SUPPORT GUIDE
FOR PHYSICS 1
SOUTH CAROLINA ACADEMIC STANDARDS AND PERFORMANCE INDICATORS FOR SCIENCE



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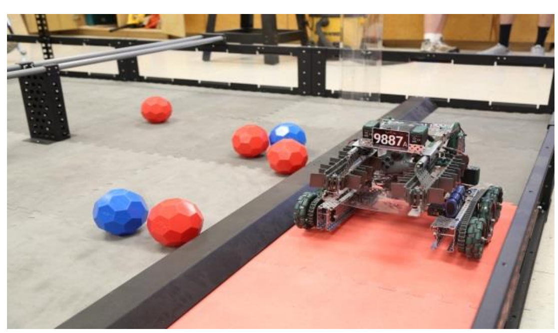

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INTRODUCTION TO PHYSICS 1 STANDARDS

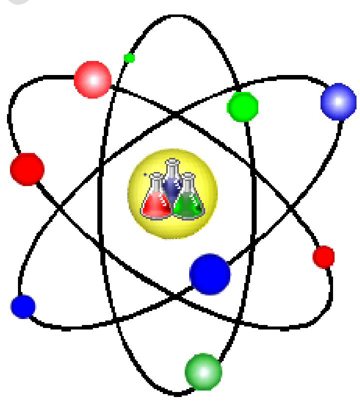
Science is a way of understanding the physical universe using observation and experimentation to explain natural phenomena. Science also refers to an organized body of knowledge that includes core ideas to the disciplines and common themes that bridge the disciplines. This document, *South Carolina Academic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

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.

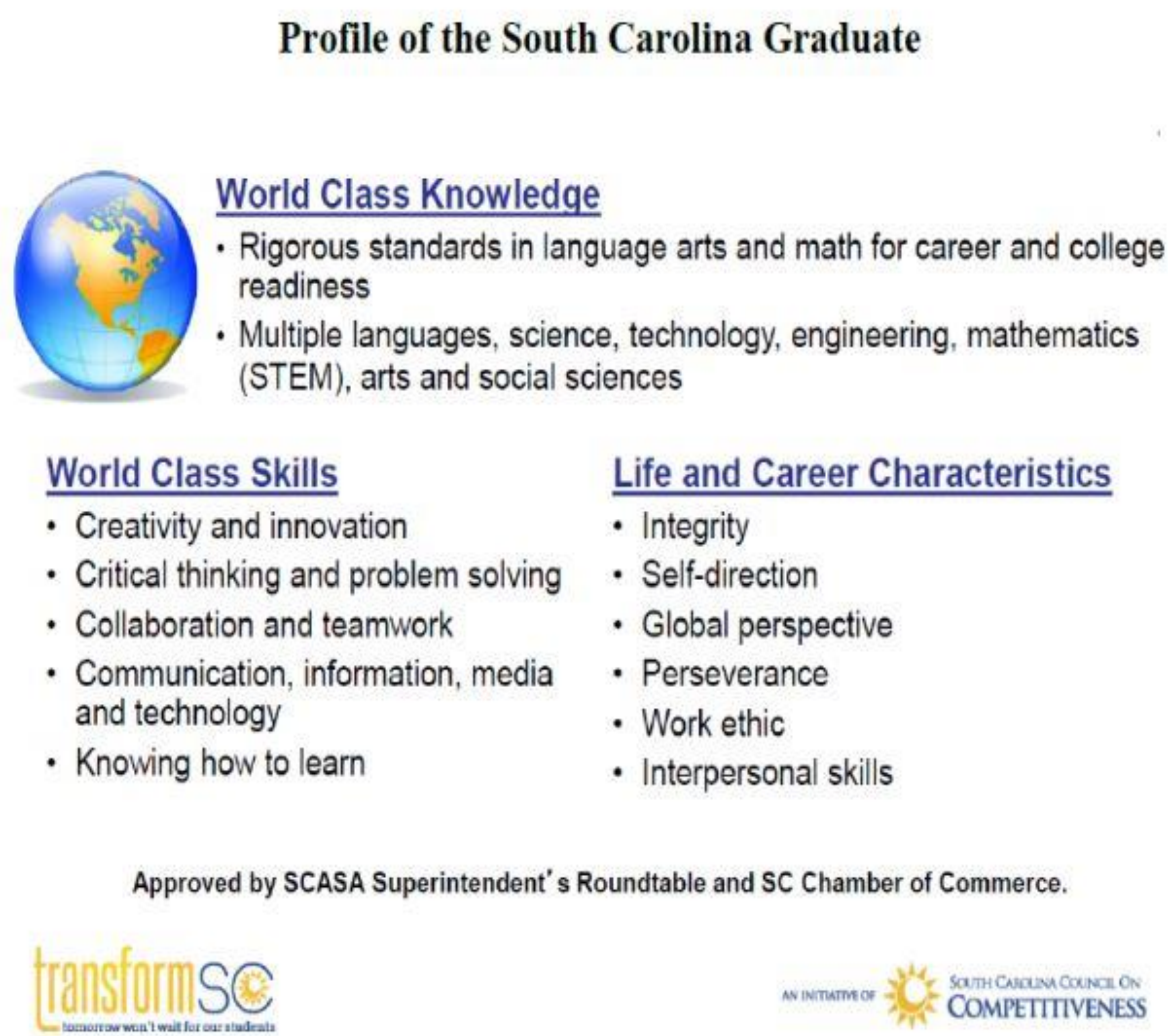
Operating procedures for the review and revision of all South Carolina academic standards were jointly developed by staff at the State Department of Education (SCDE) and the Education Oversight Committee (EOC). According to these procedures, a field review of the first draft of the revised South Carolina 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

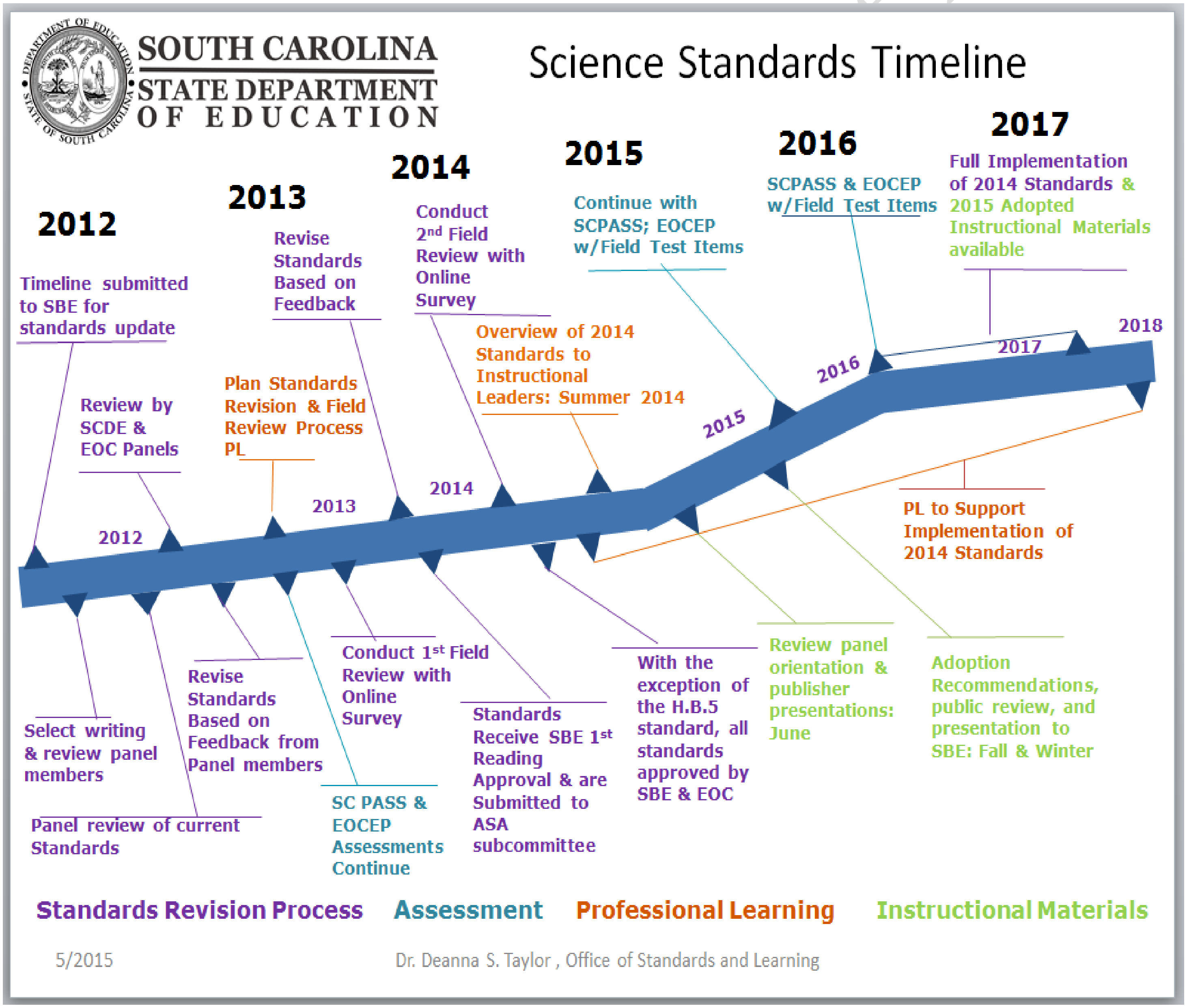
The *2014 South Carolina Academic Standards and Performance Indicators for Science* support the *Profile of the South Carolina Graduate. The Profile of the South Carolina Graduate* has been adopted and approved by the South Carolina Association of School Administrators (SCASA), the South Carolina Chamber 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.



SCIENCE STANDARDS TIMELINE

This timeline is used to illustrate the timeline for the standards revisions process, student assessment administration, provision of professional learning and the review and adoption of instructional materials. This timeline may be used with the science academic standards, science and engineering support document, and grade/content support documents to assist local districts, schools and teachers as they 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 timeline in this document does not offer a sequence for instruction and do not prescribe classroom activities; materials; or instructional strategies, approaches, or practices. The *Science Standards Timeline*, is not a curriculum.



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.

Science and Engineering Practices

In addition to the academic standards, each grade level or high school course explicitly identifies S*cience 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--- http://tinyurl.com/2014SCScience.

DECIPHERING THE STANDARDS

KINDERGARTEN
LIFE SCIENCE: EXPLORING ORGANISMS AND THE ENVIRONMENT

Standard K.L.2: The student will demonstrate an understanding of organisms found in the environment and how these organisms depend on the environment to meet those needs.

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).

K.L.2A.2 Conduct structured investigations to determine what plants need to live and grow (including water and light).

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

- **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.

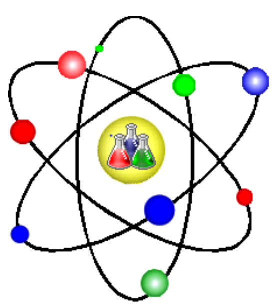
- **A: After the specific content standard, the conceptual understanding is denoted by an uppercase letter.** The conceptual understanding is a statement of the core idea for which students should demonstrate understanding. There may be more than one conceptual understanding per academic standard. The 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 PHYSICS 1

The two core areas of the Physics 1 standards include:

- Interactions and Forces: Patterns of Linear Motion; Forces and Changes in Motion; Interactions and Contact Forces; Interactions and Noncontact Forces and Fields
- Interactions and Energy: Conservation and Energy Transfer and Work; Mechanical Energy; Thermal Energy; Sound, Electricity and Magnetism; Radiation; Nuclear Energy



PHYSICS 1
SCIENCE AND ENGINEERING PRACTICES

NOTE: Scientific investigations should always be done in the context of content knowledge expected in this course. The standard describes how students should learn and demonstrate knowledge of the content outlined in the other standards.

Standard H.P.1: The student will use the science and engineering practices, including the processes and skills of scientific inquiry, to develop understandings of science content.

H.P.1A. Conceptual Understanding: The practices of science and engineering support the development of science concepts, develop the habits of mind that are necessary for scientific thinking, and allow students to engage in science in ways that are similar to those used by scientists and engineers.

Performance Indicators: Students who demonstrate this understanding can:

H.P.1A.1 Ask questions to (1) generate hypotheses for scientific investigations, (2) refine models, explanations, or designs, or (3) extend the results of investigations or challenge scientific arguments or claims.

H.P.1A.2 Develop, use, and refine models to (1) understand or represent phenomena, processes, and relationships, (2) test devices or solutions, or (3) communicate ideas to others.

H.P.1A.3 Plan and conduct controlled scientific investigations 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.

H.P.1A.4 Analyze and interpret data 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.

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 investigations, or (3) use grade-level appropriate statistics to analyze data.

H.P.1A.6 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.

H.P.1A.7 Construct and analyze scientific arguments to support claims, explanations, or designs using evidence and valid reasoning from observations, data, or informational texts.

H.P.1A.8 Obtain and evaluate scientific information 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.

H.P.1B. Conceptual Understanding: Technology is any modification to the natural world created to fulfill the wants and needs of humans. The engineering design process involves a series of iterative steps used to solve a problem and often leads to the development of a new or improved technology.

Performance Indicators: Students who demonstrate this understanding can:

H.P.1B.1 Construct devices or design solutions 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 the results.

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 Indicators: Students who demonstrate this understanding can:

H.P.2A.1 Plan and conduct controlled scientific investigations 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.

H.P.2A.2 Construct explanations for an object's change in motion using one-dimensional vector addition.

H.P.2A.3 Use mathematical and computational thinking 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.

H.P.2A.4 Develop and use models to represent an object's displacement, velocity, and acceleration (including vector diagrams, data tables, motion graphs, dot motion diagrams, and mathematical formulas).

H.P.2A.5 Construct explanations 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).

H.P.2A.6 Obtain information 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.

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 Indicators: Students who demonstrate this understanding can:

H.P.2B.1 Plan and conduct controlled scientific investigations 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, $F_{net} = ma$) and analyze collected data to construct an explanation of the object's motion using Newton's second law of motion.

H.P.2B.2 Use a free-body diagram to represent the forces on an object.

H.P.2B.3 Use Newton's Third Law of Motion to construct explanations 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.

H.P.2B.4 Use mathematical and computational thinking to derive the relationship between impulse and Newton's Second Law of Motion.

