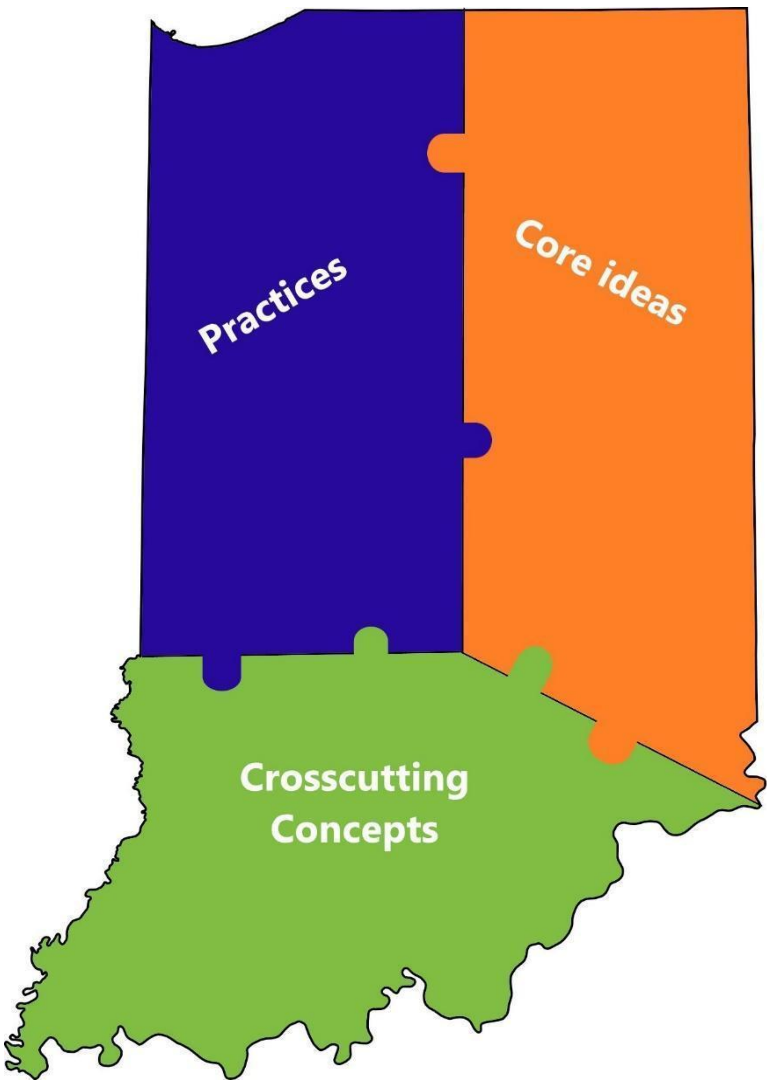
Indiana Academic Standards

Science



Physics II

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 State*s. Washington, DC: The National Academies Press.

How to read the revised Science Indiana Academic Standards

Standard Number **Title** The title for a set of performance expectations is not necessarily unique and may be reused at several different grade levels.

Students who demonstrate understanding can:

Standard Number **Performance Expectation: A statement that combines practices, core ideas, and crosscutting concepts together to describe how students can show what they have learned.** [Clarification Statement: A statement that supplies examples or additional clarification to the performance expectation.]

Science and Engineering Practices

Science and Engineering Practices are activities that scientists and engineers engage in to either understand the world or solve the problem.

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.

Connections to the Nature of Science

Connections are listed in either practices or the crosscutting concepts section.

Disciplinary Core Ideas

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.

To be considered core, the ideas should meet at least two of the following criteria and ideally all four:

- Have broad importance across multiple sciences or engineering disciplines or be a key organizing concept of a single discipline.
- Provide a key tool for understanding or investigating more complex ideas and solving problems.
- Relate to the interests and life experiences of students or be connected to societal or personal concerns that require scientific or technological knowledge.
- Be teachable and learnable over multiple grades at increasing levels of depth and sophistication.

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.

Crosscutting Concepts

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.

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.

Connections to Engineering, Technology and Applications of Science

These connections are drawn from either the Disciplinary Core Ideas or Science and Engineering Practices.

