in magnetic flux will induce a current within a conducting wire.
- The movement of electric current can produce magnetic fields, and vice versa. The lines of force of a magnetic field can be illustrated as seen below.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Describe the magnetic flux including direction using the right hand rule.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 7.P.2: The student will demonstrate an understanding of the structure and properties of matter and that matter is conserved as it undergoes changes.</p> <p>Chemistry Learning Connections: H.C.2: The student will demonstrate an understanding of atomic structure and nuclear processes.</p>
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Interactions and Forces

Standard H.P.2: The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.	
H.P.2D. Conceptual Understanding: The non-contact (at a distance) interactions among objects and their subsequent motion can be explained and predicted by analyzing the gravitational, electric, and magnetic forces acting on the objects and applying Newton’s laws of motion. These non-contact forces can be represented as fields.	
Performance Indicator	H.P.2D.9: Use Newton’s Law of Universal Gravitation and Newton’s second law of motion to <u>explain</u> why all objects near Earth’s surface have the same acceleration.
Science and Engineering Practice	H.P.1A.6: <u>Construct explanations of phenomena</u> using (1) primary or secondary scientific evidence and models, (2) conclusions from scientific investigations, (3) predictions based on observations and measurements, or (4) data communicated in graphs, tables, or diagrams.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Cause and Effect Systems and System Models

Essential Learning Experiences:

It is essential that students understand the following in order to explain acceleration due to gravity.

- Gravitational force (F_g) is dependent on the mass of both objects and the square of the distance between them.
- The weight ($F_g = mg$) of an object is the product of the object’s mass and the acceleration due to gravity.
- The gravitational force ($F = (Gm_1m_2/r^2)$) based on the Law of Universal Gravitation equals the weight (mg) in Newtons, of the object near the Earth’s surface and solve for the acceleration due to gravity.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- For advanced classes, students can derive the relationship on their own or with some guidance.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 8.P.2: The student will demonstrate an understanding of the effects of forces on the motion and stability of an object.</p> <p>Earth Science Learning Connections: H.E.2A.1: Construct explanations for how gravity and motion affect the formation and shapes of galaxies (including the Milky Way Galaxy).</p>
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Interactions and Forces

Standard H.P.2: The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.	
H.P.2D. Conceptual Understanding: The non-contact (at a distance) interactions among objects and their subsequent motion can be explained and predicted by analyzing the gravitational, electric, and magnetic forces acting on the objects and applying Newton’s laws of motion. These non-contact forces can be represented as fields.	
Performance Indicator	H.P.2D.10: <u>Use mathematical and computational thinking</u> to apply $F_{\text{net}} = ma$ to analyze problems involving non-contact interactions, including objects in free fall.
Science and Engineering Practice	H.P.1A.5: <u>Use mathematical and computational thinking</u> to (1) use and manipulate appropriate English and metric units, (2) express relationships between variables for models and investigation, or (3) use grade-level appropriate statistics to analyze data.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Cause and Effect Systems and System Models

Essential Learning Experiences:

It is essential that students understand the following in order to use mathematical and computational thinking to solve second law problems.

- Like contact forces, non-contact forces can cause accelerations.
- The acceleration can be calculated using Newton’s Second Law of Motion, $F_{\text{net}}=ma$ to solve problems using gravitational force based on the Law of Universal Gravitation.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- The acceleration of charged particles can be calculated using Newton’s Second Law of Motion and Coulomb’s Law.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

[https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete 2014SEPsGuide_SupportDoc2_0.pdf](https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete%202014SEPsGuide_SupportDoc2_0.pdf)

Learning Connections	<p>Previous Learning Connections (6-8): 8.P.2: The student will demonstrate an understanding of the effects of forces on the motion and stability of an object.</p> <p>Earth Science Learning Connections: H.E.2B.1: Analyze and interpret data to compare the properties of Earth and other planets (including composition, density, surface expression of tectonics, climate, and conditions necessary for life).</p>
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Interactions and Energy

Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.	
H.P.3A. Conceptual Understanding: Work and energy are equivalent to each other. Work is defined as the product of displacement and the force causing that displacement; this results in the transfer of mechanical energy. Therefore, in the case of mechanical energy, energy is seen as the ability to do work. This is called the work-energy principle. The rate at which work is done (or energy is transformed) is called power. For machines that do useful work for humans, the ratio of useful power output is the efficiency of the machine. For all energies and in all instances, energy in a closed system remains constant.	
Performance Indicator	H.P.3A.1: Use <u>mathematical and computational thinking</u> to determine the work done by a constant force ($W=Fd$).
Science and Engineering Practice	H.P.1A.5: Use <u>mathematical and computational thinking</u> to (1) use and manipulate appropriate metric units, (2) express relationships between variables for models and investigations, and (3) use grade-level appropriate statistics to analyze data.
Crosscutting Concepts	<p>The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6.</p> <p>Cause and Effect Systems and System Models Energy and Matter</p>

Essential Learning Experiences:

It is essential that students understand the following in order to use mathematical and computational thinking to solve work problems.

- The work done on an object is the transfer of energy to that object.
- The work done on an object is the product of the component of the force acting on the object in the direction of the distance traveled and the distance itself.
- When work is done to lift an object, the force exerted is equal to the weight (mg) of the object.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Determine the work done by a constant force at a given angle.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 6.P.3: The student will demonstrate an understanding of the properties of energy, the transfer and conservation of energy, and the relationship between energy and forces.</p> <p>Earth Science Learning Connections: H.E.6A.2: Obtain and communicate information to explain how location, movement, and energy transfers are involved in making water available for use on Earth's surface (including lakes, surface - water drainage basins, freshwater wetlands, and groundwater zones).</p>
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Interactions and Energy

Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.	
H.P.3A. Conceptual Understanding: Work and energy are equivalent to each other. Work is defined as the product of displacement and the force causing that displacement; this results in the transfer of mechanical energy. Therefore, in the case of mechanical energy, energy is seen as the ability to do work. This is called the work-energy principle. The rate at which work is done (or energy is transformed) is called power. For machines that do useful work for humans, the ratio of useful power output is the efficiency of the machine. For all energies and in all instances, energy in a closed system remains constant.	
Performance Indicator	H.P.3A.2: Use <u>mathematical and computational thinking</u> to analyze problems dealing with the work done on or by an object and its change in energy.
Science and Engineering Practice	H.P.1A.5 Use <u>mathematical and computational thinking</u> to (1) use and manipulate appropriate metric units, (2) express relationships between variables for models and investigations, and (3) use grade-level appropriate statistics to analyze data.
Crosscutting Concepts	<p>The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6.</p> <p>Cause and Effect Systems and System Models Energy and Matter</p>

Essential Learning Experiences:

It is essential that students understand the following in order to use mathematical and computational thinking to solve work and energy problems:

- When work is done on or by an object, there is a transformation of mechanical energy.
- Positive work causes an object to speed up and thus it has an increase in kinetic energy.
- Negative work causes an object to slow down and thus it has a decrease in kinetic energy.
- The work energy theorem states that the net work done on an object is equal to the change in kinetic energy. $W_{net} = \Delta KE$

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Work done during inelastic collisions can be calculated using the net change in Kinetic Energy.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 6.P.3: The student will demonstrate an understanding of the properties of energy, the transfer and conservation of energy, and the relationship between energy and forces.</p> <p>Earth Science Learning Connections: H.E.6A.2: Obtain and communicate information to explain how location, movement, and energy transfers are involved in making water available for use on Earth's surface (including lakes, surface - water drainage basins, freshwater wetlands, and groundwater zones).</p>
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Interactions and Energy

Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.	
H.P.3A. Conceptual Understanding: Work and energy are equivalent to each other. Work is defined as the product of displacement and the force causing that displacement; this results in the transfer of mechanical energy. Therefore, in the case of mechanical energy, energy is seen as the ability to do work. This is called the work-energy principle. The rate at which work is done (or energy is transformed) is called power. For machines that do useful work for humans, the ratio of useful power output is the efficiency of the machine. For all energies and in all instances, energy in a closed system remains constant.	
Performance Indicator	H.P.3A.3: <u>Obtain information to communicate</u> how energy is conserved in elastic and inelastic collisions.
Science and Engineering Practice	H.P.1A.8: <u>Obtain and evaluate scientific information</u> to (1) answer questions, (2) explain or describe phenomena, (3) develop models, (4) evaluate hypotheses, explanations, claims, or designs or (5) identify and/or fill gaps in knowledge. <u>Communicate</u> using the conventions and expectations of scientific writing or oral presentations by (1) evaluating grade-appropriate primary or secondary scientific literature, or (2) reporting the results of student experimental investigations.
Crosscutting Concepts	<p>The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6.</p> <p>Systems and System Models Energy and Matter</p>

Essential Learning Experiences:

It is essential that students obtain the following information in order to communicate how energy is conserved in collisions.

- The Law of Conservation of Momentum states that in a closed, isolated system, momentum is conserved.
- The law of Conservation of Momentum describes (both qualitatively and quantitatively) the motion of objects which collide in one dimension both elastically and inelastically.
- The Law of Conservation of Energy to describe (both qualitatively and quantitatively) the motion of objects which collide in one dimension both elastically and inelastically.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- The Laws of Conservation of Momentum and of Energy can be employed to explain the functioning of vehicle safety devices (such as airbags, seat belts, crumple zones, and helmets).

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 6.P.3: The student will demonstrate an understanding of the properties of energy, the transfer and conservation of energy, and the relationship between energy and force</p> <p>Earth Science Learning Connections: H.E.3A.3: Construct explanations of how forces cause crustal changes as evidenced in sea floor spreading, earthquake activity, volcanic eruptions, and mountain building using evidence of tectonic environments (such as mid - ocean ridges and subduction zones).</p>
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Interactions and Energy

Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.	
H.P.3A. Conceptual Understanding: Work and energy are equivalent to each other. Work is defined as the product of displacement and the force causing that displacement; this results in the transfer of mechanical energy. Therefore, in the case of mechanical energy, energy is seen as the ability to do work. This is called the work-energy principle. The rate at which work is done (or energy is transformed) is called power. For machines that do useful work for humans, the ratio of useful power output is the efficiency of the machine. For all energies and in all instances, energy in a closed system remains constant.	
Performance Indicator	H.P.3A.4: <u>Plan and conduct controlled scientific investigations</u> to determine the power output of the human body.
Science and Engineering Practice	H.P.1A.3: <u>Plan and conduct controlled scientific investigations</u> to answer questions, test hypotheses, and develop explanations: (1) formulate scientific questions and testable hypotheses based on credible scientific information, (2) identify materials, procedures, and variables, (3) use appropriate laboratory equipment, technology, and techniques to collect qualitative and quantitative data, and (4) record and represent data in an appropriate form. Use appropriate safety procedures.
Crosscutting Concepts	<p>The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6.</p> <p>Scale, Proportion, and Quantity Systems and System Models Energy and Matter</p>

Essential Learning Experiences:

It is essential that students understand the following in order to plan and conduct scientific investigations to determine human power output.