H.P.2B.5 Plan and conduct controlled scientific investigations to support the Law of Conservation of Momentum in the context of two objects moving linearly (p=mv).

H.P.2B.6 Construct scientific arguments 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.

H.P.2B.7 Apply physics principles to design a device that minimizes the force on an object during a collision and construct an explanation for the design.

H.P.2B.8 Develop and use models (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.

H.P.2B.9 Construct explanations for the practical applications of torque (such as a see-saw, bolt, wrench, and hinged door).

H.P.2B.10 Obtain information to communicate physical situations in which Newton's Second Law of Motion does not apply.

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 Indicators: Students who demonstrate this understanding can:

H.P.2C.1 Use a free-body diagram to represent the normal, tension (or elastic), applied, and frictional forces on an object.

H.P.2C.2 Plan and conduct controlled scientific investigations to determine the variables that could affect the kinetic frictional force on an object.

H.P.2C.3 Obtain and evaluate information to compare kinetic and static friction.

H.P.2C.4 Analyze and interpret data 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*.

H.P.2C.5 Use mathematical and computational thinking to apply F_{net} = ma to analyze problems involving contact interactions and gravity.

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 Indicators: Students who demonstrate this understanding can:

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.

H.P.2D.2 Use mathematical and computational thinking 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, $F=Gm_1m_2/r^2$).

H.P.2D.3 Obtain information to communicate 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.

H.P.2D.4 Use mathematical and computational thinking 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. $F=kq_1q_2/r^2$).

H.P.2D.5 Construct explanations 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.

H.P.2D.6 Use a free-body diagram to represent the gravitational force on an object.

H.P.2D.7 Use a free-body diagram to represent the electrical force on a charge.

H.P.2D.8 Develop and use models (such as computer simulations, drawings, or demonstrations) to explain the relationship between moving charged particles (current) and magnetic forces and fields.

H.P.2D.9 Use Newton's Law of Universal Gravitation and Newton's second law of motion to explain why all objects near Earth's surface have the same acceleration.

H.P.2D.10 Use mathematical and computational thinking to apply $F_{net} = ma$ to analyze problems involving non-contact interactions, including objects in free fall.

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 Indicators: Students who demonstrate this understanding can:

H.P.3A.1 Use mathematical and computational thinking to determine the work done by a constant force ($W=Fd$).

H.P.3A.2 Use mathematical and computational thinking to analyze problems dealing with the work done on or by an object and its change in energy.

H.P.3A.3 Obtain information to communicate how energy is conserved in elastic and inelastic collisions.

H.P.3A.4 Plan and conduct controlled scientific investigations to determine the power output of the human body.

H.P.3A.5 Obtain and communicate information to describe the efficiency of everyday machines (such as automobiles, hair dryers, refrigerators, and washing machines).

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 Indicators: Students who demonstrate this understanding can:

H.P.3B.1 Develop and use models (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.

H.P.3B.2 Use mathematical and computational thinking 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 ($KE = ½ mv^2$, $PE_g = mgh$, $PE_e = ½ kx^2$).

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).

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 Indicators: Students who demonstrate this understanding can:

H.P.3C.1 Plan and conduct controlled scientific investigations to determine the variables that affect the rate of heat transfer between two objects.

H.P.3C.2 Analyze and interpret data to describe the thermal conductivity of different materials.

H.P.3C.3 Develop and use models (such as a drawing or a small-scale greenhouse) to exemplify the energy balance of the Earth (including conduction, convection, and radiation).

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 Indicators: Students who demonstrate this understanding can:

H.P.3D.1 Develop and use models (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.

H.P.3D.2 Use the principle of superposition to explain everyday examples of resonance (including musical instruments and the human voice).

H.P.3D.3 Develop and use models 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).

H.P.3D.4 Use mathematical and computational thinking to analyze problems that relate the frequency, period, amplitude, wavelength, velocity, and energy of sound waves.

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 charged particles. Changing magnetic fields cause electrons in wires to move, creating current.

Performance Indicators: Students who demonstrate this understanding can:

H.P.3E.1 Plan and conduct controlled scientific investigations to determine the relationship between the current and potential drop (voltage) 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.

H.P.3E.2 Develop and use models (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.

H.P.3E.3 Use mathematical and computational thinking to analyze problems dealing with current, electric potential, resistance, and electric charge.

H.P.3E.4 Use mathematical and computational thinking to analyze problems dealing with the power output of electric devices.

H.P.3E.5 Plan and conduct controlled scientific investigations to determine how connecting resistors in series and in parallel affects the power (brightness) of light bulbs.

H.P.3E.6 Obtain and communicate information about the relationship between magnetism and electric currents to explain the role of magnets and coils of wire in microphones, speakers, generators, and motors.

H.P.3E.7 Design a simple motor and construct an explanation of how this motor transforms electrical energy into mechanical energy and work.

H.P.3F. 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 Indicators: Students who demonstrate this understanding can:

H.P.3F.1 Construct scientific arguments that support the wave model of light and the particle model of light.

H.P.3F.2 Plan and conduct controlled scientific investigations 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).

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.

H.P.3F.4 Use mathematical and computational thinking to analyze problems that relate the frequency, period, amplitude, wavelength, velocity, and energy of light.

H.P.3F.5 Obtain information to communicate 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.

H.P.3F.6 Obtain information to construct explanations on how waves are used to produce, transmit, and capture signals and store and interpret information (including ultrasound imaging, telescopes, cell phones, and bar code scanners).

H.P.3G. 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 Indicators: Students who demonstrate this understanding can:

H.P.3G.1 Develop and use models to represent the basic structure of an atom (including protons, neutrons, electrons, and the nucleus).

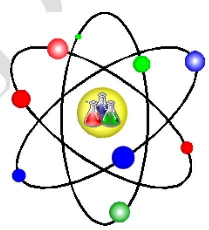
INTERACTIONS AND ENERGY *(CONTINUED)*

H.P.3G.2 Develop and use models (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.

H.P.3G.3 Construct scientific arguments to support claims for or against the viability of fusion and fission as sources of usable energy.

H.P.3G.4 Use mathematical and computational thinking to predict the products of radioactive decay (including alpha, beta, and gamma decay).

H.P.3G.5 Obtain information to communicate how radioactive decay processes have practical applications (such as food preservation, cancer treatments, fossil and rock dating, and as radioisotopic medical tracers).



PHYSICS 1 CROSSWALK FOR THE 2005 SOUTH CAROLINA SCIENCE ACADEMIC STANDARDS AND THE 2014 SOUTH CAROLINA ACADEMIC STANDARDS AND PERFORMANCE INDICATORS FOR SCIENCE

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ACKNOWLEDGEMENTS

SOUTH CAROLINA DEPARTMENT OF EDUCATION

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INTRODUCTION

This document, *Crosswalks for the 2005 South Carolina Science Academic Standards and the 2014 South Carolina Academic Standards and Performance Indicators for Science,* contains a comparison of the academic standards in science for the state's students in kindergarten through grade twelve.

HOW TO USE THE CROSSWALKS

This document may be used with the science academic standards, science and engineering support document, and grade/content support documents to assist local districts, schools and teachers as they 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. 2005 and 2014 performance indicators that share similar content knowledge and skills that students should demonstrate to meet the grade level or high school course standards have been paired. These pairings have been organized into tables and are sequenced by the 2014 academic standards. The 2005 content indicators that do not match 2014 content have been placed at the end of each table. Additionally, since the conceptual understandings are novel to the *2014 South Carolina Academic Standards and Performance Indicators for Science* these portions of the crosswalk to not correlate to the *2005 South Carolina Science Academic Standards*. Conceptual understandings are statements of the core ideas for which students should demonstrate an understanding. Some grade level topics include more than one conceptual understanding with each building upon the intent of the standard.

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 *Crosswalks for the 2005 South Carolina Science Academic Standards and the 2014 South Carolina Academic Standards and Performance Indicators for Science,* is not a curriculum.

PHYSICS 1 CROSSWALK DOCUMENT

(* The 2005 content indicators that do not match 2014 content have been placed at the end of each table.)

Standard H.P.1—Science and Engineering Practices		
2005	**2014**	**Comments**
P-1: The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.	**H.P.1:** The student will use the science and engineering practices, including the processes and skills of scientific inquiry, to develop understandings of science content.	
Conceptual Understanding		
	H.P.1A.: The practices of science and engineering support the development of science concepts, develop the habits of mind that are necessary for scientific thinking, and allow students to engage in science in ways that are similar to those used by scientists and engineers.	
Performance Indicators		
	H.P.1A.1 Ask questions to (1) generate hypotheses for scientific investigations, (2) refine models, explanations, or designs, or (3) extend the results of investigations or challenge scientific arguments or claims.	
	H.P.1A.2 Develop, use, and refine models to (1) understand or represent phenomena, processes, and relationships, (2) test devices or solutions, or (3) communicate ideas to others.	This is a new expectation in these standards.

P-1.2 Use appropriate laboratory apparatuses, technology, and techniques safely and accurately when conducting a scientific investigation. P-1.3 Use scientific instruments to record measurement data in appropriate metric units that reflect the precision and accuracy of each particular instrument. P-1.4 Design a scientific investigation with appropriate methods of control to test a hypothesis (including independent and dependent variables), and evaluate the designs of sample investigations. P-1.5 Organize and interpret the data from a controlled scientific investigation by using (including calculations in scientific notation, formulas, and dimensional analysis), graphs, tables, models, diagrams, and/or technology. P-1.10 Use appropriate safety procedures when conducting investigations.	**H.P.1A.3** Plan and conduct controlled scientific investigations 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-1.5 (see above) P-1.6 Evaluate the results of a controlled scientific investigation in terms of whether they refute or verify the hypothesis. P-1.7 Evaluate conclusions based on qualitative and quantitative data (including the impact of parallax, instrument malfunction, or human error) on experimental results.	**H.P.1A.4** Analyze and interpret data 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.	Note that A.4 is a much richer set of expectations than E-1.6, and could be done in many instructional contexts, not just for lab investigations.

P-1.1 Apply established rules for significant digits, both in reading scientific instruments and in calculating derived quantities from measurement. P-1.5 (see above)	**H.P.1A.5** Use mathematical and computational thinking 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.	
	H.P.1A.6 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.	Students constructing their own explanations, like models in A.2. is one of the hallmarks of these new standards.
P-1.4 (see above) P-1.9 Communicate and defend a scientific argument or conclusion.	**H.P.1A.7** Construct and analyze scientific arguments to support claims, explanations, or designs using evidence and valid reasoning from observations, data, or informational texts	Once again, compared to E-1.4, A.7 is intended to be taught in many different contexts. One of the ideas here is that hands-on investigations and activities are great, but in the end, if students can't explain the concepts they are not instructionally appropriate.
	H.P.1A.8 Obtain and evaluate scientific information 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.	

Conceptual Understanding		
	H.P.1B. Conceptual Understanding: Technology is any modification to the natural world created to fulfill the wants and needs of humans. The engineering design process involves a series of iterative steps used to solve a problem and often leads to the development of a new or improved technology.	
Performance Indicators		
P-1.8 Evaluate a technological design or product on the basis of designated criteria (including cost, time, and materials).	**H.P.1B.1** Construct devices or design solutions 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 the results.	

Standard H.P.2—Interactions and Forces		
2005	**2014**	**Comments**
P-2: The student will demonstrate an understanding of the principles of force and motion and relationships between them. **P-3:** The student will demonstrate an understanding of the conservation, transfer, and transformation of mechanical energy. **P-4:** The student will demonstrate an understanding of the properties of electricity and magnetism and the relationships between them. **PS-5:** The student will demonstrate an understanding of the nature of forces and motion.	**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.	
Conceptual Understanding		
	H.P.2A: The linear motion of an object can be described by its displacement, velocity, and acceleration.	
Performance Indicators		
PS-5.1 Explain the relationship among distance, time, direction, and the velocity of an object	**H.P.2A.1** Plan and conduct controlled scientific investigations 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.	
P-2.1 Represent vector quantities (including displacement, velocity, acceleration, and force) and use vector addition.	**H.P.2A.2** Construct explanations for an object's change in motion using one-dimensional vector addition.	

P-2.2 Apply formulas for velocity or speed and acceleration to one and two-dimensional problems. P-2.3 Interpret the velocity or speed and acceleration of one and two-dimensional motion on distance-time, velocity-time or speed-time, and acceleration-time graphs. PS-5.2 Use the formula v = d/t to solve problems related to average speed or velocity.	**H.P.2A.3** Use mathematical and computational thinking 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.	
P-2.1 Represent vector quantities (including displacement, velocity, acceleration, and force) and use vector addition.	**H.P.2A.4** Develop and use models to represent an object's displacement, velocity, and acceleration (including vector diagrams, data tables, motion graphs, dot motion diagrams, and mathematical formulas).	
	H.P.2A.5 Construct explanations 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).	
	H.P.2A.6 Obtain information 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.	

Conceptual Understanding		
	H.P.2B: 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 Indicators		
P-2.4 Interpret the resulting motion of objects by applying Newton's three laws of motion: inertia; the relationship among net force, mass, and acceleration (using F = ma); and action and reaction forces.	**H.P.2B.1** Plan and conduct controlled scientific investigations 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, Fnet = ma) and analyze collected data to construct an explanation of the object's motion using Newton's second law of motion.	
P-2.7 Use a free-body diagram to determine the net force and component forces acting upon an object.	**H.P.2B.2** Use a free-body diagram to represent the forces on an object.	
P-2.4 Interpret the resulting motion of objects by applying Newton's three laws of motion: inertia; the relationship among net force, mass, and acceleration (using F = ma); and action and reaction forces.	**H.P.2B.3** Use Newton's Third Law of Motion to construct explanations 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.	
P-3.5 Explain the factors involved in producing a change in momentum including impulse and the law of conservation of momentum in both linear and rotary systems).	**H.P.2B.4** Use mathematical and computational thinking to derive the relationship between impulse and Newton's Second Law of Motion.	

P-3.5 (see above) P-3.6 Compare elastic and inelastic collisions in terms of conservation laws.	**H.P.2B.5** Plan and conduct controlled scientific investigations to support the Law of Conservation of Momentum in the context of two objects moving linearly (p=mv).	
P-3.5 (see above) P-3.6 (see above)	**H.P.2B.6** Construct scientific arguments 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.	
	H.P.2B.7 Apply physics principles to design a device that minimizes the force on an object during a collision and construct an explanation for the design.	
P-2.10 Explain the relationships among speed, velocity, acceleration, and force in rotational systems	**H.P.2B.8** Develop and use models (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.	
P-2.9 Explain how torque is affected by the magnitude, direction, and point of application of force.	**H.P.2B.9** Construct explanations for the practical applications of torque (such as a see-saw, bolt, wrench, and hinged door).	
	H.P.2B.10 Obtain information to communicate physical situations in which Newton's Second Law of Motion does not apply.	

