Indiana's Academic Standards 2010 Physics	Indiana's Academic Standards 2016 Physics I
P.1.1 Using motion, maps, graphs and algebraic equations, describe, measure, and analyze constant acceleration motion in one dimension in terms of time and the vector quantities of displacement, velocity and acceleration.	**PI.1.1** Develop graphical, mathematical, and pictorial representations (e.g. a motion map) that describe the relationship between the clock reading (time) and position of an object moving at a uniform rate and apply those representations to qualitatively and quantitatively describe the motion of an object.
	PI.1.2 Describe the slope of the graphical representation of position vs. clock reading (time) in terms of the velocity of the object.
	PI.1.4 Describe the differences between the terms "distance," "displacement," "speed," "velocity," "average speed," and "average velocity" and be able to calculate any of those values given an object moving at a single constant velocity or with different constant velocities over a given time interval.
P.1.2 Using motion, maps, graphs and algebraic equations, describe, measure, and analyze constant acceleration motion in two dimensions in terms of time and the vector quantities of displacement, velocity and acceleration. Consider specifically projectile motion and uniform circular motion.	**PI.2.5** Qualitatively and quantitatively apply the models of constant velocity and constant acceleration to determine the position or velocity of an object moving in free fall near the surface of the Earth.
	PI.1.3 Rank the velocities of objects in a system based on the slope of a position vs. clock reading (time) graphical representation. Recognize that the magnitude of the slope representing a negative velocity can be greater than the magnitude of the slope representing a positive velocity.
	PI.2.1 Develop graphical, mathematical and pictorial representations (e.g. a motion map) that describe the relationship between the clock reading (time) and velocity of an object moving at a uniformly changing rate and apply those representations to qualitatively and quantitatively describe the motion of an object.

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	PI.2.2 Describe the slope of the graphical representation of velocity vs. clock reading (time) in terms of the acceleration of the object.
P.1.3 Describe the magnitude and direction of kinds of forces, including both contact forces and non-contact forces, those that act at a distance. Find the net force acting on an object using free-body diagrams and the addition of forces. Use Newton's three laws to deductively analyze static and dynamic systems.	**PI.3.1** Understand Newton's first law of motion and describe the motion of an object in the absence of a net external force according to Newton's first law.
	PI.3.2 Develop graphical and mathematical representations that describe the relationship among the inertial mass of an object, the total force applied and the acceleration of an object in one dimension where one or more forces is applied to the object and apply those representations to qualitatively and quantitatively describe how a net external force changes the motion of an object.
	PI.3.3 Construct force diagrams using appropriately labeled vectors with magnitude, direction, and units to qualitatively and quantitatively analyze a scenario and make claims (i.e. develop arguments, justify assertions) about forces exerted on an object by other objects for different types of forces or components of forces.
	PI.3.4 Understand Newton's third law of motion and describe the interaction of two objects using Newton's third law and the representation of action-reaction pairs of forces.
P.1.4 Use Newton's Law of Universal Gravitation and the laws of motion to quantitatively analyze the motions of orbiting objects such as the moon, the planets and satellites (i.e., Kepler's Third Law of Planetary Motion).	**PI.3.5** Develop graphical and mathematical representations that describe the relationship between the gravitational mass of an object and the force due to gravity and apply those representations to qualitatively and quantitatively describe how changing the gravitational mass will affect the force due to gravity acting on the object.

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	PI.3.6 Describe the slope of the force due to gravity vs. gravitational mass graphical representation in terms of gravitational field.
	PI.3.7 Explain that the equivalence of the inertial and gravitational masses leads to the observation that acceleration in free fall is independent of an object's mass.
P.2.1 Describe qualitatively and quantitatively the concepts of momentum, work, kinetic energy, potential energy and power.	**PI.5.1** For an object moving at constant rate, define linear momentum as the product of an object's mass and its velocity and be able to quantitatively determine the linear momentum of a single object.
	PI.4.3 Conceptually define "work" as the process of transferring of energy into or out of a system when an object is moved under the application of an external force and operationally define "work" as the area under a force vs. change in position curve.
	PI.4.4 For a force exerted in one or two dimensions, mathematically determine the amount of work done on a system by an unbalanced force over a change in position in one dimension.
P.2.2 Quantitatively predict changes in momentum using the impulse-momentum theorem and in kinetic energy using the work-energy theorem.	**PI.5.2** Operationally define "impulse" as the area under a force vs. change in clock reading (time) curve and be able to determine the change in linear momentum of a system acted on by an external force. Predict the change in linear momentum of an object from the average force exerted on the object and time interval during which the force is exerted.

