

# Indiana Academic Standards Science



## Physics I

## K-12 Science Indiana Academic Standards Overview

The K-12 Science Indiana Academic Standards are based on *A Framework for K-12 Science Education* (NRC, 2012) and the Next Generation Science Standards (NGSS Lead States, 2013). They are meant to reflect a new vision for science education. The following conceptual shifts reflect what is new about these science standards. The K-12 Science Indiana Academic Standards:

- Reflect science as it is practiced and experienced in the real world;
- Build logically from kindergarten through grade 12;
- Focus on deeper understanding as well as application of content; and
- Integrate practices, crosscutting concepts, and core ideas.

The K-12 Science Indiana Academic Standards outline the knowledge, science, and engineering practices that all students should learn by the end of high school. The standards are three-dimensional because each student performance expectation engages students at the nexus of the following three dimensions:

- Dimension 1 describes scientific and engineering practices.
- Dimension 2 describes crosscutting concepts, overarching science concepts that apply across science disciplines.
- Dimension 3 describes core ideas in the science disciplines.

### Science and Engineering Practices (*as found in NGSS*)

The eight practices describe what scientists use to investigate and build models and theories of the world around them or that engineers use as they build and design systems. The practices are essential for all students to learn and are as follows:

1. Asking questions (for science) and defining problems (for engineering);
2. Developing and using models;
3. Planning and carrying out investigations;
4. Analyzing and interpreting data;
5. Using mathematics and computational thinking;
6. Constructing explanations for science and designing solutions for engineering;
7. Engaging in argument from evidence; and
8. Obtaining, evaluating, and communicating information.

### Crosscutting Concepts (*as found in NGSS*)

The seven crosscutting concepts bridge disciplinary boundaries and unit core ideas throughout the fields of science and engineering. Their purpose is to help students deepen their understanding of the disciplinary core ideas, and develop a coherent, and scientifically based view of the world. The seven crosscutting concepts are as follows:

1. *Patterns*. Observed patterns of forms and events guide organization and classification, and prompt questions about relationships and the factors that influence them.
2. *Cause and Effect: Mechanism and Explanation*. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated.

Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.

3. *Scale, Proportion, and Quantity*. In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.
4. *Systems and System Models*. Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.
5. *Energy and Matter: Flows, Cycles, and Conservation*. Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.
6. *Structure and Function*. The way in which an object or living thing is shaped and its substructure determines many of its properties and functions.
7. *Stability and Change*. For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

### **Disciplinary Core Ideas** (as found in NGSS)

The disciplinary core ideas describe the content that occurs at each grade or course. The K-12 Science Indiana Academic Standards focus on a limited number of core ideas in science and engineering both within and across the disciplines and are built on the notion of learning as a developmental progression. The Disciplinary Core Ideas are grouped into the following domains:

- Physical Science (PS)
- Life Science (LS)
- Earth and Space Science (ESS)
- Engineering, Technology and Applications of Science (ETS)

The K-12 Science Indiana Academic Standards are not intended to be used as curriculum. Instead, the standards are the minimum that students should know and be able to do. Therefore, teachers should continue to differentiate for the needs of their students by adding depth and additional rigor.

### **References:**

- National Research Council. 2012. *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: The National Academies Press. <https://doi.org/10.17226/13165>.
- NGSS Lead States. 2013. *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press.