- Power is the rate of doing work. (power = work/time)
- The unit for linear power is the watt. (joule/sec)
- The human body is capable of doing work. Examples include:
 - climbing up stairs
 - push-ups
 - curls
 - pull ups

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Given a typical electric meter reading (as found on an electric bill), students will employ unit analysis to determine if the customer is charged for power or energy.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

<p>Learning Connections</p>	<p>Previous Learning Connections (6-8): 6.P.3: The student will demonstrate an understanding of the properties of energy, the transfer and conservation of energy, and the relationship between energy and forces.</p> <p>Biology Learning Connections: H.B.3A.1: Develop and use models to explain how chemical reactions among ATP, ADP, and inorganic phosphate act to transfer chemical energy within cells.</p>
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Interactions and Energy

<p>Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.</p>	
<p>H.P.3A. Conceptual Understanding: Work and energy are equivalent to each other. Work is defined as the product of displacement and the force causing that displacement; this results in the transfer of mechanical energy. Therefore, in the case of mechanical energy, energy is seen as the ability to do work. This is called the work-energy principle. The rate at which work is done (or energy is transformed) is called power. For machines that do useful work for humans, the ratio of useful power output is the efficiency of the machine. For all energies and in all instances, energy in a closed system remains constant.</p>	
<p>Performance Indicator</p>	<p>H.P.3A.5: <u>Obtain and communicate information</u> to describe the efficiency of everyday machines (such as automobiles, hair dryers, refrigerators, and washing machines).</p>
<p>Science and Engineering Practice</p>	<p>H.P.1A.8: <u>Obtain and evaluate scientific information</u> to (1) answer questions, (2) explain or describe phenomena, (3) develop models, (4) evaluate hypotheses, explanations, claims, or designs or (5) identify and/or fill gaps in knowledge. <u>Communicate</u> using the conventions and expectations of scientific writing or oral presentations by (1) evaluating grade-appropriate primary or secondary scientific literature, or (2) reporting the results of student experimental investigations.</p>
<p>Crosscutting Concepts</p>	<p>The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6.</p> <p>Cause and Effect Energy and Matter</p>

Essential Learning Experiences:

It is essential that students obtain and communicate the following information:

- Efficiency of any machine is the ratio of energy output to energy input
- Real machines cannot be 100% efficient due to energy loss to the surroundings
- Energy input and output can be measured through electronic, thermal or mechanical means

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Compare the power output of the human body during a common task (such as climbing stairs) to power used in a common device (such as a light bulb). Calculate how much of the task (such as how many flights of stairs climbed) is need to use the device for a given amount of time.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 6.P.3: The student will demonstrate an understanding of the properties of energy, the transfer and conservation of energy, and the relationship between energy and forces.</p> <p>Biology Learning Connections: H.B.3A.1: Develop and use models to explain how chemical reactions among ATP, ADP, and inorganic phosphate act to transfer chemical energy within cells.</p> <p>H.B.3A.4: Develop models of the major inputs and outputs of cellular respiration (aerobic and anaerobic) to exemplify the chemical process in which the bonds of molecules are broken, the bonds of new compounds are formed and a net transfer of energy results.</p>
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Interactions and Energy

Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.	
H.P.3B. Conceptual Understanding: Mechanical energy refers to a combination of motion (kinetic energy) and stored energy (potential energy). When only conservative forces act on an object and when no mass is converted to energy, mechanical energy is conserved. Gravitational and electrical potential energy can be modeled as energy stored in the fields created by massive objects or charged particles.	
Performance Indicator	H.P.3B.1: <u>Develop and use models</u> (such as computer simulations, drawings, bar graphs, and diagrams) to exemplify the transformation of mechanical energy in simple systems and those with periodic motion and on which only conservative forces act.
Science and Engineering Practice	H.P.1A.2: <u>Develop, use, and refine models</u> to (1) understand or represent phenomena, processes, and relationships, (2) test devices or solutions, or (3) communicate ideas to others.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Systems and System Models Energy and Matter

Essential Learning Experiences:

It is essential that students understand the following in order to develop and use models exemplifying energy transformations.

- When a body moves repeatedly over the same path in equal intervals of time, it is said to have periodic motion.
- Simple harmonic motion is a type of periodic motion which has the following characteristics:
 - A continually changing net force is exerted on the object which increases as the object moves away from the point of equilibrium.
 - Because the net force is continually changing, the rate of acceleration is continually changing.
 - The rate of acceleration is proportional to the displacement from the equilibrium position and decreases as the object approaches the point of equilibrium.
 - As the object is accelerating, the speed of the object is continually changing.
 - As the object moves toward equilibrium, there is a decreased net force acting on it in the direction of the equilibrium position.

- Even though the rate of acceleration is decreasing as the object moves towards equilibrium, the object is still accelerating the entire time that it is moving toward the equilibrium position.
- The object continually speeds up as it moves towards the equilibrium position.
- The speed of the object is at a maximum at the point of equilibrium.
- At the point of equilibrium, the direction of the net force changes.
- The new net force causes an acceleration, but this time in the direction opposite to the motion of the object.
- As the object moves past the equilibrium point, the net force causes the object to negatively accelerate (slow down).
- The speed of the object is at a minimum when the object is at the points farthest from the equilibrium and at a maximum at the point of equilibrium.
- The speed of the object is inversely proportional to the displacement from the equilibrium position.
- The motion of a pendulum and the motion of a mass hanging on a spring are based on the principles of simple harmonic motion and involve the transformation of mechanical energy.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Students should use the equation for a pendulum ($T=2\pi\sqrt{\ell/g}$) and for an object on a spring ($T=2\pi\sqrt{m/k}$) to calculate the period of motion.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8):</p> <p>6.P.3: The student will demonstrate an understanding of the properties of energy, the transfer and conservation of energy, and the relationship between energy and forces.</p> <p>Earth Science Learning Connections:</p> <p>H.E.3A.3: Construct explanations of how forces cause crustal changes as evidenced in sea floor spreading, earthquake activity, volcanic eruptions, and mountain building using evidence of tectonic environments (such as mid - ocean ridges and subduction zones).</p>
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Interactions and Energy

Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.	
H.P.3B. Conceptual Understanding: Mechanical energy refers to a combination of motion (kinetic energy) and stored energy (potential energy). When only conservative forces act on an object and when no mass is converted to energy, mechanical energy is conserved. Gravitational and electrical potential energy can be modeled as energy stored in the fields created by massive objects or charged particles.	
Performance Indicator	H.P.3B.2: <u>Use mathematical and computational thinking</u> to argue the validity of the conservation of mechanical energy in simple systems and those with periodic motion and on which only conservative forces act ($KE = \frac{1}{2}mv^2$, $PE_g = mgh$, $PE_e = \frac{1}{2}kx^2$).
Science and Engineering Practice	H.P.1A.5: <u>Use mathematical and computational thinking</u> to (1) use and manipulate appropriate English and metric units, (2) express relationships between variables for models and investigations, or (3) use grade-level appropriate statistics to analyze data.
Crosscutting Concepts	<p>The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6.</p> <p>Systems and System Models Energy and Matter</p>

Essential Learning Experiences:

It is essential that students understand the following in order to use mathematical and computational thinking to construct their arguments.

- Potential energy (energy of position) and kinetic energy (energy of motion) can be determined using energy formulas:
 - $KE = \frac{1}{2}mv^2$
 - $PE_g = mgh$
 - $PE_e = \frac{1}{2}kx^2$
- The gravitational potential energy of an object is equal to the object's weight (mass x acceleration due to gravity) multiplied by the vertical distance through which the object is lifted. ($PE_g = mgh$)
- The unit used to measure energy is the joule, J. (One Nm = one J)
- The kinetic energy of a moving object is equal to the object's mass times its velocity-squared, divided by two. ($KE = \frac{1}{2}mv^2$)
- The potential energy of an object can be converted to kinetic energy or the kinetic energy to potential energy.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Students should be able to use the concepts of conservation of momentum and conservation of energy to determine the height reached by a ballistic pendulum.
- Students can calculate the rate of energy loss for an object experiencing periodic motion from the time of release to the stop time.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 6.P.3: The student will demonstrate an understanding of the properties of energy, the transfer and conservation of energy, and the relationship between energy and forces.</p> <p>Earth Science Learning Connections: H.E.6A.2: Obtain and communicate information to explain how location, movement, and energy transfers are involved in making water available for use on Earth's surface (including lakes, surface - water drainage basins, freshwater wetlands, and groundwater zones).</p>
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Interactions and Energy

Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.	
H.P.3B. Conceptual Understanding: Mechanical energy refers to a combination of motion (kinetic energy) and stored energy (potential energy). When only conservative forces act on an object and when no mass is converted to energy, mechanical energy is conserved. Gravitational and electrical potential energy can be modeled as energy stored in the fields created by massive objects or charged particles.	
Performance Indicator	H.P.3B.3: Use drawings or diagrams to identify positions of relative high and low potential energy in a gravitational and electrical field (with the source of the field being positive as well as negative and the charge experiencing the field being positive as well as negative).
Science and Engineering Practice	H.P.1A.2: <u>Develop, use, and refine models</u> to (1) understand or represent phenomena, processes, and relationships, (2) test devices or solutions, or (3) communicate ideas to others.
Crosscutting Concepts	<p>The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6.</p> <p>Patterns Scale, Proportion, and Quantity Systems and System Models Energy and Matter</p>

Essential Learning Experiences:

It is essential that students understand the following in order to correctly construct drawings and diagrams of gravitational and electrical fields.

- Electric potential energy is the energy a charge has due to its location in an electric field.
- The potential energy of an object within a gravitational field increases as the object moves away from the center of the source of the gravitational field.
- Electrical potential energy increases as objects with like charge move closer to each other.
- Electrical potential energy increases as objects with opposite charge move away from each other.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Students must calculate voltage based on change in electrical potential energy ($V=Ed$.)