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	PI.5.3 Demonstrate that when two objects interact through a collision or separation that both the force experienced by each object and change in linear momentum of each object are equal and opposite, and as the mass of an object increases, the change in velocity of that object decreases.
	PI.5.4 Determine the individual and total linear momentum for a two-body system before and after an interaction (e.g. collision or separation) between the two objects and show that the total linear momentum of the system remains constant when no external force is applied consistent with Newton's third law.
P.2.3 Analyze evidence that illustrates the Law of Conservation of Energy and the Law of Conservation of Momentum. Apply these laws to analyze elastic and completely inelastic collisions.	**PI.4.5** Understand and apply the principle of conservation of energy to determine the total mechanical energy stored in a closed system and mathematically show that the total mechanical energy of the system remains constant as long as no dissipative (i.e. non-conservative) forces are present.
	PI.4.6 Develop and apply pictorial, mathematical or graphical representations to qualitatively and quantitatively predict changes in the mechanical energy (e.g. translational kinetic, gravitational or elastic potential) of a system due to changes in position or speed of objects or non-conservative interactions within the system.
	PI.5.5 Classify an interaction (e.g. collision or separation) between two objects as elastic or inelastic based on the change in linear kinetic energy of the system.

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P.2.4 Describe and quantify energy in its different mechanical forms (e.g., kinetic, gravitational potential, elastic potential) and recognize that these forms of energy can be transformed one into another and into non-mechanical forms of energy (e.g., thermal, chemical, nuclear and electromagnetic).	**PI.4.1** Evaluate the translational kinetic, gravitational potential, and elastic potential energies in simple situations using the mathematical definitions of these quantities and mathematically relate the initial and final values of the translational kinetic, gravitational potential, and elastic potential energies in the absence of a net external force.
	PI.4.2 Identify the forms of energy present in a scenario and recognize that the potential energy associated with a system of objects and is not stored in the object itself.
P.3.1 Describe temperature, thermal energy and thermal energy transfer in terms of the kinetic molecular model. Expand the concept of conservation of mechanical energy to include thermal energy.	
P.3.2 Describe the kinetic molecular model, use it to derive the ideal gas law and show how it explains the relationship between the temperature of an object and the average kinetic energy of its molecules.	
P.3.3 Use the kinetic theory to explain that the transfer of heat occurs during a change of state.	
P.3.4 Use examples from everyday life to describe the transfer of thermal energy by conduction, convection and radiation.	
P.4.1 Using Coulomb's law, describe and determine the force on a stationary charge due to other stationary charges. Know that this force is many times greater than the gravitational force.	
P.4.2 Define electric field and describe the motion of a charged particle in a simple electric field.	

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P.4.3 Describe electric potential energy and electric potential (i.e., voltage). Use voltage to explain the motion of electrical charges and the resulting electric currents in conductors.	
P.4.4 Explain and analyze simple arrangements of electrical components in series and parallel circuits in terms of current, resistance, voltage and power. Use Ohm's and Kirchhoff's laws to analyze circuits.	**PI.8.1** Develop graphical, mathematical, and pictorial representations that describe the relationship between length, cross-sectional area, and resistivity of an ohmic device and apply those representations to qualitatively and quantitatively describe how changing the composition, size, or shape of the device affect the resistance.
	PI.8.2 Describe the slope of the graphical representation of resistance vs. the ratio of length to cross-sectional area in terms of the resistivity of the material.
	PI.8.4 Describe the slope of the graphical representation of current vs. voltage or voltage vs. current in terms of the resistance of the device.
	PI.8.6 Qualitatively and quantitatively describe how changing the voltage or resistance of a simple parallel (i.e. ladder) circuit affects the voltage, current and power measurements of individual resistive devices and for the entire circuit.
P.4.5 Describe the magnetic forces and fields produced by and acting on moving charges and magnetic materials.	
P.5.1 Identify properties of objects that vibrate by using Newton's laws to describe and explain the vibrational motion resulting from restoring forces, such as Hooke's Law in the case of spring or gravity in the case of a small amplitude pendulum.	**PI.6.1** Develop graphical and mathematical representations that describe the relationship between the amount of stretch of a spring and the restoring force and apply those representations to qualitatively and quantitatively describe how changing the stretch or compression will affect the restoring force and vice versa, specifically for an ideal spring.

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	PI.6.2 Describe the slope of the graphical representation of restoring force vs. change in length of an elastic material in terms of the elastic constant of the material, specifically for an ideal spring.
	PI.6.3 Develop graphical and mathematical representations which describe the relationship between the mass, elastic constant, and period of a simple horizontal mass-spring system and apply those representations to qualitatively and quantitatively describe how changing the mass or elastic constant will affect the period of the system for an ideal spring.
	PI.6.5 Explain the limit in which the amplitude does not affect the period of a simple mass-spring (i.e. permanent deformation) or mass-string (i.e. pendulum, small angles) harmonic oscillating system.
P.5.2 Describe how vibrating objects can generate transverse and/or longitudinal waves so that energy is transmitted without the transfer of energy. Distinguish longitudinal waves from transverse waves.	**PI.7.1** Differentiate between transverse and longitudinal modes of oscillation for a mechanical wave traveling in one dimension.
	PI.7.2 Understand that a mechanical wave requires a medium to transfer energy, unlike an electromagnetic wave, and that only the energy is transferred by the mechanical wave, not the mass of the medium.
P.5.3 Describe and analyze propagating waves in terms of their fundamental characteristics such as wave speed, wavelength, frequency or period, and amplitude.	**PI.7.3** Develop graphical and mathematical representations that describe the relationship between the frequency of a mechanical wave and the wavelength of the wave and apply those representations to qualitatively and quantitatively describe how changing the frequency of a mechanical wave affects the wavelength and vice versa.
	PI.7.4 Describe the slope of the graphical representation of wavelength vs. the inverse of the frequency in terms of the speed of the mechanical wave.