## How to read the revised Science Indiana Academic Standards

Standard Number	Title <small>The title for a set of performance expectations is not necessarily unique and may be reused at several different grade levels.</small>
<p>Students who demonstrate understanding can:</p> <p><b>Standard Number</b>      <b>Performance Expectation: A statement that combines practices, core ideas, and crosscutting concepts together to describe how students can show what they have learned.</b> [Clarification Statement: A statement that supplies examples or additional clarification to the performance expectation.]</p>	
<p style="text-align: center;"><b>Science and Engineering Practices</b></p> <p>Science and Engineering Practices are activities that scientists and engineers engage in to either understand the world or solve the problem.</p> <p>There are 8 practices. These are integrated into each standard. They were previously found at the beginning of each grade level content standard and known as SEPs.</p> <p style="text-align: center;"><b>Connections to the Nature of Science</b></p> <p>Connections are listed in either practices or the crosscutting concepts section.</p>	<p style="text-align: center;"><b>Disciplinary Core Ideas</b></p> <p>Disciplinary Core Ideas are concepts in science and engineering that have broad importance within and across disciplines as well as relevance in people’s lives.</p> <p>To be considered core, the ideas should meet at least two of the following criteria and ideally all four:</p> <ul style="list-style-type: none"> <li>● Have broad importance across multiple sciences or engineering disciplines or be a key organizing concept of a single discipline.</li> <li>● Provide a key tool for understanding or investigating more complex ideas and solving problems.</li> <li>● Relate to the interests and life experiences of students or be connected to societal or personal concerns that require scientific or technological knowledge.</li> <li>● Be teachable and learnable over multiple grades at increasing levels of depth and sophistication.</li> </ul> <p>Disciplinary ideas are grouped in four domains: the physical sciences; the life sciences; the earth and space sciences; and engineering, technology, and applications of science.</p> <p style="text-align: center;"><b>Crosscutting Concepts</b></p> <p>Crosscutting concepts are seven ideas such as Patterns and Cause and Effect, which are not specific to any one discipline but cut across them all.</p> <p>Crosscutting concepts have value because they provide students with connections and intellectual tools that are related across the differing areas of disciplinary content and can enrich their application of practices and their understanding of core ideas.</p> <p style="text-align: center;"><b>Connections to Engineering, Technology and Applications of Science</b></p> <ul style="list-style-type: none"> <li>● These connections are drawn from either the Disciplinary Core Ideas or Science and Engineering Practices.</li> </ul>

\*Denotes Indiana Specific Standard

HS-PS2-1 Forces and Interactions	
<p>Students who demonstrate understanding can:</p> <p><b>HS-PS2-1.</b> Analyze data to support the claim that Newton’s second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. [Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.]</p>	
<p>Science and Engineering Practices</p>	<p>Disciplinary Core Ideas</p>
<p><b>SEP.4: Analyzing and Interpreting Data</b></p> <p>Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.</p> <ul style="list-style-type: none"> <li>Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.</li> </ul> <p style="text-align: center;">----- <b>Connections to Nature of Science</b></p> <p><b>Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena</b></p> <ul style="list-style-type: none"> <li>Theories and laws provide explanations in science.</li> <li>Laws are statements or descriptions of the relationships among observable phenomena.</li> </ul>	<p><b>PS2.A: Forces and Motion</b></p> <ul style="list-style-type: none"> <li>Newton’s second law accurately predicts changes in the motion of macroscopic objects.</li> </ul>
	<p>Crosscutting Concepts</p>
	<p><b>CC.2: Cause and Effect</b></p> <ul style="list-style-type: none"> <li>Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</li> </ul>

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<b>HS-PS2-2 Forces and Interactions</b>	
<p>Students who demonstrate understanding can:</p> <p><b>HS-PS2-2. Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. [Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.]</b></p>	
<p><b>Science and Engineering Practices</b></p>	<p><b>Disciplinary Core Ideas</b></p>
<p><b>SEP.5: Using Mathematics and Computational Thinking</b></p> <p>Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis; a range of linear and nonlinear functions including trigonometric functions, exponentials, and logarithms; and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.</p> <ul style="list-style-type: none"> <li>● Use mathematical representations of phenomena to describe explanations.</li> </ul>	<p><b>PS2.A: Forces and Motion</b></p> <ul style="list-style-type: none"> <li>● Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object.</li> <li>● If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system.</li> </ul>
	<p><b>Crosscutting Concepts</b></p>
	<p><b>CC.4: Systems and System Models</b></p> <ul style="list-style-type: none"> <li>● When investigating or describing a system, the boundaries and initial conditions of the system need to be defined.</li> </ul>

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<b>HS-PS2-3 Forces and Interactions</b>	
<p>Students who demonstrate understanding can:</p> <p><b>HS-PS2-3.</b> Apply scientific and engineering ideas to design, evaluate, and refine a device for example, one that minimizes the force on a macroscopic object during a collision. [Clarification Statement: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.]</p>	
<p style="text-align: center;"><b>Science and Engineering Practices</b></p> <p><b>SEP.6: Constructing Explanations and Designing Solutions</b></p> <p>Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.</p> <ul style="list-style-type: none"> <li>Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects.</li> </ul>	<p style="text-align: center;"><b>Disciplinary Core Ideas</b></p> <p><b>PS2.A: Forces and Motion</b></p> <ul style="list-style-type: none"> <li>If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system.</li> </ul> <p><b>ETS1.A: Defining and Delimiting an Engineering Problem</b></p> <ul style="list-style-type: none"> <li>Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. <i>(secondary)</i></li> </ul> <p><b>ETS1.C: Optimizing the Design Solution</b></p> <ul style="list-style-type: none"> <li>Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed. <i>(secondary)</i></li> </ul>
	<p style="text-align: center;"><b>Crosscutting Concepts</b></p> <p><b>CC.2: Cause and Effect</b></p> <ul style="list-style-type: none"> <li>Systems can be designed to cause a desired effect.</li> </ul>