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 6.P.3: Work, energy transfer, Kinetic and Potential Energy</p> <p>Earth Science Learning Connections: H.E.6A.2: Obtain and communicate information to explain how location, movement, and energy transfers are involved in making water available for use on Earth’s surface (including lakes, surface - water drainage basins, freshwater wetlands, and groundwater zones).</p>
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Interactions and Energy

Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.	
H.P.3C. Conceptual Understanding: When there is a temperature difference between two objects, an interaction occurs in the form of a transfer of thermal energy (heat) from the hotter object to the cooler object. Thermal energy is the total internal kinetic energy of the molecules and/or atoms of a system and is related to temperature, which is the average kinetic energy of the particles of a system. Energy always flows from hot to cold through the processes of conduction, convection, or radiation.	
Performance Indicator	H.P.3C.1: <u>Plan and conduct controlled scientific investigations</u> to determine the variables that affect the rate of heat transfer between two objects.
Science and Engineering Practice	H.P.1A.3: <u>Plan and conduct controlled scientific investigations</u> to answer questions, test hypotheses, and develop explanations: (1) formulate scientific questions and testable hypotheses based on credible scientific information, (2) identify materials, procedures, and variables, (3) use appropriate laboratory equipment, technology, and techniques to collect qualitative and quantitative data, and (4) record and represent data in an appropriate form. Use appropriate safety procedures.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Systems and System Models Energy and Matter

Essential Learning Experiences:

It is essential that students understand the following in order to plan and conduct investigations of heat transfer.

- Heat is a form of energy that is transferred between objects of different temperatures.
- Heat always flows from warmer to colder objects until the objects are the same temperature.
- Heat energy is transferred via conduction, convection and radiation.
- The heat energy transferred to or from an object is dependent upon the mass, temperature, and specific heat and can be calculated using the equation $Q=mC\Delta T$.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Apply the concept of heat exchange to solve calorimetry problems.

- Summarize the functioning of heat transfer mechanisms (including engines and refrigeration systems)

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 6.P.3: The student will demonstrate an understanding of the properties of energy, the transfer and conservation of energy, and the relationship between energy and forces.</p> <p>Earth Science Learning Connections: H.E.5A.1: Develop and use models to describe the thermal structures (including the changes in air temperature due to changing altitude in the lower troposphere), the gaseous composition, and the location of the layers of Earth’s atmosphere.</p> <p>H.E.6A.7: Obtain and communicate information to explain how the convection of ocean water due to temperature and density influence the circulation of oceans.</p>
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Interactions and Energy

Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.	
H.P.3C. Conceptual Understanding: When there is a temperature difference between two objects, an interaction occurs in the form of a transfer of thermal energy (heat) from the hotter object to the cooler object. Thermal energy is the total internal kinetic energy of the molecules and/or atoms of a system and is related to temperature, which is the average kinetic energy of the particles of a system. Energy always flows from hot to cold through the processes of conduction, convection, or radiation.	
Performance Indicator	H.P.3C.2: <u>Analyze and interpret data</u> to describe the thermal conductivity of different materials.
Science and Engineering Practice	H.P.1A.4: <u>Analyze and interpret data</u> from informational texts and data collected from investigations using a range of methods (such as tabulation, graphing, or statistical analysis) to (1) reveal patterns and construct meaning, (2) support or refute hypotheses, explanations, claims, or designs, or (3) evaluate the strength of conclusions.
Crosscutting Concepts	<p>The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6.</p> <p>Cause and Effect Systems and System Models Matter and Energy</p>

Essential Learning Experiences:

It is essential that students understand the following in order to analyze and interpret data describing the thermal conductivity of different materials.

- The thermal conductivity of a material is the property indicating the ability of a material to transfer heat particle-by-particle.
- Each substance has its own thermal conductivity value.
- Heat conducted through a material also depends on the thickness, area, and length of the material.
- A higher conductivity value indicates a greater conductor.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Use the equation $Q = kA\Delta T/d$ where k is thermal conductivity of material, A is cross sectional area, ΔT is temperature difference, and d is thickness of material.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

[https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete 2014SEPsGuide_SupportDoc2_0.pdf](https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete%202014SEPsGuide_SupportDoc2_0.pdf)

Learning Connections	<p>Previous Learning Connections (6-8): 6.P.3:The student will demonstrate an understanding of the properties of energy, the transfer and conservation of energy, and the relationship between energy and forces.</p> <p>Earth Science Learning Connections: H.E.5A.1: Develop and use models to describe the thermal structures (including the changes in air temperature due to changing altitude in the lower troposphere), the gaseous composition, and the location of the layers of Earth’s atmosphere.</p> <p>H.E.6A.7: Obtain and communicate information to explain how the convection of ocean water due to temperature and density influence the circulation of oceans.</p>
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Interactions and Energy

Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.	
H.P.3C. Conceptual Understanding: When there is a temperature difference between two objects, an interaction occurs in the form of a transfer of thermal energy (heat) from the hotter object to the cooler object. Thermal energy is the total internal kinetic energy of the molecules and/or atoms of a system and is related to temperature, which is the average kinetic energy of the particles of a system. Energy always flows from hot to cold through the processes of conduction, convection, or radiation.	
Performance Indicator	H.P.3C.3: <u>Develop and use models</u> (such as a drawing or a small-scale greenhouse) to exemplify the energy balance of the Earth (including conduction, convection, and radiation).
Science and Engineering Practice	H.P.1A.2: <u>Develop, use, and refine models</u> to (1) understand or represent phenomena, processes, and relationships, (2) test devices or solutions, or (3) communicate ideas to others.
Crosscutting Concepts	<p>The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6.</p> <p>Systems and System Models Energy and Matter Structure and Function Stability and Change</p>

Essential Learning Experiences:

It is essential that students understand the following in order to develop and use models to exemplify the Earth's energy balance.

- Energy is transferred from the sun to the Earth as radiation. The Earth's atmosphere keeps the Earth habitable. The interactions between the Earth's atmosphere and surface recycle the energy via conduction and convection.
- The Greenhouse Effect allows the Earth and lower atmosphere to become warmer.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Explain the role of greenhouse gases in the atmosphere, including why these are greenhouse gases.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

[https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete 2014SEPsGuide_SupportDoc2_0.pdf](https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete%202014SEPsGuide_SupportDoc2_0.pdf)

Learning Connections	<p>Previous Learning Connections (6-8): 6.P.3: The student will demonstrate an understanding of the properties of energy, the transfer and conservation of energy, and the relationship between energy and forces.</p> <p>Earth Science Learning Connections: H.E.5A.7: Construct scientific arguments to support claims of past changes in climate caused by various factors (such as changes in the atmosphere, variations in solar output, Earth’s orbit, changes in the orientation of Earth’s axis of rotation, or changes in the biosphere). H.E.5A.8: Analyze scientific arguments regarding the nature of the relationship between human activities and climate change.</p>
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Interactions and Energy

Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.	
H.P.3D. Conceptual Understanding: Sound is a mechanical, longitudinal wave that is the result of vibrations (kinetic energy) that transfer energy through a medium.	
Performance Indicator	H.P.3D.1: <u>Develop and use models</u> (such as drawings) to exemplify the interaction of mechanical waves with different boundaries (sound wave interference) including the formation of standing waves and two-source interference patterns.
Science and Engineering Practice	H.P.1A.2: <u>Develop, use, and refine models</u> to (1) understand or represent phenomena, processes, and relationships, (2) test devices or solutions, or (3) communicate ideas to others.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Patterns Cause and Effect Systems and System Models

Essential Learning Experiences:

It is essential that students develop and use models to demonstrate the following:

- Sound is a wave that is created by vibrating objects and is propagated through a medium from one location to another.
- Because it requires a medium, it is a mechanical wave. Examples of media include: solids, liquids and gases, with sound having the greatest speed in solids.
- In a longitudinal wave, the motion of the individual particles of the medium is in a direction that is parallel to the direction of the energy transported.
- Standing waves occur when a reflected wave interferes with an existing incident wave to form areas of constructive interference and areas of destructive interference.
 - Areas of constructive interference are called antinodes.
 - Areas of destructive interference are called nodes.
- When two wave sources are near each other, they produce nodes and antinodes.
- Wave interference is the phenomenon that occurs when two waves meet while traveling along the same medium.
- The principle of superposition involves an algebraic sum of the displacements of the medium of the waves interfering.
- Destructive interference occurs at any location along the medium where the interfering waves have displacement in the opposite direction.
- Constructive interference occurs where displacement is in the same direction.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Construct explanations for examples of diffraction of sound waves (such as hearing around corners).

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

[https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete 2014SEPsGuide_SupportDoc2_0.pdf](https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete%202014SEPsGuide_SupportDoc2_0.pdf)

Learning Connections	<p>Previous Learning Connections (6-8): 8.P.3: The student will demonstrate an understanding of the properties and behaviors of waves.</p> <p>Earth Science Learning Connections: H.E.3A.1: Analyze and interpret data to explain the differentiation of Earth’s internal structure using (1) the production of internal heat from the radioactive decay of unstable isotopes, (2) gravitational energy, (3) data from seismic waves, and (4) Earth’s magnetic field.</p>
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Interactions and Energy

Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.	
H.P.3D. Conceptual Understanding: Sound is a mechanical, longitudinal wave that is the result of vibrations (kinetic energy) that transfer energy through a medium.	
Performance Indicator	H.P.3D.2: Use the principle of superposition to explain everyday examples of resonance (including musical instruments and the human voice).
Science and Engineering Practice	H.P.1A.6: <u>Construct explanations of phenomena</u> using (1) primary or secondary scientific evidence and models, (2) conclusions from scientific investigations, (3) predictions based on observations and measurements, or (4) data communicated in graphs, tables, or diagrams.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Patterns Cause and Effect

Essential Learning Experiences:

It is essential that students understand the following in order to construct explanations of everyday examples of resonance.

- Wave interference is the phenomenon that occurs when two waves meet while traveling along the same medium.
- The principle of superposition involves an algebraic sum of the displacements of the medium of the waves interfering.
- Destructive interference occurs at any location along the medium where the interfering waves have displacement in the opposite direction.
- Constructive interference occurs where displacement is in the same direction.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Explain resonant frequencies in open and closed tubes.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

**Learning
Connections****Previous Learning Connections (6-8):**

8.P.3: The student will demonstrate an understanding of the properties and behaviors of waves.

Earth Science Learning Connections:

H.E.3A.1: Analyze and interpret data to explain the differentiation of Earth's internal structure using (1) the production of internal heat from the radioactive decay of unstable isotopes, (2) gravitational energy, (3) data from seismic waves, and (4) Earth's magnetic field.

Interactions and Energy

Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.	
H.P.3D. Conceptual Understanding: Sound is a mechanical, longitudinal wave that is the result of vibrations (kinetic energy) that transfer energy through a medium.	
Performance Indicator	H.P.3D.3: <u>Develop and use models</u> to explain what happens to the observed frequency of a sound wave when the relative positions of an observer and wave source changes (Doppler effect).
Science and Engineering Practice	H.P.1A.2: <u>Develop, use, and refine models</u> to (1) understand or represent phenomena, processes, and relationships, (2) test devices or solutions, or (3) communicate ideas to others.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Patterns Cause and Effect Systems and System Models

Essential Learning Experiences:

It is essential that students develop and use models to explain the Doppler Effect.