Standard 1: Energy and Momentum in Two Dimensions

Students who demonstrate understanding can:

HS-PSII-1.1. **For a system consisting of a single object with a net external force applied, qualitatively and quantitatively predict changes in its linear momentum using the impulse-momentum theorem and in its translational kinetic energy using the work-energy theorem.**

HS-PSII-1.2. **For a system consisting of two objects with no net external forces applied, qualitatively and quantitatively analyze a two-dimensional interaction (i.e., collision or separation) to show that the total linear momentum of the system remains constant**

HS-PSII-1.3. **For a system consisting of two objects moving in two dimensions with no net external forces applied, apply the principles of conservation of linear momentum and of mechanical energy to quantitatively predict changes in the linear momentum, velocity, and kinetic energy after the interaction between the two objects.**

HS-PSII-1.4 **Classify interactions between two objects moving in two dimensions as elastic, inelastic, and completely inelastic.**

Science and Engineering Practices

SEP.5: Using Mathematics and Computational Thinking

- Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis; a range of linear and nonlinear functions including trigonometric functions, exponentials, and logarithms; and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.
- Use mathematical representations of phenomena to describe explanations.

Developing and Using Models

- Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.

Disciplinary Core Ideas

PS2.A: Forces and Motion

- Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object.
- 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.

Crosscutting Concepts

CC.4: Systems and System Models

- When investigating or describing a system, the boundaries and initial conditions of the system need to be defined.

Standard 2: Temperature and Thermal Energy Transfer

Students who demonstrate understanding can:

HS-PSII-2.1.* **Develop graphical and mathematical representations that describe the relationship among the temperature, thermal energy, and thermal energy transfer (i.e., heat) in the kinetic molecular theory and apply those representations to qualitatively and quantitatively describe how changing the temperature of a substance affects the motion of the molecules.**

HS-PSII-2.2.* **Describe the process of the transfer of thermal energy (i.e., heat) that occurs during the heating cycle of a substance from solid to gas and relate the changes in molecular motion to temperature changes that are observed.**

HS-PSII-2.3.* **Cite evidence from everyday life to describe the transfer of thermal energy by conduction, convection, and radiation.**

HS-PSII-2.4.* **Develop graphical and mathematical representations that describe the relationship among the volume, temperature, and number of molecules of an ideal gas in a closed system and the pressure exerted by the system and apply those representations to qualitatively and quantitatively describe how changing any of those variables affects the others.**

HS-PSII-2.5.* **Describe the slope of the graphical representation of pressure vs. the product of: the number of particles, temperature of the gas, and inverse of the volume of the gas in terms of the ideal gas constant.**

HS-PSII-2.6.* **Using PV graphs, qualitatively and quantitatively determine how changes in the pressure, volume, or temperature of an ideal gas allow the gas to do work and classify the work as either done on or done by the gas.**

Science and Engineering Practices

SEP.5: Using Mathematics and Computational Thinking

- Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis; a range of linear and nonlinear functions including trigonometric functions, exponentials, and logarithms; and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.
- Use mathematical representations of phenomena to describe explanations.

SEP.2: Developing and Using Models

- Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter

- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.

PS3.A: Definitions of Energy

- The term “heat” as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects. *(secondary)*
- The temperature of a system is proportional to the average internal kinetic energy and potential energy per atom or molecule (whichever is the appropriate building block for the system’s material). The details of that relationship depend on the type of atom or molecule and the interactions among the atoms in the material. Temperature is not a direct measure of a

	system's total thermal energy. The total thermal energy (sometimes called the total internal energy) of a system depends jointly on the temperature, the total number of atoms in the system, and the state of the material. *(secondary)*
	Crosscutting Concepts **CC.5: Energy and Matter** • Energy cannot be created or destroyed. It only moves between one place and another place, between objects and/or fields, or between systems. When evaluating the energy of a system, students could describe how they take into account that energy cannot be created or destroyed. **CC.1: Patterns** • Mathematical representations are needed to identify some patterns. Students could use mathematical representations of data to identify patterns [caused by] the transfer of energy. **CC.4: Systems and Systems Models** • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. Students could define the boundaries and initial conditions of a system [where] energy is transported from one place to another [and then] analyze.