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<b>HS-PS2-4 Forces and Interactions</b>	
<p>Students who demonstrate understanding can:</p> <p><b>HS-PS2-4. Use mathematical representations of Newton’s Law of Gravitation and Coulomb’s Law to describe and predict the gravitational and electrostatic forces between objects.</b> [Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.]</p>	
<p><b>Science and Engineering Practices</b></p>	<p><b>Disciplinary Core Ideas</b></p>
<p><b>SEP.5: Using Mathematics and Computational Thinking</b></p> <p>Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis; a range of linear and nonlinear functions including trigonometric functions, exponentials, and logarithms; and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.</p> <ul style="list-style-type: none"> <li>Use mathematical representations of phenomena to describe explanations.</li> </ul> <p style="text-align: center;">-----</p> <p style="text-align: center;"><i>Connections to Nature of Science</i></p> <p><b>Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena</b></p> <ul style="list-style-type: none"> <li>Theories and laws provide explanations in science.</li> <li>Laws are statements or descriptions of the relationships among observable phenomena.</li> </ul>	<p><b>PS2.B: Types of Interactions</b></p> <ul style="list-style-type: none"> <li>Newton’s law of universal gravitation and Coulomb’s law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects.</li> <li>Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.</li> </ul>
	<p><b>Crosscutting Concepts</b></p>
	<p><b>CC.1: Patterns</b></p> <ul style="list-style-type: none"> <li>Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.</li> </ul>

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<b>HS-PS2-6 Forces and Interactions</b>	
<p>Students who demonstrate understanding can:</p> <p><b>HS-PS2-6.* Use mathematical representations to represent simple harmonic motion and pendulums.</b></p>	
<b>Science and Engineering Practices</b>	<b>Disciplinary Core Ideas</b>
<p><b>SEP.5: Using Mathematics and Computational Thinking</b></p> <p>Mathematical and computational thinking at the 9-12 level builds on K-8 and progresses to using algebraic thinking and analysis; a range of linear and nonlinear functions including trigonometric functions, exponentials, and logarithms; and computational tools for statistical analysis to analyze, represent and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.</p> <ul style="list-style-type: none"> <li>Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations.</li> </ul>	<p><b>PS2.A: Forces and Motion</b></p> <ul style="list-style-type: none"> <li>If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system.</li> </ul>
	<p style="text-align: center; background-color: #4caf50; color: white; padding: 5px;"><b>Crosscutting Concepts</b></p> <p><b>CC.1: Patterns</b></p> <ul style="list-style-type: none"> <li>Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.</li> </ul>

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<b>HS-PS3-1 Energy</b>	
<p>Students who demonstrate understanding can:</p> <p><b>HS-PS3-1.</b>     <b>Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.</b> [Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.]</p>	
<p><b>Science and Engineering Practices</b></p>	<p><b>Disciplinary Core Ideas</b></p>
<p><b>SEP.5: Using Mathematics and Computational Thinking</b></p> <p>Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis; a range of linear and nonlinear functions including trigonometric functions, exponentials, and logarithms; and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.</p> <ul style="list-style-type: none"> <li>● Create a computational model or simulation of a phenomenon, designed device, process, or system.</li> </ul>	<p><b>PS3.A: Definitions of Energy</b></p> <ul style="list-style-type: none"> <li>● Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system’s total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.</li> </ul> <p><b>PS3.B: Conservation of Energy and Energy Transfer</b></p> <ul style="list-style-type: none"> <li>● Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.</li> <li>● Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.</li> <li>● Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.</li> <li>● The availability of energy limits what can occur in any system.</li> </ul>
	<p><b>Crosscutting Concepts</b></p> <p><b>CC.4: Systems and System Models</b></p> <ul style="list-style-type: none"> <li>● Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.</li> </ul> <p style="text-align: center;">-----</p> <p style="text-align: center;"><b>Connections to Nature of Science</b></p> <p><b>Scientific Knowledge Assumes an Order and Consistency in Natural Systems</b></p> <ul style="list-style-type: none"> <li>● Science assumes the universe is a vast single system in which basic laws are consistent.</li> </ul>