- The Doppler Effect is the apparent change in frequency due to position between a listener and source changing.
 - Frequency appears to increase when the distance between source and listener decreases.
 - Frequency appears to decrease when the distance between source and listener increase.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Students could use mathematical formulae to calculate apparent frequency when source and/or listener move.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

[https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete 2014SEPsGuide_SupportDoc2_0.pdf](https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete%202014SEPsGuide_SupportDoc2_0.pdf)

Learning Connections	<p>Previous Learning Connections (6-8): 8.P.3: The student will demonstrate an understanding of the properties and behaviors of waves.</p> <p>Earth Science Learning Connections: H.E.2A.4: Construct and analyze scientific arguments to support claims about the origin of the universe (including the redshift of light from distant galaxies, the measured composition of stars and non-stellar gases, and the cosmic background radiation).</p>
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Interactions and Energy

Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.	
H.P.3D. Conceptual Understanding: Sound is a mechanical, longitudinal wave that is the result of vibrations (kinetic energy) that transfer energy through a medium.	
Performance Indicator	H.P.3D.4: Use <u>mathematical and computational thinking</u> to analyze problems that relate the frequency, period, amplitude, wavelength, velocity, and energy of sound waves.
Science and Engineering Practice	H.P.1A.5: Use <u>mathematical and computational thinking</u> to (1) use and manipulate appropriate English and metric units, (2) express relationships between variables for models and investigations, or (3) use grade-level appropriate statistics to analyze data.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Cause and Effect Scale, Proportion, and Quantity Systems and System Models

Essential Learning Experiences:

It is essential that students understand the following in order to use mathematical and computational thinking to analyze problems.

- Characteristics of waves include amplitude, wavelength, frequency, period and speed.
- Amplitude is a measure of the maximum displacement of a particle from its position of equilibrium. Amplitude and energy are directly related.
- Wavelength, (λ) is the distance between two consecutive rarefactions or two consecutive compressions and is measured in meters.
- Frequency, (f), refers to the number of waves that pass a point in a given period of time and is measured in hertz (cycles/second).
- Period, (T), is the time for one wave to pass a point and is measured in seconds.
- Frequency and period are inverses of one another. ($T = 1/f$ and $f = 1/T$)
- The speed, (v), of a sound wave is equal to frequency times wavelength. ($v = f\lambda$)
- The speed of a wave depends on the medium.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Calculate beat frequencies produced by two sound waves.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 8.P.3- The student will demonstrate an understanding of the properties and behaviors of waves.</p> <p>Earth Science Learning Connections: H.E.3A.1: Analyze and interpret data to explain the differentiation of Earth's internal structure using (1) the production of internal heat from the radioactive decay of unstable isotopes, (2) gravitational energy, (3) data from seismic waves, and (4) Earth's magnetic field.</p>
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Interactions and Energy

<p>Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.</p>	
<p>H.P.3E. Conceptual Understanding: During electric circuit interactions, electrical energy (energy stored in a battery or energy transmitted by a current) is transformed into other forms of energy and transferred to circuit devices and the surroundings. Charged particles and magnets create fields that store energy. Magnetic fields exert forces on moving objects.</p>	
<p>Performance Indicator</p>	<p>H.P.3E.1: <u>Plan and conduct controlled scientific investigations</u> to determine the relationship between the current and potential drop across an Ohmic resistor. Analyze and interpret data to verify Ohm’s law, including constructing an appropriate graph in order to draw a line-of-best-fit whose calculated slope will yield R, the resistance of the resistor.</p>
<p>Science and Engineering Practice</p>	<p>H.P.1A.3: <u>Plan and conduct controlled scientific investigations</u> to answer questions, test hypotheses, and develop explanations: (1) formulate scientific questions and testable hypotheses based on credible scientific information, (2) identify materials, procedures, and variables, (3) use appropriate laboratory equipment, technology, and techniques to collect qualitative and quantitative data, and (4) record and represent data in an appropriate form. Use appropriate safety procedures.</p>
<p>Crosscutting Concepts</p>	<p>The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6.</p> <p>Patterns Cause and Effect Scale, Proportion, and Quantity Systems and System Models Energy and Matter</p>

Essential Learning Experiences:

It is essential that students understand the following in order to plan and conduct scientific investigations analyzing resistors in a circuit.

- Electric current is the flow of electrons through a conductor and is measured in amperes or amps. The symbol for amp is (A).
- Electric resistance is the resistance of a material to the flow of electric current, measured in units of ohms. (Ω)
- Voltage is electric potential energy per unit of charge and is measured in volts. The symbol for volt is (v).
- The relationship between the resistance, current, and voltage is known as Ohm's Law and states that the ratio of voltage to current for a fixed resistor is constant. ($V = IR$)

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Use the color code chart to find the value of fixed resistors.
- Find resistance based on material, length, and cross sectional area. $R = \rho l/A$

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 6.P.3: The student will demonstrate an understanding of the properties of energy, the transfer and conservation of energy, and the relationship between energy and forces.</p> <p>Chemistry Learning Connections: H.C.2 A .1: Obtain and communicate information to describe and compare subatomic particles with regard to mass, location, charge, electrical attractions and repulsions, and impact on the properties of an atom.</p>
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Interactions and Energy

Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.	
H.P.3E. Conceptual Understanding: During electric circuit interactions, electrical energy (energy stored in a battery or energy transmitted by a current) is transformed into other forms of energy and transferred to circuit devices and the surroundings. Charged particles and magnets create fields that store energy. Magnetic fields exert forces on moving objects.	
Performance Indicator	H.P.3E.2: <u>Develop and use models</u> (such as circuit drawings and mathematical representations) to explain how an electric circuit works by tracing the path of the electrons and including concepts of energy transformation, transfer, and the conservation of energy and electric charge.
Science and Engineering Practice	H.P.1A.2: <u>Develop, use, and refine models</u> to (1) understand or represent phenomena, processes, and relationships, (2) test devices or solutions, or (3) communicate ideas to others.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Patterns Systems and System Models Energy and Matter

Essential Learning Experiences:

It is essential that students understand the following in order to develop and use models of electric circuits.

- An electric circuit is a closed path through which current flows.
- The four components of an electric circuit are voltage source, conductor, switch and load.
- Electric circuits can be represented by drawing a schematic circuit diagram from a circuit which is pictured or described.
- The following symbols are used by convention in circuit diagrams:

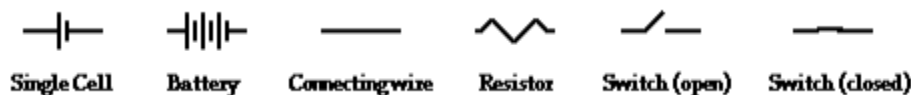


Figure 6. Circuits (SCDE 2005).

- Arrows can be used in the diagrams to show direction of charges in the circuit.
- Energy transformations occur as charges move in and around a circuit.
- Circuits could be constructed in series or parallel.
- Series circuits a single path through which charges may flow.
- Parallel circuits have multiple paths through which charges may flow.
- The resistance is calculated in a series circuit using $R_1 + R_2 + R_3 + R_n = \sum R$
- The resistance is calculated in a parallel circuit using $1/R_1 + 1/R_2 + 1/R_3 + 1/R_n = 1/\sum R$

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Students could draw compound circuits and set up compound circuits given a schematic diagram.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8):</p> <p>6.P.3: The student will demonstrate an understanding of the properties of energy, the transfer and conservation of energy, and the relationship between energy and forces.</p> <p>Chemistry Learning Connections:</p> <p>H.C.2 A .1: Obtain and communicate information to describe and compare subatomic particles with regard to mass, location, charge, electrical attractions and repulsions, and impact on the properties of an atom.</p>
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Interactions and Energy

Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.	
H.P.3E. Conceptual Understanding: During electric circuit interactions, electrical energy (energy stored in a battery or energy transmitted by a current) is transformed into other forms of energy and transferred to circuit devices and the surroundings. Charged particles and magnets create fields that store energy. Magnetic fields exert forces on moving objects.	
Performance Indicator	H.P.3E.3: Use <u>mathematical and computational thinking</u> to analyze problems dealing with current, electric potential, resistance, and electric charge.
Science and Engineering Practice	H.P.1A.5: Use <u>mathematical and computational thinking</u> to (1) use and manipulate appropriate English and metric units, (2) express relationships between variables for models and investigations, or (3) use grade-level appropriate statistics to analyze data.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Cause and Effect Scale, Proportion, and Quantity Systems and System Models

Essential Learning Experiences:

It is essential that students understand the following in order to use mathematical and computational thinking to solve problems related to electric circuits.

- Current (I) is the rate of flow of electric charge (Q) and is found using, $I = \Delta Q/\Delta t$
- Electric current is measured in units of coulombs per second.
- One ampere (symbol A) is defined as a flow of one coulomb of charge per second
- Electric potential energy is the energy that a charge has due to its location in an electric field and is measured in Joules. $PE_e = F_e d$
- Electric potential, commonly called voltage, is the electric potential energy per coulomb at a location in an electric field. Electric potential is a measure of the potential energy per charge, and has units of joules/ coulomb. $V = PE_e/q$
- One volt (symbol V) is defined as one joule/coulomb.
- If an electric potential causes a charge to move, the voltage can be described as the work per charge. $V=W/q$
- Electric potential difference is the difference in electric potential (voltage) between two points. $\Delta V = Ed$
- Electric resistance is the resistance of a material to the flow of electric current, measured in units of ohms (Ω). $R = V/I$.

- One ohm (Ω) is defined as the resistance of a material that allows a current of one ampere to flow when a voltage of one volt is impressed across it.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Analyze V/I graphs to determine if a given resistor obeys Ohm's Law (is an ohmic resistor).

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 6.P.3: The student will demonstrate an understanding of the properties of energy, the transfer and conservation of energy, and the relationship between energy and forces.</p> <p>Chemistry Learning Connections: H.C.2 A .1: Obtain and communicate information to describe and compare subatomic particles with regard to mass, location, charge, electrical attractions and repulsions, and impact on the properties of an atom.</p>
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Interactions and Energy

Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.	
H.P.3E. Conceptual Understanding: During electric circuit interactions, electrical energy (energy stored in a battery or energy transmitted by a current) is transformed into other forms of energy and transferred to circuit devices and the surroundings. Charged particles and magnets create fields that store energy. Magnetic fields exert forces on moving objects.	
Performance Indicator	H.P.3E.4: <u>Use mathematical and computational thinking</u> to analyze problems dealing with the power output of electric devices.
Science and Engineering Practice	H.P.1A.5: <u>Use mathematical and computational thinking</u> to (1) use and manipulate appropriate English and metric units, (2) express relationships between variables for models and investigations, or (3) use grade-level appropriate statistics to analyze data.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Cause and Effect Scale, Proportion, and Quantity Systems and System Models

Essential Learning Experiences:

It is essential that students understand the following in order to use mathematical and computational thinking to solve problems related to power output.