Standard 3: Fluids

Students who demonstrate understanding can:

HS-PSII-3.1.* **For a static, incompressible fluid, develop and apply graphical and mathematical representations that describe the relationship between the density and the pressure exerted at various positions in the fluid, and apply those representations to qualitatively and quantitatively describe how changing the depth or density affects the pressure.**

HS-PSII-3.2.* **Qualitatively and quantitatively determine how the density of fluid or volume of fluid displaced is related to the force due to buoyancy acting on either a floating or submerged object as described by Archimedes' principle of buoyancy.**

HS-PSII-3.3.* **Develop and apply the principle of constant volume flow rate to determine the relationship between cross-sectional area of a pipe and the velocity of an incompressible fluid flowing through a pipe.**

HS-PSII-3.4.* **Develop and apply Bernoulli's principle and continuity equations to predict changes in the speed and pressure of a moving incompressible fluid.**

HS-PSII-3.5.* **Describe how a change in the pressure of as static fluid in an enclosed container is transmitted equally in all directions (Pascal's Principle) and apply Pascal's Principle to determine the mechanical advantage of a hydraulic system.**

Science and Engineering Practices

SEP.3: Planning and Carrying Out Investigations

Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.

- Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.

SEP.2: Developing and Using Models

Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

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

Disciplinary Core Ideas

PS2.A Forces and Motion

- If a system interacts with objects outside itself, the total momentum of the system can change; however, any change is balanced by changes in the momentum of objects outside the system.

Crosscutting Concepts

CC.6: Structure and Function

- Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.

Standard 4: Electricity

Students who demonstrate understanding can:

HS-PSII-4.1.* **Describe the methods of charging an object (i.e., contact, induction, and polarization) and apply the principle of conservation of charge to determine the charges on each object after charge is transferred between two objects by contact.**

HS-PSII-4.2.* **For a single isolated charge, develop and apply graphical and mathematical representations that describe the relationship between the amount of charge, the distance from the charge and the strength of the electric field created by the charge and apply those representations to qualitatively and quantitatively describe how changing either the amount of charge or distance from the charge affects the strength of the electric field.**

HS-PSII-4.3.* **Using Coulomb's law, pictorially and mathematically describe the force on a stationary charge due to other stationary charges. Understand that these forces are equal and opposite as described by Newton's third law and compare and contrast the strength of this force to the force due to gravity.**

HS-PSII-4.4.* **For a single isolated charge, develop graphical and mathematical representations that describe the relationship between the amount of charge, the distance from the charge and the electric potential created by the charge and apply those representations to qualitatively and quantitatively describe how changing either the amount of charge or distance from the charge affects the electric potential.**

HS-PSII-4.5.* **Map electric fields and equipotential lines, showing the electric field lines are perpendicular to the equipotential lines, and draw conclusions about the motion of a charged particle either between or along equipotential lines due the electric field.**

HS-PSII-4.6.* **Distinguish between electric potential energy and electric potential (i.e., voltage).**

HS-PSII-4.7.* **Apply conservation of energy to determine changes in the electric potential energy, translational kinetic energy, and speed of a single charged object (i.e., a point particle) placed in a uniform electric field.**

Science and Engineering Practices

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Disciplinary Core Ideas

PS1.A Structure and Properties of Matter

- The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.

PS3.C: Relationship Between Energy and Forces

- When two objects interacting through a field change relative position, the energy stored in the field is changed.

Crosscutting Concepts

CC.2: Cause and Effect

- 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.

Standard 5: Simple and Complex Circuits

Students who demonstrate understanding can:

HS-PSII-5.1.* **Relate the idea of electric potential energy to electric potential (i.e., voltage) in the context of electric circuits.**

HS-PSII-5.2.* **Develop graphical and mathematical representations that describe the relationship between the between the amount of current passing through an ohmic device and the amount of voltage (i.e., EMF) applied across the device according to Ohm's Law. Apply those representations to qualitatively and quantitatively describe how changing the current affects the voltage and vice versa for an ohmic device of known resistance.**

HS-PSII-5.3.* **Describe the slope of the graphical representation of current vs. voltage or voltage vs. current in terms of the resistance of the device.**

HS-PSII-5.4.* **Define and describe a device as ohmic or non-ohmic based on the relationship between the current passing through the device and the voltage across the device based on the shape of the curve of a current vs. voltage or voltage vs. current graphical representation.**

HS-PSII-5.5.* **Explain and analyze simple arrangements of electrical components in series and parallel DC circuits in terms of current, resistance, voltage, and power. Use Ohm's and Kirchhoff's laws to analyze DC circuits.**

Science and Engineering Practices

SEP.2: Developing and Using Models

- Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system

SEP.5: Using Mathematics and Computational Thinking

- Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis; a range of linear and nonlinear functions including trigonometric functions, exponentials, and logarithms; and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.
- Use mathematical representations of phenomena to describe explanations.