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HS-PS3-2 Energy	
<p>Students who demonstrate understanding can:</p> <p><b>HS-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects).</b> [Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically-charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.]</p>	
<p><b>Science and Engineering Practices</b></p>	<p><b>Disciplinary Core Ideas</b></p>
<p><b>SEP.2: Developing and Using Models</b></p> <p>Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.</p> <ul style="list-style-type: none"> <li>Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.</li> </ul>	<p><b>PS3.A: Definitions of Energy</b></p> <ul style="list-style-type: none"> <li>Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.</li> <li>At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.</li> <li>These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases, the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.</li> </ul>
	<p><b>Crosscutting Concepts</b></p>
	<p><b>CC.5: Energy and Matter</b></p> <ul style="list-style-type: none"> <li>Energy cannot be created or destroyed; it only moves between one place and another place, between objects and/or fields, or between systems.</li> </ul>

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<b>HS-PS3-3 Energy</b>	
<p>Students who demonstrate understanding can:</p> <p><b>HS-PS3-3.</b>     <b>Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.</b> [Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency.]</p>	
<p style="background-color: #4b4b9b; color: white; padding: 2px;"><b>Science and Engineering Practices</b></p> <p><b>SEP.6: Constructing Explanations and Designing Solutions</b></p> <p>Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.</p> <ul style="list-style-type: none"> <li>Design, evaluate, and/or refine a solution to a complex real-world problem based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.</li> </ul>	<p style="background-color: #f4a460; color: white; padding: 2px; text-align: center;"><b>Disciplinary Core Ideas</b></p> <p><b>PS3.A: Definitions of Energy</b></p> <ul style="list-style-type: none"> <li>At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.</li> </ul> <p><b>PS3.D: Energy in Chemical Processes</b></p> <ul style="list-style-type: none"> <li>Although energy cannot be destroyed, it can be converted to less useful forms — for example, to thermal energy in the surrounding environment.</li> </ul> <p><b>ETS1.A: Defining and Delimiting an Engineering Problem</b></p> <ul style="list-style-type: none"> <li>Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (<i>secondary</i>)</li> </ul>
	<p style="background-color: #92d050; color: white; padding: 2px; text-align: center;"><b>Crosscutting Concepts</b></p> <p><b>CC.5: Energy and Matter</b></p> <ul style="list-style-type: none"> <li>Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.</li> </ul> <p style="text-align: center;">-----</p> <p style="text-align: center;"><b>Connections to Engineering, Technology, and Applications of Science</b></p> <p><b>Influence of Science, Engineering and Technology on Society and the Natural World</b></p> <ul style="list-style-type: none"> <li>Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.</li> </ul>

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<b>HS-PS3-5 Energy</b>	
<p>Students who demonstrate understanding can:</p> <p><b>HS-PS3-5. Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.</b> [Clarification Statement: Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.]</p>	
<p style="text-align: center;"><b>Science and Engineering Practices</b></p> <p><b>SEP.2: Developing and Using Models</b></p> <p>Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s).</p> <ul style="list-style-type: none"> <li>Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.</li> </ul>	<p style="text-align: center;"><b>Disciplinary Core Ideas</b></p> <p><b>PS3.C: Relationship Between Energy and Forces</b></p> <ul style="list-style-type: none"> <li>When two objects interacting through a field change relative position, the energy stored in the field is changed.</li> </ul>
	<p style="text-align: center;"><b>Crosscutting Concepts</b></p> <p><b>CC.2: Cause and Effect</b></p> <ul style="list-style-type: none"> <li>Cause and effect relationships can be suggested and predicted for complex natural and human-designed systems by examining what is known about smaller scale mechanisms within the system.</li> </ul>

<b>HS-PS3-6 Energy</b>	
<p>Students who demonstrate understanding can:</p> <p><b>HS-PS3-6.* Design, develop and analyze simple circuits and circuit elements.</b></p>	
<p style="background-color: #333399; color: white; text-align: center; padding: 2px;"><b>Science and Engineering Practices</b></p> <p><b>SEP.6: Constructing Explanations and Designing Solutions</b></p> <p>Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.</p> <ul style="list-style-type: none"> <li>Design, evaluate, and/or refine a solution to a complex real-world problem based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.</li> </ul>	<p style="background-color: #ff9933; color: white; text-align: center; padding: 2px;"><b>Disciplinary Core Ideas</b></p> <p><b>PS3.B: Conservation of Energy and Energy Transfer</b></p> <ul style="list-style-type: none"> <li>Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.</li> <li>Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.</li> <li>Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.</li> <li>The availability of energy limits what can occur in any system.</li> </ul>
	<p style="background-color: #99cc66; color: white; text-align: center; padding: 2px;"><b>Crosscutting Concepts</b></p> <p><b>CC.5: Energy and Matter</b></p> <ul style="list-style-type: none"> <li>Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.</li> </ul> <p style="text-align: center;">-----</p> <p style="text-align: center;"><b><i>Connections to Engineering, Technology, and Applications of Science</i></b></p> <p><b>Influence of Science, Engineering and Technology on Society and the Natural World</b></p> <ul style="list-style-type: none"> <li>Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.</li> </ul>