Conceptual Understanding		
	H.P.2C: 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 Indicators		
P-2.7 Use a free-body diagram to determine the net force and component forces acting upon an object.	**H.P.2C.1** Use a free-body diagram to represent the normal, tension (or elastic), applied, and frictional forces on an object.	
P-2.8 Distinguish between static and kinetic friction and the factors that affect the motion of objects	**H.P.2C.2** Plan and conduct controlled scientific investigations to determine the variables that could affect the kinetic frictional force on an object.	
P-2.8 (see above)	**H.P.2C.3** Obtain and evaluate information to compare kinetic and static friction.	
	H.P.2C.4 Analyze and interpret data 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*.	
P-2.4 Interpret the resulting motion of objects by applying Newton's three laws of motion: inertia; the relationship among net force, mass, and acceleration (using F = ma); and action and reaction forces.	H.P.2C.5 Use mathematical and computational thinking to apply Fnet = ma to analyze problems involving contact interactions and gravity.	

Conceptual Understanding		
	H.P.2D: 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 Indicators		
P-4.1 Recognize the characteristics of static charge and explain how a static charge is generated.	**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.	
PS-5.10 Explain how the gravitational force between two objects is affected by the mass of each object and the distance between them.	**H.P.2D.2** Use mathematical and computational thinking 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=Gm1m2/r2).	
PS-5.10 Explain how the gravitational force between two objects is affected by the mass of each object and the distance between them.	**H.P.2D.3** Obtain information to communicate 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.	

P-4.2 Use diagrams to illustrate an electric field (including point charges and electric field lines).	**H.P.2D.4** Use mathematical and computational thinking 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=kq1q2/r2).	
	H.P.2D.5 Construct explanations 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.	See resources for 2005 Standard P-2
	H.P.2D.6 Use a free-body diagram to represent the gravitational force on an object.	See resources for 2005 Standard P-2
P-4.2 (see above)	**H.P.2D.7** Use a free-body diagram to represent the electrical force on a charge.	
P-4.2 (see above)	**H.P.2D.8** Develop and use models (such as computer simulations, drawings, or demonstrations) to explain the relationship between moving charged particles (current) and magnetic forces and fields.	
P-2.5 Explain the factors that influence the dynamics of falling objects and projectiles. P-2.6 Apply formulas for velocity and acceleration to solve problems related to projectile motion.	**H.P.2D.9** Use Newton's Law of Universal Gravitation and Newton's second law of motion to explain why all objects near Earth's surface have the same acceleration.	

P-2.5 (see above) P-2.6 (see above)	**H.P.2D.10** Use mathematical and computational thinking to apply Fnet = ma to analyze problems involving non-contact interactions, including objects in free fall	

Standard H.P.3—Interactions and Energy		
2005	**2014**	**Comments**
P-3: The student will demonstrate an understanding of the conservation, transfer, and transformation of mechanical energy. **P-4:** The student will demonstrate an understanding of the properties of electricity and magnetism and the relationships between them. **P-5:** The student will demonstrate an understanding of the properties and behaviors of mechanical and electromagnetic waves. **P-6:** The student will demonstrate an understanding of the properties and behaviors of sound. **P-7:** The student will demonstrate an understanding of the properties and behaviors of light and optics. **P-8**: The student will demonstrate an understanding of nuclear physics and modern physics. **P-10:** The student will demonstrate an understanding of the principles of thermodynamics. **PS-2** The student will demonstrate an understanding of the structure and properties of atoms.	**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.	

PS-6: The student will demonstrate an understanding of the nature, conservation, and transformation of energy.		
	Conceptual Understanding	
	H.P.3A: 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 Indicators	
P-3.3 Explain, both conceptually and quantitatively, how energy can transfer from one system to another (including work, power, and efficiency).	**H.P.3A.1** Use mathematical and computational thinking to determine the work done by a constant force (W=Fd).	
P-3.3 (see above)	**H.P.3A.2** Use mathematical and computational thinking to analyze problems dealing with the work done on or by an object and its change in energy.	
P-3.6 Compare elastic and inelastic collisions in terms of conservation laws.	**H.P.3A.3** Obtain information to communicate how energy is conserved in elastic and inelastic collisions.	

P-3.3 (see above)	**H.P.3A.4** Plan and conduct controlled scientific investigations to determine the power output of the human body.	
P-3.3 (see above)	**H.P.3A.5** Obtain and communicate information to describe the efficiency of everyday machines (such as automobiles, hair dryers, refrigerators, and washing machines).	
	Conceptual Understanding	
	H.P.3B: 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 Indicators	
P-3.4 Explain, both conceptually and quantitatively, the factors that influence periodic motion.	**H.P.3B.1** Develop and use models (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.	

P-3.1 Apply energy formulas to determine potential and kinetic energy and explain the transformation from one to the other	**H.P.3B.2** Use mathematical and computational thinking 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 = ½ mv2, PEg = mgh, PEe = ½ kx2). 99	
	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).	
	Conceptual Understanding	
	H.P.3C: 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 Indicators	
P-10.2 Explain the relationship among internal energy, heat, and work.	**H.P.3C.1** Plan and conduct controlled scientific investigations to determine the variables that affect the rate of heat transfer between two objects.	

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	H.P.3C.2 Analyze and interpret data to describe the thermal conductivity of different materials.	
	H.P.3C.3 Develop and use models (such as a drawing or a small-scale greenhouse) to exemplify the energy balance of the Earth (including conduction, convection, and radiation).	
	Conceptual Understanding	
	H.P.3D: Sound is a mechanical, longitudinal wave that is the result of vibrations (kinetic energy) that transfer energy through a medium.	
	Performance Indicators	
P-6.1 Summarize the production of sound and its speed and transmission through various media.	**H.P.3D.1** Develop and use models (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.	
P-6.1 (see above) P-6.8 Explain how musical instruments produce resonance and standing waves.	**H.P.3D.2** Use the principle of superposition to explain everyday examples of resonance (including musical instruments and the human voice).	
PS-7.7 Explain the Doppler effect conceptually in terms of the frequency of the waves and the pitch of the sound.	**H.P.3D.3** Develop and use models 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).	See P-6 resources

P-6.3 Explain pitch, loudness, and tonal quality in terms of wave characteristics that determine what is heard P-6.6 Apply formulas in order to solve for resonant wavelengths in problems involving open and closed tubes. P-6.8 Explain how musical instruments produce resonance and standing waves.	**H.P.3D.4** Use mathematical and computational thinking to analyze problems that relate the frequency, period, amplitude, wavelength, velocity, and energy of sound waves.	P-6.8 gives the example of musical instruments
	Conceptual Understanding	
	H.P.3E: 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 charged particles. Changing the magnetic fields cause electrons in wires to move, creating current.	
	Performance Indicators	
P-4.3 Summarize current, potential difference, and resistance in terms of electrons P-4.5 Analyze the relationships among voltage, resistance, and current in a complex circuit by using Ohm's law to calculate voltage, resistance, and current at each resistor, any branch, and the overall circuit.	**H.P.3E.1** Plan and conduct controlled scientific investigations to determine the relationship between the current and potential drop (voltage) 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-4.3 gives needed background re: Ohm's law

	H.P.3E.2 Develop and use models (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.	
P-4.3 Summarize current, potential difference, and resistance in terms of electrons	**H.P.3E.3** Use mathematical and computational thinking to analyze problems dealing with current, electric potential, resistance, and electric charge.	
P-4.4 Compare how current, voltage, and resistance are measured in a series and in a parallel electric circuit and identify the appropriate units of measurement. P-4.7 Carry out calculations for electric power and electric energy for circuits.	**H.P.3E.4** Use mathematical and computational thinking to analyze problems dealing with the power output of electric devices.	
PS-6.8 Represent an electric circuit by drawing a circuit diagram that includes the symbols for a resistor, switch, and voltage source. PS-6.9 Compare the functioning of simple series and parallel electrical circuits.	**H.P.3E.5** Plan and conduct controlled scientific investigations to determine how connecting resistors in series and in parallel affects the power (brightness) of light bulbs.	
P-4.9 Explain the effects of magnetic forces on the production of electrical currents and on current carrying wires and moving charges. P-4.10 Distinguish between the function of motors and generators on the basis of the use of electricity and magnetism by each	**H.P.3E.6** Obtain and communicate information about the relationship between magnetism and electric currents to explain the role of magnets and coils of wire in microphones, speakers, generators, and motors.	

P-4.9 and 4.10 (see above) PS-6.11 Explain the relationship of magnetism to the movement of electric charges in electromagnets, simple motors, and generators.	**H.P.3E.7** Design a simple motor and construct an explanation of how this motor transforms electrical energy into mechanical energy and work.	
	Conceptual Understanding	
	H.P.3F: 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 Indicators	
P-7.1 Explain the particulate nature of light as evidenced in the photoelectric effect.	**H.P.3F.1** Construct scientific arguments that support the wave model of light and the particle model of light.	
P-5.3 Analyze wave behaviors (including reflection, refraction, diffraction, and constructive and destructive interference). P-5.4 Distinguish the different properties of waves across the range of electromagnetic spectrum. P-5.5 Illustrate the interaction of light waves with optical lenses and mirrors by using Snell's law and ray diagrams.	**H.P.3F.2** Plan and conduct controlled scientific investigations 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).	In physical science students "Summarize the characteristics of the electromagnetic spectrum (including the range of frequencies, wavelengths, energy, and propagation without a medium)." (PS-7.5) "Summarize reflection and interference of both sound and light waves and the refraction and diffraction of light waves." (PS-7.6)

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PS-7.6 Summarize reflection and interference of both sound and light waves and the refraction and diffraction of light waves. P-5.3 Analyze wave behaviors (including reflection, refraction, diffraction, and constructive and destructive interference).	**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.	
PS-7.4 Use the formulas v = f λ and v = d/t to solve problems related to the velocity of waves. P-5.1 Analyze relationships among the properties of waves (including energy, frequency, amplitude, wavelength, period, phase, and speed).	**H.P.3F.4** Use mathematical and computational thinking to analyze problems that relate the frequency, period, amplitude, wavelength, velocity, and energy of light.	
P-5.4 Distinguish the different properties of waves across the range of the electromagnetic spectrum.	**H.P.3F.5** Obtain information to communicate 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.	In physical science students "Summarize the characteristics of the electromagnetic spectrum (including the range of frequencies, wavelengths, energy, and propagation without a medium)." (PS-7.5)
P-7.5 Summarize image formation in microscopes and telescopes (including reflecting and refracting).	**H.P.3F.6** Obtain information to construct explanations on how waves are used to produce, transmit, and capture signals and store and interpret information (including ultrasound imaging, telescopes, cell phones, and bar code scanners).	

Conceptual Understanding		
	H.P.3G: 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 Indicators		
P-8.1 Compare the strong and weak nuclear forces in terms of their roles in radioactivity PS-2.1 Compare the subatomic particles (protons, neutrons, electrons) of an atom with regard to mass, location, and charge, and explain how these particles affect the properties of an atom (including identity, mass, volume, and reactivity).	**H.P.3G.1** Develop and use models to represent the basic structure of an atom (including protons, neutrons, electrons, and the nucleus).	

P-8.2 Compare the nuclear binding energy to the energy released during a nuclear reaction, given the atomic masses of the constituent particles. PS-2.6 Compare fission and fusion (including the basic processes and the fact that both fission and fusion convert a fraction of the mass of interacting particles into energy and release a great amount of energy).	**H.P.3G.2** Develop and use models (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.	
	H.P.3G.3 Construct scientific arguments to support claims for or against the viability of fusion and fission as sources of usable energy.	
P-8.3 Predict the resulting isotope of a given alpha, beta, or gamma emission. P-8.4 Apply appropriate procedures to balance nuclear equations (including fusion, fission, alpha decay, beta decay, and electron capture). P-8.5 Interpret a representative nuclear decay series.	**H.P.3G.4** Use mathematical and computational thinking to predict the products of radioactive decay (including alpha, beta, and gamma decay).	
PS-2.7 Explain the consequences that the use of nuclear applications (including medical technologies, nuclear power plants, and nuclear weapons) can have.	**H.P.3G.5** Obtain information to communicate how radioactive decay processes have practical applications (such as food preservation, cancer treatments, fossil and rock dating, and as radioisotopic medical tracers).	

CONTENT SUPPORT GUIDE
FOR PHYSICS 1
2014 SOUTH CAROLINA ACADEMIC STANDARDS
AND PERFORMANCE INDICATORS
FOR SCIENCE

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SOUTH CAROLINA DEPARTMENT OF EDUCATION

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Office of Standards and Learning

PHYSICS 1 CURRICULUM DOCUMENT DEVELOPMENT TEAM

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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 essential knowledge, extended knowledge, connections to previous and future knowledge, and assessment recommendations.

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.
- **Assessment Guidance**
  - This section provides guidelines for educators and assessors to check for student mastery of content utilizing interrelated science and engineering practices.
- **Previous and Future Knowledge**
  - 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. Please note that the kindergarten curriculum support document does not contain previous knowledge. Additionally, although the high school support document may not contain future knowledge, this section may list overlapping concepts from other high school science content areas.
- **Essential Knowledge**
  - This section illustrates the knowledge of the content contained in the performance indicator for which it is fundamental for students to demonstrate mastery.
- **Extended Knowledge**
  - This section provides educators with topics that will enrich students' knowledge related to topics learned with the explicated performance indicator.
- **Science and Engineering Practices**
  - This section lists the specific science and engineering practice that is 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.*

PHYSICS 1 CONTENT SUPPORT GUIDE

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.

Conceptual Understanding:
H.P.2A The linear motion of an object can be described by its displacement, velocity, and acceleration.

Performance Indicator:
H.P.2A.1 Plan and conduct controlled scientific investigations 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.