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	PI.7.5 Apply the mechanical wave model to sound waves and qualitatively and quantitatively determine how the relative motion of a source and observer affects the frequency of a wave as described by the Doppler Effect.
P.5.4 Describe and explain the behavior of waves such as transmission, reflection, interference and polarizations. Qualitatively describe and explain the production and properties of standing waves.	**PI.7.6** Qualitatively and quantitatively apply the principle of superposition to describe the interaction of two mechanical waves or pulses.
	PI.7.7 Qualitatively describe the phenomena of both resonance frequencies and beat frequencies that arise from the interference of sound waves of slightly different frequency and define the beat frequency as the difference between the frequencies of two individual sound wave sources.
P.6.1 Understand the geometric nature of light in reflection and refraction and in image formation by lenses and mirrors. Use that geometric nature to graphically predict the formation of images by lens and mirrors.	
P.6.2 Describe the electromagnetic spectrum (i.e., radio waves, microwaves, infrared, visible light, ultraviolet, X-rays and gamma rays) in terms of frequency, wavelength and energy. Recognize that all these waves travel in a vacuum at the same speed.	
P.6.3 Understand that electromagnetic waves are produced by the acceleration of charged particles. Describe how electromagnetic waves interact with matter both as packets (i.e., photons) and as waves. Show qualitatively how wave theory helps explain polarization and diffraction.	

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P.7.1 Explain that electrons, protons and neutrons are parts of the atom and that the nuclei of atoms are composed of protons and neutrons, which experience forces of attraction and repulsion consistent with their charges and masses. Distinguish elements from isotopes.	
P.7.2 Explain that the stability of the nucleus, containing only positive or neutral particles, indicates the existence of a new force that is only evident within the nucleus, as it holds the particles together despite the strong repulsive electrical force.	
P.7.3 Distinguish fission from fusion processes. Describe how the binding energies of protons and neutrons determine the stability and instability of nuclei.	
P.7.4 Describe qualitatively how nuclear reactions (i.e. fission and fusion) convert very small amounts of matter into large amounts of energy.	
P.7.5 Understand that fission results from large, less stable nuclei decomposing to form smaller, more stable nuclei. Understand that fusion results from small nuclei at high temperatures and pressures combining to form larger, more stable nuclei and releasing thermonuclear energy.	
	PI.2.3 Rank the accelerations of objects in a system based on the slope of a velocity vs. clock reading (time) graphical representation. Recognize that the magnitude of the slope representing a negative acceleration can be greater than the magnitude of the slope representing a positive acceleration.

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	PI.2.4 Given a graphical representation of the position, velocity, or acceleration vs. clock reading (time), be able to identify or sketch the shape of the other two graphs.
	PI.5.6 Mathematically determine the center of mass of a system consisting of two or more masses. Given a system with no external forces applied, show that the linear momentum of the center of mass remains constant during any interaction between the masses.
	PI.6.4 Develop graphical and mathematical representations which describe the relationship between the strength of gravity, length of string, and period of a simple mass-string (i.e. pendulum) system apply the those representations to qualitatively and quantitatively describe how changing the length of string or strength of gravity will affect the period of the system in the limit of small amplitudes.
	PI.8.3 Develop graphical and mathematical representations that describe the relationship 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 and apply those representations to qualitatively and quantitatively describe how changing the current affects the voltage and vice versa.
	PI.8.5 Qualitatively and quantitatively describe how changing the voltage or resistance of a simple series (i.e. loop) circuit affects the voltage, current and power measurements of individual resistive devices and for the entire circuit.
	PI.8.7 Apply conservation of energy concepts to the design of an experiment that will demonstrate the validity of Kirchhoff's loop rule ($\sum \Delta V = 0$) in a circuit with only a battery and resistors either in series or in, at most, one pair of parallel branches.

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	PI.8.8 Apply conservation of electric charge (i.e. Kirchhoff's junction rule) to the comparison of electric current in various segments of an electrical circuit with a single battery and resistors in series and in, at most, one parallel branch and predict how those values would change if configurations of the circuit are changed.
	PI.8.9 Use a description or schematic diagram of an electrical circuit to calculate unknown values of current, voltage or resistance in various components or branches of the circuit according to Ohm's Law, Kirchhoff's junction rule, and Kirchhoff's loop rule.