- Power is the rate of doing work. ($P = W/t$)
- Electric power is the rate at which electric energy is converted into another form such as mechanical energy, heat, or light.
- In an electric system:
 - $P = IV$ or $P = I^2R$
 - Power is measured in units of watts
 - A kilowatt is 1000 watts
- Energy is the product of power and time and is often measured in kilowatt-hours.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Calculate the cost to operate various appliances.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 6.P.3: The student will demonstrate an understanding of the properties of energy, the transfer and conservation of energy, and the relationship between energy and forces.</p> <p>Chemistry Learning Connections: H.C.2 A .1: Obtain and communicate information to describe and compare subatomic particles with regard to mass, location, charge, electrical attractions and repulsions, and impact on the properties of an atom.</p>
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Interactions and Energy

Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.	
H.P.3E. Conceptual Understanding: During electric circuit interactions, electrical energy (energy stored in a battery or energy transmitted by a current) is transformed into other forms of energy and transferred to circuit devices and the surroundings. Charged particles and magnets create fields that store energy. Magnetic fields exert forces on moving objects.	
Performance Indicator	H.P.3E.5: <u>Plan and conduct controlled scientific investigations</u> to determine how connecting resistors in series and in parallel affects the power (brightness) of light bulbs.
Science and Engineering Practice	H.P.1A.3: <u>Plan and conduct controlled scientific investigations</u> to answer questions, test hypotheses, and develop explanations: (1) formulate scientific questions and testable hypotheses based on credible scientific information, (2) identify materials, procedures, and variables, (3) use appropriate laboratory equipment, technology, and techniques to collect qualitative and quantitative data, and (4) record and represent data in an appropriate form. Use appropriate safety procedures.
Crosscutting Concepts	<p>The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6.</p> <p>Patterns Cause and Effect Scale, Proportion, and Quantity Systems and System Models</p>

Essential Learning Experiences:

It is essential that students plan and conduct controlled scientific investigations of simple circuits to determine the effects of loads in series and parallel, as well as sources of current connected in series and parallel. Students' investigations should reveal the following:

Series Circuits:

- In a series circuit there is a single path for electrons.
- When another resistor is wired in series with the resistors in a circuit, the total resistance increases because all of the current must go through each resistor and encounters the resistance of each.
 - The current in the circuit decreases when additional resistors are added.
 - The current will be the same in each resistor.
- When another light bulb is added to lights wired in series the lights will dim.
- When light bulbs are wired in series and one is removed or burns out all of the lights in the circuit go out.

- When the light bulb is removed from the circuit, it opens the circuit and current cannot flow.

Parallel Circuits:

- When resistors are wired in parallel, there is more than one path that the electrons can travel.
- The voltage in each path is the same.
- When another resistor is wired in parallel then the total resistance is reduced.
- The total current in the circuit will increase when another path is added.
- If light bulbs are wired in parallel and one burns out or is removed the other bulbs keep burning because the circuit is still complete.

Chemical cells in series and parallel:

- Chemical cells can be wired in series to make a battery.
- Cells wired in series will increase the voltage of the battery.
- Chemical cells can be wired in parallel to make a battery.
- Cells wired in parallel do not change the voltage of the battery.
- Cells are in parallel to make the battery last longer.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Investigate light bulb brightness in compound circuits.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

[https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete 2014SEPsGuide_SupportDoc2_0.pdf](https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete%202014SEPsGuide_SupportDoc2_0.pdf)

Learning Connections	<p>Previous Learning Connections (6-8): 6.P.3-The student will demonstrate an understanding of the properties of energy, the transfer and conservation of energy, and the relationship between energy and forces.</p> <p>Chemistry Learning Connections: H.C.2 A .1: Obtain and communicate information to describe and compare subatomic particles with regard to mass, location, charge, electrical attractions and repulsions, and impact on the properties of an atom.</p>
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Interactions and Energy

Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.	
H.P.3E. Conceptual Understanding: During electric circuit interactions, electrical energy (energy stored in a battery or energy transmitted by a current) is transformed into other forms of energy and transferred to circuit devices and the surroundings. Charged particles and magnets create fields that store energy. Magnetic fields exert forces on moving objects.	
Performance Indicator	H.P.3E.6: <u>Obtain and communicate information</u> about the relationship between magnetism and electric currents to explain the role of magnets and coils of wire in microphones, speakers, generators, and motors.
Science and Engineering Practice	H.P.1A.8: <u>Obtain and evaluate scientific information</u> to (1) answer questions, (2) explain or describe phenomena, (3) develop models, (4) evaluate hypotheses, explanations, claims, or designs or (5) identify and/or fill gaps in knowledge. <u>Communicate</u> using the conventions and expectations of scientific writing or oral presentations by (1) evaluating grade-appropriate primary or secondary scientific literature, or (2) reporting the results of student experimental investigations.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Patterns Cause and Effect Systems and System Models

Essential Learning Experiences:

It is essential that students obtain and communicate these basic concepts:

- Magnetic fields can be produced by moving charges, current. Current can also produce a magnetic field. Two wires, with current flowing, when placed next to each other, may attract or repel like two magnets.
- An electromagnet is a type of magnet in which the magnetic field is produced by a current. They are used in many objects such as motors, generators, speakers, generator, loudspeakers, and MRI machines.
- A metal coil creates a magnetic field when electric current flows through it. This enables speakers and microphones to translate audible signals.
- In motors, current passes through magnets and induces a magnetic field around the rotor, causing it to spin.
- In generators a magnet is moved near a wire to induce current.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Use the right hand rule to illustrate the direction that current flows in a magnetic field.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

[https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete 2014SEPsGuide_SupportDoc2_0.pdf](https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete%202014SEPsGuide_SupportDoc2_0.pdf)

Learning Connections	<p>Previous Learning Connections (6-8): 6.P.3: The student will demonstrate an understanding of the properties of energy, the transfer and conservation of energy, and the relationship between energy and forces.</p> <p>Chemistry Learning Connections: H.C.2 A .1: Obtain and communicate information to describe and compare subatomic particles with regard to mass, location, charge, electrical attractions and repulsions, and impact on the properties of an atom.</p>
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Interactions and Energy

<p>Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.</p>	
<p>H.P.3E. Conceptual Understanding: During electric circuit interactions, electrical energy (energy stored in a battery or energy transmitted by a current) is transformed into other forms of energy and transferred to circuit devices and the surroundings. Charged particles and magnets create fields that store energy. Magnetic fields exert forces on moving objects.</p>	
<p>Performance Indicator</p>	<p>H.P.3E.7: <u>Design</u> a simple motor and <u>construct an explanation</u> of how this motor transforms electrical energy into mechanical energy and work.</p>
<p>Science and Engineering Practice</p>	<p>H.P.1A.2: <u>Develop, use, and refine models</u> to (1) understand or represent phenomena, processes, and relationships, (2) test devices or solutions, or (3) communicate ideas to others.</p> <p>H.P.1B.1: <u>Construct devices or design solutions</u> using scientific knowledge to solve specific problems or needs: (1) ask questions to identify problems or needs, (2) ask questions about the criteria and constraints of the device or solutions, (3) generate and communicate ideas for possible devices or solutions, (4) build and test devices or solutions, (5) determine if the devices or solutions solved the problem and refine the design if needed, and (6) communicate results.</p> <p>H.P.1A.6: <u>Construct explanations of phenomena</u> using (1) primary or secondary scientific evidence and models, (2) conclusions from scientific investigations, (3) predictions based on observations and measurements, or (4) data communicated in graphs, tables, or diagrams.</p>
<p>Crosscutting Concepts</p>	<p>The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6.</p> <p>Cause and Effect Systems and System Models Energy and Matter</p>

Essential Learning Experiences:

It is essential that students construct explanations that employ the following ideas:

- Electric motors change electrical energy to mechanical energy by running an electric current through coils to make an electromagnetic.
- Motors use magnets to push and pull other magnets and create motion.
- Motors use the magnetic force from magnets to spin an armature (usually an electromagnetic.)

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Measure the electrical energy used and the mechanical work done by the motor to calculate its efficiency.
- Spinning an electric motor will produce electric current, whereas running current through the motor will cause it to spin. This may be used to show the relationship between motors and generators.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 6.P.3: The student will demonstrate an understanding of the properties of energy, the transfer and conservation of energy, and the relationship between energy and forces.</p> <p>Chemistry Learning Connections: H.C.2 A .1: Obtain and communicate information to describe and compare subatomic particles with regard to mass, location, charge, electrical attractions and repulsions, and impact on the properties of an atom.</p>
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Interactions and Energy

Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.	
H.P.3F. Conceptual Understanding: Conceptual Understanding: During radiant energy interactions, energy can be transferred over long distances without a medium. Radiation can be modeled as an electromagnetic wave or as a stream of discrete packets of energy (photons); all radiation travels at the same speed in a vacuum (speed of light). This electromagnetic radiation is a major source of energy for life on Earth.	
Performance Indicator	H.P.3F.1: <u>Construct scientific arguments</u> that support the wave model of light and the particle model of light.
Science and Engineering Practice	H.P.1A.7: <u>Construct and analyze scientific arguments</u> to support claims, explanations, or designs using evidence and valid reasoning from observations, data, or informational texts.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Patterns Cause and Effect Systems and System Models

Essential Learning Experiences:

It is essential that students construct scientific arguments which demonstrate their understanding of the following:

- The unique nature of light gives it properties that resemble those of both waves and particles.
- The wave model of light specifies how light behaves like a wave, as exemplified by the characteristics of the electromagnetic spectrum. Light can experience the Doppler Effect and interference like other waves.
- The particle model of light explains how light can behave like any other object that has mass and takes up space (matter). Shadows can be described as examples supporting the particle model of light.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Understand the quantum theory and use the equation $E = hf$ where f is the frequency in hertz, h is Planck's constant, and E is energy expressed in joules.
- Explain how the interference pattern produced in the double slit experiment is evidence for light's wave nature.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 8.P.3: The student will demonstrate an understanding of the properties and behaviors of waves.</p> <p>Earth Science Learning Connections: H.E.2A.4: Construct and analyze scientific arguments to support claims about the origin of the universe (including the redshift of light from distant galaxies, the measured composition of stars and non-stellar gases, and the cosmic background radiation). H.E.2A.5: Obtain and evaluate information to describe how the use of x-ray, gamma-ray, radio, and visual (reflecting, refracting, and catadioptric) telescopes and computer modeling have increased the understanding of the universe.</p>
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Interactions and Energy

<p>Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.</p>	
<p>H.P.3F. Conceptual Understanding: Conceptual Understanding: During radiant energy interactions, energy can be transferred over long distances without a medium. Radiation can be modeled as an electromagnetic wave or as a stream of discrete packets of energy (photons); all radiation travels at the same speed in a vacuum (speed of light). This electromagnetic radiation is a major source of energy for life on Earth.</p>	
<p>Performance Indicator</p>	<p>H.P.3F.2: <u>Plan and conduct controlled scientific investigations</u> to determine the interaction between the visible light portion of the electromagnetic spectrum and various objects (including mirrors, lenses, barriers with two slits, and diffraction gratings) and to construct explanations of the behavior of light (reflection, refraction, transmission, interference) in these instances using models (including ray diagrams).</p>
<p>Science and Engineering Practice</p>	<p>H.P.1A.3: <u>Plan and conduct controlled scientific investigations</u> to answer questions, test hypotheses, and develop explanations: (1) formulate scientific questions and testable hypotheses based on credible scientific information, (2) identify materials, procedures, and variables, (3) use appropriate laboratory equipment, technology, and techniques to collect qualitative and quantitative data, and (4) record and represent data in an appropriate form. Use appropriate safety procedures.</p> <p>H.P.1A.6: <u>Construct explanations of phenomena</u> using (1) primary or secondary scientific evidence and models, (2) conclusions from scientific investigations, (3) predictions based on observations and measurements, or (4) data communicated in graphs, tables, or diagrams.</p>
<p>Crosscutting Concepts</p>	<p>The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6.</p> <p>Cause and Effect Systems and System Models Structure and Function</p>

Essential Learning Experiences:

It is essential that students plan and conduct scientific investigations of the behavior of light as it encounters different media, obstacles, and/or openings.