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<b>HS-PS4-1 Wave Properties</b>	
<p>Students who demonstrate understanding can:</p> <p><b>HS-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.</b> [Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.]</p>	
<p style="text-align: center;"><b>Science and Engineering Practices</b></p> <p><b>SEP.5: Using Mathematics and Computational Thinking</b></p> <p>Mathematical and computational thinking at the 9-12 level builds on K-8 and progresses to using algebraic thinking and analysis; a range of linear and nonlinear functions including trigonometric functions, exponentials, and logarithms; and computational tools for statistical analysis to analyze, represent and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.</p> <ul style="list-style-type: none"> <li>Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations.</li> </ul>	<p style="text-align: center;"><b>Disciplinary Core Ideas</b></p> <p><b>PS4.A: Wave Properties</b></p> <ul style="list-style-type: none"> <li>The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing.</li> </ul>
	<p style="text-align: center;"><b>Crosscutting Concepts</b></p> <p><b>CC.2: Cause and Effect</b></p> <ul style="list-style-type: none"> <li>Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</li> </ul>

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HS-PS4-3 Electromagnetic Radiation	
<p>Students who demonstrate understanding can:</p> <p><b>HS-PS4-3.</b> Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other. <i>[Clarification Statement: Emphasis is on how the experimental evidence supports the claim and how a theory is generally modified in light of new evidence. Examples of a phenomenon could include resonance, interference, diffraction, and photoelectric effect.]</i></p>	
<p style="text-align: center;"><b>Science and Engineering Practices</b></p> <p><b>SEP.7: Engaging in Argument from Evidence</b></p> <p>Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.</p> <ul style="list-style-type: none"> <li>Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.</li> </ul> <p style="text-align: center;">-----</p> <p style="text-align: center;"><b>Connections to Nature of Science</b></p> <p><b>Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena</b></p> <ul style="list-style-type: none"> <li>A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment. The science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.</li> </ul>	<p style="text-align: center;"><b>Disciplinary Core Ideas</b></p> <p><b>PS4.A: Wave Properties</b></p> <ul style="list-style-type: none"> <li>[From the 3–5 grade band endpoints] Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.)</li> </ul> <p><b>PS4.B: Electromagnetic Radiation</b></p> <ul style="list-style-type: none"> <li>Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features.</li> </ul>
	<p style="text-align: center;"><b>Crosscutting Concepts</b></p> <p><b>CC.4: Systems and System Models</b></p> <ul style="list-style-type: none"> <li>Models (e.g., physical, mathematical, and computer models) can be used to simulate systems and interactions — including energy, matter, and information flows — within and between systems at different scales.</li> </ul>

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<b>HS-PS4-4 Electromagnetic Radiation</b>	
<p>Students who demonstrate understanding can:</p> <p><b>HS-PS4-4.</b> Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter. [Clarification Statement: Emphasis is on the idea that photons associated with different frequencies of light have different energies, and the damage to living tissue from electromagnetic radiation depends on the energy of the radiation. Examples of published materials could include trade books, magazines, web resources, videos, and other passages that may reflect bias.]</p>	
<p><b>Science and Engineering Practices</b></p>	<p><b>Disciplinary Core Ideas</b></p>
<p><b>SEP.8: Obtaining, Evaluating, and Communicating Information</b></p> <p>Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.</p> <ul style="list-style-type: none"> <li>Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible.</li> </ul>	<p><b>PS4.B: Electromagnetic Radiation</b></p> <ul style="list-style-type: none"> <li>When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells.</li> </ul>
	<p><b>Crosscutting Concepts</b></p>
	<p><b>CC.2: Cause and Effect</b></p> <ul style="list-style-type: none"> <li>Cause and effect relationships can be suggested and predicted for complex natural and human-designed systems by examining what is known about smaller scale mechanisms within the system.</li> </ul>

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