Previous Knowledge:
5.P.5- Speed, Velocity
8.P.2- Position, Speed, Average Velocity

Assessment Guidance:
The objective of this indicator is to *plan and conduct investigations* 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.; therefore the focus of this assessment should be for students to *plan and conduct controlled scientific investigations 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.* This could include but is not limited to having students design and conduct investigations to collect and present data (position, distance traveled, displacement, time, velocity) from an exploration using a constant speed cart, a ball rolling down a ramp, a ball rolling up a ramp, and a ball in free fall.

In addition to *plan and conduct investigations*, students may be expected to *ask questions; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations;* and *develop and use models*.

Essential Knowledge:

- 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.

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- *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 Knowledge:
Students could predict the motion of an object by analyzing a tape timer pattern.

Science Engineering Practices:
S.1A.3

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.

Conceptual Understanding:
H.P.2A The linear motion of an object can be described by its displacement, velocity, and acceleration.

Performance Indicator:
H.P.2A.2 Construct explanations for an object's change in motion using one-dimensional vector addition.

Previous Knowledge:
5.P.5- Speed, Velocity
8.P.2- Position, Speed, Average Velocity

Assessment Guidance:
The objective of this indicator is to *construct explanations* for an object's change in motion using one-dimensional vector addition; therefore the focus of assessment should be for students to *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* to describe the magnitude of a value based on the size of the vector tail and *make claims* about the sum of vector quantities based on the tip to tail method of vector addition. This could include but is not limited to having students use vector diagrams to add displacement or velocity vectors to communicate the magnitude and direction of the resultant vector.

In addition to *construct explanations*, students should be asked to *ask questions; plan and carry out investigations; engage in argument from evidence; obtain, evaluate and communicate information; develop and use models;* and *construct devices or design solutions.*

Essential Knowledge:
- *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 Knowledge:

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

Science and Engineering Practices
S.1A.6

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.

Conceptual Understanding:
H.P.2A The linear motion of an object can be described by its displacement, velocity, and acceleration.

Performance Indicator:
H.P.2A.3 Use mathematical and computational thinking 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.

Previous Knowledge:
5.P.5- Speed, Velocity
8.P.2- Position, Speed, Average Velocity

Assessment Guidance:
The objective of this indicator is to *use mathematical and computational thinking* 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. Therefore, the focus of assessment should be for students to *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* to analyze problems with given variables to solve for any unknowns based on given quantities. This could include but is not limited to having students solve word problems to determine unknown quantities or to have students analyze traffic accident data to determine if the object had a constant acceleration throughout the problem.
In addition to *using mathematical and computational thinking,* students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; engage in argument from evidence; construct explanations; develop and use models; obtain, evaluate and communicate information;* and *construct devices or design solutions.*

Essential Knowledge:

- 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 Knowledge:

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

Science and Engineering Practices

S.1A.5

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.

Conceptual Understanding:

H.P.2A The linear motion of an object can be described by its displacement, velocity, and acceleration.

Performance Indicator:

H.P.2A.4 Develop and use models to represent an object's displacement, velocity, and acceleration (including vector diagrams, data tables, motion graphs, dot motion diagrams, and mathematical formulas).

Assessment Guidance:

The objective of this indicator is to *develop and use models* to represent an object's displacement, velocity, and acceleration (including vector diagrams, data tables, motion graphs, dot motion diagrams, and mathematical formulas). Therefore, the primary focus of assessment should be for students to *develop and use models to understand or represent phenomena, processes and relationships and communicate ideas to others about* how velocity affects displacement and further how acceleration affects velocity. This could include but is not limited to students creating and analyzing data tables, motion graphs or dot motion diagrams to describe motion of an object.

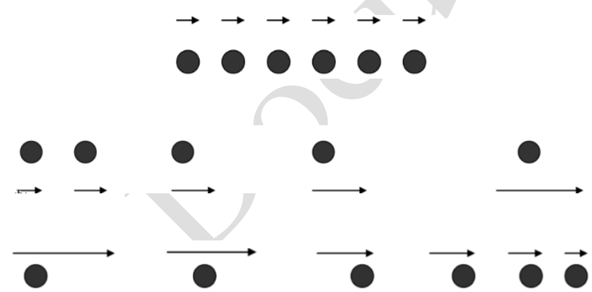
In addition to *develop and use models*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations; obtain, evaluate, and communicate information;* and *construct devices or define solutions.*

Previous Knowledge:
5.P.5- Speed, Velocity
8.P.2- Position, Speed, Average Velocity

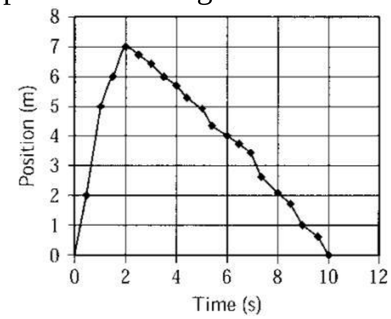
Essential Knowledge:

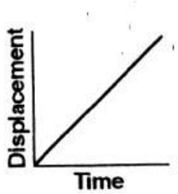
- A *scalar* quantity is a value that includes a magnitude with no direction while *vector* quantities include a magnitude and a direction.
- Vector diagrams are graphical representations of the magnitude and direction of vector quantities.
- Vectors can be added graphically to solve linear mechanical 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.

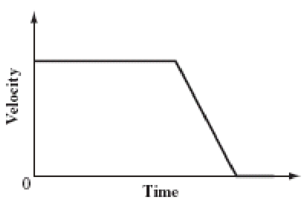
- A dot diagram is a way of analyzing the motion of objects. The distance between dots represents the change in distance during that time period. If the distance between the dots does not change, the velocity is constant.



- 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*.







Extended Knowledge:

- 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.

Science and Engineering Practices
S.1A.2

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.

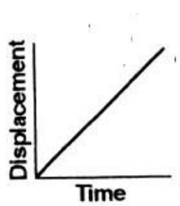
Conceptual Understanding:
H.P.2A The linear motion of an object can be described by its displacement, velocity, and acceleration.

Performance Indicator:
H.P.2A.5 Construct explanations 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).

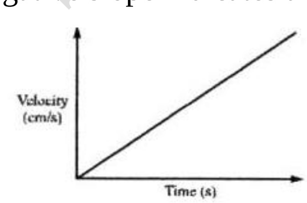
Assessment Guidance:
The objective of this indicator is to *construct explanations* for what is meant by "constant" velocity and "constant" acceleration. Therefore, the focus of assessment should be for students to *construct explanations of phenomena using data communicated in graphs, tables, or diagrams* to make a claim identifying objects with constant acceleration or velocity by using the slope of the line in a position-time or velocity-time graph as evidence to support the claim. This could include but is not limited to having students collect data and support that the object has a constant velocity or acceleration based on the slope of a graph.
In addition to *construct explanations*, students should be asked to *ask questions; plan and carry out investigations; engage in argument from evidence; obtain, evaluate and communicate information; develop and use models;* and *construct devices or design solutions.*

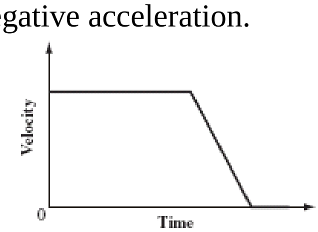
Previous Knowledge:
5.P.5- Speed, Velocity
8.P.2- Position, Speed, Average Velocity

Essential Knowledge:
- 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.



- 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.





Extended Knowledge:

- 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.

Science and Engineering Practices
S.1A.6

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.

Conceptual Understanding:
H.P.2A The linear motion of an object can be described by its displacement, velocity, and acceleration.

Performance Indicator:
H.P.2A.6 Obtain information 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.

Assessment Guidance:
The objective of this indicator is to *obtain information* 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. Therefore, the primary focus of assessment should be for students to *obtain and evaluate scientific information to (1) generate and answer questions, (2) explain or describe phenomena, or (3) develop models* in order to compare and contrast the listed word pairs using terms appropriate for describing motion. This could include but is not limited to having students analyze graphs, word problems, videos and motion diagrams to determine differences in word pairs using evidence from these sources.
In addition to *obtain information*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations; develop and use models*; and *construct devices or define solutions.*

Previous Knowledge:
5.P.5- Speed, Velocity
8.P.2- Position, Speed, Average Velocity

Essential Knowledge:

- 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 Knowledge:

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

Science and Engineering Practices
S.1A.8

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.

Conceptual Understanding:
H.P.2B. 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 Plan and conduct controlled scientific investigations 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, $F_{net} = ma$), and analyze collected data to construct an explanation of the object's motion using Newton's second law of motion.

Assessment Guidelines:
The objective of this indicator is to *plan and conduct investigations* 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, $F_{net} = ma$), and analyze collected data to construct an explanation of the object's motion using Newton's second law of motion. Therefore, the focus of this assessment should be for students to *plan and conduct controlled scientific investigations 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. This could include but is not limited to having students design an experiment to determine the effect of changing force or mass of an object on the acceleration of that object. Students will then make claims about the relationship using collected data from their experiments.
In addition to *plan and conduct investigations,* students may be expected to *ask questions; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations;* and *develop and use models*.

Previous Knowledge:
5.P.5- Forces
8.P.2- Forces, Newton's Laws of Motion

Essential Knowledge:
- 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 $F_{net} = ma$.
- 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 Knowledge:

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

Science and Engineering Practices
S.1A.3

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.

Conceptual Understanding:
H.P.2B. 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.

Assessment Guidance:
The objective of this indicator is to *develop and use models* to represent the forces on an object. Therefore, the primary focus of assessment should be for students to *develop and use models to understand or represent phenomena, processes and relationships and communicate ideas to others about* forces acting on an object by using free body diagrams. This could include but is not limited to having students identify the forces acting on objects and include those forces on a free body diagram quantitatively or qualitatively.
In addition to *develop and use models,* students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations; obtain, evaluate, and communicate information;* and *construct devices or define solutions.*

Previous Knowledge:
5.P.5- Forces
8.P.2- Forces, Newton's Laws of Motion

Essential Knowledge:

- 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 Knowledge:

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

Science and Engineering Practices

S.1A.2

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.

Conceptual Understanding:

H.P.2B. 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 construct explanations 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.

Assessment Guidance:

The objective of this indicator is to *construct explanations* of everyday phenomena using Newton's Third Law and identify the force pairs in each given situation involving two objects and compare the size and direction of each force. Therefore, the focus of assessment should be for students to *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* to describe the forces acting between objects and to *make claims* about the size and direction of those forces. This could include but is not limited to having students use data collected to defend that forces acting between objects in a collision (such as an accident between a truck and a small car) are always equal in magnitude and opposite in direction.
In addition to *construct explanations*, students should be asked to *ask questions; plan and carry out investigations; engage in argument from evidence; obtain, evaluate and communicate information; develop and use models;* and *construct devices or design solutions.*

Previous Knowledge:

5.P.5- Forces
8.P.2- Forces, Newton's Laws of Motion

Essential Knowledge:

- *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 Knowledge:

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

Science and Engineering Practices
S.1A.6

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.

Conceptual Understanding:
H.P.2B. 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 Use mathematical and computational thinking to derive the relationship between impulse and Newton's Second Law of Motion.

Assessment Guidance:
The objective of this indicator is to *use mathematical and computational thinking t*o derive the relationship between impulse and Newton's Second Law of Motion Therefore, the focus of assessment should be for students 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* collected from a collision to relate force and time of collision to the mass of the object and the acceleration. This could include but is not limited to having students analyze data from a collision between a cart and a soft device like a soda can.
In addition to *use mathematical and computational thinking*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; engage in argument from evidence; construct explanations; develop and use models; obtain, evaluate and communicate information;* and *construct devices or design solutions.*

Previous Knowledge:
5.P.5- Forces
8.P.2- Forces, Newton's Laws of Motion

Essential Knowledge:

- *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 Knowledge:

- 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.

Science and Engineering Practices
S.1A.5

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.

Conceptual Understanding:
H.P.2B. 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 Plan and conduct controlled scientific investigations to support the Law of Conservation of Momentum in the context of two objects moving linearly (p=mv).

Assessment Guidance:
The objective of this indicator is to *plan and conduct investigations* to support the Law of Conservation of Momentum in the context of two objects moving linearly; therefore the focus of this assessment should be for students to *plan and conduct controlled scientific investigations 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.* This could include but is not limited to having students design, conduct, and present data from a collision to determine if the total momentum of the system remains constant, is reduced or is increased. In addition to *plan and conduct investigations*, students may be expected to *ask questions; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations;* and *develop and use models*.

Previous Knowledge:
5.P.2- Properties of Matter (Mass)
5.P.5- Forces
8.P.2- Forces, Newton's Laws of Motion

Essential Knowledge:

- 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 Knowledge:

- 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.

Science and Engineering Practices
S.1A.3

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.

Conceptual Understanding:
H.P.2B. 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 Construct scientific arguments 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.

Assessment Guidelines:
The objective of this indicator is to *construct scientific arguments 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. Therefore, the primary focus of assessment should be for students to c*onstruct scientific arguments to support claims or explanations using evidence from observations, data, or informational texts* regarding how data from a collision can be used to determine the initial motion of an object before a collision. This could include but is not limited to having students analyze crash investigation data such as tire marks and location of objects after a collision to determine what each car was doing directly before the collision.

In addition to *construct scientific arguments to support claims*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; construct explanations; obtain, evaluate and communicate information; develop and use models*; and *construct devices or define solutions.*

Previous Knowledge:
5.P.2- Properties of Matter (Mass)
5.P.5- Forces
8.P.2- Forces, Newton's Laws of Motion

Essential Knowledge:

- 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.

Science and Engineering Practices
S.1A.7

Standard: 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.

Conceptual Understanding:
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 design a device that minimizes the force on an object during a collision and construct an explanation for the design.

Assessment Guidelines:
The objective of this indicator is to *design* a device that minimizes the force on an object during a collision and construct an explanation for the design. Therefore, the primary focus of assessment should be for students to *construct or design a device 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 devices 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 (6) communicate the results.* This could include but is not limited to having students hypothesize effective means of minimizing force during a collision and create a device to protect an object such as an egg during the collision.
In addition to *define problems* and *design possible solutions*, students should be asked to *develop and use models; plan and carry out tests; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence*; and *obtain, evaluate, and communicate information.*

Previous Knowledge:
5.P.2- Properties of Matter (Mass)
5.P.5- Forces
8.P.2- Forces, Newton's Laws of Motion

Essential Knowledge:
- 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 Knowledge:
- Mathematically compute the force of impact of devices

Science and Engineering Practices
S.1B.1

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.