- The behaviors of a wave are influenced by a number of factors. Some of these factors may include mirrors, lenses, barriers with two slits, and diffraction gratings.
- Ray diagrams may be created to show the path that light travels as it interacts with the factors listed above.

- Some of the behaviors that light exhibits can include reflection, refraction, transmission and interference.
- Transmission occurs when light passes through an object.
- Reflection occurs when light is cast back from a surface without being absorbed.
- The Law of Reflection states that the angle of incidence (measured between the incoming ray and the normal) is equal to the angle of reflection (measured between the reflected ray and the normal).
- Refraction occurs when light is bent as it passes from one medium to the next where the speeds of travel are different.
- When light passes from one transparent medium to another, it is refracted, but part of the incoming light is reflected back from the boundary between the media.
- Diffraction occurs when light bends around obstacles and/or openings.
- The degree to which waves are diffracted depends on the size of the opening in relation to the wavelength of the wave. Waves are diffracted to a greater degree when the width of the opening is closer to the wavelength.
- Interference occurs when waves traveling through the same medium interact to produce a combined wave with greater or lesser amplitude.
- Light passing on each side of an obstacle or through multiple openings results in diffracted rays which interfere with each other.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Distinguish how the energy, frequency, amplitude, wavelength, period, phase, and speed distinguish the specific types of electromagnetic radiation (radio waves, microwaves, infrared, visible light, ultraviolet, x-rays and gamma rays).
- Use Huygens' Principle to create models explaining the diffraction of waves.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

**Learning
Connections****Previous Learning Connections (6-8):**

8.P.3: The student will demonstrate an understanding of the properties and behaviors of waves.

Earth Science Learning Connections:

H.E.2A.4: Construct and analyze scientific arguments to support claims about the origin of the universe (including the redshift of light from distant galaxies, the measured composition of stars and non-stellar gases, and the cosmic background radiation).

H.E.2A.5: Obtain and evaluate information to describe how the use of x-ray, gamma-ray, radio, and visual (reflecting, refracting, and catadioptric) telescopes and computer modeling have increased the understanding of the universe.

Interactions and Energy

Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.	
H.P.3F. Conceptual Understanding: Conceptual Understanding: During radiant energy interactions, energy can be transferred over long distances without a medium. Radiation can be modeled as an electromagnetic wave or as a stream of discrete packets of energy (photons); all radiation travels at the same speed in a vacuum (speed of light). This electromagnetic radiation is a major source of energy for life on Earth.	
Performance Indicator	H.P.3F.3: Use drawings to exemplify the behavior of light passing from one transparent medium to another and construct explanations for this behavior.
Science and Engineering Practice	H.P.1A.2: <u>Develop, use, and refine models</u> to (1) understand or represent phenomena, processes, and relationships, (2) test devices or solutions, or (3) communicate ideas to others.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Cause and Effect Systems and System Models Energy and Matter

Essential Learning Experiences:

It is essential that students use models to demonstrate their understanding of Snell's Law, and how to find an image produced by a lens.

- Refraction is the bending of light when it passes from one media to another. In a diagram of refraction, arrows represent light rays.
- The incoming ray is referred to as the incident ray. The angle of incidence (θ_i) is the angle between the incident ray and the normal.
- The angle of refraction (θ_r) is the angle between the refracted ray and the normal.
- Every material that light moves through has an index of refraction, which is determined by the way light moves through that medium. The higher the index, the slower light moves in that medium. When light slows down, the refracted ray bends towards the normal. When light speeds up, the refracted ray bends away from the normal.
- The relationship between the angles of incidence and refraction and the indices of refraction of the two media is known as Snell's Law. $n_1 \sin \theta_1 = n_2 \sin \theta_2$.
- Ray diagrams are used to locate an image produced by a lens. The intersection of two rays represents where the image is formed. Rays intersecting above the principle axis (PA) indicate that an image is erect. Rays meeting below the PA indicate an inverted image.
- A ray may be drawn from the top of the object straight thru the center of the lens.

- A ray may be drawn from the top of the object parallel to the principle axis. At the center of the lens this ray will converge through the focal point (converging lens) or diverge from the focal point (diverging lens.)
- A ray may be drawn from the top of the object through the focal point to the center of the lens and then runs parallel to the PA.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Understand the origin of Continuous, Emission, and Absorption Spectra

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	<p>Previous Learning Connections (6-8): 8.P.3: The student will demonstrate an understanding of the properties and behaviors of waves.</p> <p>Earth Science Learning Connections: H.E.2A.5: Obtain and evaluate information to describe how the use of x-ray, gamma-ray, radio, and visual (reflecting, refracting, and catadioptric) telescopes and computer modeling have increased the understanding of the universe.</p>
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Interactions and Energy

Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.	
H.P.3F. Conceptual Understanding: Conceptual Understanding: During radiant energy interactions, energy can be transferred over long distances without a medium. Radiation can be modeled as an electromagnetic wave or as a stream of discrete packets of energy (photons); all radiation travels at the same speed in a vacuum (speed of light). This electromagnetic radiation is a major source of energy for life on Earth.	
Performance Indicator	H.P.3F.4: <u>Use mathematical and computational thinking</u> to analyze problems that relate the frequency, period, amplitude, wavelength, velocity, and energy of light.
Science and Engineering Practice	H.P.1A.5: <u>Use mathematical and computational thinking</u> to (1) use and manipulate appropriate English and metric units, (2) express relationships between variables for models and investigations, or (3) use grade-level appropriate statistics to analyze data.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Cause and Effect Scale, Proportion, and Quantity

Essential Learning Experiences:

It is essential that students use mathematical and computational thinking that employs the following to solve problems.

- Amplitude is a measure of the maximum displacement of a particle from its position of equilibrium. Amplitude and energy are directly related.
- Wavelength, (λ) is the distance between two consecutive crests or two consecutive troughs and is measured in meters.
- Frequency, (f), refers to the number of waves that pass a point in a given period of time and is measured in hertz (cycles/second).
- Period, (T), is the time for one wave to pass a point and is measured in seconds.
- Frequency and period are inverses of one another. ($T = 1/f$ and $f = 1/T$)
- The speed, (v), of a sound wave is equal to frequency times wavelength. ($v = f\lambda$)
- Light is an electromagnetic wave and, as such, does not require a medium.

NOTE TO TEACHER:

- Wavelength can be measured from any point on a wave to the corresponding point on the next wave. It is commonly measured crest-to-crest or trough-to-trough because these points are easy to identify consistently.

- Hertz is interpreted as cycles/second or waves/second, but in mathematical solutions the unit Hz is equivalent to a “per second” or 1/second (also written s^{-1}).

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Period and wavelength can be plotted on a graph whose slope will give wave speed.
- Frequency of visible light waves indicates color.
- Amplitude of visible light waves indicates brightness.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

[https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete 2014SEPsGuide_SupportDoc2_0.pdf](https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete%2014SEPsGuide_SupportDoc2_0.pdf)

Learning Connections	<p>Previous Learning Connections (6-8): 8.P.3: The student will demonstrate an understanding of the properties and behaviors of waves.</p> <p>Earth Science Learning Connections: H.E.6A.8: Develop and use models to describe how waves and currents interact with the ocean shore.</p>
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Interactions and Energy

Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.	
H.P.3F. Conceptual Understanding: Conceptual Understanding: During radiant energy interactions, energy can be transferred over long distances without a medium. Radiation can be modeled as an electromagnetic wave or as a stream of discrete packets of energy (photons); all radiation travels at the same speed in a vacuum (speed of light). This electromagnetic radiation is a major source of energy for life on Earth.	
Performance Indicator	H.P.3F.5: <u>Obtain information to communicate</u> the similarities and differences among the different bands of the electromagnetic spectrum (including radio waves, microwaves, infrared, visible light, ultraviolet, and gamma rays) and give examples of devices or phenomena from each band.
Science and Engineering Practice	H.P.1A.8: <u>Obtain and evaluate scientific information</u> to (1) answer questions, (2) explain or describe phenomena, (3) develop models, (4) evaluate hypotheses, explanations, claims, or designs or (5) identify and/or fill gaps in knowledge. <u>Communicate</u> using the conventions and expectations of scientific writing or oral presentations by (1) evaluating grade-appropriate primary or secondary scientific literature, or (2) reporting the results of student experimental investigations.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Patterns Systems and System Models

Essential Learning Experiences:

It is essential that students obtain the following information:

- All electromagnetic waves travel at the speed of light in a vacuum.
- The type of EM waves depends on the wavelength or frequency of the radiation.
- Radio waves have the longest wavelength and the lowest frequency.
- Gamma waves are the shortest, have the greatest frequency and greatest energy.
- Visible light is made of all colors and the only ones humans are sensitive to.
- The order of EM waves from longest to shortest are: radio, microwave, infrared, visible, ultraviolet, X-ray, and gamma.
- All EM waves have properties (speed, period, wavelength, frequency, amplitude)
- All EM waves behave similarly (diffract, interfere, refract, reflect)

- There are two atmospheric windows for EM waves: radio and visible light reach the ground.
 - Infrared is stopped by water vapor in clouds and ultraviolet by ozone.
 - The other forms are stopped by Earth's atmosphere.