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CC.4: Systems and System Models

- When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

CC.5: Energy and Matter

- 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.

Standard 6: Magnetism

Students who demonstrate understanding can:

HS-PSII-6.1.* **Describe the magnetic properties of ferromagnetic, paramagnetic, and diamagnetic materials on a macroscopic scale and atomic scale.**

HS-PSII-6.2.* **Develop and apply a mathematical representation that describes the relationship between the magnetic field created by a long straight wire carrying an electric current, the magnitude of the current, and the distance to the wire.**

HS-PSII-6.3.* **Describe the motion of a charged or uncharged particle through a uniform magnetic field.**

HS-PSII-6.4.* **Determine the magnitude of the magnetic force acting on a charged particle moving through a uniform magnetic field and apply the right hand rule to determine the direction of either the magnetic force or the magnetic field.**

HS-PSII-6.5.* **Describe the practical uses of magnetism in motors, electronic devices, mass spectroscopy, MRIs, and other applications.**

Science and Engineering Practices

SEP.3: Planning and Carrying Out Investigations

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SEP.5: Using Mathematics and Computational Thinking

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SEP.2: Developing and Using Models

- Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system

Disciplinary Core Ideas

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PS3.C: Relationship Between Energy and Forces

- When two objects interacting through a field change relative position, the energy stored in the field is changed.

Crosscutting Concepts

CC.2: Cause and Effect

- 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.

CC.4: Systems and System Models

- When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

CC.5: Energy and Matter

- 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.

*Denotes Indiana Specific Standards

Standard 7: Electromagnetic Induction

Students who demonstrate understanding can:

HS-PSII-7.1.* **Given the magnitude and direction of a uniform magnetic field, calculate the flux through a specified area in terms of the field magnitude and the size and orientation of the area with respect to the field.**

HS-PSII-7.2.* **Develop graphical and mathematical representations that describe the relationship between the rate of change of magnetic flux and the amount of voltage induced in a simple loop circuit according to Faraday's Law of Induction and apply those representations to qualitatively and quantitatively describe how changing the voltage across the device affects the current through the device.**

HS-PSII-7.3.* **Apply Ohm's Law, Faraday's Law, and Lenz's Law to determine the amount and direction of current induced by a changing magnetic flux in a loop of wire or simple loop circuit.**

Science and Engineering Practices

SEP.3: Planning and Carrying Out Investigations

Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.

- Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.

SEP.2: Developing and Using Models

Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

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

Disciplinary Core Ideas

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- The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.

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Crosscutting Concepts

CC.2: Cause and Effect

- 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.

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- When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

CC.5: Energy and Matter

- 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.

*Denotes Indiana Specific Standards

Standard 8: Geometric Optics

Students who demonstrate understanding can:

HS-PSII-8.1.* **Develop graphical, mathematical, and pictorial representations (e.g., ray diagrams) that describe the relationships between the focal length, the image distance, and the object distance for planar, converging, and diverging mirrors and apply those representations to qualitatively and quantitatively describe how changing the object distance affects the image distance.**

HS-PSII-8.2.* **Develop graphical, mathematical, and pictorial representations (e.g., ray diagrams) that describe the relationship between the angles of incidence and refraction of monochromatic light passed between two different media and apply those representations to qualitatively and quantitatively describe how changing the angle of incidence affects the angle of refraction.**

HS-PSII-8.3.* **Develop graphical, mathematical, and pictorial representations (e.g., ray diagrams) that describe the relationships between the focal length, the image distance, and the object distance for both converging and diverging lenses and apply those representations to qualitatively and quantitatively describe how changing the object distance affects the image distance.**

HS-PSII-8.4.* **Describe an image as real or virtual for both a curved mirror and lens system based on the position of the image relative to the optical device.**

Science and Engineering Practices

SEP.3: Planning and Carrying Out Investigations

Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.

- Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.

SEP.2: Developing and Using Models

Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

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

Disciplinary Core Ideas

PS4.A: Wave Properties

- 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.

Crosscutting Concepts

CC.2: Cause and Effect

- 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.

CC.4: Systems and Stem Models

- Models can be used to simulate systems and interactions-including energy, matter, and information flows-within and between systems at different scales.

*Denotes Indiana Specific Standards

Standard 9: Particle and Wave Nature of Light

Students who demonstrate understanding can:

HS-PSII-9.1.* **Develop the relationship among frequency, wavelength, and energy for electromagnetic waves across the entire spectrum.**

HS-PSII-9.2.* **Explain how electromagnetic waves interact with matter both as particles (i.e., photons) and as waves and be able to apply the most appropriate model to any particular scenario.**

HS-PSII-9.3.* **Develop graphical and mathematical representations that describe the relationship between the frequency of a photon and the kinetic energy of an electron emitted through the photoelectric effect and apply those representations to qualitatively and quantitatively describe how changing the frequency or intensity of light affect the current produced in the photoelectric effect.**

HS-PSII-9.4.* **Describe the slope of the graphical representation of the kinetic energy of a photoelectron vs. frequency in terms of Planck's constant.**

HS-PSII-9.5.* **Develop graphical and mathematical representations that describe the relationship between the wavelength of monochromatic light, spacing between slits, distance to screen, and interference pattern produced for a double-slit scenario and apply those representations to qualitatively and quantitatively describe how changing any of the independent variables affects the position of the bright fringes.**

HS-PSII-9.6.* **Develop graphical and mathematical representations that describe the relationship between the angle between two polarizing filters and the intensity of light passed through the filters from an unpolarized light source and apply those representations to qualitatively and quantitatively describe how changing the angle between polarizing filters affects the intensity of light passing through both filters.**

Science and Engineering Practices

SEP.3: Planning and Carrying Out Investigations

Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.

- Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.

SEP.2: Developing and Using Models

Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

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

Disciplinary Core Ideas

PS4.A: Wave Properties

- 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.

PS4.B: Electromagnetic Radiation

- Photoelectric materials emit electrons when they absorb light of a high enough frequency.

Crosscutting Concepts

CC.2: Cause and Effect

- 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.

CC.4: Systems and Stem Models

- Models can be used to simulate systems and interactions-including energy, matter, and information flows-within and between systems at different scales.

Standard 10: Modern Physics

Students who demonstrate understanding can:

HS-PSII-10.1.* **Describe the Standard Model and explain the composition and decay of subatomic particles using the Standard Model and Feynman diagrams.**

HS-PSII-10.2.* **Explain the stability of the nucleus considering the electromagnetic repulsion in the nucleus and how forces govern binding energy and radioactive decay for different elements.**

HS-PSII-10.3.* **Qualitatively compare and contrast how particle interactions, fission, and fusion can convert matter into energy and energy into matter and calculate the relative amounts of matter and energy in such processes.**

HS-PSII-10.4.* **Apply the conservation of mass, conservation of charge, and conservation of linear momentum principles to describe the results of a radioactive particle undergoing either alpha or beta decay.**

HS-PSII-10.5.* **Know and describe how a particle accelerator functions and how current high energy particle physics experiments are being used to develop the Standard Model.**

Science and Engineering Practices

SEP.5: Using Mathematics and Computational Thinking

- Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis; a range of linear and nonlinear functions including trigonometric functions, exponentials, and logarithms; and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.
- Use mathematical representations of phenomena to describe explanations.

SEP.2: Developing and Using Models

Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

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

Disciplinary Core Ideas

PS1.C: Nuclear Processes

- Nuclear Processes, including fusion, fission, and radioactive decays or unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process.

Crosscutting Concepts

CC.5: Energy and Matter

- Energy cannot be created or destroyed. It only moves between one place and another place, between objects and/or fields, or between systems. When evaluating the energy of a system, students could describe how they take into account that energy cannot be created or destroyed.

CC.1: Patterns

- Mathematical representations are needed to identify some patterns. Students could use mathematical representations of data to identify patterns [caused by] the transfer of energy.