Conceptual Understanding:
H.P.2B. 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 Develop and use models (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.

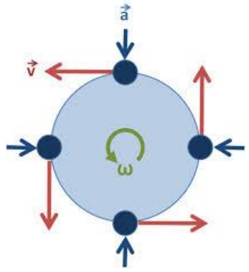
Assessment Guidelines:
The objective of this indicator is to *develop and use models* to explain why an object moving at a constant speed in a circle is accelerating. Therefore, the primary focus of assessment should be for students to *develop and use models to understand or represent phenomena, processes and relationships and communicate ideas to others about* the direction of the force and therefore of the acceleration of an object in circular motion. This could include but is not limited to having students develop a model to illustrate what might happen to the motion of the object in the absence of a force and with the force acting in directions other than towards the center of the circle.

In addition to *develop and use models*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations; obtain, evaluate, and communicate information;* and *construct devices or define solutions.*

Previous Knowledge:
5.P.2- Properties of Matter (Mass)
5.P.5- Forces
8.P.2- Forces, Newton's Laws of Motion

Essential Knowledge:
- Use Newton's Second Law to assess, measure and calculate the relationship among the force acting on a body, the mas 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.



Extended Knowledge:

- 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*.
- Create a diagram of an object moving in a circle. Include vectors for *tangential velocity*, *centripetal force* and *centripetal acceleration*.
- 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.

Science and Engineering Practices
S.1A.2

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.

Conceptual Understanding:
H.P.2B. 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.9 Construct explanations for the practical applications of torque (such as a see-saw, bolt, wrench, and hinged door).

Assessment Guidance:
The objective of this indicator is to *construct explanations* for the practical applications of torque; therefore, the focus of assessment should be for students to *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* to describe how the concept of torque is applied in the situations of a see-saw, bolt, wrench, and hinged door. This could include but is not limited to having students analyze forces for objects which are rotating to determine what happens to the required force as it moves away from the center of rotation.

In addition to *construct explanations*, students should be asked to *ask questions; plan and carry out investigations; engage in argument from evidence; obtain, evaluate and communicate information; develop and use models;* and *construct devices or design solutions.*

Previous Knowledge:
5.P.2- Properties of Matter (Mass)
5.P.5- Forces
8.P.2- Forces, Newton's Laws of Motion

Essential Knowledge:
- *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 Knowledge:
- 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°.

Science and Engineering Practices
S.1A.6

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.

Conceptual Understanding:
H.P.2B. 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 Obtain information to communicate physical situations in which Newton's Second Law of Motion does not apply.

Assessment Guidance:
The objective of this indicator is to *obtain information* to communicate physical situations in which Newton's Second Law of Motion does not apply. Therefore, the primary focus of assessment should be for students to *obtain and evaluate informational texts, observations, data collected or discussions to (1) generate and answer questions, (2) explain or describe phenomena, (3) develop models, or (4) support explanations* regarding situations when Newton's Second Law of Motion does not apply. This could include but is not limited to having students hold a class discussion about relativistic effects on an object approaching the speed of light. In addition to *obtain information*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations; develop and use models*; and *construct devices or define solutions.*

Previous Knowledge:

5.P.2- Properties of Matter (Mass)
5.P.5- Forces
8.P.2- Forces, Newton's Laws of Motion

Essential Knowledge:

- *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 Knowledge:
Students will explain Einstein's Theory of Relativity and Special Theory of Relativity.

Science and Engineering Practices
S.1A.8

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.

Conceptual Understanding:
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.

Assessment Guidance:
The objective of this indicator is to *develop and use models to r*epresent the normal, tension (or elastic), applied, and frictional forces on an object. Therefore, the primary focus of assessment should be for students to *develop and use models to understand or represent phenomena, processes and relationships and communicate ideas to others about* how forces are represented to act on an object. This could include but is not limited to having students draw free body diagrams of objects within the room that are stationary and then move when different forces act on the objects.

In addition to *develop and use models*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations; obtain, evaluate, and communicate information;* and *construct devices or define solutions.*

Previous Knowledge:
5.P.2- Properties of Matter (Mass)
5.P.5- Forces
8.P.2- Forces, Newton's Laws of Motion, Frictional Forces

Essential Knowledge:

- 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 Knowledge:

- 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

Science and Engineering Practices
S.1A.2

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.

Conceptual Understanding:
H.P.2C. 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 Plan and conduct controlled scientific investigations to determine the variables that could affect the kinetic frictional force on an object.

Assessment Guidelines:
The objective of this indicator is to *plan and conduct investigations* to determine the variables that could affect the kinetic frictional force on an object; therefore the focus of this assessment should be for students to *plan and conduct controlled scientific investigations 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.* This could include but is not limited to having students design, conduct, and present data from an experiment they design to determine the factors which can change the kinetic friction acting on an object.
In addition to *plan and conduct investigations*, students may be expected to *ask questions; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations;* and *develop and use models*.

Previous Knowledge:
5.P.2- Properties of Matter (Mass)
5.P.5- Forces
8.P.2- Forces, Newton's Laws of Motion, Frictional Forces

Essential Knowledge:

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

Science and Engineering Practices
S.1A.3

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.

Conceptual Understanding:
H.P.2C. 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 Obtain and evaluate information to compare kinetic and static friction.

Assessment Guidance:
The objective of this indicator is to *obtain information* to compare kinetic and static friction. Therefore, the primary focus of assessment should be for students to *obtain and evaluate informational texts, observations, data collected or discussions to (1) generate and answer questions, (2) explain or describe phenomena, (3) develop models, or (4) support explanations* regarding the differences and similarities between static and kinetic friction. This could include but is not limited to having students analyze data for a varying force acting on an object both at rest and in motion.

In addition to *obtain information*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations; develop and use models*; and *construct devices or define static and kinetic of friction.*

Previous Knowledge:
5.P.2- Properties of Matter (Mass)
5.P.5- Forces
8.P.2- Forces, Newton's Laws of Motion, Frictional Forces

Essential Knowledge:
Students must be able to:
- *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 Knowledge:

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

Science and Engineering Practices
S.1A.8

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.

Conceptual Understanding:
H.P.2C. 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 Analyze and interpret data 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.

Assessment Guidelines:
The objective of this indicator is to *analyze and interpret data o*n force and displacement to determine the spring (or elastic) constant of an elastic material. Therefore, the primary focus of assessment should be for students to *analyze and interpret data 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* using data from a graph of force versus displacement for a mass on a spring to determine the experimental spring constant. This could include but is not limited to having students hang various masses on a spring and plot the force versus displacement to experimentally determine the slope (spring constant).
In addition to *analyze and interpret data*, students should be asked to *ask questions; plan and carry out investigations; use mathematics and computational thinking; engage in argument from evidence; construct explanations; develop and use models; obtain, evaluate, and communicate information;* and *construct devices.*

Previous Knowledge:
5.P.2- Properties of Matter (Mass)
5.P.5- Forces
8.P.2- Forces, Newton's Laws of Motion, Frictional Forces

Essential Knowledge:

- *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.

Extended Knowledge:
Explain how positioning springs in series and parallel affect the k value.

Science and Engineering Practices
S.1A.4

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.

Conceptual Understanding:
H.P.2C. 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 $F_{net} = ma$ to analyze problems involving contact interactions and gravity.

Assessment Guidelines:
The objective of this indicator is to *use mathematical and computational thinking* to apply $F_{net} = ma$ to analyze problems involving contact interactions and gravity. Therefore, the focus of assessment should be for students to *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* to determine the acceleration of objects with contact forces and gravity affecting them. This could include but is not limited to having students solve basic word problems with objects experiencing a force, as well as use of Microsoft Excel or Numbers to analyze the effects that changing forces have on the accelerating object.
In addition to *use mathematical and computational thinking*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; engage in argument from evidence; construct explanations; develop and use models; obtain, evaluate and communicate information;* and *construct devices or design solutions.*

Previous Knowledge:
5.P.2- Properties of Matter (Mass)
5.P.5- Forces
8.P.2- Forces, Newton's Laws of Motion, Frictional Forces

Essential Knowledge:
- The basic mathematical relationship that supports *Newton's Second Law* is defined in H.P.2B.1 with the equation $F_{net} = ma$.
- 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 Knowledge:
- Use a free body diagram to explain why a falling object reaches terminal velocity.

Science and Engineering Practices
S.1A.5

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.

Conceptual Understanding:
H.P.2D. 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.

Assessment Guidelines:
The objective of this indicator is to *develop and use models* 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.
Therefore, the primary focus of assessment should be for students to *develop and use models to understand or represent phenomena, processes and relationships and communicate ideas to others about* how objects become charged and how they interact when charged. This could include but is not limited to having students make their own electroscopes or draw a diagram showing how electrons move when a charged balloon touches an electroscope, or a charged balloon sticks to the wall, or a charged balloon is brought near an electroscope which is then grounded.

In addition to *develop and use models*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations; obtain, evaluate, and communicate information;* and *construct devices.*

Previous Knowledge:
7.P.2- Parts of the Atom
H.C.2- Structure of the Atom

Essential Knowledge:
- 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.

Science and Engineering Practices
S.1A.2

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.

Conceptual Understanding:
H.P.2D. 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 Use mathematical and computational thinking 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, $F=Gm_1m_2/r^2$).
Fundamental Knowledge, Skills, and Processes
Assessment Guidelines:
The objective of this indicator is to *use mathematical and computational thinking* to predict the relationships among the masses of two objects, the attractive gravitational force between them, and the distance between them. Therefore, the focus of assessment should be for students 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* in order to predict the relationships among the masses of two objects, the attractive gravitational force between them, and the distance between them. This could include but is not limited to having students solve basic word problems with objects experiencing a gravitational force as well as use of Microsoft Excel or Numbers to analyze how changing mass or distance affects the gravitational force. In addition to *use mathematical and computational thinking*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; engage in argument from evidence; construct explanations; develop and use models; obtain, evaluate and communicate information;* and *construct devices or design solutions.*

Previous Knowledge:
(8.P.2)- predicting the effects of gravity
(2.P.4)- Gravity as a force
(5.P.5)- Gravity as a force
(H.E.2A.1)- Shape and Motion of Galaxies
Essential Knowledge:
- *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 an constant and equals 6.67×10^{-11} Nm^2/kg^2
- Law of Universal Gravitation is an inverse square law.

Science and Engineering Practices
S.1A.5

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.

Conceptual Understanding:
H.P.2D. 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 Obtain information to communicate 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.

Assessment Guidelines:
The objective of this indicator is to *obtain information* to communicate 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.
Therefore, the primary focus of assessment should be for students to *obtain and evaluate informational texts, observations, data collected or discussions to (1) generate and answer questions, (2) explain or describe phenomena, (3) develop models, (4) support explanations or (5) identify gaps in knowledge* regarding the long term gravitational interactions in the universe. This could include but is not limited to having students obtain information on cosmology, and then calculate and compare gravitational force between: inner and outer planets and the sun.

In addition to *obtain information*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations; develop and use models*; and *construct devices.*

Previous Knowledge:
(8.P.2)- predicting the effects of gravity
(2.P.4)- Gravity as a force
(5.P.5)- Gravity as a force
(H.E.2A.1)- Shape and Motion of Galaxies

Essential Knowledge:
- Students must have an understanding of *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 Knowledge:
- Derive Kepler's Third Law mathematically.

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

Science and Engineering Practices
S.1A.8

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.

Conceptual Understanding:
H.P.2D. 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 Use mathematical and computational thinking 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. $F=kq_1q_2/r^2$).
Fundamental Knowledge, Skills, and Processes
Assessment Guidelines:
The objective of this indicator is to *use mathematical and computational thinking* to predict the relationships among charges of two particles, the attractive or repulsive electrical force between them, and the distance between them. Therefore, the focus of assessment should be for students 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* in order to predict the relationships among the quantity of two charges, the electric force between them, and the distance between them. This could include but is not limited to having students solve basic word problems with objects experiencing an electrical force as well as the use of a computerized spreadsheet to analyze how the effect of changing charge or distance affects the electric force.
In addition to *use mathematical and computational thinking,* students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; engage in argument from evidence; construct explanations; develop and use models; obtain, evaluate and communicate information;* and *construct devices or design solutions.*
Previous Knowledge:
2.P.4- Forces
5.P.5- Forces
Essential Knowledge:

- *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 charges objects can be attractive or repulsive.
- *Coulomb's law* is an inverse square law.
- k is a constant and equals 8.99×10^9 Nm^2/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 Knowledge:
Use superposition principle or vector analysis to find the net electric force on three or more charges in a straight line and perpendicular.

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.

Conceptual Understanding:
H.P.2D. 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 Construct explanations 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.

Assessment Guidelines:
The objective of this indicator is to *construct explanations* of 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. Therefore, the focus of assessment should be for students to *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* to show how the non-contact forces of gravity, electricity, and magnetism can be modeled as fields. This could include but is not limited to having students observe and draw magnetic field lines around magnets, view diagrams of the Earth's magnetosphere and watch video clips of CMEs (Coronal Mass Ejections) hitting earth's gravitational field.

In addition to *construct explanations*, students should be asked to *ask questions; plan and carry out investigations; engage in argument from evidence; obtain, evaluate and communicate information; develop and use models;* and *construct devices or design solutions.*

Previous Knowledge:
2.P.4- Forces
5.P.5- Forces

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

Science and Engineering Practices
S.1A.6

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.

Conceptual Understanding:
H.P.2D. 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.

Assessment Guidelines:
The objective of this indicator is to *develop and use models of a* free-body diagram to represent the gravitational force on an object. Therefore, the primary focus of assessment should be for students to *develop and use models to understand or represent phenomena, processes and relationships and communicate ideas to others about* the gravitational force on an object. This could include but is not limited to having students hand draw or a use a computerized drawing program to show gravitational force on everyday objects or students in the school elevator.

In addition to *develop and use models,* students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations; obtain, evaluate, and communicate information;* and *construct devices.*

Previous Knowledge:
2.P.4- Forces, Gravity
5.P.5- Forces, Gravity

Essential Knowledge:
Students should--
- 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 Knowledge:
- Use vector analysis to determine the magnitude of the effective gravitational force (either analytically or by graphical analysis)

Science and Engineering Practices
S.1A.2

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.

Conceptual Understanding:
H.P.2D. 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.