NOTE TO TEACHER: White light is not one color of light, but the interpretation of the human eye when it receives all colors.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Discuss ground versus space based telescopes.
- Discuss why microwaves excite water molecules in food resulting in heating.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

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Learning Connections	<p>Previous Learning Connections (6-8): 8.P.3: Light The student will demonstrate an understanding of the properties and behaviors of waves.</p> <p>Earth Science Learning Connections: H.E.2A.5: Obtain and evaluate information to describe how the use of x-ray, gamma-ray, radio, and visual (reflecting, refracting, and catadioptric) telescopes and computer modeling have increased the understanding of the universe.</p>
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Interactions and Energy

<p>Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.</p>	
<p>H.P.3F. Conceptual Understanding: Conceptual Understanding: During radiant energy interactions, energy can be transferred over long distances without a medium. Radiation can be modeled as an electromagnetic wave or as a stream of discrete packets of energy (photons); all radiation travels at the same speed in a vacuum (speed of light). This electromagnetic radiation is a major source of energy for life on Earth.</p>	
<p>Performance Indicator</p>	<p>H.P.3F.6: <u>Obtain information to construct explanations</u> on how waves are used to produce, transmit, and capture signals and store and interpret information (including ultrasound imaging, telescopes, cell phones, and barcode scanners).</p>
<p>Science and Engineering Practice</p>	<p>H.P.1A.8: <u>Obtain and evaluate scientific information</u> to (1) answer questions, (2) explain or describe phenomena, (3) develop models, (4) evaluate hypotheses, explanations, claims, or designs or (5) identify and/or fill gaps in knowledge. Communicate using the conventions and expectations of scientific writing or oral presentations by (1) evaluating grade-appropriate primary or secondary scientific literature, or (2) reporting the results of student experimental investigations.</p> <p>H.P.1A.6: <u>Construct explanations of phenomena</u> using (1) primary or secondary scientific evidence and models, (2) conclusions from scientific investigations, (3) predictions based on observations and measurements, or (4) data communicated in graphs, tables, or diagrams.</p>
<p>Crosscutting Concepts</p>	<p>The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6.</p> <p>Patterns Cause and Effect Systems and System Models Energy and Matter</p>

Essential Learning Experiences:

It is essential that students obtain information to construct explanations for:

- Optical devices depend on the laws of reflection and refraction.
- The function of the lens in the eye and that of the telescope work in similar ways.
- Electromagnetic radiation has a myriad of uses such as bar code scanners, and/or cell phones.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Students may obtain, evaluate and communicate information regarding the magnification of telescopes and microscopes.

Assessment Guidelines:

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[https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete 2014SEPsGuide_SupportDoc2_0.pdf](https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete%202014SEPsGuide_SupportDoc2_0.pdf)

Learning Connections	<p>Previous Learning Connections (6-8): 8.P.3: The student will demonstrate an understanding of the properties and behaviors of waves.</p> <p>Earth Science Learning Connections: H.E.2A.5: Obtain and evaluate information to describe how the use of x - ray, gamma - ray, radio, and visual (reflecting, refracting, and catadioptric) telescopes and computer modeling have increased the understanding of the universe.</p>
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Interactions and Energy

Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.	
H.P.3G. Conceptual Understanding: Conceptual Understanding: Nuclear energy is energy stored in an atom's nucleus; this energy holds the atom together and is called binding energy. Binding energy is a reflection of the equivalence of mass and energy; the mass of any nucleus is always less than the sum of the masses of the individual constituent nucleons that comprise it. Binding energy is also a measure of the strong nuclear force that exists in the nucleus and is responsible for overcoming the repulsive forces among protons. The strong and weak nuclear forces, gravity, and the electromagnetic force are the fundamental forces in nature. Strong and weak nuclear forces determine nuclear sizes, stability, and rates of radioactive decay. At the subatomic scale, the conservation of energy becomes the conservation of mass-energy.	
Performance Indicator	H.P.3G.1: <u>Develop and use models</u> to represent the basic structure of an atom (including protons, neutrons, electrons, and the nucleus)
Science and Engineering Practice	H.P.1A.2: <u>Develop, use, and refine models</u> to (1) understand or represent phenomena, processes, and relationships, (2) test devices or solutions, or (3) communicate ideas to others.
Crosscutting Concepts	<p>The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6.</p> <p>Scale, Proportion, and Quantity Systems and System Models Structure and Function</p>

Essential Learning Experiences:

It is essential that students develop and use models that demonstrate understanding of the following concepts:

- The atom is composed of subatomic particles (protons, neutrons, and electrons) that affect the properties of an atom.
- Protons and neutrons have about the same mass (but not exactly - students do not need to know the amount by which they differ).
- The mass of an electron is much less than the mass of protons and neutrons.
- Protons have a positive charge.
- Neutrons are neutral in charge.
- The net charge of the nucleus is positive and equal to the number of protons.
- Electrons have a negative charge.
- There is an attractive force between electrons and protons.
- Atoms are neutrally charged because the number of electrons is the same as the number of protons.
- Protons and neutrons are tightly bound in a tiny nucleus.

- The nucleus is located in the center of an electron cloud.
- The electron cloud is the space where electrons are moving erratically in areas of space called energy levels.
- Energy levels are regions of space at increasing distances from the nucleus.
- Electrons with more energy occupy energy levels further from the nucleus. There are a maximum number of electrons that can occupy each energy level and that number increases the further the energy level is from the nucleus.
- The nucleus consists of protons and neutrons and that there is a repulsive force between the protons; likewise, there is a repulsive force between electrons.

NOTE TO TEACHER: Electron orbitals and energy levels are not paths that electrons follow like lanes on a highway. Orbitals within each energy level describe areas where there is a high probability of finding the electron.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Write balanced nuclear equations representing alpha and beta decay reactions.

Assessment Guidelines:

Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:

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Learning Connections	<p>Previous Learning Connections (6-8): 7.P.2: The student will demonstrate an understanding of the structure and properties of matter and that matter is conserved as it undergoes changes.</p> <p>Chemistry Learning Connections: H.C.2: The student will demonstrate an understanding of atomic structure and nuclear processes.</p>
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Interactions and Energy

Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.	
H.P.3G. Conceptual Understanding: Conceptual Understanding: Nuclear energy is energy stored in an atom's nucleus; this energy holds the atom together and is called binding energy. Binding energy is a reflection of the equivalence of mass and energy; the mass of any nucleus is always less than the sum of the masses of the individual constituent nucleons that comprise it. Binding energy is also a measure of the strong nuclear force that exists in the nucleus and is responsible for overcoming the repulsive forces among protons. The strong and weak nuclear forces, gravity, and the electromagnetic force are the fundamental forces in nature. Strong and weak nuclear forces determine nuclear sizes, stability, and rates of radioactive decay. At the subatomic scale, the conservation of energy becomes the conservation of mass-energy.	
Performance Indicator	H.P.3G.2: <u>Develop and use models</u> (such as drawings, diagrams, computer simulations, and demonstrations) to communicate the similarities and differences between fusion and fission. Give examples of fusion and fission reactions and include the concept of conservation of mass-energy.
Science and Engineering Practice	H.P.1A.2: <u>Develop, use, and refine models</u> to (1) understand or represent phenomena, processes, and relationships, (2) test devices or solutions, or (3) communicate ideas to others.
Crosscutting Concepts	<p>The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6.</p> <p>Scale, Proportion, and Quantity Systems and System Models Energy and Matter</p>

Essential Learning Experiences:

It is essential that students develop and use models to compare fusion and fission. The essential background knowledge is outlined below.

- Nuclear reactions involve the particles in the nucleus of the atom (as opposed to chemical reactions, which involve the electrons in an atom and where the nucleus remains intact).
- There is a great deal more energy change involved in nuclear reactions than in chemical reactions.
- Nuclear Fission
 - Nuclear fission occurs when a heavy nucleus, such as the U-235 nucleus, splits into two or more parts, and a large amount of energy is released. The penetration of a large nucleus (such as U- 235) by a neutron is one way to initiate a fission reaction. When an atom with a large nucleus undergoes fission, atoms that have

smaller nuclei result. In the process smaller particles such as neutrons may be ejected from the splitting nucleus. If one or more ejected neutron strikes another U-235 nucleus, another fission reaction may occur. The continuation of this process is called a chain reaction. There must be a certain critical mass of fissionable material in close proximity for a chain reaction to occur.

- Fission is the type of nuclear reaction that occurs in nuclear power plants and other nuclear applications (weapons, submarines, etc.)
- The mass of the products of a fission reaction is less than the mass of the reactants. This lost mass (m) is converted into energy (E). The equation $E = mc^2$ shows the relationship of this “lost mass” to the energy released. The conversion of mass to energy during a nuclear reaction involves far more energy than the amount of energy involved in a chemical reaction. (It is not essential for students to use this equation.)
- Nuclear Fusion
 - Nuclear fusion occurs when light nuclei (such as hydrogen) fuse, or combine, to form a larger single nucleus (such as helium).
 - In fusion reactions the mass of the products is less than the mass of the reactants and the “lost mass” is converted to energy.
 - Fusion is the type of nuclear reaction that occurs on the sun (and other stars).
 - Forcing small nuclei to fuse requires huge amounts of energy; however, when fusion reactions occur on the sun, more energy is released than the amount of energy required to produce the reaction.
 - Using fusion for human applications is still in the developmental stage.
- The total mass of a nucleus is always less than the sum of the masses of its nucleons.
 - Because mass is another manifestation of energy, the total energy of the bound system (the nucleus) is less than the combined energy of the separated nucleons.
- This difference in (mass equivalent) energy is called the binding energy of the nucleus and can be thought of as the energy that must be added to a nucleus to break it apart into its components.
 - In order to separate a nucleus into protons and neutrons energy must be put into the system.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Write and balance nuclear equations representing fission and fusion reactions.

Assessment Guidelines:

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Learning Connections	<p>Previous Learning Connections (6-8): 7.P.2: The student will demonstrate an understanding of the structure and properties of matter and that matter is conserved as it undergoes changes.</p> <p>Chemistry Learning Connections: H.C.2: The student will demonstrate an understanding of atomic structure and nuclear processes.</p> <p>Earth Science Learning Connections: H.E.2A.3: Construct explanations for how elements are formed using evidence from nuclear fusion occurring within stars and/or supernova explosions.</p>
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Interactions and Energy

Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.	
H.P.3G. Conceptual Understanding: Conceptual Understanding: Nuclear energy is energy stored in an atom's nucleus; this energy holds the atom together and is called binding energy. Binding energy is a reflection of the equivalence of mass and energy; the mass of any nucleus is always less than the sum of the masses of the individual constituent nucleons that comprise it. Binding energy is also a measure of the strong nuclear force that exists in the nucleus and is responsible for overcoming the repulsive forces among protons. The strong and weak nuclear forces, gravity, and the electromagnetic force are the fundamental forces in nature. Strong and weak nuclear forces determine nuclear sizes, stability, and rates of radioactive decay. At the subatomic scale, the conservation of energy becomes the conservation of mass-energy.	
Performance Indicator	H.P.3G.3: <u>Construct scientific arguments</u> to support claims for or against the viability of fusion and fission as sources of usable energy.
Science and Engineering Practice	H.P.1A.7: <u>Construct and analyze scientific arguments</u> to support claims, explanations, or designs using evidence and valid reasoning from observations, data, or informational texts.
Crosscutting Concepts	<p>The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6.</p> <p>Cause and Effect Scale, Proportion, and Quantity Systems and System Models Energy and Matter</p>

Essential Learning Experiences:

It is essential that students construct scientific arguments that demonstrate an understanding of the advantages and disadvantages of each.