Assessment Guidance:
The objective of this indicator is to *develop and use models of a* free-body diagram to represent the electrical force on a charge. Therefore, the primary focus of assessment should be for students to *develop and use models to understand or represent phenomena, processes and relationships and communicate ideas to others about* the electrical force on a charge. This could include but is not limited to having students hand draw or use a computerized drawing program to show electric force on charged objects.
In addition to *develop and use models*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations; obtain, evaluate, and communicate information;* and *construct devices.*

Previous Knowledge:
2.P.4- Forces
5.P.5- Forces

Essential Knowledge:
- 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.

Science and Engineering Practices
S.1A.2

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.

Conceptual Understanding:
H.P.2D. 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 Develop and use models (such as computer simulations, drawings, or demonstrations) to explain the relationship between moving charged particles (current) and magnetic forces and fields.

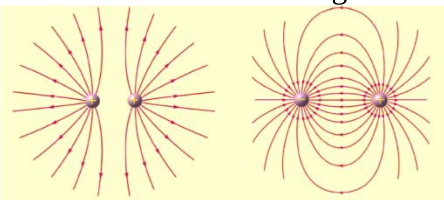
Assessment Guidelines:

The objective of this indicator is to *develop and use models* to explain the relationship between moving charged particles (current) and magnetic forces and fields. Therefore, the primary focus of assessment should be for students to *develop and use models to understand or represent phenomena, processes and relationships and communicate ideas to others about* the relationship between-moving charged particles (current) and magnetic forces and fields. This could include but is not limited to drawing magnetic field lines around a current carrying wire as a compass is moved in the field.

In addition to *develop and use models*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations; obtain, evaluate, and communicate information;* and *construct devices.*

Previous Knowledge:
2.P.4- Forces
5.P.5- Forces

Essential Knowledge:
- 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 Knowledge:
- Describe the magnetic flux including direction using the right hand rule

Science and Engineering Practices
S.1A.2

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.

Conceptual Understanding:
H.P.2D. 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 explain why all objects near Earth's surface have the same acceleration.

Assessment Guidance:
The objective of this indicator is to *construct explanations* of why all objects near Earth's surface have the same acceleration; therefore the focus of assessment should be for students to *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* to describe why the mass of an object does not affect its free fall acceleration. This could include but is not limited to having students combine the equations for Newton's 2^{nd} Law and Universal Gravitation.
In addition to *construct explanations*, students should be asked to *ask questions; plan and carry out investigations; engage in argument from evidence; obtain, evaluate and communicate information; develop and use models;* and *construct devices or design solutions.*

Previous Knowledge:
2.P.4- Forces
5.P.5- Forces
8.P.2- Newton's Second Law of Motion

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

Science and Engineering Practices
S.1A.6

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.

Conceptual Understanding:
H.P.2D. 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 Use mathematical and computational thinking to apply F_{net} = ma to analyze problems involving non-contact interactions, including objects in free fall.

Assessment Guidance:
The objective of this indicator is to *use mathematical and computational thinking* to apply F_{net} = ma to analyze problems involving non-contact interactions, including objects in free fall. Therefore the focus of assessment should be for students 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* in order to apply F_{net} = ma to analyze problems involving non-contact interactions. This could include but is not limited

to having students solve basic word problems with objects in freefall as well as using a computerized spreadsheet to analyze how the effect of changing mass or acceleration due to gravity changes gravitational force.

In addition to *use mathematical and computational thinking* students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; engage in argument from evidence; construct explanations; develop and use models; obtain, evaluate and communicate information;* and *construct devices or design solutions.*

Previous Knowledge:
2.P.4- Forces
5.P.5- Forces
8.P.2- Newton's Second Law of Motion

Essential Knowledge:
- Like contact forces, non-contact forces can cause accelerations.
- The acceleration can be caused using Newton's Second Law of Motion, F_{net}=ma to solve problems using gravitational force based on the *Law of Universal Gravitation.*

Science and Engineering Practices
S.1A.5

Standard: H.P.3The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.

Conceptual Understanding:
H.P.3A 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 mathematical and computational thinking to determine the work done by a constant force (W=Fd).

Assessment Guidance:
The objective of this indicator is *use mathematical and computational thinking* to explain the work done by a constant force. Therefore, the primary focus of the assessment should be for students to *construct 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 to determine the work done by a constant force.* This could include but is not limited to having students analyze and manipulate experimentally derived data to explain the work done by a constant force on an object being pulled up an inclined plane or pushed across the floor.
In addition to *use mathematical and computational thinking*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; engage in argument from evidence; construct*

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explanations; develop and use models; obtain, evaluate and communicate information; and *construct devices or design solutions.*

Previous Knowledge:
6.P.3- Work, energy transfer

Essential Knowledge:

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

Science and Engineering Practices
S.1A.5

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.

Conceptual Understanding:
H.P.3A- 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 mathematical and computational thinking to analyze problems dealing with the work done on or by an object and its change in energy.

Assessment Guidance:
The objective of this indicator is *use mathematical and computational thinking* to analyze problems dealing with the work done on or by an object and its change in energy. Therefore, the primary focus of the assessment should be for students 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 to determine the work done on or by an object.* This could include but is not limited to having students analyze and manipulate experimentally derived data to calculate the work done by friction stopping a ball rolling down a ramp.

In addition to *use mathematical and computational thinking,* students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; engage in argument from evidence; construct explanations; develop and use models; obtain, evaluate and communicate information;* and *construct devices or design solutions.*

Previous Knowledge:
6.P.3- Work, energy transfer, types of energy

Essential Knowledge:

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} = KE

Science and Engineering Practices
S.1A.5

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.

Conceptual Understanding:
H.P.3A- 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 Obtain information to communicate how energy is conserved in elastic and inelastic collisions.

Assessment Guidance:
The objective of this indicator is to *obtain information to communicate* how energy is conserved in elastic and inelastic collisions. Therefore, the primary focus of assessment should be for students to *(1) obtain and evaluate informational text on conservation of energy in elastic and inelastic collisions,(2) collect data on elastic and inelastic collisions; (3) develop real life models on elastic and inelastic collisions.* This could include but is not limited to watching videos on elastic and inelastic collisions or playing a game of pool and describing the interaction of the billiard balls.

Previous Knowledge:
6.P.3- Work, energy transfer, types of energy

Essential Knowledge:
Students should--

- 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.

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Science and Engineering Practices
S.1A.8

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.

Conceptual Understanding:
H.P.3A- 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, the ratio of work in to work out 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 Plan and conduct controlled scientific investigations to determine the power output of the human body.

Assessment Guidelines:
The objective of this indicator is to *plan and conduct investigations* to determine the power output of the human body. The focus of the assessment should be for students to (1) *plan and conduct controlled scientific investigations, (2) identify materials, procedures and variables, (3) use appropriate laboratory equipment and techniques to collect qualitative and quantitative data, (4) record and represent data* in appropriate forms to determine the power output of the human body. This could include but is not limited to (1) designing, conducting and presenting data from work experiments (2) calculating power from doing work such as climbing stairs, doing pushups, or lifting weights.
In addition to *plan and conduct investigations*, students may be expected to *ask questions; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations;* and *develop and use model.*

Previous Knowledge:
6.P.3- Work, energy transfer, types of energy

Essential Knowledge:
Students should--
- 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

Science and Engineering Practices
S.1A.3

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.

Conceptual Understanding:
H.P.3A- 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.5 Obtain and communicate information to describe the efficiency of everyday machines (such as automobiles, hair dryers, refrigerators, and washing machines).

Assessment Guidelines:
The objective of this indicator is to *obtain information* to communicate the efficiency of everyday machines (such as automobiles, hair dryers, refrigerators, and washing machines). Therefore, the primary focus of assessment should be for students to *obtain and evaluate informational texts, observations, data collected or discussions to (1) generate and answer questions, (2) explain or describe phenomena, (3) develop models, (4) support explanations or (5) identify gaps in knowledge* regarding the efficiency of everyday machines. This could include but is not limited to analyzing energy guides or collecting data and calculating the efficiency of single, double, and triple pulley systems.

In addition to *obtain information,* students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations; develop and use models;* and *construct devices or define efficiency.*

Previous Knowledge:
6.P.3- Work, energy transfer, types of energy

Essential Knowledge:
- 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 electric means, thermal means or mechanical means

Science and Engineering Practices
S.1A.8

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.

Conceptual Understanding:
H.P.3B: 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 Develop and use models (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.

Assessment Guidance:
The objective of this indicator is to *develop and use models to* explain the transformation of mechanical energy in simple systems. Therefore, the primary focus of assessment should be for students *to develop and use models to understand or represent phenomena, processes and relationships and communicate ideas to others about the transformation of mechanical energy.* This could include but is not limited to making diagrams illustrating potential and kinetic energies at various positions of a pendulum bob or a stretched spring.

In addition to *develop and use models*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations; obtain, evaluate, and communicate information;* and *construct devices.*

Previous Knowledge:
6.P.3- Work, energy transfer, types of energy

Essential Knowledge:
Students should--

- 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 decreases 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 accelerate by slowing 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 based on the principles of simple harmonic motion and involve transformation of mechanical energy.

Extended Knowledge:-

- 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.

Science and Engineering Practices
S.1A.2

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.

Conceptual Understanding:
H.P.3B: 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 Use mathematical and computational thinking 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 ($KE = ½ mv^2$, $PE_g = mgh$, $PE_e = ½ kx^2$).

Assessment Guidance:
The objective of this indicator is *use mathematical and computational thinking* 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. Therefore, the primary focus of the assessment should be for students 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 to determine* the validity of the conservation of mechanical energy in simple systems and those with periodic motion and on which only conservative forces act. This could include but is not limited to having students analyze and manipulate experimentally derived data to calculate the starting potential energy of a pendulum bob and compare it to the kinetic energy at equilibrium position for a ball rolling down a ramp.

In addition to *use mathematical and computational thinking*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; engage in argument from evidence; construct explanations; develop and use models; obtain, evaluate and communicate information;* and *construct devices or design solutions.*

Previous Knowledge:
6.P.3- Work, energy transfer, types of energy

Essential Knowledge:

- *Potential energy* (energy of position) and *kinetic energy* (energy of motion) can be determined using energy formulas:
  - $KE = ½mv^2$
  - $PE_g = mgh$
  - $PE_e = ½kx^2$

- 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 Knowledge:
- 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.

Science and Engineering Practices
S.1A.5

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.

Conceptual Understanding:
H.P.3B: 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).

Assessment Guidance:
The objective of this indicator is to *develop and use models* to identify positions of relative high and low potential energy in a gravitational and electrical field. Therefore, the focus of assessment for the student should be *develop and use models to understand or represent phenomena, processes and relationships and communicate ideas to others about* gravitational and electric fields. This could include but is not limited to watching videos on how the solar wind affects the earth's magnetosphere, and drawing field lines between two or more electric charges.

In addition to *develop and use models*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations; obtain, evaluate, and communicate information;* and *construct devices.*

Previous Knowledge:
6.P.3- Work, energy transfer, Kinetic and Potential Energy

Essential Knowledge:

- The 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.
  The *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 Knowledge:

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

Science and Engineering Practices
S.1A.2

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.

Conceptual Understanding:
H.P.3C: 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 Plan and conduct controlled scientific investigations to determine the variables that affect the rate of heat transfer between two objects.

Assessment Guidelines:
The objective of this indicator is to *plan and conduct investigations* to determine the variables that affect the rate of heat transfer between two objects. The focus of the assessment should be for students *to (1) plan and conduct controlled investigations involving different methods of heat transfer, (2) identify materials, procedures and variables used to collect qualitative and quantitative data, (3) record and represent data in appropriate forms* to determine the variables that affect the rate of heat transfer between two objects. This could include but is not limited to designing, conducting and presenting data from heat experiments such as dropping a piece of hot metal into a cup of cold water to calculate heat transfer.

In addition to plan and *conduct investigations*, students should be asked *to ask questions; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations; develop and use models;* and *construct devices or define ways to transfer heat.*

Previous Knowledge:
6.P.3- Heat, Heat Transfer, Conduction, Convection, Radiation

Essential Knowledge:

- Heat is a form of energy that is transferred between objects of different temperatures.
- Heat always flows from warm to cold 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 Knowledge:

- Apply the concept of heat exchange to solve calorimetry problems.
- Summarize the functioning of heat transfer mechanisms (including engines and refrigeration systems)

Science and Engineering Practices

S.1A.3

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.

Conceptual Understanding:

H.P.3C: 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 Analyze and interpret data to describe the thermal conductivity of different materials.

Assessment Guidance:

The objective of this indicator is to *analyze and interpret data* to describe the thermal conductivity of different materials. Therefore, the primary focus of assessment for the students should be to *analyze and interpret experimentally derived data using a range of methods to (1) reveal patterns and construct meaning, (2) support or refute hypotheses, explanations, claims, or designs, or (3) evaluate the strength of conclusions* regarding thermal conductivity of different materials. This could include but is not limited to having students analyze and interpret data collected from experiments to determine which material makes the best insulator or to determine how the thickness of insulation material affects thermal conductivity.

In addition to *analyze and interpret data*, students should be asked to *ask questions; plan and carry out investigations; use mathematics and computational thinking; engage in argument from evidence; construct explanations; develop and use models; obtain, evaluate, and communicate information;* and *construct devices or define thermal conductivity.*

Previous Knowledge:

6.P.3- Heat, Heat Transfer, Conduction, Convection, Radiation

Essential Knowledge:

- The *thermal conductivity* of a material is the property of a material to conduct heat. It depends on the thickness, area, and length of the material.
- Each substance has its own thermal conductivity value.
- A higher conductivity value indicates a greater conductor.

Extended Knowledge:

- 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.

Science and Engineering Practices
S.1A.4

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.

Conceptual Understanding:
H.P.3C: 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 Develop and use models (such as a drawing or a small-scale greenhouse) to exemplify the energy balance of the Earth (including conduction, convection, and radiation).

Assessment Guidance:
(S.1.A.2) The objective of this indicator is *to develop and use models* to exemplify the energy balance of the Earth. Therefore, the focus of assessment for the student should be to *develop and use models to understand or represent phenomena, processes and relationships and communicate ideas to others* regarding the energy balance of the Earth. This could include but is not limited to students: (1) developing drawings that illustrate radiation energy coming from the sun and (2) explaining what happens to energy in the earth's atmosphere (convection currents and conduction with different surfaces) or (3) using different materials to design an ecosystem that shows heat absorption and heat transfer in soil, water and air.

In addition to *develop and use models*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations; obtain, evaluate, and communicate information;* and *construct devices.*

Previous Knowledge:
6.P.3- Heat, Heat Transfer, Conduction, Convection, Radiation

Essential Knowledge:

- 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.

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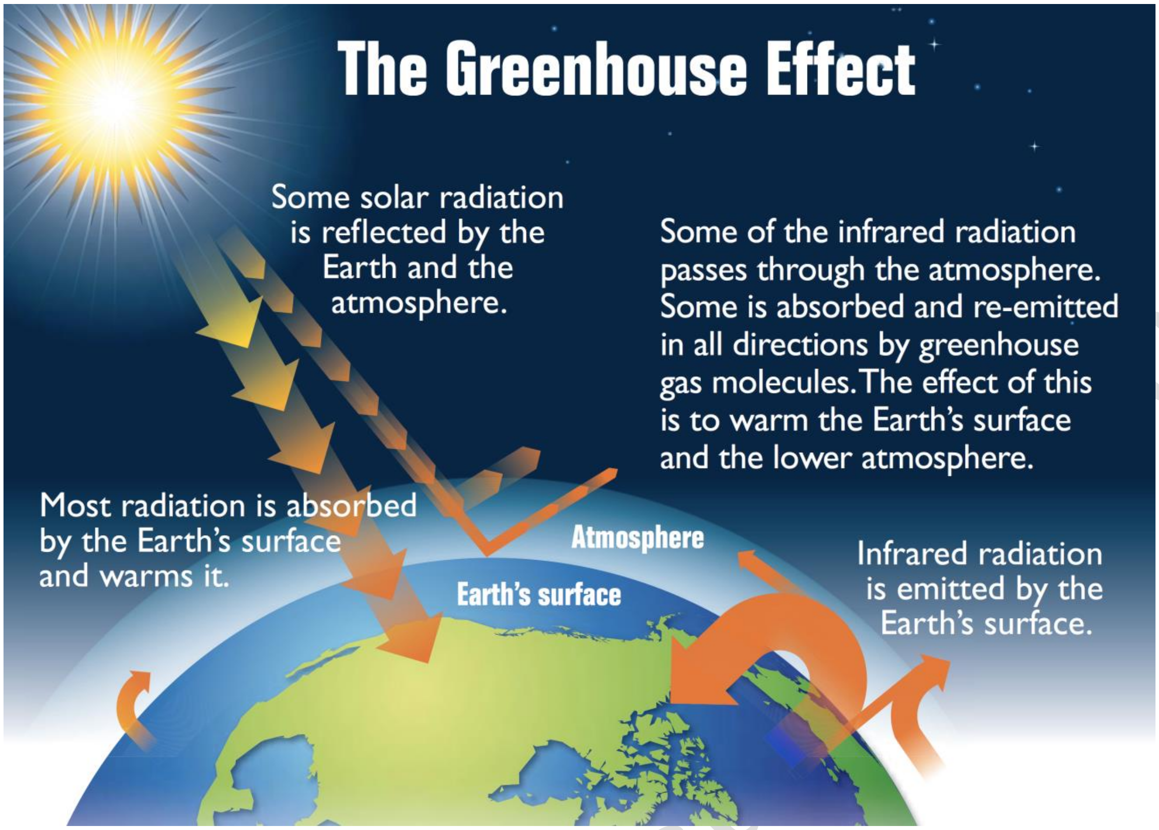


Science and Engineering Practices
S.1A.2

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.

Conceptual Understanding:
H.P.3D**:** 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 Develop and use models (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.

Assessment Guidelines:
The objective of this indicator is to *develop and use models to understand or represent phenomena, processes and relationships and communicate ideas to others about* how waves act when they encounter a barrier or change in medium. Therefore, the primary focus of assessment for students should be to use a diagram or flow chart to indicate the behavior of the waves when they encounter that barrier. This could include but is not limited to students using graph paper to draw interference wave patterns or using a function generator to create interfering waves.

In addition to *develop and use models*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations; obtain, evaluate, and communicate information;* and *construct devices.*

Previous Knowledge:
8.P.3- Wave characteristics, properties of waves, amplitude, medium

Essential Knowledge:

- *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 waves 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.

Science and Engineering Practices
S.1A.2

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.

Conceptual Understanding:
H.P.3D**:** 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).

Assessment Guidance:
The objective of this indicator is to *develop and use models* of superposition to explain everyday examples of resonance. Therefore, the primary focus of assessment for students should be to *develop and use models to understand or represent phenomena, processes and relationships and communicate ideas to others about* interfering waves and use the principle of superposition to determine if the interference is constructive or

destructive. This could include but is not limited to having students using graph paper to draw interference wave patterns or using a function generator to create interfering waves.

In addition to *develop and use models*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations; obtain, evaluate, and communicate information;* and *construct devices.*

Previous Knowledge:
8.P.3- Wave characteristics, properties of waves, amplitude, medium

Essential Knowledge:

- *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.

Science and Engineering Practices
S.1A.6

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.

Conceptual Understanding:
H.P.3D: 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 Develop and use models 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).

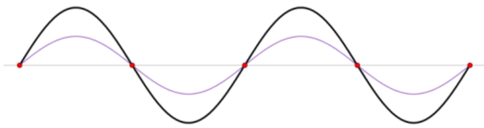
Assessment Guidance:
The objective of this indicator is to *develop and use models* to explain what happens to the observed frequency of a sound wave when the relative positions of an observer and wave source changes. Therefore, the primary focus of assessment for students is to *develop and use models to understand or represent phenomena, processes and relationships and communicate ideas to others about* what happens to the observed frequency of a sound wave when the relative positions of an observer and wave source changes. This could include but is not limited to having students develop models and diagrams to illustrate the Doppler Effect.

In addition to *develop and use models*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations; obtain, evaluate, and communicate information;* and *construct devices.*

Previous Knowledge:
8.P.3- Wave characteristics, properties of waves, amplitude, medium

Essential Knowledge:

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

Science and Engineering Practices
S.1A.2

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.

Conceptual Understanding:
H.P.3D: 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 mathematical and computational thinking to analyze problems that relate the frequency, period, amplitude, wavelength, velocity, and energy of sound waves.

Assessment Guidance:
The objective of this indicator is to *use mathematical and computational thinking* to relate the frequency, period, amplitude, wavelength, velocity, and energy of sound waves. Therefore, the focus of assessment should be for students 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* derived from experiments involving waves. This could include but is not limited to having students analyze data from tuning forks and resonance tubes.
In addition to *use mathematical and computational thinking* students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; engage in argument from evidence; construct explanations; develop and use models; obtain, evaluate and communicate information;* and *construct devices or design solutions.*

Previous Knowledge:
8.P.3- Wave characteristics, properties of waves, amplitude, medium, longitudinal waves

Essential Knowledge:

- 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.

Science and Engineering Practices
S.1A.5

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.

Conceptual Understanding:
H.P.3E: 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.1 Plan and conduct controlled scientific investigations 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.

Assessment Guidance:
The objective of this indicator is to *plan and conduct investigations 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. Therefore, the focus of this assessment should be for students to *plan and conduct controlled scientific investigations 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*. This could include but is not limited to having students design an experiment to determine what happens to current when the potential drop across a resistor changes.

In addition to *plan and conduct investigations*, students may be expected to *ask questions; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations;* and *develop and use models*.

Previous Knowledge:
3.P.3- Basic circuits and electricity
6.P.3- Electrical circuits and current

Essential Knowledge:

- E*lectric 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 Knowledge:
Use the color code chart to find the value of fixed resistors. Find resistance based on material, length, and cross sectional area. R = pl/A

Science and Engineering Practices
S.1A.3

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.

Conceptual Understanding:
H.P.3E**:** 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.

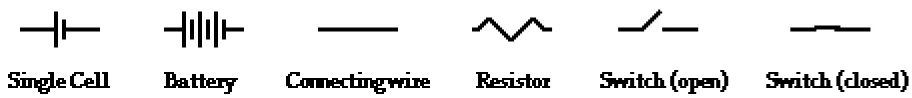
Performance Indicator:
H.P.3E.2 Develop and use models (such as circuit drawings and mathematical representations) to explain how an electric circuit works by tracing the path of the electrons and including concepts of energy transformation, transfer, and the conservation of energy and electric charge.
Assessment Guidelines:
The objective of this indicator is to *develop and use models* 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. Therefore, the primary focus of assessment for students should be *develop and use models to understand or represent phenomena, processes and relationships and communicate ideas to others about* circuits. This could include but is not limited to having students draw schematic diagrams of circuits and build 3D models of circuits from schematic diagrams.

In addition to *develop and use models*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations; obtain, evaluate, and communicate information;* and *construct devices.*

Previous Knowledge:
3.P.3- Basic circuits and electricity
6.P.3- Electrical circuits and current

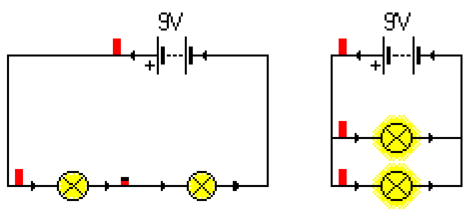
Essential Knowledge:

- 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:



(Image from SC Science Academic Standards Support Document 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 $1/R1 + 1/R2 + 1/R3 + 1/Rn = 1/\sum R$



Extended Knowledge:

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

Science and Engineering Practices

S.1A.2

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.

Conceptual Understanding:

H.P.3E: 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 mathematical and computational thinking to analyze problems dealing with current, electric potential, resistance, and electric charge.

Assessment Guidance:

The objective of this indicator is to *use mathematical and computational thinking* to analyze problems dealing with current, electric potential, resistance, and electric charge. Therefore, the focus of assessment should be for students 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* to analyze problems with given variables to solve for any unknowns based on given quantities. This could include but is not limited to having students solve word problems to determine unknown quantities or to having students analyze experimentally derived data from circuit activities.

In addition to *using mathematical and computational thinking*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; engage in argument from evidence; construct explanations; develop and use models; obtain, evaluate and communicate information;* and *construct devices or design solutions.*

Previous Knowledge:
3.P.3- Basic circuits and electricity
6.P.3- Electrical circuits and current

Essential Knowledge:

- *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.

Science and Engineering Practices
S.1A.5

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.

Conceptual Understanding:
H.P.3E: 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 Use mathematical and computational thinking to analyze problems dealing with the power output of electric devices.

Assessment Guidance:
The objective of this indicator is to *use mathematical and computational thinking* to analyze problems dealing with the power output of electric devices. Therefore, the focus of assessment should be for students to *(1) construct, use, and manipulate appropriate metric units, (2) express relationships among variables for models and investigations, and (3) use grade-level appropriate statistics to analyze data.* Students should analyze problems dealing with the power output of electric devices. This could include but is not limited to having students solve word problems to determine power of electrical devices or the cost to operate electrical appliances.

In addition to *use mathematical and computational thinking*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; engage in argument from evidence; construct explanations; develop and use models; obtain, evaluate and communicate information;* and *construct devices or design solutions.*

Previous Knowledge:
3.P.3- Basic circuits and electricity
6.P.3- Electrical circuits and current

Essential Knowledge:
- *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 Knowledge
Calculate the cost to operate various appliances.

Science and Engineering Practices
S.1A.5

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.

Conceptual Understanding:
H.P.3E: 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.

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Performance Indicator:
H.P.3E.5 Plan and conduct controlled scientific investigations to determine how connecting resistors in series and in parallel affects the power (brightness) of light bulbs.

Assessment Guidance:
The objective of this indicator is to *plan and conduct scientific investigations* to determine how connecting resistors in series and in parallel affects the power (brightness) of light bulbs. Therefore, the focus of this assessment should be for students to *plan and conduct controlled scientific investigations 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*. This could include but is not limited to having students design an experiment to determine what happens to brightness of bulbs when they are connected in various circuit configurations.

In addition to *plan and conduct investigations*, students may be expected to *ask questions; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations;* and *develop and use models*.

Previous Knowledge:
3.P.3- Basic circuits and electricity
6.P.3- Electrical circuits and current

Essential Knowledge:
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.
- When another light bulb is added to lights wired in series the lights will dim.
- The current will be the same in each resistor.
- 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 Knowledge:
Investigate light bulb brightness in compound circuits.

Science and Engineering Practices
S.1A.3

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.

Conceptual Understanding:
H.P.3E: 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 Obtain and communicate information about the relationship between magnetism and electric currents to explain the role of magnets and coils of wire in microphones, speakers, generators, and motors.

Assessment Guidance:
The primary objective of this indicator is to *obtain and communicate information* about the relationship between magnetism and electric currents to explain the role of magnets and coils of wire in microphones, speakers, generators, and motors. Therefore, the focus of assessment for students should be to *obtain and evaluate scientific information to (1) answer questions, (2) explain or describe phenomena, (3) develop models and (4) communicate using written or oral presentations*. This could include but is not limited to viewing simulations of motors and generators, and report results of student experimental investigations involving motors and generators.

In addition to *obtain information*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations; develop and use models*; and *construct devices.*

Previous Knowledge:
3.P.3- Basic circuits and electricity
6.P.3- Electrical circuits and current, motors and generators

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

Science and Engineering Practices
S.1A.8

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.

Conceptual Understanding:
H.P.3E: 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.7 Design a simple motor and construct an explanation of how this motor transforms electrical energy into mechanical energy and work.

Assessment Guidance:
The primary objective of this indicator is to *develop and use models* to illustrate how a motor transforms electrical energy into mechanical energy and work. Therefore, the primary focus of assessment for students should be to *develop and use models to understand or represent phenomena, processes and relationships and communicate ideas to others* regarding how a motor transforms electrical energy into mechanical energy and work. This could include but is not limited to drawing a design of a motor, building a motor, or transforming a motor into a generator.

In addition to *develop and use models*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations; obtain, evaluate, and communicate information;* and *construct devices.*

Previous Knowledge:
3.P.3- Basic circuits and electricity
6.P.3- Electrical circuits and current, motors and generators

Essential Knowledge:
- *Electric motors* change *electric 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.)

Science and Engineering Practices
S.1A.2

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.

Conceptual Understanding:
H.P.3F. 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 Construct scientific arguments that support the wave model of light and the particle model of light.