Nuclear Fission

Advantages

- Relatively little fuel is needed, and the fuel is relatively inexpensive and available in trace amounts around the world.
- Fission is not believed to contribute to global warming or other pollution effects associated with fossil fuel combustion
- Fission plants exist - the technology to employ fission to produce electricity is available.

Disadvantages

- Possibility of nuclear meltdown from uncontrolled reaction--leads to nuclear fallout with potentially harmful effects on civilians

- Waste products must be stored safely for long periods of time.
- Waste products can be used to manufacture weapons
- High initial cost because plant requires containment safeguards

Nuclear fusion

Advantages

- Abundance of fuel from ordinary water, land deposits or sea water
- No nuclear waste or possibility of a nuclear meltdown
- No air pollution

Disadvantages

- Economic feasibility of generating the extreme temperature for fusion to occur.
- Engineering challenges of containing the extreme temperatures necessary for fusion have yet to be solved.
- Fusion plants do not exist - the technology to employ fusion to produce electricity is not yet available.

NOTE TO TEACHER: Though fusion employs Hydrogen, which is a component of water, the Hydrogen isotopes needed are not the most common isotope; therefore, fuel is not as plentiful as water (common misconception).

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Use balanced nuclear equations and the concept of mass defect to determine the amount of energy given off during a fission or fusion reaction.

Assessment Guidelines:

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Learning Connections	<p>Previous Learning Connections (6-8): 7.P.2: The student will demonstrate an understanding of the structure and properties of matter and that matter is conserved as it undergoes changes.</p> <p>Chemistry Learning Connections: H.C.2: The student will demonstrate an understanding of atomic structure and nuclear processes.</p> <p>Earth Science Learning Connections: H.E.3B.2: Construct scientific arguments to support claims that responsible management of natural resources is necessary for the sustainability of human societies and the biodiversity that supports them.</p>
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Interactions and Energy

<p>Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.</p>	
<p>H.P.3G. Conceptual Understanding: Conceptual Understanding: Nuclear energy is energy stored in an atom's nucleus; this energy holds the atom together and is called binding energy. Binding energy is a reflection of the equivalence of mass and energy; the mass of any nucleus is always less than the sum of the masses of the individual constituent nucleons that comprise it. Binding energy is also a measure of the strong nuclear force that exists in the nucleus and is responsible for overcoming the repulsive forces among protons. The strong and weak nuclear forces, gravity, and the electromagnetic force are the fundamental forces in nature. Strong and weak nuclear forces determine nuclear sizes, stability, and rates of radioactive decay. At the subatomic scale, the conservation of energy becomes the conservation of mass-energy.</p>	
<p>Performance Indicator</p>	<p>H.P.3G.4: Use <u>mathematical and computational thinking</u> to predict the products of radioactive decay (including alpha, beta, and gamma decay).</p>
<p>Science and Engineering Practice</p>	<p>H.P.1A.5: Use <u>mathematical and computational thinking</u> to (1) use and manipulate appropriate English and metric units, (2) express relationships between variables for models and investigations, or (3) use grade-level appropriate statistics to analyze data.</p>
<p>Crosscutting Concepts</p>	<p>The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6.</p> <p>Patterns Cause and Effect Systems and System Models Stability and Change</p>

Essential Learning Experiences:

It is essential that students use mathematical and computational thinking as outlined below to predict radioactive decay products.

- A beta decay results when a neutron transforms into a proton and a beta particle.
- An alpha particle is a helium nucleus that consists of two neutrons and two protons.
- Isotopes from an alpha or beta decay can be predicted when told which type of decay will occur. It not essential that students understand neutrino or antineutrino emissions that may occur with beta decay.
- After a nucleus undergoes a radioactive decay it is often left in an excited state. The nucleus may undergo a second decay to a lower energy state by emitting one or more photons. The photons emitted in such a de-excitation process are called gamma rays which have a very high energy relative to the energy of visible light.
- Gamma emissions that come from excited nuclei do not change the identity of the isotope.

- Nuclear equations are balanced when given all of the particles on both sides of the equation. As a general rule: The sum of the mass numbers “A” must be the same on both sides of the equation. The sum of the atomic numbers “Z” must be the same on both sides of the equation.
- A beta decay results when a neutron transforms into a proton and a beta particle.
- An alpha particle is a helium nucleus which consists of two neutrons and two protons.
- Isotopes are transmuted into new isotopes through alpha and beta decay.
- A substance’s half-life is defined as the amount of time required for half the particles of the substance to go through spontaneous decay.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Write and balance nuclear equations representing radioactive decay.

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Learning Connections	<p>Previous Learning Connections (6-8): 7.P.2: The student will demonstrate an understanding of the structure and properties of matter and that matter is conserved as it undergoes changes.</p> <p>Chemistry Learning Connections: H.C.2: The student will demonstrate an understanding of atomic structure and nuclear processes.</p> <p>Earth Science Learning Connections: H.E.4A.5: Develop and use models of various dating methods (including index fossils, ordering of rock layers, and radiometric dating) to estimate geologic time. H.E.4A.6: Use mathematical and computational thinking to calculate the age of Earth materials using isotope ratios (actual or simulated).</p>
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Interactions and Energy

<p>Standard H.P.3: The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.</p>	
<p>H.P.3G. Conceptual Understanding: Conceptual Understanding: Nuclear energy is energy stored in an atom’s nucleus; this energy holds the atom together and is called binding energy. Binding energy is a reflection of the equivalence of mass and energy; the mass of any nucleus is always less than the sum of the masses of the individual constituent nucleons that comprise it. Binding energy is also a measure of the strong nuclear force that exists in the nucleus and is responsible for overcoming the repulsive forces among protons. The strong and weak nuclear forces, gravity, and the electromagnetic force are the fundamental forces in nature. Strong and weak nuclear forces determine nuclear sizes, stability, and rates of radioactive decay. At the subatomic scale, the conservation of energy becomes the conservation of mass-energy.</p>	
<p>Performance Indicator</p>	<p>H.P.3G.5: <u>Obtain information to communicate</u> how radioactive decay processes have practical applications (such as food preservation, cancer treatments, fossil and rock dating, and as radioisotopic medical tracers).</p>
<p>Science and Engineering Practice</p>	<p>H.P.1A.8: <u>Obtain and evaluate scientific information</u> to (1) answer questions, (2) explain or describe phenomena, (3) develop models, (4) evaluate hypotheses, explanations, claims, or designs or (5) identify and/or fill gaps in knowledge. <u>Communicate</u> using the conventions and expectations of scientific writing or oral presentations by (1) evaluating grade-appropriate primary or secondary scientific literature, or (2) reporting the results of student experimental investigations.</p>
<p>Crosscutting Concepts</p>	<p>The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6.</p> <p>Cause and Effect Systems and System Models</p>

Essential Learning Experiences:

It is essential that students understand the identified radioactive decay processes in the indicator and other practical applications of radioactive decay processes.

Nuclear medicine

- Radioactive materials are used in medical technologies.
 - Using radiation that results from the decay of certain isotopes to destroy targeted cells, such as cancer cells.
 - Cells are most susceptible to damage from radiation during the process of cell division. As cancer cells divide at a very fast rate, they are destroyed in greater numbers than normal cells, which divide less often.

- Using the radiation that results from the decay of certain isotopes as a way of mapping the path of various substances through targeted organ systems. Most substances that naturally pass through specific body systems can be “spiked” with radioactive samples of the same substances. The radioactivity can then be traced (using a Geiger counter or with photographic film) as the “spiked” substance naturally makes its way through the targeted body system thus revealing how the body system is functioning. In this manner, the natural functioning of the body system can be observed.

Food Preservation

- Food irradiation is a technology for food preservation through which bacteria and other pathogens that could result in spoilage or food poisoning are destroyed through ionizing radiation.
 - Ionizing radiation utilizes high energy to break chemical bonds in molecules that are vital for cell growth and integrity. Breaking chemical bonds with radiation is known as radiolysis.
- Food irradiation is also called "cold pasteurization" or "irradiation pasteurization."
- The type of food and the specific purpose of the irradiation determine the amount of radiation, or dose, necessary to process a particular product.
- Cobalt-60 is the most commonly used radionuclide for food irradiation.
 - Cobalt-60 emits ionizing radiation in the form of intense gamma rays.
 - The advantages of Cobalt-60 include:
 - up to 95% of its emitted energy is available for use
 - penetrates deeply
 - yields substantial uniformity of the dose in the food product
 - decays to non-radioactive nickel
 - considered to pose low risk to the environment
 - The main disadvantage of Cobalt-60 is its 5.3-year half-life which requires frequent replenishment of the radioactive isotope and causes the treatment of the food to be relatively slow.

Fossil and Rock Dating

- Materials that were once living or composed of living materials can be dated using carbon-14 which has a half-life of 5,700 years.
- As long as an organism is alive, the ratio of carbon-14 to carbon-12 remains stable.
- When a living organism dies, it ceases exchanging carbon with the environment. As the carbon-14 decays, the ratio of carbon-14 to carbon-12 gets smaller.
- By measuring this ratio, an archaeologist can determine how long it has been since the material has been alive since one half of the atoms decay during every time interval of one half-life.
- Rocks may be dated through potassium-argon dating which involves electron capture or positron decay of potassium-40 to argon-40.
 - Potassium-40 has a half-life of 1.3 billion years, and so this method is applicable to the oldest rocks.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Students may obtain, evaluate and communicate information regarding other fossil or rock dating methods.
- Students may also construct scientific arguments using evidence regarding the advantages and disadvantages of additional food irradiation methods.

Assessment Guidelines:

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Learning Connections	<p>Previous Learning Connections (6-8) 7.P.2: The student will demonstrate an understanding of the structure and properties of matter and that matter is conserved as it undergoes changes.</p> <p>Chemistry Learning Connections: H.C.2: The student will demonstrate an understanding of atomic structure and nuclear processes.</p> <p>Earth Science Learning Connections: H.E.4A.5: Develop and use models of various dating methods (including index fossils, ordering of rock layers, and radiometric dating) to estimate geologic time. H.E.4A.6: Use mathematical and computational thinking to calculate the age of Earth materials using isotope ratios (actual or simulated).</p>
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