Assessment Guidance:
The objective of this indicator is to *construct scientific arguments to support claims* that support the wave model of light and the particle model of light. Therefore, the primary focus of assessment should be for students to c*onstruct scientific arguments to support claims or explanations using evidence from observations, data, or informational texts* that discuss how light may be considered either a wave or a particle based on experimental evidence. This could include but is not limited to having students analyze and communicate data from interference patterns and particle models of light.

In addition to *construct scientific arguments to support claims*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; construct explanations; obtain, evaluate and communicate information; develop and use models*; and *construct devices or define solutions.*

Previous Knowledge:
1.P.2- Visible light
4.P.4- Light and Energy
8.P.3- Light waves, electromagnetic waves

Essential Knowledge:
- 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).

Extended Knowledge:
Understand the quantum theory and the equation $E = hf$ where f is the frequency in hertz, h is Plank's constant, and E is energy expressed in joules

Science and Engineering Practices
S.1A.7

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.

Conceptual Understanding:
H.P.3F. 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

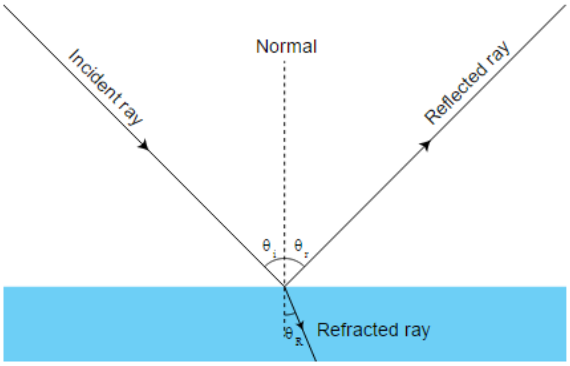
Performance Indicator:
H.P.3F.2 Plan and conduct controlled scientific investigations to determine the interaction between the visible light portion of the electromagnetic spectrum and various objects (including mirrors, lenses, barriers with two slits, and diffraction gratings) and to construct explanations of the behavior of light (reflection, refraction, transmission, interference) in these instances using models (including ray diagrams).

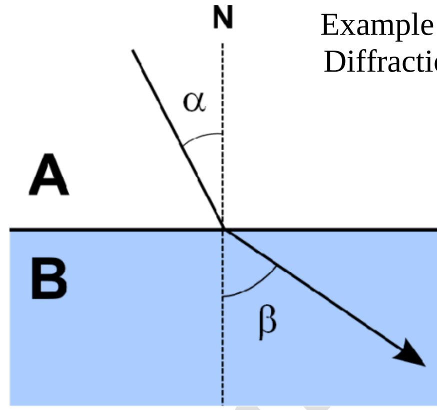
Assessment Guidance:
The objective of this indicator is to *plan and conduct investigations* to determine the interaction between the visible light portion of the electromagnetic spectrum and various objects (including mirrors, lenses, barriers with two slits, and diffraction gratings); therefore, the focus of this assessment should be for students to *plan and conduct controlled scientific investigations 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.* This could include but is not limited to having students design, conduct, and presenting data from an experiment to answer the question: how does light behave when interacting with the objects listed above?
The second objective of this indicator is to *construct explanations* of the behavior of light (reflection, refraction, transmission, interference) in these instances using models (including ray diagrams); therefore, the focus of assessment should be for students to *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* to describe the behavior of the light using ray diagrams. This could include but is not limited to students drawing ray diagrams of the behavior of light when interacting with mirrors, lenses, barriers with two slits and diffraction gratings.
In addition to *plan and conduct investigations*, students may be expected *to ask questions; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations;* and *develop and use models.*

Previous Knowledge:
1.P.2- Visible light
4.P.4- Light and Energy
8.P.3- Light waves, Electromagnetic Waves, Reflection, Refraction and Diffraction

Essential Knowledge:
- 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.
- *Reflection* occurs when light is cast back from a surface without being absorbed.
- *Refraction* occurs when light is bent as it passes from one medium to the next where the speeds of travel are different.

- *Transmission* occurs when light passes through an object.
- *Interference* occurs when waves traveling through the same medium interact to produce a combined wave with greater or lesser amplitude.
- *Diffraction* occurs when light bends around obstacles and/or openings.





Example of Diffraction

Extended Knowledge

- 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).

Science and Engineering Practices

S.1A.3 and S.1A.6

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.

Conceptual Understanding:

H.P.3F. 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.

Assessment Guidance:

The objective of this indicator is to *develop and use models* to explain how light changes direction when passing from one medium to another. Therefore, the primary focus of assessment should be for students to *develop and use models to understand or represent phenomena, processes and relationships and communicate ideas to others regarding* how light changes direction when changing media. This could include but is not limited to having students draw ray diagrams for converging and diverging lenses and use Snell's Law to determine the resulting direction of the light.

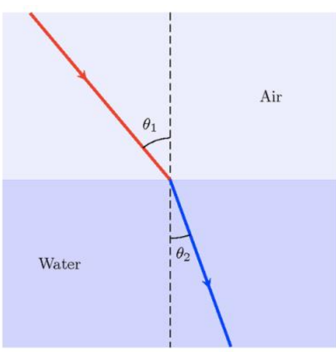
In addition to *develop and use models*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations; obtain, evaluate, and communicate information;* and *construct devices or define solutions.*

Previous Knowledge:
1.P.2- Visible light
4.P.4- Light and Energy
8.P.3- Light waves, Electromagnetic Waves, Reflection, Refraction and Diffraction

Essential Knowledge:

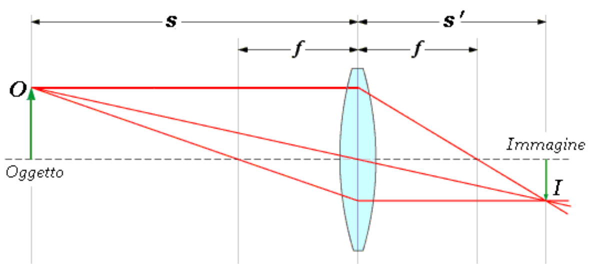
Snell's Law

- 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_1) is the angle between the incident ray and the normal.
- The angle of refraction (θ_2) 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 for lenses

- *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 Knowledge:
- Understand the origin of Continuous, Emission, and Absorption Spectra

Science and Engineering Practices
S.1A.2

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.

Conceptual Understanding:
H.P.3F. 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 Use mathematical and computational thinking to analyze problems that relate the frequency, period, amplitude, wavelength, velocity, and energy of light.

Assessment Guidance:
The objective of this indicator is to *use mathematical and computational thinking* to analyze problems that relate the frequency, period, amplitude, wavelength, velocity, and energy of light. Therefore the focus of assessment should be for students to *(1)construct, 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* to determine the wavelength or frequency of a wave based on the speed of the wave. This could

include but is not limited to students analyzing data regarding particular properties of waves and determining their effect on other properties (for example, the effect of frequency on wavelength).
In addition to *use mathematical and computational thinking* students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; engage in argument from evidence; construct explanations; develop and use models; obtain, evaluate and communicate information;* and *construct devices or design solutions.*

Previous Knowledge:
1.P.2- Visible light
4.P.4- Light and Energy
8.P.3- Light waves, Electromagnetic Waves, Reflection, Refraction and Diffraction

Essential Knowledge:
- *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. ($v = f\lambda$)
- Light is an electromagnetic wave and, as such, does not require a medium.

Science and Engineering Practices
S.1A.5

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.

Conceptual Understanding:
H.P.3F. 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 Obtain information to communicate 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.

Assessment Guidance:
The objective of this indicator is to *obtain information* to communicate 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. Therefore, the primary focus of assessment should be for students to *obtain and evaluate informational texts, observations, data collected or discussions to (1) generate and answer questions, (2) explain or describe phenomena, (3)*

develop models, or (4) support explanations regarding the uses of different frequencies of electromagnetic waves. This could include but is not limited to having students discuss the electromagnetic spectrum and the placement of different types of waves in the spectrum and their uses.

In addition to *obtain information*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations; develop and use models*; and *construct devices or define solutions.*

Previous Knowledge:
1.P.2- Visible light
4.P.4- Light and Energy
8.P.3- Light waves, Electromagnetic Waves, Reflection, Refraction and Diffraction

Essential Knowledge:

- 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.

Extended Knowledge:
Discuss ground versus space based telescopes.

Science and Engineering Practices
S.1A.8

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.

Conceptual Understanding:
H.P.3F 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.6 Obtain information to construct explanations on how waves are used to produce, transmit, and capture signals and store and interpret information (including ultrasound imaging, telescopes, cell phones, and bar code scanners).

Assessment Guidance:
The objective of this indicator is to *obtain information* to *construct explanations* on how waves are used to produce, transmit, and capture signals and store and interpret information (including ultrasound imaging, telescopes, cell phones, and bar code scanners). Therefore, the primary focus of assessment should be for students to *obtain and evaluate informational texts, observations, data collected or discussions to (1) generate and answer questions, (2) explain or describe phenomena, (3) develop models, or (4) support explanations* regarding the function of electromagnetic waves within the defined applications. This could include but is not limited to having students present a description of how each device works using electromagnetic waves.

In addition to *obtain information*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations; develop and use models*; and *construct devices or define solutions.*

Previous Knowledge:
1.P.2- Visible light
4.P.4- Light and Energy
8.P.3- Light waves, Electromagnetic Waves, Reflection, Refraction and Diffraction

Essential Knowledge:
- 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, cell phones, etcetera.

Extended Knowledge:
Students may obtain, evaluate and communicate information regarding the magnification of telescopes and microscopes.

Science and Engineering Practices
S.1A.8

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.
Conceptual Understanding:
H.P.3G. 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 Develop and use models to represent the basic structure of an atom (including protons, neutrons, electrons, and the nucleus)

Assessment Guidance:
The objective of this indicator is to *develop and use models* to represent the basic structure of an atom (including protons, neutrons, electrons, and the nucleus). Therefore, the primary focus of assessment should be for students to *develop and use models to understand or represent phenomena, processes and relationships and communicate ideas to others* regarding the structure of the atom. This could include but is not limited to having students develop a model to illustrate the current structure of the atom as well as some historical models that led to the current understanding of the atom's structure.

In addition to *develop and use models*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations; obtain, evaluate, and communicate information;* and *construct devices or define solutions*

Previous Knowledge:
7.P.2- Atomic models, Subatomic Particles, Periodic Table
H.C.2- Atomic Models, Bohr Model, Subatomic Particles

Essential Knowledge:
- 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.
- 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.

Extended Knowledge:
Complete alpha and beta decay reactions.

Science and Engineering Practices
S.1A.2

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.

Conceptual Understanding:
H.P.3G. 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 Develop and use models (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.

Assessment Guidance:
The objective of this indicator is to *develop and use models* to communicate the similarities and differences between fusion and fission. Therefore, the primary focus of assessment should be for students to *develop and use models to understand or represent phenomena, processes and relationships and communicate ideas to others* regarding similarities and difference between fission and fusion. This could include but is not limited to having students develop a model to illustrate the products of fission and fusion, or having students complete nuclear reaction problems to determine products.

In addition to *develop and use models*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations; obtain, evaluate, and communicate information;* and *construct devices or define solutions*

Previous Knowledge:
7.P.2- Atomic models, Subatomic Particles, Periodic Table
H.C.2- Atomic Models, Bohr Model, Subatomic Particles, Nuclear Processes

Essential Knowledge:
- *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.

Science and Engineering Practices
S.1A.2

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.

Conceptual Understanding:
H.P.3G. 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 Construct scientific arguments to support claims for or against the viability of fusion and fission as sources of usable energy.

Assessment Guidance:
The objective of this indicator is to *construct scientific arguments* to support claims for or against the viability of fusion and fission as sources of usable energy. Therefore, the primary focus of assessment should be for students to c*onstruct scientific arguments to support claims or explanations using evidence from observations, data, or informational texts* regarding the positive and negative aspects of using each type of energy. This

could include but is not limited to having students research the pros and cons of each type of energy and present information to others.

In addition to *construct scientific arguments to support claims*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; construct explanations; obtain, evaluate and communicate information; develop and use models*; and *construct devices or define solutions.*

Previous Knowledge:
7.P.2- Atomic models, Subatomic Particles, Periodic Table
H.C.2- Atomic Models, Bohr Model, Subatomic Particles, Nuclear Processes

Essential Knowledge:
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

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

Disadvantage
- Economic feasibility of generating the extreme temperature for fusion to occur.

Science and Engineering Practices
S.1A.7

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.

Conceptual Understanding:
H.P.3G. 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.4 Use mathematical and computational thinking to predict the products of radioactive decay (including alpha, beta, and gamma decay).

Assessment Guidance:
The objective of this indicator is to *use mathematical and computational thinking* to predict the products of radioactive decay (including alpha, beta, and gamma decay). Therefore the focus of assessment should be for students 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* regarding nuclear reactions and *to predict* products of alpha, beta and gamma decay. This could include but is not limited to having students complete one step and two step nuclear reactions.
In addition to *use mathematical and computational thinking* students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; engage in argument from evidence; construct explanations; develop and use models; obtain, evaluate and communicate information;* and *construct devices or design solutions.*

Previous Knowledge:
7.P.2- Atomic models, Subatomic Particles, Periodic Table
H.C.2- Atomic Models, Bohr Model, Subatomic Particles, Nuclear Processes

Essential Knowledge:
- 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.

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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.

Conceptual Understanding:
H.P.3G. 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.5 Obtain information to communicate how radioactive decay processes have practical applications (such as food preservation, cancer treatments, fossil and rock dating, and as radioisotopic medical tracers).

Assessment Guidance:
The objective of this indicator is to *obtain information* to communicate how radioactive decay processes have practical applications (such as food preservation, cancer treatments, fossil and rock dating, and as radioisotopic medical tracers). Therefore, the primary focus of assessment should be for students to *obtain and evaluate informational texts, observations, data collected or discussions to (1) generate and answer questions, (2) explain or describe phenomena, (3) develop models, or (4) support explanations* regarding these practical applications of nuclear physics. This could include but is not limited to students researching how nuclear physics is used within these applications and communicating their results to others.

In addition to *obtain information*, students should be asked to *ask questions; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; engage in argument from evidence; construct explanations; develop and use models*; and *construct devices or define solutions.*

Previous Knowledge:
7.P.2- Atomic models, Subatomic Particles, Periodic Table
H.C.2- Atomic Models, Bohr Model, Subatomic Particles, Nuclear Processes

Essential Knowledge:
Students need to 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 archeologist 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 Knowledge

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.

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